4 ENVIRONMENTAL CONSEQUENCES

The proposed action is to resume L-Reactor operation as soon as practicable to produce needed defense material (i.e., plutonium). The Department of Energy's (DOE) preferred alternative is to operate L-Reactor after the construction of a 1000-acre lake to cool the reactor's thermal discharge to meet water-quality standards of the State of South Carolina. DOE has changed the preferred alternative it presented in the Draft Environmental Impact Statement (EIS), which was to operate L-Reactor with direct discharge to Steel Creek with subsequent mitigation, as a result of public comment and discussions with regulatory authorities.

The Department of Energy has identified the 1000-acre lake, with modifications of the reactor power levels, as the preferred thermal mitigation alternative following discussions with the South Carolina Department of Health and Environmental Control (SCDHEC) and the U.S. Army Corps of Engineers (COE). This alternative would comply with the State's water-quality standards by assuring the existence of a balanced biological community (balanced indigenous population and balanced biological community are used interchangeably in this EIS) and it could be constructed by the Corps of Engineers in about 6 months. The 1000-acre lake is one of 33 cooling-water alternatives evaluated in the Final EIS; its expected environmental effects were bracketed by the cooling-water alternatives evaluated in the Draft EIS (i.e., a once-through 500-acre lake, a 1300-acre recirculating lake, and modified reactor power operation). The 1000-acre lake is the largest lake possible considering the terrain of the Steel Creek valley that can be constructed by the Corps of Engineers within a single construction season and the smallest lake allowing maximum operational flexibility. TC

This chapter discusses the potential environmental effects of L-Reactor for normal operation under reference-case assumptions, for postulated accidents, transportation, mitigation alternatives (safety, cooling water, disassembly-basin purge-water disposal, and 186-Basin sediment disposal), decontamination and decommissioning, and safeguards and security. The expected environmental effects of the preferred alternatives are discussed separately in Section 4.5.

4.1 NORMAL L-REACTOR OPERATION

This section characterizes the expected nonradiological and radiological effects due to normal operation of L-Reactor. Nonradiological effects include those that might result from an increased workforce, the withdrawal and discharge of cooling water, the discharge of liquid and atmospheric chemical effluents, and the disposal of solid nonradioactive wastes. This section does not consider cooling-water mitigation measures, which are described in Section 4.4.2; however, it does discuss the effects of direct discharge to Steel Creek, which is referred to as the reference case, to which other alternative cooling-water mitigation measures can be compared. Radiological effects include those that might result from airborne and liquid radionuclide releases, the disposal of radioactive wastes, and the resuspension and transport of radiocesium and cobalt-60 in Steel Creek. TC

4.1.1 Nonradiological impacts

4.1.1.1 Land use and socioeconomics

Land use

The proposed resumption of L-Reactor operation under the reference case would not alter existing land use on the Savannah River Plant (SRP) site, nor would it require the acquisition or the use of land off the SRP site; therefore, no direct land-use impacts are expected.

Four historic sites and one prehistoric site in the Steel Creek terrace and floodplain system have been determined to be eligible for inclusion in the National Register of Historic Places. A mitigation plan has been developed to ensure the preservation of these resources, and the plan has been approved by the South Carolina State Historic Preservation Officer (Du Pont, 1983b). Stage I of this mitigation plan involves monitoring to ensure that the sites would not be directly impacted by L-Reactor operation. This monitoring phase has been
TC ongoing; during cold-flow testing conducted in 1983, erosion of three sites (38BR112, 38BR269, and 38BR286) was observed. Stage II (mitigation) has been implemented and protection of the sites by riprap as specified in the mitigation plan is being accomplished under the guidance of the University of South Carolina Institute of Archeology and Anthropology.

Socioeconomics

Operational employment for L-Reactor, which began in 1981, peaked at about 400 employees in mid-1983 and is expected to decrease to 350 by mid-1984, or about 4 percent of the current workforce at the Savannah River Plant (Du Pont, 1982b). Essentially all the operating workforce for L-Reactor has been hired and resides in the SRP area; therefore, no additional impacts are expected to local communities and services due to in-migrating workers.

L-Reactor operation is expected to have annual total local expenditures on materials and services of approximately $3 million and a total payroll and overhead expenditure of about $21 million. These expenditures are expected to result in the creation of about 50 regional job opportunities. In addition, these are expected expenditures to produce an additional direct and indirect income of another $3 million. The total economic benefit to the SRP region during L-Reactor operation would amount to at least 400 direct and indirect job opportunities, about $25 million in direct and indirect annual income and payroll, and $3 million in direct annual expenditures on materials and services.

These contributions to the local economy would help pay for public services directly through income, property, and license taxes and user fees and indirectly through sales taxes on goods and services. The benefits provided by the project would help offset the small increase in demands for local services that it generates.

4.1.1.2 Surface-water usage

Under the reference case (direct discharge to Steel Creek), the once-through cooling-water system, similar to that used during the previous L-Reactor operation, would withdraw about 11 cubic meters per second of water from the Savannah River. This would be less than 4 percent of the average flow and 7 percent of the 7-day, 10-year low flow of 295 and 159 cubic meters per second, respectively. Because little L-Reactor cooling water would be consumed, essentially all water withdrawn from the river would be returned to the river after passing through the L-Reactor heat exchanger and the Steel Creek system. The estimated consumptive water use by L-Reactor is 0.85 cubic meter per second (Neill and Babcock, 1971). EL-2

Withdrawal of cooling water for L-Reactor operation would affect the aquatic ecology of the Savannah River by (1) the entrainment in the cooling water of aquatic organisms (predominantly fish eggs and larvae) smaller than the screen mesh in the intake system, and (2) the impingement of aquatic organisms (primarily fish) on the intake screens.

Entrainment

An expanded Savannah River aquatic ecology program was initiated in March 1982 to evaluate the impact of the Savannah River Plant, particularly L-Reactor restart, on the Savannah River fisheries (Appendix C). Data from previous studies conducted in 1977 (McFarlane et al., 1978) were also used in this impact analysis (see Appendix C). In general, the projected levels of entrainment and impingement developed from the 1982 investigations are similar to those based on the 1977 results. However, some differences do exist. A discussion of these impacts is given in the following sections.

The analysis of the data obtained in 1983, during the second year of the expanded aquatic ecology program, is still preliminary. However, the 1983 results have been used in certain parts of the impact assessments below. AY-6

Estimates of the numbers of fish larvae that could be entrained by the cooling water of the L-Reactor and the other SRP installations were obtained in the following manner. The average density of larvae found in the replicate samples taken from the intake canals was multiplied by the total volume of water pumped into the intakes during each 24-hour sampling period. This calculation estimated the total number of larvae that was entrained during each day of sampling. These individual totals were extrapolated for the days when samples were not taken to estimate entrainment numbers for the entire spawning period.

Estimates of the numbers of fish eggs that could be entrained were made in a similar manner. However, densities of eggs found in the samples taken from the river adjacent to the intake canals were used as a basis for the calculations instead of the densities obtained in the canals themselves because samples from the intake canals are believed to underestimate the egg densities; the water velocities in the canals are not sufficient to support drifting semibuoyant eggs. Entrainment in the 3G and 5G intake canals was calculated using the density of eggs immediately upstream from 3G. The egg densities for 1G were calculated as a volume-weighted average of the egg densities in the river upstream from 1G and in Upper Three Runs Creek, because a large portion of the discharge of Upper Three Runs Creek enters the 1G intake canal.

According to the results of the 1982 studies and predicted L-Reactor withdrawal rates, it is estimated that approximately 7.7 x 10^6 fish eggs and 7.6 x 10^6 fish larvae would be entrained by the L-Reactor cooling water each year during the spawning season. The corresponding projections based on the 1983 data are 3.8 x 10^6 eggs and 11.9 x 10^6 larvae (see Table 4-1). These totals represent approximately 6 percent of the fish eggs and larvae contained in the Savannah River water passing the intake canal during the 1982 spawning season and 3 percent during the 1983 spawning season.

AY-6

Table 4-1 compares the entrainment projections derived from the 1977, 1982, and 1983 ichthyoplankton surveys. In general, the loss estimates from all three studies are similar, although the 1982 estimates of egg entrainment and the 1983 estimates of larval entrainment are somewhat higher than those of the other years. (Appendix C contains data on the relative abundance and species composition of eggs and larvae collected.) This might be due either to differences in collection methods used during the two studies or to natural year-to-year variations in abundance. One of the objectives of the current Savannah River fisheries program is to attempt to determine the cause of these differences.

For the impact assessments made in this document, the worst-case situation is assumed and the highest projections of fish egg and larvae entrainment are AY-6 used (i.e., egg data from 1982 and larval data from 1983). Accordingly, the restart of L-Reactor would result in the entrainment of 7.7 x 10^6 additional fish eggs and 11.9 x 10^6 additional fish larvae annually.

Impingement

Impingement studies were first performed at SRP in 1977 (McFarlane et al., TC 1978) and were resumed in March 1982 as part of the expanded Savannah River aquatic ecology program. The results of these investigations indicate that the impingement rate is influenced to some degree by several factors, including the number of pumps in operation, the volume of water pumped, the river water level, the water temperature, and the density and species of fish in the intake canal; only some of these factors will be affected when the L-Reactor begins operation. Accordingly, the estimates of incremental increases in impingement due to L-Reactor should be used for comparative purposes only.

A total of 684 fish representing 35 species was collected during 52 impingement samplings from March 1982 through February 1983 at the 1G, 3G, and 5G pumphouses. The number of fish impinged varied from 0 to 98 in a 24-hour period, with an average of 13.2 fish per sample. This is higher than the impingement estimates from 1977 of 7.3 fish per sample (McFarlane et al., 1978). According to the 1982 data, the restart of L-Reactor would result in an additional 6 fish per day impinged during normal river flow conditions, or a cumulative total of about 19 fish per day for all SRP operations.

The data from the 1983 portion of the ongoing impingement studies indicate AY-6 that more fish were impinged that year than previously. The information for the 12-month period ending August 1983 (the last date for which data are available) was analyzed to evaluate the latest data.

A total of 3604 fish representing 48 species were impinged on the SRP intake screens during ninety-eight 24-hour samples taken between September 1982 and August 1983. The impingement ranged from 0 to 540 fish per day. The weight

Table 4-1. A comparison of ichthyoplankton entrainment for 1977, 1982, and 1983[a]

Year	SRP pumphouses				L-Reactor impact[a]	Cumulative impact
	1G	3G	5G	Total		
1977[b]						
Eggs	--	--	--	6.8×10^6	2.9×10^6	9.7×10^6
Larvae	--	--	--	19.6×10^6	8.3×10^6	27.9×10^6
Total				26.4×10^6	11.1×10^6	37.5×10^6
1982[c]						
Eggs	8.7×10^6	8.2×10^6	1.2×10^6	18.1×10^6	7.7×10^6	25.8×10^6
Larvae	5.2×10^6	12.0×10^6	0.7×10^6	17.9×10^6	7.6×10^6	25.5×10^6
Total	13.9×10^6	20.2×10^6	1.9×10^6	36.0×10^6	15.3×10^6	51.3×10^6
1983[c]						
Eggs	4.2×10^6	4.1×10^6	0.7×10^6	9.1×10^6	3.8×10^6	12.9×10^6
Larvae	12.9×10^6	13.3×10^6	1.8×10^6	28.1×10^6	11.9×10^6	40.0×10^6
Total	17.1×10^6	17.4×10^6	2.5×10^6	37.2×10^6	15.7×10^6	52.9×10^6

[a]L-Reactor 1982 estimates are calculated using the ratio 11 m^3/sec to 26 m^3/sec, which is the ratio of estimated L-Reactor cooling-water usage to the average current cooling-water usage. Accordingly, L-Reactor entrainment estimates and cumulative estimates should be used for comparison only because they do not reflect measured cooling-water withdrawal.

[b]Adapted from McFarlane et al. (1978); McFarlane (1982).

[c]Adapted from Du Pont (1983b).

AY-6

of fish impinged ranged from 0.1 gram to 22.9 kilograms per day. The total weight of the fish impinged during the entire period was 91.3 kilograms. During this 12-month period, an average of about 37 fish per day were collected in the impingement samples. At this rate, a total of 13,505 fish would be impinged annually.

The majority of the fish were in the family Centrarchidae (71 percent) or the family Clupeidae (15 percent). The most common fish, bluespotted sunfish, represented 35 percent (1259) of the total fish collected.

AY-6

The total number of fish impinged showed a sharp increase in mid-March 1983 and remained high through early May 1983. This high impingement coincided with considerably higher river water levels than those that occurred during the remainder of the sampling year. During the period of high impingement, most species had only slight increases in numbers impinged; however, a sharp increase was observed in the numbers of bluespotted sunfish and pirate perch caught on the screens. Both species generally inhabit slower moving areas of the river, but they could have been driven out by high water.

Figure 4-1 shows the average number of fish impinged at the three intake canals and the Savannah River water levels from March 1982 through August 1983.

AY-6

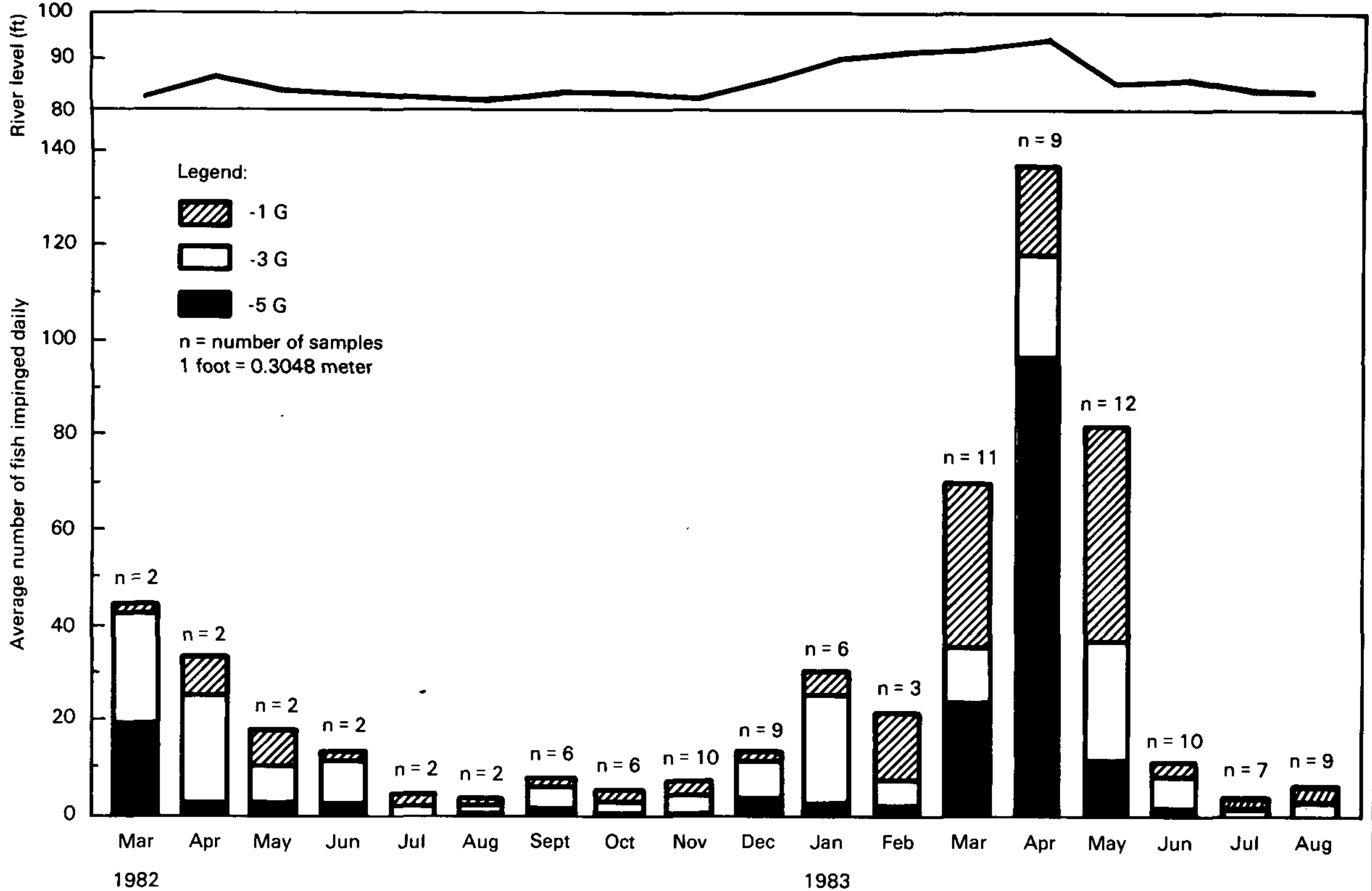
It is estimated that, under average conditions (based on 1983 data), an additional 16 fish would be impinged each day due to the restart of L-Reactor, owing to increased withdrawal. An estimated 5840 fish per year could be impinged due to L-Reactor operation.

Surveys of the recreational fishery in the fresh-water portions of the Savannah River indicate that the species caught in greatest numbers by anglers are bream (i.e., bluegill, warmouth, and sunfish), crappie, and catfish (i.e., catfish and bullheads). These species make up about 37 percent of the total number of fish collected during the impingement studies. Using these data, estimates can be made of the numbers of these recreationally important fish that would be lost due to impingement. Table 4-2 summarizes these estimates.

~~The largemouth bass is another important sportfish; it is the second-most~~ sought-after fresh-water species in the Savannah River. However, because it is not often caught, it does not rank highly in annual catch statistics. This species is impinged rarely at SRP, comprising about 0.3 percent of the total fish collected (i.e., 2 individuals from a total of 684). The projection of annual losses under present operating conditions is 14 fish. An additional 6 largemouth bass would be lost annually as a result of L-Reactor operations.

4.1.1.3 Ground-water usage

During the renovation of L-Reactor, two new wells were drilled. In 1981 and 1982, they produced about 0.28 cubic meter per minute from the Tuscaloosa Formation. They produced about 0.94 cubic meter per minute in 1983. This withdrawal rate is not expected to increase when L-Reactor operation is resumed (Du Pont, 1981b).



Source: ECS (1983 a,b).

Figure 4-1. Average number of fish impinged daily at 1G, 3G, and 5G intakes compared to Savannah River water level from March 1982 through August 1983.

AY-6

Table 4-2. Estimated numbers of fish that would be lost annually due to impingement under average river flow conditions (based on data from September 1982-August 1983)

AY-6

Species	Percentage of total number impinged	Estimated loss under present operating conditions	Loss due to L-Reactor operation (estimated)	Total loss with L-Reactor operational (estimated)
Bream	20	2,633	1114	3,747
Crappie	3	436	184	620
Catfish	3	335	142	477
Largemouth bass	0	30	13	43
Other species	74	9,989	4226	14,215
All species	100	13,423	5679	19,102

When L-Reactor is operational, withdrawal of ground water from the Tuscaloosa Aquifer (excluding incremental pumping by its support facilities), is estimated to be 20.5 cubic meters per minute at the Savannah River Plant and about 56.5 cubic meters per minute from all users within about 32 kilometers of Savannah River Plant (Sections 3.4.2.5 and 5.1.1.4). Siple (1967) concluded that the Tuscaloosa aquifer could supply 37.8 cubic meters per minute at SRP with no adverse effects on the pumping capabilities in existing 1960 wells. Total SRP pumping from the Tuscaloosa in 1960 was about 18.9 cubic meters per minute.

Drawdown calculations for the Tuscaloosa Aquifer suggest that water levels at the Plant boundary opposite A- and M-Areas would rise in relation to the levels measured in 1982 (Georgia Power Company, 1982; Du Pont, 1983h) if the SRP
AW-1 pumping rate decreases from 23.8 (1982) to 20.5 cubic meters per minute. These projected increases would be about 0.5 meter at Jackson and 0.4 meter at Talatha. Long-term cyclic water-level fluctuations near SRP often exceed 2 meters (see Figure F-12).

Computer modeling (Marine and Routt, 1975) indicates that the best estimate of the ground-water flux in the aquifer is about 110 cubic meters per minute throughout the Savannah River Plant and adjacent areas (Figures F-25 and F-31 show the study area). The current ground-water flux through the Tuscaloosa in the Marine-Routt study area is conservatively estimated to be 51 cubic meters per minute, which is the study's lower-bound estimate (see Section F.4.2). This compares with a withdrawal rate from the study area of 32.0 cubic meters per minute (20.5 for SRP + 11.5 for neighboring offsite users). Incremental and cumulative ground-water withdrawals are described in Sections 5.1.1.4 and 5.2.3, respectively.

Pumping tests were conducted on both new L-Area wells. One well had a drawdown of 8.2 meters and the other a drawdown of 12.2 meters when tested for a short period of time at flow rates of 2.8 cubic meters per minute. From the average specific capacity of 0.27 cubic meter per minute per meter derived during the pumping tests, a short-time drawdown of 3.5 meters (including well entrance losses) at the center of the cone of depression is calculated for an L-Area well producing 0.94 cubic meter per minute.

The total drawdown 0.3 meter from the center of the cone of depression is 4.6 meters when the entrance losses are subtracted and the effects of pumping elsewhere on the Savannah River Plant are included. The upward head differential between the Tuscaloosa and Congaree Formations in L-Area is calculated to be about 3.7 meters (Figure 3-9). Thus, 0.3 meter from the center of the cone of depression, the head differential is about 0.9 meter downward. The upward head differential at the L-Area seepage basin, about 400 meters from the A-Area wells, is calculated to be 1.4 meters, principally in response to pumping in L-Area. Measurements of upward differentials over the last 10 years show a gradual decline of about 0.16 meter per year (Section 3.4.2.5). This rate of decline, if it continues, will further reduce the upward head differential beneath the L-Area seepage basin. However, because pumping rates at SRP are expected to remain less than the 1983 rate (see Table F-10) over the next 6 years (Sections 5.1.1.4 and 5.2.3), this trend is expected to be retarded. The hydrostratigraphic properties of the formations underlying the L-Area seepage basin [principally the green clay (see Section 4.1.2.2) and the pisolitic clay at the base of the McBean and Congaree Formations, and the thick upper clay layer of the Ellenton Formation (Table F-1)] will tend to protect the Tuscaloosa from contamination by the seepage of pollutants that enter the overlying shallow ground-water units. The upward head differential will provide additional protection.

As noted in Section 4.1.2.2, contaminants from the L-Reactor seepage basin that reach the water table are expected to follow a ground-water travel path to Steel Creek, where they will be discharged through seepline springs. Any contamination that might reach the Congaree or Tuscaloosa from L-Area would flow beneath the SRP to the Savannah River and would not affect offsite ground-water users; the following ground-water transient times have been estimated (Figures F-25 and F-26 for flow paths and Table F-1 for flow velocities): AW-1

- Congaree Formation -- 76 years
  [(12.2×10^3 meters)/(160 meters per year) = 76 years]

- Tuscaloosa Formation -- 250 years
  [(13.1×10^3 meters)/(52.2 meters per year) = 250 years]

Pumping from the Tuscaloosa in L-Area will have no effect on the heads in the Congaree and overlying formations because this aquifer has a very poor hydraulic connection with them. The withdrawal of ground water from the Tuscaloosa in L-Area is not expected to affect either the quality of the water or the offsite water levels in the aquifer.

In conclusion, the withdrawal of ground water for L-Reactor would be about 0.94 cubic meter per minute. The ground-water withdrawal from the Tuscaloosa is projected to decrease when L-Reactor operation resumes (excluding incremental pumping in support of L-Reactor) compared to 1982 pumping; water levels are expected to rise as a new equilibrium piezometric surface is established at SRP and neighboring areas. At Jackson and Talatha, projected water levels would

AW-1 increase by 0.5 and 0.4 meter, respectively, if sitewide pumping decreases to 20.5 cubic meters per minute. However, pumping at L-Area would draw down the water in the Tuscaloosa locally, and thereby reduce the upward head difference between the Tuscaloosa and Congaree to about 1.4 meters beneath the L-Reactor seepage basin. The withdrawal of ground water from the Tuscaloosa would not affect water levels in overlying aquifers because of the thick Ellenton clay unit and the basal Congaree Clay. Important clay layers, principally the green clay, beneath the L-Reactor seepage basin would tend to protect the Congaree and Tuscaloosa Aquifers; any contaminants that might reach these aquifers are expected to flow beneath the SRP to the Savannah River in an estimated 76 to 250 years, respectively, and would not affect offsite ground-water users.

4.1.1.4 Thermal discharge

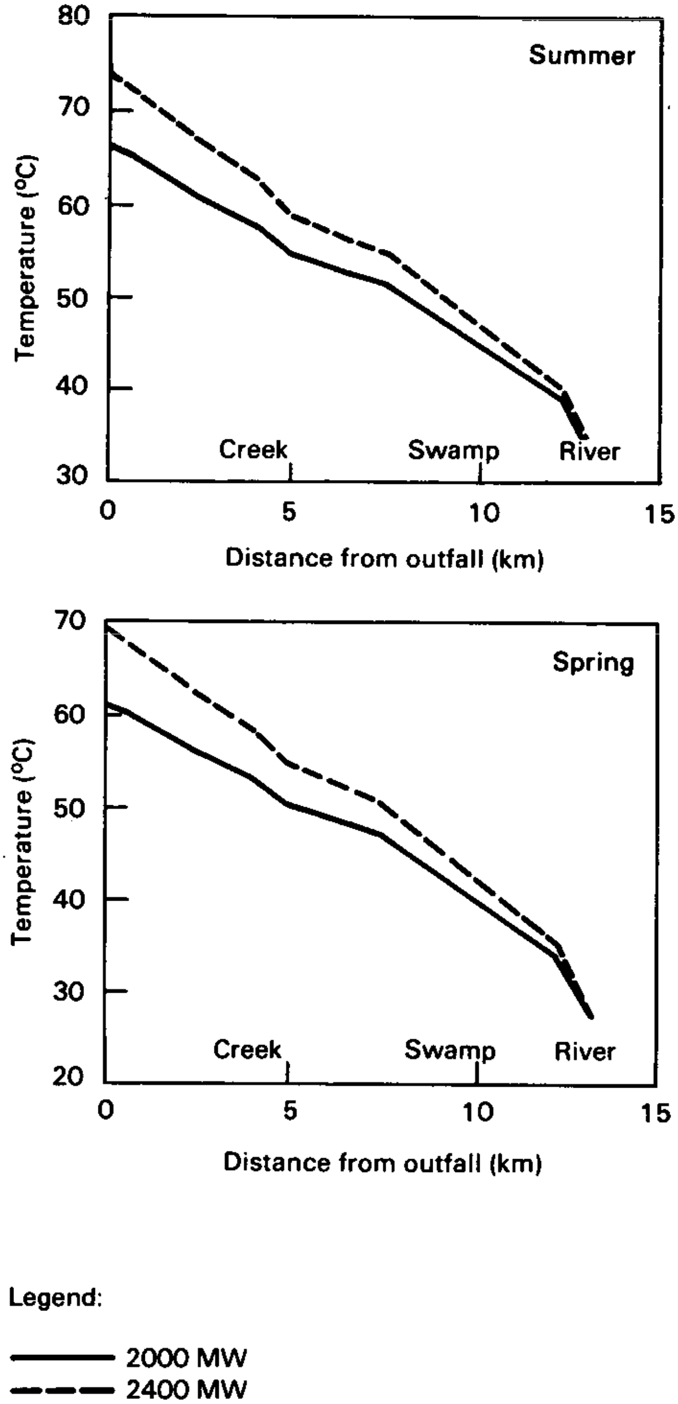
TC The direct discharge of L-Reactor cooling water to Steel Creek, discussed here, is the reference case to which all mitigation measures (including the preferred alternative) are compared (see Section 4.4.2). The preferred alternative is discussed in Section 4.5 and Appendix L. Section 7.5 discusses the NPDES permit for L-Reactor.

TC The L-Reactor cooling system would discharge thermal effluent directly into Steel Creek, one of five major creeks that drain the Savannah River Plant and flow into the Savannah River. The temperature of the effluent at the outfall canal would reach 73°C during extreme meteorological conditions. The effluent would flow at a rate of about 11 cubic meters per second (natural flow in the creek at Road B is about 0.17 cubic meter per second; see Section 3.4.1.2). Modeling (Du Pont, 1982b) of L-Reactor thermal effluents at two power levels (Figure 4-2) indicated that the thermal discharge would enter the swamp at temperatures between 40°C (spring) and 45°C (summer). Table 4-3 presents temperatures that could occur at selected points along Steel Creek under the most severe 5-day meteorological conditions (as determined from conditions between 1976 and 1980). If L-Reactor is operated under these severe conditions, the water temperature of Steel Creek above its delta would exceed 40°C; the temperature of the effluent when it reaches the Savannah River would be about 33°C

TC (Table 4-3).

TC The thermal impact to wetlands would be expected to be similar to conditions that occurred when L-Reactor operated previously. During the past 15 years, through the process of natural succession, these wetlands have become reestablished. They are, however, structurally different from the closed canopy of mature cypress and tupelo gum that existed before SRP began operations (Sharitz, Irwin, and Christy, 1974). Elevated temperatures and water levels would eliminate between 420 and 580 acres of wetland vegetation within the Steel Creek corridor. Portions of these areas would revert to mudflats. Sediments would be transported downstream and deposited on the delta, contributing to its physical buildup and impacting vegetation.

With the reference case and other once-through alternatives, emergent wetland flora and submergent hydrophytes, which have revegetated the Steel Creek delta since 1968, would be eliminated and their substrates would also revert to mudflats after resumption of operations. Some herbaceous flora have also become established on exposed floodplain sediments and elevated stumps and logs of



Source: Du Pont, 1982b.

Figure 4-2. Calculated temperature profiles for Steel Creek.

Table 4-3. Predicted seasonal water temperatures of Steel Creek as a result of L-Reactor operation (maximum load) and direct discharge

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
L-Reactor outfall	73[c]	71	69	66
Road A	54	53	50	46
Road A-17	47	46	42	37
Swamp at delta	46	45	41	36
Mid-swamp	37	35	31	25
Mouth of creek at Savannah River	34	33	28	21

[a]Based on the worst 5-day meteorological conditions (July 11-15, 1980) and the estimated operating power of the reactor. Five-day worst-case meteorological conditions provide the basis for a conservatively high estimate of discharge and downstream temperatures that are likely to result from the implementation of a thermal mitigation alternative. The selection of 5-day worst-case meteorology is also based on a typical cycle of consecutive meteorological conditions; it is considered representative of extreme temperatures for which the maintenance of a balanced biological community can be measured under Section 316(a) of the Federal Water Pollution Control Act of 1972.

[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]The secondary cooling-water discharge temperature during extreme summer meteorological conditions has been reduced to 73°C. This reduced temperature reflects reduced reactor operating power to compensate for increased temperatures in the cooling-water supply drawn from the Savannah River during the warmest summer months.

TC

fallen trees. Most of the scrub-shrub and willow-dominated communities would be eliminated. Between 310 and 420 acres of the delta and swamp vegetation would be lost. Riverine vegetation near the mouth of Steel Creek consists primarily of bottomland hardwood forests; emergent and submergent macrophytes are sparse or absent. Temperatures as high as 11°C above ambient for short periods of time probably would not impact these flora. Temperatures of 11°C or higher above ambient are expected to occur about 10 times a year; each occurrence is expected to last about 2.5 days.

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Flooding and siltation (from erosion of the stream bed and banks) associated with the thermal discharge at 11 cubic meters per second are expected to modify aquatic habitat in the Steel Creek floodplain and delta. The delta is expected to expand into the swamp at a maximum rate of about 3 acres per year. This growth rate was calculated using historic data (Ruby, Rinehart, and Reel, 1981) for the period when L-Reactor discharged 186-Basin and cooling-water effluents to Steel Creek. Wetland habitat is expected to be eliminated or modified at a rate of about 7 to 10 acres per year due to thermal discharge and its associated flooding, siltation (Smith et al., 1981), and fluctuating water

AW-3

levels. If the L-Reactor resumed operation with direct discharge, about 420 acres of the wetlands in the Steel Creek corridor and about 310 acres in the swamp area, or about 730 acres total, would be initially affected (reference case). The 1000 acres of eliminated habitat represent a conservative estimate of the wetlands that would be affected over a number of years of reactor operation. |TC

Wildlife

Except for backwater pools or other cool-water refuges, the high water temperatures from the outfall to the delta (resulting from direct discharge, the reference case) would make the section of Steel Creek below L-Reactor uninhabitable for amphibian eggs and larvae. Adult life forms might survive along the stream margins or relocate to adjacent habits.

Reptiles are more dependent on aquatic habitat for food (i.e., insects, fish, amphibians) and shelter than for reproduction. The elevated water temperature and the elimination of prey organisms would eliminate the habitats of semiaquatic snakes and turtles upstream from the delta and would cause a marked decrease in species richness. Portions of the delta might provide marginal habitat for water snakes and turtles following L-Reactor restart.

The endangered American alligator inhabits all parts of Steel Creek from the L-Reactor outfall to the cypress-tupelo forest adjacent to the Steel Creek delta; it also uses areas lateral to Steel Creek, including Carolina bays, backwater lagoons, and beaver ponds. The number of alligators inhabiting the Steel Creek area ranges during the year between 23 and 35 individuals. Telemetry studies showed that males had larger home ranges than juveniles and females; males sometimes moved from the delta into the Savannah River swamp. The release of cooling water from L-Reactor would eliminate alligator habitat in Steel Creek from the reactor outfall to the Savannah River, except for backwater pools or other cool-water refuges, by increasing the water temperature above physiologically tolerable limits, eliminating principal food sources, and possibly inundating nests and shallow-water wintering habitats (Smith et al., 1981, 1982). Red sore, a bacterium-caused disease that affects fish and reptiles, could become more prevalent with thermal loading and could affect the American alligator. Conditions conducive to the reproduction of this bacterium, however, are very specific (i.e., water temperature, pH, etc.).

L-Reactor startup would take several days. Adult alligators should be able to avoid heated areas and emigrate to suitable nearby habitats. During winter, alligators might seek the warmer effluent waters until temperatures again rise above acceptable limits in late spring and summer. Juveniles also would be expected to avoid thermal effluents, but these smaller alligators would have more difficulty relocating to suitable habitats and would be exposed to greater predation. A startup in late spring and summer could destroy both nests and eggs. Winter startup could be fatal to torpid individuals that overwinter in shallow-water areas along the creek and in the delta. The DOE has initiated the consultation process with the U.S. Fish and Wildlife Service to determine the needed mitigation measures in the event of a winter or spring startup.

The Savannah River swamp and Steel Creek delta provide an important regional sanctuary and refuge for waterfowl. Over 400 wood ducks and nearly 1200 mallards have been observed roosting and feeding in the Steel Creek delta.

Seven other species of waterfowl also use this area. The Steel Creek delta also provides important foraging habitat for the wood stork, a large wading bird that is listed as an endangered species (USDOI, 1984). A total of 102 birds was observed feeding in the Steel Creek delta in 1983. No wood stork nests occur on the SRP site. (DOE has initiated a consultation process with the U.S. Fish and Wildlife Service on the wood stork.) Thermal discharge would eliminate feeding and roosting habitat due to vegetative mortality and would adversely affect food sources such as fish because water temperatures would preclude their presence.

Semiaquatic mammals that would be affected by the thermal effluent include the beaver, river otter, mink, and muskrat. Adults should not experience mortality due to increased flow and temperature, but flooding during the breeding season could adversely affect the young. Except for the muskrat, these species are common throughout the Savannah River Plant.

Aquatic biota

The direct discharge of cooling-water effluent to Steel Creek (reference case) would eliminate most of the biota of the main channel from the L-Reactor outfall downstream to the delta. Populations of thermotolerant and thermophilic algae, such as blue-greens, would be expected to increase (Gibbons and Sharitz, 1974). These organisms thrive in areas where species more sensitive to elevated temperatures cannot compete. According to information on the SRP thermal streams (Four Mile Creek and Pen Branch), few higher organisms are likely to survive in the main-stream channel of Steel Creek. As the effluent moves away from the L-Reactor outfall, the temperature would decline and more organisms would occur, beginning with the most thermally tolerant (Du Pont, 1982b).

During thermal discharge, Steel Creek would not be suitable for fish of recreational or commercial importance; fish presently in Steel Creek would move to avoid heated effluents. In addition, the warmer waters of Steel Creek might prevent access to the floodplain swamp by fish from the river. Temperature tolerance data indicate that most, if not all, spawning activity could be eliminated by the thermal effluent; however, other similar spawning habitat is available in thermally unaffected areas on the Savannah River Plant and along the Savannah River. The most common fish remaining in the Steel Creek area probably would be the mosquitofish, although a few centrarchids might occur in backwater areas and tributary streams such as Meyers Branch (Cherry et al., 1976; Falke and Smith, 1974; Ferens and Murphy, 1974; McFarlane, 1976; McFarlane et al., 1978).

Although 2280 acres of the wetlands along Steel Creek above L-Area and along Meyers Branch above its confluence with Steel Creek would not receive direct thermal discharges, access to these areas by fish from the Savannah River will be restricted. The entrance to Boggy Gut Creek, an offsite tributary immediately downriver of Steel Creek, could be blocked by the thermal plume at times and fish access would be limited. Wetland areas of Boggy Gut total about 230 acres.

Thermal discharge to the Savannah River

Existing thermal discharges from the Savannah River Plant to the Savannah River include those from K-Reactor, which discharges to Steel Creek via Pen Branch, and C-Reactor and the D-Area powerhouse, which discharge to the Savannah

River via Four Mile Creek and Beaver Dam Creek, respectively. With the reference case, the resumption of L-Reactor operations would increase the thermal discharge to Steel Creek below its confluence with Pen Branch and increase the size of the thermal plume in the Savannah River.

Thermal plume. Since 1968 (K-Reactor operating and L-Reactor on standby), the discharge to the Savannah River from Steel Creek has been about 15.6 cubic meters per second at temperatures typically less than 5.6°C above ambient river temperature (Du Pont, 1982b). Judging from previous operating experience, the discharge with both K- and L-Reactors operating should increase to about 27.4 cubic meters per second; during the warmer months, the creek-to-river delta-T should average about 7.2°C.

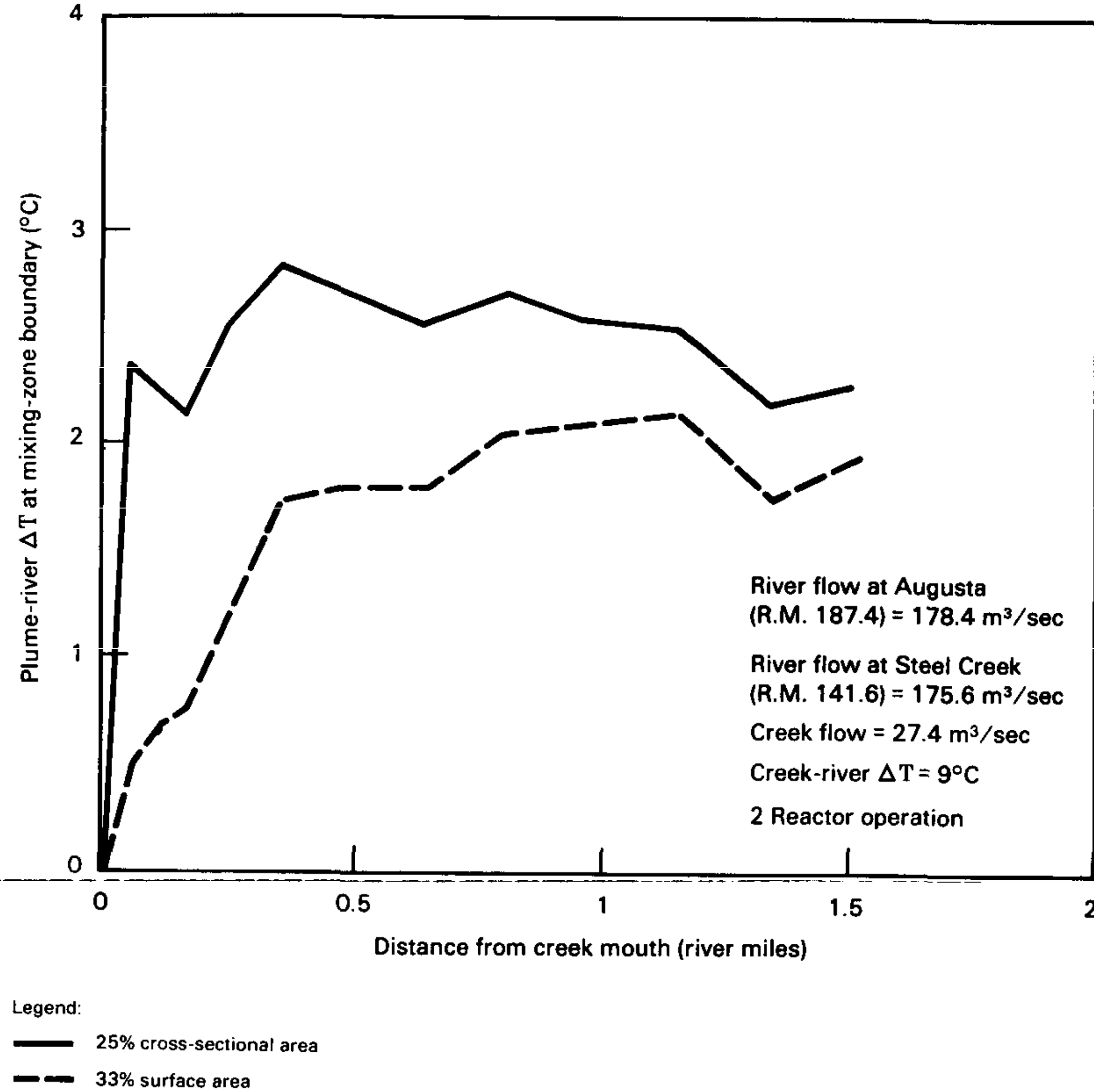
The thermal plume from Steel Creek would remain on the South Carolina side of the Savannah River until it becomes completely mixed with the river water, typically about 1.5 river miles (2.4 kilometers) downstream from the mouth of the Steel Creek (Du Pont, 1983b). Thus, a zone of passage for anadromous fish would exist in the river.

Computer simulations were used to predict the temperature in the Steel Creek thermal plume and at the point of entry into the Savannah River to the point of complete mixing of the plume with river water, about 1.5 river miles downstream from the mouth of the Steel Creek (Du Pont, 1983b). Figure 4-3 shows the results of this modeling for a river flow of 175.6 cubic meters per second at the mouth of Steel Creek that, with two reactors operating, corresponds to a flow of 178.4 cubic meters per second at Augusta (River Mile 187.4). A flow of at least 178.4 cubic meters per second is maintained 80 percent of the time at Augusta by the Army Corps of Engineers (see Section 3.4.1). Under the conditions shown in Figure 4-3, a creek-to-river delta-T greater than 9°C would be required to exceed a 2.8°C temperature difference across a mixing zone boundary in the river defined by 25 percent of the cross-sectional area of the river (see the upper, solid curve). The lower, dashed curve represents the temperature difference along a 33-percent surface-area mixing zone boundary.

Figure 4-4 is a compilation of the modeling results discussed above. The upper (solid) curve represents the calculated creek-to-river delta-T for corresponding river flows and only L-Reactor discharging to Steel Creek. Similarly, the lower (dashed) curve represents the case when the thermal effluent from both K- and L-Reactors is discharged through the mouth of Steel Creek.

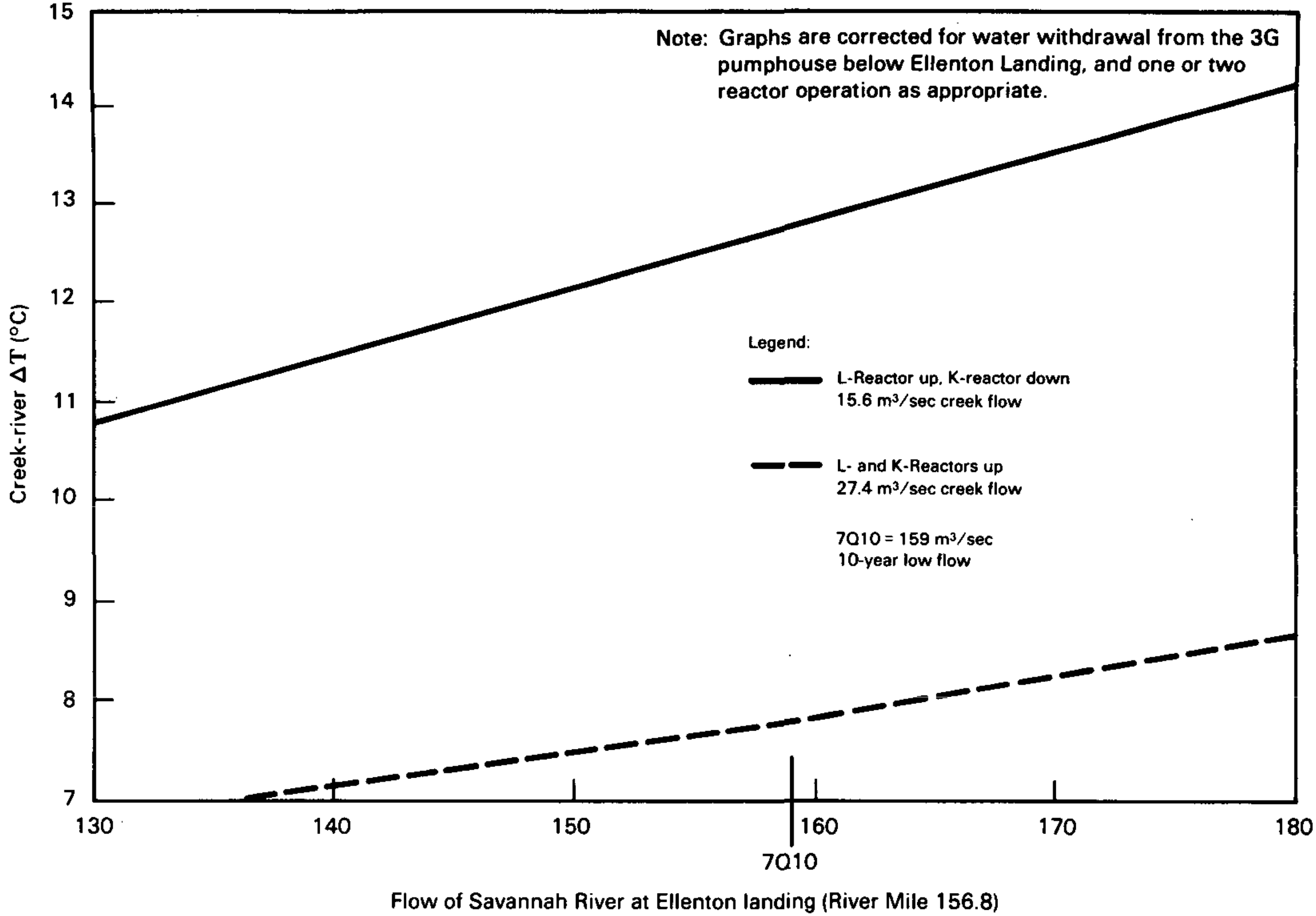
The temperature increase of the Savannah River would depend on several factors: the time of the year, flow rates of the river, and SRP operating conditions. Table 4-4 lists the projected increases in water temperature from L-Reactor during August as a function of flow with three reactors discharging to the river.

Computer simulations also show that the mouth of Boggy Gut Branch would be affected by the L-Reactor thermal plume. These effects for the spawning months of February through June are shown in Figure 4-5; the computed temperature at the mouth of Boggy Gut Branch is plotted for the case of both K- and L-Reactors discharging through the mouth of Steel Creek and a river flow of 320 cubic meters per second. This river flow, which is 82 percent of the average flow during the 5-month spawning season (Figure 3-6), was chosen to reflect lower



Adapted from Du Pont (1982b).

Figure 4-3. Temperature difference across mixing-zone boundary with distance down Savannah River below the mouth of Steel Creek (K- and L-Reactor operating).



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Adapted from Du Pont (1982b).

Figure 4-4. Calculated creek-to-river delta-T(°C) to maintain a plume-to-river delta-T of no more than 2.8°C at a mixing-zone boundary defined by a 25-percent cross-sectional area and 33 percent of the surface area of the Savannah River.

Table 4-4. Projected L-Reactor contribution to the mixed river temperature increase during August[a]

Savannah River flow at Ellenton Landing (m^3/sec)	L-Reactor contribution to river temperature increase (°C)	Description of flow at Ellenton Landing
159.0	0.70	7-day, 10-year low flow
179.4	0.67	Mean for annual 7-day low flows, 1964-1983
295.0	0.45	Long-term average flow

[a]Adapted from Du Pont (1982b).

flows that might occur as the result of the filling of Russell Dam (Section 3.4.1) and lower flows during periods of drought. Two temperature curves are plotted for the mouth of Boggy Gut Branch, one for a Steel Creek-to-river delta-T of 7.2°C (average) and another for a delta-T of 11.1°C (24 events per year with a 2.5-day duration on the average). Figure 4-5 also shows the monthly average maximum river temperature measured daily at Ellenton Landing.

Ecological impacts. Direct discharge would produce a thermal impact on the Savannah River only near the mouth of Steel Creek. Downriver from the confluence of Steel Creek with the river, no adverse impacts to reptiles, birds, or mammals that inhabit the river's riparian habitats are expected.

The temperatures near the mouth of Steel Creek could be high enough to exclude the creek and its floodplain as potential spawning areas for riverine and anadromous fish such as the blueback herring during the spawning season. However, temperature measurements in the river (Du Pont, 1982b) and thermal modeling indicate that the thermal plume would remain close enough to the South Carolina shore to permit a zone of passage for migrating fish such as American shad, blueback herring, striped bass, and Atlantic and shortnose sturgeon (Du Pont, 1982b).

Studies were conducted by the Academy of Natural Sciences of Philadelphia (ANSP, 1953, 1957, 1961, 1967, 1970, 1977) to monitor the effects of SRP operations on the general health of the Savannah River. ANSP studies (Matthews, 1982) indicate that no major changes in the presence of species have occurred from past Savannah River operations at their stations or are expected to occur from the addition of heat and cooling water from L-Reactor.

4.1.1.5 Wastewater discharges

Liquid effluent discharges to Steel Creek

Liquid effluent from L-Area would have chemical compositions that are similar to those from other SRP reactor areas. The L-Area effluent streams and their approximate annual flow rates are listed in Table 4-5.

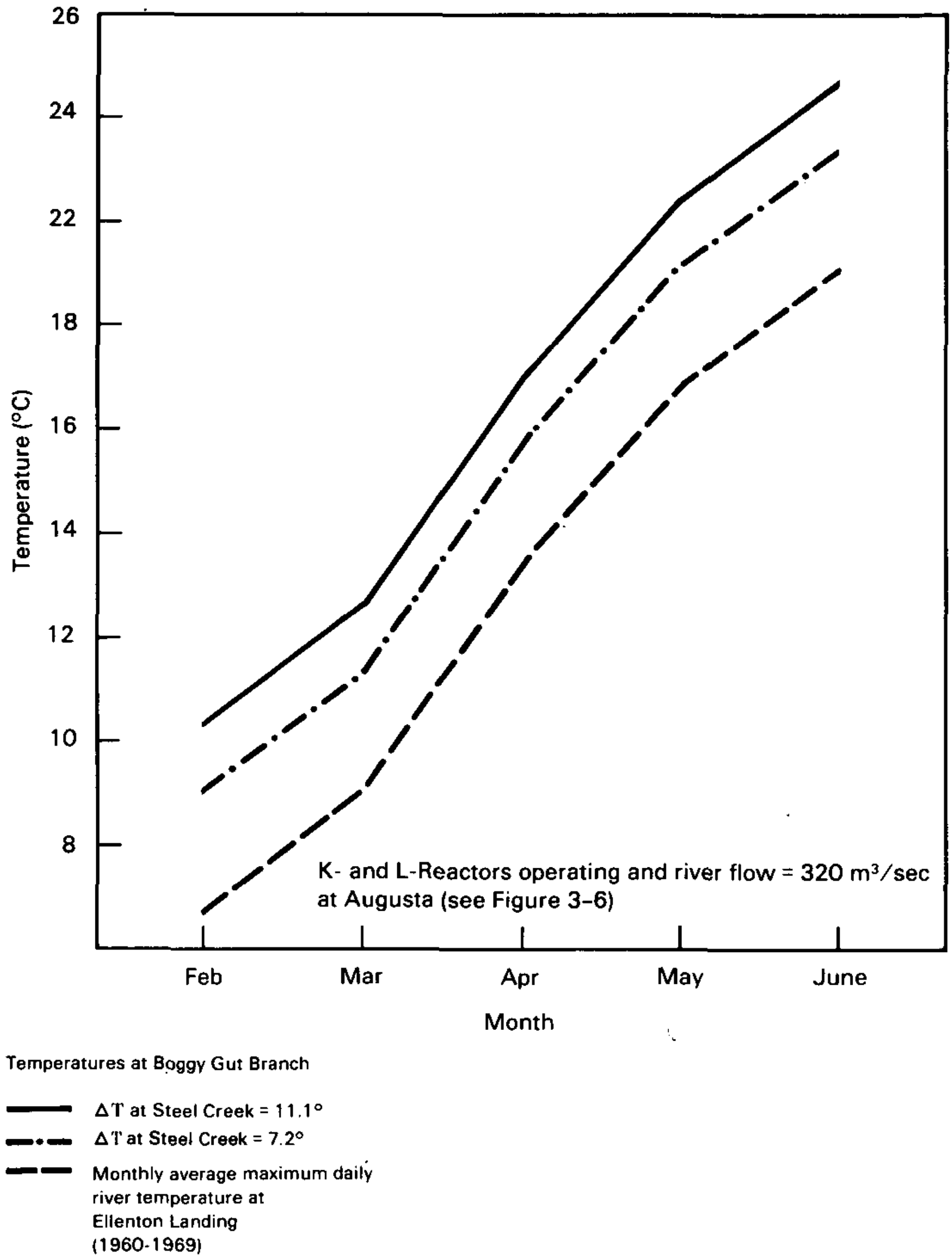

Figure 4-5. Temperatures at Boggy Gut Branch during the spawning season.

Table 4-5. Sources of effluent streams to Steel Creek from L-Area[a]

Effluent stream sources	Approximate annual flow rate (m^3)
Cooling water, process water, cooling reservoir, sanitary wastewater	3.4×10^8
Heating/cooling, offices	1.4×10^4
Water treatment plant	2.6×10^5
Cooling water for engine building	1.6×10^6

[a]Adapted from Du Pont (1982b).

With the reference case, some of the chemicals discharged through these outfalls to Steel Creek would originate from the Savannah River water pumped through the reactor secondary cooling system. Table 4-6 lists estimated L-Area liquid effluent chemical loads and compares them with the corresponding water quality or drinking-water standard and with concentrations measured in Steel Creek and in the Savannah River above and below the Savannah River Plant. Available measurements from the Savannah River (Table 4-6; Marter, 1970; Matthews, 1982) indicate little variation in measured quantities between upstream and downstream locations from present SRP operations; L-Reactor operation would not be expected to alter this situation significantly. Because of the high cooling-water flow rates to Steel Creek, most chemical contaminants would be expected to be transported through the swamp into the Savannah River, although flocculated suspended sediments would be expected to settle and accumulate in the swamp. No significant impact on swamp-water quality would be expected.

Sanitary discharges

Sanitary wastewater would be chlorinated at a packaged treatment plant and discharged through the L-Reactor area wastewater sewer to Steel Creek. The sanitary wastewater-treatment plant is designed for a maximum flow of 132 cubic meters per day. The treatment-plant size was selected to be adequate for the expected operating work force. The discharge would meet NPDES permit (Du Pont, 1981a) requirements and would have no major impact on Steel Creek (Du Pont, 1982b). Sewage sludge would be transported to an existing basin near the Central Shops. Samples of sludge from similar treatment facilities indicate that it is not hazardous (Du Pont, 1982b).

Cooling-water reservoir (186-Basin)

The 95-million-liter cooling-water processing basin (186-Basin) is cleaned annually during periods of reactor shutdown to remove accumulated solids. About 110 metric tons of the 5530 metric tons of suspended solids that would enter the 186-Basin annually are expected to be deposited in the basin. This sediment would be flushed to Steel Creek over a period of several days. During flushing, the suspended solids concentrations in the effluent would be about 60 to 160 parts per million. This operation, which requires a variance from NPDES permit

Table 4-6. Comparison of L-Area effluents with water-quality standards and Savannah River and Steel Creek measurements

Constituent[a]	Water quality/ drinking water standard[b]	Savannah River (3.6 km above SRP) 1982 avg[c]	Projected L-Area effluent[d]	Steel Creek (Road A) 1982 avg[c]	Savannah River (16 km below SRP) 1982 avg[c]
pH (no units)	6.5-8.5 (S)	6.2-7.0	6.4-7.1	6.4-7.8	6.4-7.1
Dissolved oxygen (DO)	>4 (WQS)	9.4	+[e]	8.6	9.3
Total suspended solids (TSS)	<50 (WQS)	10	17.6	7.8	12
Total dissolved solids (TDS)	<500 (S)	67	+	55	67
Biological oxygen demand (BOD)	--[f]	1.9	5.1	+	1.9
Chemical oxygen demand (COD)	--	+	20.6	13	+
Ammonia (NH_3)	--	0.2	0.84	0.02	0.1
Chloride (Cl)	<250 (S)	6.1	6.2	5.6	5.3
Sulfite/sulfate - S (SO_3/SO_4)	<250 (S)	7.6	12.1	3.7	7.2
Nitrite/nitrate - N (NO_2/NO_3)	<10 (P)	0.52	0.68	0.14	0.51
Total phosphate (PO_4)	--	0.19	0.19	<0.03	0.18
Surfactants	<0.5 (S)	+	0.09	+	+
Oil and grease	--	+	6.4	+	+
Calcium (Ca)	--	3.8	+	4.9	3.7
Sodium (Na)	--	10	7.4	4.7	9.5
Fluoride (F)	1.4-2.4 (S)	+	+	+	+
Aluminum (Al)	--	1.3	1.4	<0.85	1.0
Iron (Fe)	<0.3 (S)	0.58	0.98	0.43	0.1
Magnesium (Mg)	--	+	0.12	+	+
Molybdenum (Mo)	--	+	0.01	+	+
Manganese (Mn)	<0.05 (S)	+	0.05	+	+
Cadmium (Cd)	<0.01 (P)	+	<0.003	+	+
Chromium (Cr)	<0.05 (P)	+	<0.04	+	+
Copper (Cu)	<1 (S)	+	<0.01	+	+

Table 4-6. Comparison of L-Area effluents with water-quality standards and Savannah River and Steel Creek measurements (continued)

Constituent[a]	Water quality/ drinking water standard[b]	Savannah River (3.6 km above SRP) 1982 avg[c]	Projected L-Area effluent[d]	Steek Creek (Road A) 1982 avg[c]	Savannah River (16 km below SRP) 1982 avg[c]
Lead (Pb)	<0.05 (P)	+	0.001	<0.05	+
Mercury (Hg)	<0.002 (P)	+	2.9×10^{-4}	+	+
Nickel (Ni)	<0.13 (WQS)	+	<0.03	+	+
Selenium (Se)	<0.01 (P)	+	0.004	+	+
Silver (Aq)	<0.05 (P)	+	4×10^{-4}	+	+
Zinc (Zn)	<5 (S)	+	0.07	+	+
$^{t}{}_{,i}$ BHC	$<9.2 \times 10^{-6}$ (WQS)	+	2.2×10^{-7}	+	+
Cyanide (CN)	<0.02 (WQS)	+	<0.02	+	+
Benzenze	<0.007 (WQS)	+	<0.002	+	+
Chloroform	<0.002 (WQS)	+	<0.001	+	+
Bis (2 chloro- isopropyl) ether	<34.7 (WQS)	+	0.002	+	+
Heptachlor	$<2.8 \times 10^{-6}$ (WQS)	+	4.4×10^{-8}	+	+
Total phenol	<3.5 (WQS)	+	<0.002	+	+
Methylene chloride	--	+	<0.001	+	+
Pthalates	<15 (WQS)	+	<0.001	+	+
Tetrachloro- ethylene	<0.0002 (WQS)	+	1.3×10^{-5}	+	+
Trichloroethane	<18.4 (WQS)	+	<0.001	+	+
Toluene	<14.3 (WQS)	+	0.001	+	+

[a]All concentrations expressed as milligrams per liter unless otherwise noted. The L-Area effluent, which will be discharged at a rate of about 11 cubic meters per second, will be diluted on reaching the Savannah River, which has a 7-day, 10-year low flow of 159 cubic meters per second and an average flow of 295 cubic meters per second.

[b](P) = 40 CFR Part 141; (S) = 40 CFR Part 143; (WQS) = Water Quality Standards--Federal Register, Part V, Vol. 45, No. 231, 28 November 1980.

[c]Du Pont (1983c).

[d]Du Pont (1982b).

[e]+ = No data.

[f]-- = No standard.

limits, is a continuation of current practice. It has been performed many times at the other reactors with no evidence of detrimental impact. Most of the suspended solids released from the 186-Basin would settle in the streambed before reaching the swamp (Kiser, 1977; Geisy and Briese, 1978; Du Pont, 1981a; Ruby et al., 1981). When L-Reactor discharges resume (about 11 cubic meters per second), the resuspension of some of this settled sediment could contribute a small amount of material to the delta, which is expected to grow at a rate of about 3 acres per year with direct discharge (reference case).

4.1.1.6 Atmospheric releases

Nonradiological pollutants emitted into the atmosphere as a direct result of the operation of L-Reactor would come primarily from the K-Area coal-fired steam plant and the diesel generators at the L-Area.

The steam demands for L-Reactor would require an additional 6400 metric tons of coal to be burned annually at the K-Area steam plant. Emissions of particulates, sulfur oxides, nitrogen oxides, carbon monoxide, and volatile organic compounds from the steam plant would increase 15 percent, as illustrated in Table 4-7. This facility was constructed before 1975. No modifications are required; therefore, existing permits allow the production of additional power. TC

Fourteen emergency diesel generators are located in L-Area; six would operate continuously. The estimated annual diesel fuel consumption rate is 940 cubic meters for all generators. The emissions from these generators are listed in Table 4-7.

The operation of the L-Reactor would not violate any ambient air quality standard.

4.1.1.7 Solid wastes

Solid nonradioactive wastes generated by the resumption of L-Reactor operation would consist of trash and sanitary waste sludge. Trash would be generated at a rate comparable to those experienced by other SRP reactors; it would be disposed of in the SRP sanitary landfill. This landfill will be expanded from about 0.04 to 0.13 square kilometer. This expansion, which will occur in any event, ensures an adequate capacity for SRP operation, including L-Reactor, for many years (Du Pont, 1982b). Ten wells monitor the effluent from the landfill to the ground water of the McBean Formation. Quarterly analyses of water from these wells have shown little impact on the McBean ground water.

Periodically, treated sludge would be pumped from the sanitary waste treatment plant sludge holding tank to a mobile tank and transported to the sludge pit near the Central Shops area. Approximately 48,000 liters (50 percent water) of the sludge from L-Area would be disposed of in the sludge pit annually. No impact is expected on the operation of the sludge pit.

Table 4-7. Air pollutant emissions from K-Area steam plant and from sources supporting L-Reactor operation

Pollutant	Annual emissions[a] K-Area steam plant (metric tons/yr)	Incremented annual emissions[b] projected 1984 to support additional steam to L-Reactor (metric tons/yr)	Annual emissions[c] diesel generators at L-Reactor area (metric tons/yr)
Particulate matter	187	28	4
Sulfur oxides	870	130	4
Nitrogen oxides	345	52	59
Carbon monoxides	46	7	
Volatile organic compounds	23	4	

[a]Based on present coal consumptions of 46,400 metric tons per year.
[b]Based on 6400 metric tons per year coal consumption.
[c]Based on burning 940 cubic meters diesel per year.

4.1.1.8 Noise

During the normal operation of L-Reactor, external noise levels would primarily be those associated with the movement of motor vehicles; they would be well within acceptable levels in the area. At the nearest offsite residence, about 10 kilometers away, noise from normal operations would not be detectable. Inside buildings, operators exposed to noise from machinery and other operating equipment would wear protective equipment in accordance with SRP standards and regulations of the U.S. Occupational Safety and Health Administration. TC

4.1.2 Radiological impacts of L-Reactor operation

The operation of L-Reactor would have radiological impacts similar to those of the currently operating SRP reactors. The net effect would be about a one-third increase in the release of radioactive materials to the environment, in the total occupational dose of SRP workers, and in the amount of radioactive waste to be disposed of in the high-level waste tanks and in the low-level waste burial ground. This section characterizes these radiological impacts due to the normal operation of L-Reactor only under the reference case (direct discharge of cooling water to Steel Creek). Radiological impacts due to SRP facilities that would support L-Reactor are addressed in Section 5.1.2. Appendix B describes dose calculation models and basic assumptions.

Figure 4-6 shows potential pathways for radiation exposures to man from radionuclides released from a nuclear facility. External doses result from exposure to airborne effluents, from swimming and other recreational activities, and from exposure to ground deposition of radionuclides. There are no known users of Savannah River water for irrigation downstream from SRP (Section 3.4.1.3); contaminants that might reach the ground water beneath SRP will not reach offsite sources that are used for irrigation (Section 5.1.1.2; Appendix F, Figures F-25 and F-26). Internal doses result from the inhalation of airborne effluents and the ingestion of food and water that contain radionuclides. DA-17

4.1.2.1 Atmospheric releases of radioactivity

Radioactive materials would be released to the atmosphere during L-Reactor operation from three release points: (1) from the 61-meter stack, which would discharge most of the gaseous effluents generated in reactor-building operation, (2) at ground level from evaporation of water from the fuel and target disassembly basin, and (3) at ground level from evaporation of water from the L-Area seepage basin. The releases from the stack would consist of radionuclide gases that enter the reactor ventilation system from the evaporation of process water, from the pressurized reactor blanket gas system, and from the air space between the reactor and the thermal shield.

Tritium releases would increase as the tritium content of reactor process water builds up to equilibrium. Table 4-8 lists the expected first- and tenth-year (equilibrium) atmospheric releases from normal L-Reactor operation (Du Pont, 1982b). The values are based on annual releases from P-, K-, and C-Reactor operations for 1978, 1979, and 1980; however, the values for tritium

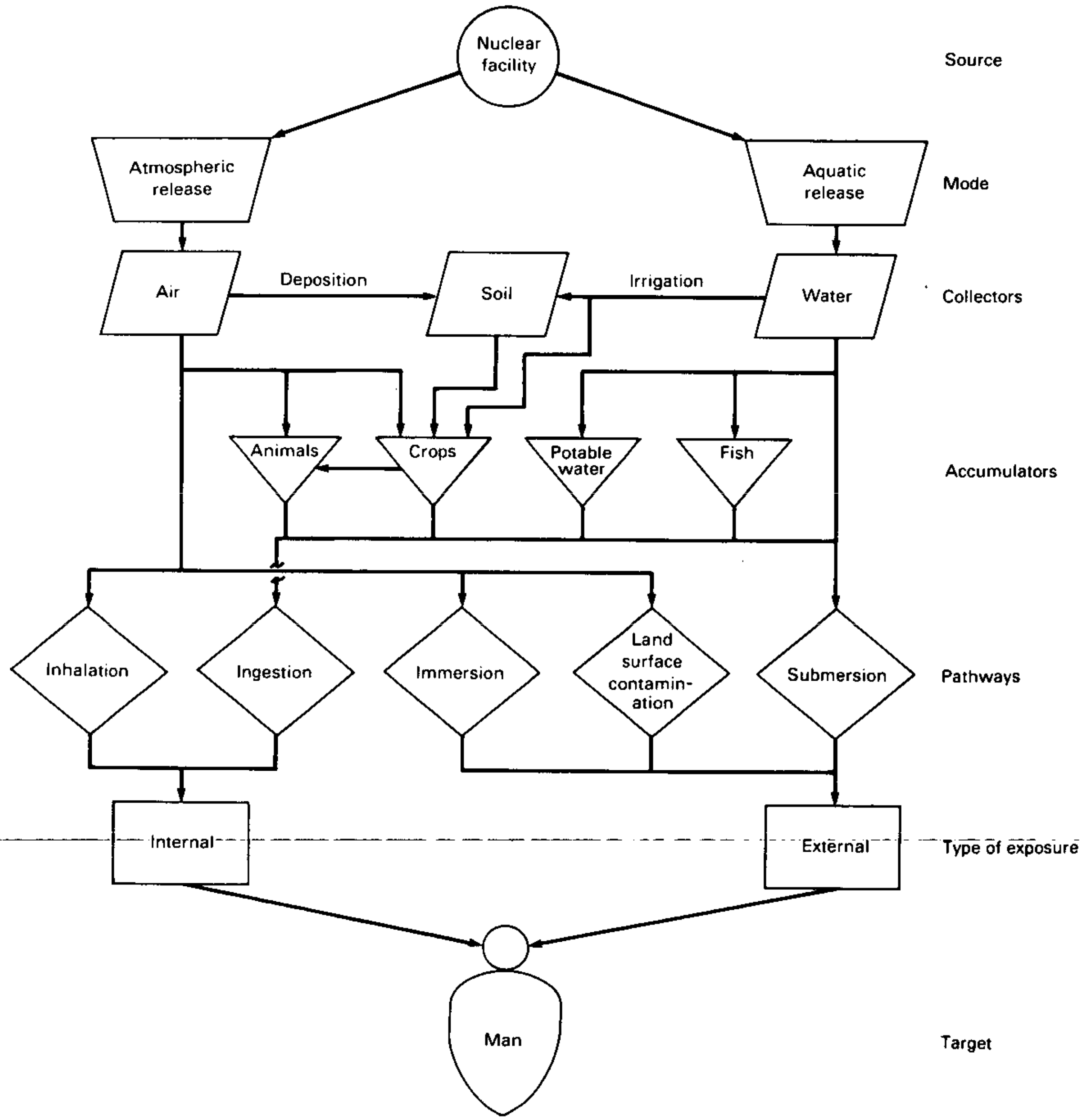

Figure 4-6. Assessment methodology used to calculate radiological impact on man.

Table 4-8. Expected annual atmospheric releases from L-Reactor operation[a] (curies per year)

Radionuclide	1st-year operation	10th-year operation
H-3[b]	5,490	54,900
C-14	12	12
Ar-41	19,500	19,500
Kr-85m	600	600
Kr-87	540	540
Kr-88	790	790
I-131	0.00414	0.00414
Xe-133	1,700	1,700
Xe-135	1,400	1,400
Unidentified beta-gamma[c]	0.0002	0.0002
Unidentified alpha[d]	0.000001	0.000001

[a]The expected annual average concentrations at the SRP site boundary would be well within the DOE concentration guides for uncontrolled areas (DOE, 1981b).

[b]Includes evaporative losses at ground level from the disassembly basin and the seepage basin.

[c]Assumed to be strontium-90.

[d]Assumed to be plutonium-239.

evaporation from the disassembly basin and for tritium from the seepage basin have been adjusted for more frequent target discharges expected at L-Reactor.

4.1.2.2 Wastewater discharges of radioactivity

During normal operations, radioactive materials would be discharged in liquid effluents from L-Reactor to Steel Creek as a result of small process-water leaks into the cooling water in the reactor heat exchangers, and by releases into the process sewer. Liquids (as much as 1890 cubic meters) would also be discharged about twice a year from the disassembly basin to the L-Reactor seepage basin (Figure 3-10). This purge of water would be necessary to keep the tritium concentration in the disassembly basin water below the level that ensures safe working conditions. The water in the disassembly basin would become contaminated when fuel and target assemblies are discharged from the reactor; some tritium and other radionuclides would be carried over in the process water adhering to the assemblies, and some as tritiated heavy water (DTO) contained as water of hydration in aluminum oxide on the assemblies. The disassembly basin water would be filtered, deionized, and monitored before it is discharged. The amount of tritium discharged in liquid effluents from L-Reactor would gradually

TC

increase with time as the tritium content of process water increases from neutron activation. After about 10 years of operation, the tritium content of process water would reach equilibrium (i.e., amount of new tritium produced equals amount lost through radioactive decay, leakage, and carryover and discharge operations) and remain relatively constant with continued reactor operation.

The migration of the discharged liquid in a shallow aquifer from the seepage basin to the outcrop along Steel Creek would allow the tritium to partially decay before being discharged to the creek. Only local and minor changes in watertable elevations are expected. The green clay and important confining clays in underlying formations would prevent releases to the seepage basin from impacting the upward head differential between the Tuscaloosa and Congaree Formations. It would also be an important barrier to the migration of contaminants from the seepage basin 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
AW-1, DA-8 DA-18 [well 35-D (Figure F-34)], the green clay has effectively protected the Congaree ground water from contamination that enters the shallow ground-water system from the H-Area seepage basins (Marine, 1965). Water samples obtained in February 1984 from Well 35-D confirm the absence of tritium contamination in Congaree ground water. In the L-Area, the green clay is about 7 meters thick. Along the strike at the Par Pond pumphouse well (Figure F-13), the green clay also supports a large head difference. The water pumped from the Congaree Formation at the Par Pond pumphouse shows no evidence of tritium contamination, even though the tritium concentration in this lake was 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).

These discharges to a seepage basin would cause contamination of the uppermost layer of the water-table aquifer (Barnwell Formation). Subsurface contaminant migration is controlled by the rate and direction of ground-water flow, the absorptive capabilities of the sediments, and hydrodynamic dispersion. The sediments of the Savannah River Plant exhibit greater horizontal than vertical hydraulic conductivities, enhancing lateral movement (Root, 1983). Analyses indicate that the filtered and deionized disassembly-basin wastewater, after its discharge to the L-Reactor seepage basin, would seep into the shallow ground water and flow laterally to seepline springs along Steel Creek. The upward head differential between the Tuscaloosa and Congaree Formations at L-Area is presently about 3.7 meters (Figure 3-9; Section 3.4.2.1), except near the production wells, where the differential becomes 0.9 meter downward at 0.3 meter from
AW-1, DA-8 the centers of the cones of depression; current projections call for the continued presence of an upward differential for 10 or more years after L-Reactor operation resumes. This head differential and the clay layers beneath L-Area would tend to protect the Tuscaloosa Aquifer (see Section 4.1.1.3). The SRP has discharged contaminated wastewater to seepage basins in the central part of the Plant site since the mid-1950s. To date, no contamination of the Tuscaloosa Aquifer has occurred in this area (Ashley and Zeigler, 1981; Marine, 1965). Contaminants that might reach the Congaree or Tuscaloosa would be discharged to the Savannah River in about 76 or 250 years, respectively, as noted in Sections 4.1.1.3 and F.2.3.2, and in Du Pont (1983h).

Amounts of radioactive materials that reach the outcrop area on Steel Creek were calculated as a function of time, considering ground-water travel time from the seepage basin area to Steel Creek (4.4 years), radionuclide retardation by ion exchange, and radioactive decay (Du Pont, 1982b; also see Appendix B). However, based on a travel path of 490 meters, a gradient of 1.88 percent, and a ground-water velocity of 14.5 meters per year per percent gradient, a more realistic travel-time estimate is 18 years (Root, 1983; also see Table F-1).

Ashley, Zeigler, and Culp (1982) also considered the radioactive material released to the seepage basin during previous L-Reactor operations. Isotopes that are highly mobile (e.g., tritium, rubidium-106, and promethium-147) will already have left the area (in accordance with the ground-water travel time of 4.4 years and the fact that the previous radioactive releases to the seepage stopped in 1969). Other discharged isotopes (e.g., cobalt-60, strontium-90, and cesium-137), which are almost immobile, will result in negligible doses because they decay almost completely before they exit at the outcrop. EN-44

Table 4-9 shows expected annual liquid releases from L-Reactor operation for the first year and after the tenth year of operation (Du Pont, 1982b). The direct releases to Steel Creek and to the seepage basin are based on average annual releases from P-, K-, and C-Reactors during 1978, 1979, and 1980, but have been adjusted upward for the more frequent assembly discharges expected from L-Reactor operation. As noted in the table, 30 percent of the tritium discharged to the seepage basin is expected to be released to the atmosphere by evaporation. The expected average annual concentrations of radionuclides at the Steel Creek mouth are calculated to be well within the DOE concentration guides for uncontrolled areas (DOE, 1981b).

4.1.2.3 Dose commitments from releases from L-Reactor operation

Maximum individual dose from atmospheric releases. The individual who would receive the highest dose from atmospheric releases from L-Reactor was assumed to reside continuously at the SRP boundary about 12 kilometers from the reactor. The selection of the location of maximum potential dose was based on considerations of distance to the plant boundary, releases to the atmosphere, and meteorological dispersion characteristics.

The maximum total-body dose to an individual (a child) was calculated to range from 0.062 to 0.29 millirem in the first and tenth year, respectively (Table 4-10). These doses are only 0.067 and 0.31 percent, respectively, of the average dose of 93 millirem (Du Pont, 1982b) received by an individual living near the SRP site from natural radiation. More detailed dose data by age groups, organs, and exposure pathways are given in Appendix B.

Population dose from atmospheric releases. The total-body dose to the population of 852,000 (projected for year 2000) who would be living within 80 kilometers of the Savannah River Plant was calculated to range from 3.0 to 13.5 person-rem in the first and tenth year, respectively. More detailed dose data by age groups, organs, and exposure pathways are given in Appendix B.

Table 4-9. Expected average annual liquid radioactive releases from L-Reactor operation (curies per year)

Radionuclide	1st year of operation: To Steel Creek	1st year of operation: To seepage basin	1st year of operation: To Steel Creek from ground water[a]	1st year of operation: Total to Steel Creek	10th year of operation: To Steel Creek	10th year of operation: To seepage basin	10th year of operation: To Steel Creek from ground water[b]	10th year of operation: Total to Steel Creek
H-3	3.6×10^{2}	[c]1.1×10^{3}	--	3.6×10^{2}	3.6×10^{3}	[c]1.1×10^{4}	6.0×10^{3}	9.6×10^{3}
P-32	--	1.2×10^{-3}	--	--	--	1.2×10^{-3}	--	--
S-35	--	9.5×10^{-3}	--	--	--	9.5×10^{-3}	2.9×10^{-8}	2.9×10^{-8}
Cr-51	--	1.8×10^{-1}	--	--	--	1.8×10^{-1}	--	--
Co-58,60	4.5×10^{-2}	3.7×10^{-4}	--	4.5×10^{-2}	4.5×10^{-2}	3.7×10^{-4}	2.1×10^{-4}	4.5×10^{-2}
Sr-89	--	7.0×10^{-5}	--	--	--	7.0×10^{-5}	--	--
Sr-90	1.6×10^{-4}	2.0×10^{-4}	--	1.6×10^{-4}	1.6×10^{-4}	2.0×10^{-4}	--	1.6×10^{-4}
Y-91	--	5.1×10^{-3}	--	--	--	5.1×10^{-3}	--	--
Zr-95	--	1.1×10^{-2}	--	--	--	1.1×10^{-2}	--	--
Ru-106	--	3.4×10^{-4}	--	--	--	3.4×10^{-4}	1.7×10^{-5}	1.7×10^{-5}
Sb-125	--	8.0×10^{-3}	--	--	--	8.0×10^{-3}	2.6×10^{-3}	2.6×10^{-3}
I-131	--	6.9×10^{-3}	--	--	--	6.9×10^{-3}	--	--
Cs-134	--	5.1×10^{-3}	--	--	--	5.1×10^{-3}	--	--
Cs-137	4.1×10^{-4}	4.4×10^{-2}	--	4.1×10^{-4}	4.1×10^{-4}	4.4×10^{-2}	--	4.1×10^{-4}
Ce-144	--	1.9×10^{-2}	--	--	--	1.9×10^{-2}	3.8×10^{-4}	3.8×10^{-4}
Pm-147	--	2.8×10^{-3}	--	--	--	2.8×10^{-3}	8.8×10^{-4}	8.8×10^{-4}
Unidentified beta-gamma[d]	1.1×10^{-1}	8.9×10^{-2}	--	1.1×10^{-1}	1.1×10^{-1}	8.9×10^{-2}	--	1.1×10^{-1}
Unidentified alpha[e]	2.0×10^{-5}	3.2×10^{-4}	--	2.0×10^{-5}	2.0×10^{-5}	3.2×10^{-4}	--	2.0×10^{-5}

[a]Outcrop activities will not occur during the first 4 years of reactor operation; see Table B-19 and Section F.2.10. TC

[b]Outcrop activities after 15 years of L-Reactor operation. Due to long transport times in ground water, strontium-90, cesium-134, cesium-137, and plutonium-239 do not reach outcrop in the 15-year period.

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

[d]Assumed to be strontium-90.

[e]Assumed to be plutonium-239.

Table 4-10. Annual total-body dose to maximally exposed individual from atmospheric releases from L-Reactor (millirem per year)

Age group	1st year	10th year
Adult	0.052	0.21
Teen	0.054	0.23
Child	0.062	0.29
Infant	0.051	0.16

Maximum individual dose from liquid releases. The individual who would receive the highest dose from liquid effluents from L-Reactor operation is assumed to live near the Savannah River, downstream from the Savannah River Plant. This individual is assumed to use river water regularly for drinking, to consume fish from the river, and to receive external exposures from shoreline activities, swimming, and boating. This individual is also assumed to drink more water and eat more fish than an average person.

Total-body doses to the various age groups for the maximally exposed individual are shown in Table 4-11. Detailed dose tables by age groups, organs, and exposure pathways are presented in Appendix B. Generally, children would receive the highest dose, ranging from 0.0094 millirem in the first year to 0.11 millirem in the tenth year. More than 75 percent of these doses would be from drinking water; most of the remainder would be from fish consumption. The highest calculated organ dose would be about 0.26 millirem to the child's bone in both the first and tenth year of L-Reactor operation.

Table 4-11. Annual total-body dose to maximally exposed individual from liquid releases from L-Reactor (millirem per year)

Age group	1st year	10th year
Adult	0.0072	0.087
Teen	0.0056	0.062
Child	0.0094	0.11
Infant	0.0062	0.11

Population dose from liquid releases. Savannah River water is not used for drinking within 80 kilometers of Savannah River Plant; therefore the dose to the population in this area would come from eating fish and shellfish, from shoreline activities, and from swimming and boating.

The total-body dose to the population of 852,000 estimated to be living within 80 kilometers of the Savannah River Plant in the year 2000 was calculated to range from 0.0088 to 0.018 person-rem in the first and tenth year, respectively (Table 4-12). About 90 percent of this dose would be from the consumption of fish.

DA-20 Table 4-12. Population total-body doses (100-year dose equivalents) from liquid releases from L-Reactor operation (person-rem per year)

Population group	1st year	10th year
80-km radius	0.0088	0.018
Beaufort-Jasper	0.29	5.0
Port Wentworth	0.46	8.2
Total	0.76	13.2

The Beaufort-Jasper and Port Wentworth population groups use the Savannah River as a source of potable water. While these groups are beyond the 80-kilometer radius of the Savannah River Plant (about 100 river miles downstream), the drinking-water doses have been calculated. The total-body dose delivered to these populations (about 317,000 people are expected to consume water from the Beaufort-Jackson and Port Wentworth water treatment plants by the year 2000) from drinking water was calculated to range from 0.75 to 13 person-rem in the first and tenth year of operation, respectively (Table 4-12). These doses would be about 0.0025 and 0.044 percent, respectively, of the exposure of about 29,500 TC person-rem to these populations received from natural radiation. Approximately 65 percent of the drinking-water dose would be from tritium in the first year of operation, increasing to greater than 95 percent in the tenth year. More detailed dose data by age groups, by organs, and by exposure pathways are given in Appendix B.

4.1.2.4 Cesium-137 and cobalt-60 redistribution dose commitment

As shown by Table 4-9, resumption of L-Reactor operation would add only small amounts of radionuclides to Steel Creek. However, the reactivation would transport a portion of the cesium-137 and cobalt-60 inventories that remain in the Steel Creek channel and floodplain.

The amount of cesium-137 and cobalt-60 transported from Steel Creek to the Savannah River and to the offsite Creek Plantation Swamp as the result of L-Reactor operation with the direct discharge of cooling water to Steel Creek (reference case) was calculated using empirical models based on monitoring in 1976 and 1982 of sediment and cesium-137/cobalt-60 transport in Steel Creek and on the historic flooding record for the swamp (Du Pont, 1982a, 1983a; Langley and Marter, 1973; Appendix D).

The total (both suspended solid and dissolved fraction) amount of radiocesium estimated to be remobilized and transported from Steel Creek during the first year of resumed L-Reactor operation would be 4.4 ± 2.2 curies. In the second year, it is anticipated that this value would be reduced to 2.3 ± 1.8 curies. Thereafter, a 20-percent reduction in transport per year is assumed. Thus, after 10 years of resumed operation, approximately 14.4 curies of cesium-137 would have been transported to the Savannah River-swamp system (Du Pont, 1983a).

The 2.1-curie decrease from the first to the second year is based on the assumption that the cooling-water effluent would no longer desorb radiocesium from the creekbed and floodplain sediments in Steel Creek and that no more radiocesium would be contributed from vegetation. Based on recent studies (Du Pont, 1983a), the sediment-water transport estimate presented here is substantially less than initially estimated (Du Pont, 1982a); however, the original estimates of transport resulting from hot water desorption (1.7 ± 0.2 curies) and the loss of vegetation containing 0.4 ± 0.2 curie remain unchanged (see Section D.4).

The total amount of radiocobalt to be remobilized and transported from Steel Creek during the first year of resumed L-Reactor operation is conservatively estimated to be 0.25 ± 0.13 curie. This total would consist of a 0.16-curie-per-year fraction associated with sediment-water transport and a 0.09-curie-per-year fraction associated with desorptive transport. During the second year, as much as 0.14 ± 0.10 curie would be transported in association with the suspended sediments (0.16 curie per year x 0.876 decay factor = 0.14 curie per year; Hayes and Watts, 1983). Approximately 0.6 curie of cobalt-60 would be transported to the Savannah River-swamp system during the first 10 years of resumed L-Reactor operation (Du Pont, 1983a).

Tables 4-13 and 4-14 list the amounts of cesium-137 and cobalt-60, respectively, that would be transported and concentrations in water for the first, second, and tenth years after resumption of L-Reactor operation. Maximum concentrations of cesium-137 and cobalt-60 occurring 1.5 river miles below Steel Creek mouth (the point of complete mixing of Steel Creek and river water) is predicted to be 1/425 and 1/3300, respectively, of the Environmental Protection Agency (EPA) drinking-water standard. Concentrations in finished water from the Beaufort-Jasper and Cherokee Hill water treatment plants are predicted to be small fractions (at most 1/2200 and 1/4160 for cesium-137 and cobalt-60, respectively) of these drinking-water standards (Du Pont, 1983a).

The methodology used to calculate dose commitments for remobilized radiocesium and cobalt-60 is discussed in Appendix B. The dose calculations were made with the assumption that all cesium-137 and cobalt-60 released from Steel Creek would reach the Savannah River and complete mixing in the river would occur within 2.4 kilometers of the mouth of Steel Creek at an annual average river flow rate of 295 cubic meters per second. The dose associated with the first year of L-Reactor operation was analyzed because releases would be highest in that year (4.4 curies of cesium-137 and 0.25 curie of cobalt-60) and would decrease continuously in subsequent years.

Table 4-13. Estimated cesium-137 remobilization from Steel Creek compared with current transport values (direct discharge)[a]

Location	River Mile	Inventory transported (Ci/yr) Current values	Inventory transported (Ci/yr) After restart 1st year	Inventory transported (Ci/yr) After restart 2nd year	Inventory transported (Ci/yr) After restart 10th year	Concentration in water (pCi/ℓ) Current values	Concentration in water (pCi/ℓ) After restart 1st year	Concentration in water (pCi/ℓ) After restart 2nd year	Concentration in water (pCi/ℓ) After restart 10th year
Steel Creek mouth	141.6	0.25	4.4	2.3	0.4	5.3	11.15	5.80	1.01
Savannah River at 1.5 river miles below Steel Creek	140.1	0.41[b]	4.4	2.3	0.4	0.04[b]	0.47	0.25	0.04
Hwy. 301 bridge	118.7	0.39[b]	4.3	2.2	0.4	0.04[b]	0.44	0.23	0.04
Hwy. 17 bridge	21.4	0.20[b]	2.7	1.4	0.2	0.02[b]	0.23	0.12	0.02
WATER-TREATMENT PLANTS									
Finished water									
Beaufort-Jasper	39.2	--	--	--	--	0.028	0.01	<0.01	<<0.01
Cherokee Hill	29.0	--	--	--	--	0.033	0.09	0.05	<0.01
EPA interim primary drinking-water standard	--	--	--	--	--	200	200	200	200

[a]Based on mean transportation estimates made by Hayes (1983) and Hayes and Watts (1983) and data presented in Table D-16, and average flow rates in the Savannah River at locations indicated. Estimates of concentration and transport for the first, second, and tenth years represent only the contribution resulting from the remobilization of cesium-137 in Steel Creek by the resumed operation of L-Reactor. No alteration of existing water-treatment-plant systems was assumed.

[b]1979-1982 average concentration measured at the Hwy. 301 bridge was 0.04 picocurie per liter; other values derived using appropriate flow rates and reduction factors.

Table 4-14. Estimated cobalt-60 remobilization from Steel Creek compared with current transport values (direct discharge)[a]

Location	River Mile	Inventory transported (Ci/yr)				Concentration in water (pCi/ℓ)			
			After restart				After restart		
		Current values	1st year	2nd year	10th year	Current values	1st year	2nd year	10th year
Steel Creek mouth	141.6	0.02[b]	0.25	0.14	<0.01	0.3[b]	0.63	0.35	0.02
Savannah River at 1.5 river miles below Steel Creek	140.1	0.02[b]	0.25	0.14	<0.01	<<0.01[b]	0.03	0.02	<<0.01
Hwy. 301 bridge	118.7	0.02[b]	0.24	0.14	<0.01	<<0.01[b]	0.03	0.02	<<0.01
Hwy. 17 bridge	21.4	0.01[b]	0.15	0.09	<<0.01	<<0.01[b]	0.02	<0.02	<<0.01
WATER-TREATMENT PLANTS									
Finished water									
Beaufort-Jasper	39.2	--	--	--	--	<0.003[c]	0.02	<0.02	<<0.01
Cherokee Hill	29.0	--	--	--	--	<0.003[c]	0.02	<0.02	<0.01
EPA interim primary drinking water standard	--	--	--	--	--	100	100	100	100

[a]Based on mean transportation estimates made by Hayes (1983) and Hayes and Watts (1983) and average flow rates in the Savannah River at locations indicated. Estimates of concentration and transport for the first, second, and tenth years represent only the contribution resulting from the remobilization of cobalt-60 in Steel Creek by the resumed operation of L-Reactor. No credit is taken for removal of cobalt-60 by the waste-treatment process.

[b]Estimated on the basis of 0.06 times the value for cesium-137.

[c]Based on Kantelo and Milham (1983).

Maximum individual dose. The dose to the maximally exposed individual from redistribution of cesium-137 and cobalt-60 in the first year is shown in Table 4-15 by age groups. An adult would receive the maximum total-body dose of 3.5 millirem. Greater than 99 percent of this dose is from cesium-137. Fish consumption (34 kilograms per year) would account for 99 percent of the dose, and drinking water (730 liters per year) for 0.7 percent. Shoreline activities, swimming, and boating would account for the remainder of the dose. The maximum dose to an organ was calculated to be 5.3 millirem to the liver of a teenager and an adult. The total-body dose to an adult would decrease to 0.31 millirem in the tenth year.

Population dose. The total-body dose to the population within 80 kilometers of the Savannah River Plant from freshwater fish and saltwater shellfish consumption and from recreational activities on the river was calculated to be 9.0 person-rem in the first year (Table 4-16). About 99 percent of this dose would be from consumption of river fish and is almost entirely from cesium-137. Total-body dose to water consumers in Port Wentworth and Beaufort-Jasper was calculated to be 0.80 person-rem in the first year. About 95 percent of this dose would be accounted for by cesium-137. The dose calculations for these water consumers take into account the removal of a large fraction of the cesium-137 during the water-treatment process (Du Pont, 1983a). In the tenth year, the 80-kilometer-radius population dose would decrease to 0.80 person-rem and the combined Beaufort-Jasper and Port Wentworth water consumer dose would decrease to 0.067 person-rem. Additional tables providing detailed cesium-137 and cobalt-60 dose results by age groups, organs, and exposure pathways are given in Appendix B.

4.1.2.5 Summary of offsite dose commitments from L-Reactor operation

Table 4-17 summarizes the maximum individual and population dose commitments resulting from the resumption of L-Reactor operation. The numbers listed as totals for individual and population doses are conservative maximums; to receive these doses, the "composite" individual (or population) would have to occupy several locations simultaneously. In addition, the dose for radiocesium and cobalt-60 transport calculated for the first year would decrease continuously in subsequent years.

The composite maximum individual dose of 3.6 millirem would occur in the first year of L-Reactor operation and is about 26 times less than the average dose of 93 millirem (Du Pont, 1982a) received by an individual living near the SRP site from natural radiation. The composite dose in the tenth year would be 0.61 millirem. These doses are on the order of 1 percent or less of the DOE radiation protection guides (DOE Order 5480.1A, Chapter 11). The maximum population dose of 27.6 person-rem in the tenth year of L-Reactor operation would be less than 0.025 percent of the exposure of about 109,000 person-rem to the population living within 80 kilometers of the Savannah River Plant and the Beaufort-Jasper and Port Wentworth drinking-water population from natural radiation sources.

TC

Table 4-15. First-year dose to the maximally exposed individual from redistribution of cesium-137 and cobalt-60 from Steel Creek (millirem per year)

Age group	Skin	Bone	Liver	Total body	Thyroid	Kidney	Lung	GI-LLI
Adult	3.28×10^{-3}	3.88	5.30	3.48	2.83×10^{-3}	1.80	6.01×10^{-1}	1.08×10^{-1}
Teen	1.10×10^{-2}	4.00	5.31	1.86	9.42×10^{-3}	1.81	7.11×10^{-1}	8.66×10^{-2}
Child	2.29×10^{-3}	5.28	5.06	7.48×10^{-1}	1.99×10^{-3}	1.65	5.95×10^{-1}	3.45×10^{-2}
Infant	--	8.15×10^{-2}	9.55×10^{-2}	6.99×10^{-3}	--	2.56×10^{-2}	1.04×10^{-2}	5.26×10^{-4}

Table 4-16. First-year population dose from redistribution of cesium-137 and cobalt-60 from Steel Creek (person-rem per year)

Population group	Skin	Bone	Liver	Total body	Thyroid	Kidney	Lung	GI-LLI
80-km radius[a]	3.28×10^{-2}	1.38×10^{1}	1.74×10^{1}	9.04	2.84×10^{-2}	5.85	2.01	2.86×10^{-1}
Beaufort-Jasper[b]	--	4.45×10^{-1}	5.51×10^{-1}	2.94×10^{-1}	--	1.77×10^{-1}	6.11×10^{-2}	3.22×10^{-1}
Port Wentworth[b]	--	5.48×10^{-1}	7.53×10^{-1}	5.01×10^{-1}	--	2.55×10^{-1}	8.49×10^{-2}	9.59×10^{-2}
Total	3.28×10^{-2}	1.48×10^{1}	1.87×10^{1}	9.84	2.84×10^{-2}	6.28	2.16	7.04×10^{-1}

[a]Dose from consumption of fish and shellfish and recreational activities on the river.
[b]Dose from consumption of water from water-treatment plants.

Table 4-17. Summary of total-body dose commitments from the operation of L-Reactor

Source of exposure	1st-year dose	10th-year dose
MAXIMUM INDIVIDUAL ADULT DOSE (MILLIREM PER YEAR)		
Atmospheric releases	0.052	0.21
Liquid releases	0.0072	0.087
Radiocesium and cobalt transport	3.5	0.31
Total	3.6	0.61

Source of exposure	Dose within 80 kilometers of SRP		Port Wentworth and Beaufort-Jasper dose	
	1st year	10th year	1st year	10th year
REGIONAL POPULATION DOSE (PERSON-REM PER YEAR)				
Atmospheric releases	3.0	13.5	--	--
Liquid releases	0.0088	0.018	0.75	13.2
Radiocesium and cobalt transport	9.0	0.80	0.80	0.067
Total	12.0	14.3	1.6	13.3

4.1.2.6 Health effects from L-Reactor operation

Radiation-induced health effects that could occur as a result of the resumption of L-Reactor operation (including atmospheric and liquid radioactive releases and radiocesium remobilization) were calculated using BEIR III risk estimators (Appendix B). The risk estimators used were 120 cancers and 257 genetic effects per 1,000,000 person-rem exposure. Multiplying the regional population doses (from Table 4-17) by these risk estimators projects the following effects: a maximum of 0.001 excess cancer fatality in the population within 80 kilometers of the Savannah River Plant from first-year L-Reactor operations, 0.002 excess cancer fatality from tenth-year operations, 0.003 genetic disorders from the first year of operation and 0.004 from the tenth year. Health effects that could occur in the downstream Savannah River water-consuming populations of Port Wentworth and Beaufort-Jasper include a maximum of 0.0004 excess cancer fatality from first-year operations, and 0.002 from tenth-year operations. The maximum risk of genetic disorders to these populations would be 0.0004 from first-year operations, and 0.003 from tenth-year operations.

4.1.2.7 Occupational dose

At the L-Reactor, occupational doses would be maintained as low as reasonably achievable. All personnel who work in or enter areas that have radiation-exposure potential receive personal monitoring devices. In addition, a comprehensive bioassay program is maintained for all employees who work in areas where there is a potential for a biological uptake of radioactivity.

Table 4-18 lists the total whole-body dose commitments to workers in the P-, K-, and C-Reactor areas for 1976 through 1980. Based on these data, the total average annual dose commitment to workers in the L-Area would be about 69 person-rem per year. The average work force in each reactor area is about 375 people; thus, the average annual individual dose to workers in the L-Area would be about 185 millirem per year.

Table 4-18. Total doses to workers in P-, K-, and C-Areas

Year	Dose (person-rem)
1976	217.2
1977	231.2
1978	202.0
1979	184.4
1980	203.7
Average	207.7
Average per reactor-year	69.2

The dose commitment to workers during this recent period can be compared to the experience of the 1960-1968 period, during which the annual occupational dose commitment in the P-, K-, C-, and L-Areas averaged 200 person-rem per reactor year (Du Pont, 1982a). A continuing program is maintained to reduce the occupational dose further.

4.1.2.8 *Solid radioactive waste*

About 570 cubic meters of solid radioactive waste would be generated annually at L-Reactor. This waste would be packaged and transported to the SRP low-level waste burial ground. The burial ground is divided into sections to accommodate different levels of radioactivity. The waste is buried in earthen trenches that are about 6 meters deep and 6 meters wide. The exact location of the burial trenches is defined, and accurate records are kept of the contents of each trench. About 40 acres of the burial ground area are available for future use.

The volume of low-level waste added to the burial ground due to L-Reactor operation would occupy about 1 acre of the burial ground area for each 10 years of operation. Offsite radiological effects of burial operations would be negligible.

4.2 ACCIDENTS

TC This section describes the environmental impacts and risks of reactor accidents. It demonstrates that L-Reactor safety systems are designed and would be operated in such a manner that the risk to the public from accidental releases of radioactivity would be extremely small.

4.2.1 Reactor accidents

Radiological protection for the operating staff, the public, and the plantsite would be provided by extensive protective devices and systems at L-Reactor, all designed to ensure that accidents would be prevented, arrested, or accommodated safely. The requirements for these protection systems are based on a spectrum of postulated occurrences and accidents that the plant design must accommodate safely.

The occurrences considered range from relatively minor events such as routine equipment malfunctions to postulated accident situations with a potential for serious consequences. The predominant focus is on prevention of any accidents that could release radioactive material in excess of permissible limits.

Analyses of accidents postulated for the Savannah River Plant reactors are applicable to L-Reactor and used to:

- Ensure that the reactor would operate with acceptably low risk to the public and plant employees and to provide a basis for improved reactor systems that could lower these risks still further.
- Set reactor operating limits for each operating cycle, such that the reactor protective instrumentation and shutdown systems could terminate postulated transients without damaging reactor fuel, the reactor tank, or the radioactivity confinement system.
- Provide assurance that the radioactivity confinement system would operate reliably even in the most serious accidents.
- Specify the offsite emergency response system needed and how the system should be used.

Appendix G describes reactor-accident analyses in more detail.

4.2.1.1 Characteristics of reactor accidents

Accident types

The two types of reactor accidents of primary concern at SRP are release of fission products or other radionuclides from the irradiated reactor fuel and targets, and release of activation tritium from the reactor moderator. The release of fission products is most likely to occur due to fuel or target melting, which might result from either power surges or cooling-system failures. The release of activation tritium from the reactor heavy water is most likely to occur from spills or pipe breaks.

The principal hazard of these accidents is that the released radionuclides become airborne and are carried either to the plant worker onsite or to the offsite population. Radionuclides can also be dispersed by the reactor liquid effluent streams, but the hazards of such dispersal are several orders of magnitude lower than those of airborne dispersal in an accident situation.

If a reactor fuel assembly melts, the materials that can be released to the reactor-room air have been assumed to be:

- 100 percent of the noble gases, primarily krypton and xenon
- 100 percent of the tritium from the lithium-aluminum components |TC
- 50 percent of the halogens, mainly iodine
- 1 percent of the other fuel materials as airborne particulates

If the reactor heavy water (D_2O) is spilled it can evaporate, carrying off any tritium present as DTO vapor. As initially charged, the L-Reactor heavy water would contain trace amounts of tritium, but the tritium in the heavy water could eventually build up to an equilibrium inventory of 5 million curies over a period of 10 years or longer. (The inventory varies with the operating history of the reactor and is now about 3.5 to 3.7 million curies in operating SRP reactors. To be conservative, a higher value of 5 million curies is assumed for accident consequence calculations. This is about 20 percent higher than the highest value ever observed in SRP reactors.) In the event of a spill of the full moderator inventory, about 3 percent of the tritium is assumed to evaporate during the 2-hour period after the spill and then to be released from the stack and dispersed during that period. |TC

The SRP reactors, including L, are fitted with a confinement system to remove a large fraction of the radioactivity that might be released to the reactor room. In this confinement system, the reactor room is kept at a negative pressure by use of exhaust fans. The exhaust air is passed through moisture separators and then through high-efficiency particulate air (HEPA) filters and carbon filters to remove more than 99 percent of the particulates and the iodine. The noble gases are not removed by the filters. Airborne tritium is also assumed to be fully released. After filtration, the exhaust air is released through a 61-meter-high stack.

Fission products

Table 4-19 lists the radioactive fission product content for a fully irradiated SRP fuel assembly, the half lives of these fission products, the amounts

Table 4-19. Activity of radionuclides (typical) for one SRP fuel assembly at saturation

Group/radionuclide	Radioactive inventory (curies)	Half-life[a]	Percentage of inventory released by melting	Percentage of inventory passing through confinement
		NOBLE GASES		
Krypton-85	5.702×10^2	10.7y	100	100
Krypton-85m	6.734×10^4	4.48h	100	100
Krypton-87	1.283×10^5	1.27h	100	100
Krypton-88	1.809×10^5	2.86h	100	100
Xenon-133	3.516×10^5	5.25d	100	100
Xenon-135	2.317×10^4	9.10h	100	100
		IODINES		
Iodine-131	1.495×10^5	8.04d	50	0.6
Iodine-132	2.237×10^5	2.28h	50	0.6
Iodine-133	3.547×10^5	20.9h	50	0.6
Iodine-134	3.995×10^5	52.5m	50	0.6
Iodine-135	3.303×10^5	6.61h	50	0.6
		ALKALI METALS		
Rubidium-86	5.072×10^1	18.8d	1	0.005
Cesium-134	3.813×10^3	2.06y	1	0.005
Cesium-136	1.234×10^3	13.0d	1	0.005
Cesium-137	4.633×10^3	30.1y	1	0.005
		TELLURIUM-ANTIMONY		
Tellurium-127	6.977×10^3	9.35h	1	0.005
Tellurium-127m	4.040×10^2	109.d	1	0.005
Tellurium-129	3.210×10^4	1.16h	1	0.005
Tellurium-129m	8.705×10^3	33.5d	1	0.005
Tellurium-131m	1.930×10^4	1.25d	1	0.005
Tellurium-132	2.226×10^5	3.26d	1	0.005
Antimony-127	7.305×10^3	3.91d	1	0.005
Antimony-129	3.361×10^4	4.41h	1	0.005
		ALKALINE EARTHS		
Strontium-89	2.385×10^5	50.6d	1	0.005
Strontium-90	6.980×10^2	28.8y	1	0.005
Strontium-91	3.050×10^5	9.48h	1	0.005
Barium-140	3.298×10^5	12.8d	1	0.005

Table 4-19. Activity of radionuclides (typical) for one SRP fuel assembly at saturation (continued)

Group/radionuclide	Radioactive inventory (curies)	Half-life[a]	Percentage of inventory released by melting	Percentage of inventory passing through confinement
		COBALT AND NOBLE METALS		
Cobalt-58	none	70.8d	1	0.005
Cobalt-60	none	5.27y	1	0.005
Molybdenum-99	3.215×10^5	2.75d	1	0.005
Technetium-99m	2.774×10^5	6.01h	1	0.005
Ruthenium-103	1.638×10^5	39.4d	1	0.005
Ruthenium-105	5.879×10^4	4.44h	1	0.005
Ruthenium-106	3.800×10^3	1.00y	1	0.005
Rhodium-105	4.919×10^4	1.48d	1	0.005
		RARE EARTHS, REFRACTORY OXIDES AND TRANSURANICS		
Yttrium-90	7.600×10^3	2.67d	1	0.005
Yttrium-91	2.858×10^5	58.5d	1	0.005
Zirconium-95	3.059×10^5	64.0d	1	0.005
Zirconium-97	3.107×10^5	16.9h	1	0.005
Niobium-95	2.743×10^5	35.0d	1	0.005
Lanthanum-140	3.359×10^5	40.3h	1	0.005
Cerium-141	3.028×10^5	32.6d	1	0.005
Cerium-143	3.111×10^5	33.0h	1	0.005
Cerium-144	1.202×10^5	284.d	1	0.005
Praseodymium-143	3.067×10^5	13.6d	1	0.005
Neodymium-147	1.163×10^5	11.0d	1	0.005
Neptunium-239	1.360×10^5	2.35d	1	0.005
Plutonium-238	0.300×10^2	87.7y	1	0.005
Plutonium-239	9.902×10^{-1}	2.4×10^4y	1	0.005
Plutonium-240	9.033×10^{-1}	6.6×10^3y	1	0.005
Plutonium-241	2.241×10^2	14.4y	1	0.005
Americium-241	none	432.y	1	0.005
Curium-242	none	163.d	1	0.005
Curium-244	none	18.1y	1	0.005

[a]Half-life units are indicated by m for minutes, h for hours, d for days or y for years.

that might become airborne in a meltdown, and the amounts that might be released through the confinement system.

As seen from the table, the fission products of primary concern from an SRP reactor accident would be noble gases and iodine. Most of these fission products have short half lives and are quite volatile.

Radiation exposures and health effects

The possible pathways by which accidental releases of airborne radioactivity from L-Reactor could result in radiation exposure to the offsite public and to the SRP workers include:

- Exposure to gamma radiation emitted by the radionuclides as they pass overhead (plume shine)
- Immersion in the plume of the release, resulting in inhalation of the radionuclides either with immediate exhalation or with retention in the body (depending on the radionuclide biochemistry)

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- Immersion in the plume of the release, resulting in a skin contact dose due to tritium
- Exposure to gamma radiation emitted by radionuclides deposited on the ground from the air (ground shine)
- Ingestion of radionuclides in contaminated drinking water and food

Because of the volatile nature of the radionuclides that could be emitted in an L-Reactor accident and their associated short half lives (tritium has a comparatively long radioactive half life, but a short biological half life), the last two pathways would be less important than the first three in the accident analysis.

The radiation doses calculated from the spectrum of postulated accidents associated with L-Reactor (Section 4.2.1.4) are too low to produce any short-term clinical effects or fatalities. The concern, rather, is with possible latent health effects (i.e., cancers or genetic changes).

Extensive studies have been made in relating comparatively low levels of radiation exposure and health effects. The problem is difficult primarily because the effects are statistically so low as to be difficult to measure. For purposes of this analysis, radiation doses were calculated based on dose conversion factors from the International Council on Radiological Protection report ICRP-30.

4.2.1.2 Accident experience and prevention at SRP

Safe operation of the production reactors is implemented by (1) explicit definition of the safe limits of operation, (2) explicit written procedures for normal and abnormal operations, (3) multiple and diverse engineered safety systems and (4) in-depth technical support onsite. This system of operation was in place when the first reactor was started at SRP and has been improved over the years when deficiencies were identified.

For long-term safety, an important function is the ability to spot weaknesses or adverse trends. Each deviation from approved operating procedures is recorded and promptly investigated by onsite technical personnel. If there appears to be a significant question of reactor safety, the reactor is shut down until it can be demonstrated that operation will be within the envelope of acceptable conditions required by the reactor operation and Technical Specifications and Technical Standards, which are established by DOE and the operating contractor, respectively.

Safety considerations override production considerations, and precautionary reactor shutdowns have occurred to investigate possible safety questions. The research at Savannah River Laboratory (SRL) ensures that the latest methods and equipment are evaluated for application to Savannah River Plant. Many important improvements have been made to SRP reactors; in the safety-related areas of thermal analysis, core physics, and monitoring and diagnosis, they equal the current state of the art. These improvements are summarized in Appendix J. Research at SRL includes human factors as well as plant equipment. The incident at Three Mile Island has been studied; lessons learned that are applicable to SRP reactors are being implemented (e.g., an improved reactor training program, the construction of a reactor simulator).

A comprehensive Safety Analysis is the basis for a defense-in-depth safety approach in which possible accident initiators are identified and eliminated to the maximum extent practical, multiple shutdown systems are provided to terminate, without damage, any accidents that do occur, and radioactivity confinement and other systems are installed to minimize the offsite effects of reactor damage if it does happen (Du Pont, 1983a). The emphasis in the Safety Analysis is on accident prevention and mitigation, but it also calculates the consequences of possible occurrences. TC

Provisions for independent safety reviews are required by DOE policy for each level of organization, including contractors, the field offices, and Headquarters. As part of this process, the Atomic Energy Commission's Advisory Committee on Reactor Safeguards served as an independent review body from 1960 to 1974. Numerous reviews by special committees and boards have been conducted periodically, including the Shon Committee in 1971, the Crawford Committee in 1980, and the Ditto Committee in 1981. The process also included the use of consultants. A formal safety consultant review policy was established after 1974. Currently, consultants are used on the Reactor Safety Advisory Committee initiated by the contractor in 1982. Significant steps to strengthen independent reviews were identified and taken as a result of post-TMI-2 reviews. These steps included organizational changes and staff to provide additional independent overview within DOE organizations.

SRP reactors have operated for more than 115 reactor-years with no accidental criticality or abnormal releases to the environment.

The most serious accidents that have occurred at SRP reactors are:

- A sizable moderator spill that occurred during the early stages of operation. At the time of the spill, the moderator contained very little tritium, so the radiation effects of the spill were negligible.

- In 1970, a special source rod melted while it was being held in the discharge machine. The confinement system worked as designed and 99.99 percent of the radioactivity released was trapped and recovered with negligible offsite exposure. This accident was the result of administrative error; appropriate procedural controls have been implemented to prevent a recurrence.

These and other reactor incidents are described in more detail in Appendix G and the Safety Analysis Report (Du Pont, 1983a).

4.2.1.3 Mitigation of accident consequences

Numerous reactor design features provide the ability to reduce the consequences of accidents. The most important of these include the following:

Reactor shutdown systems

Several redundant and diverse systems operate to shut down the reactor rapidly, if necessary.

L-Reactor would have the same defenses against reactivity transients that other SRP reactors have. These defenses would include flow and temperature sensors for each fuel assembly, which are monitored by two sets of redundant computers (control computers and safety computers). The control computer(s) would detect rapidly any reactivity transient that might begin and would cause the normal control-rod system to insert to terminate the transient safely--the first line of defense. If the normal control-rod system fails to terminate the transient, the safety computer(s) would activate the safety-rod drop system that would shut down the reactor within about 1 second--the second line of defense. If the safety rods do not shut down the reactor rapidly, the safety computer(s) would automatically activate the injection of liquid "poison" into the reactor moderator/coolant to accomplish the same safe shutdown--the third line of defense. The few reactivity transients that have occurred have been of a small magnitude, were controlled by the normal control-rod system, and did not require either backup system to operate (safety-rod drop or "poison" injection).

Emergency cooling system

An emergency cooling system (ECS) is provided to protect against the consequences of two postulated accidents: (1) loss of heavy-water coolant and (2) loss of heavy-water circulation.

Emergency cooling of the SRP reactors is accomplished by the addition of light water to the primary reactor cooling system. This water is enhanced in loss-of-coolant accidents by recirculation of the emergency light water by the primary heavy-water circulating pumps.

On activation, the ECS system provides an initial 75,000 liters of borated water for nuclear poisoning by directing all ECS water flow through a large pipe that contains the borated water. The poison solution is forced through the assembly coolant channels and into the moderator. By the time unpoisoned H_2O reaches the coolant channels, sufficient heavy water moderator is displaced with poisoned water to prevent any possible criticality.

Three primary sources and a secondary source of water for the emergency cooling system are provided and include the following:

1. A diesel-driven booster pump that supplies water from the 95-million-liter 186-L basin (primary).

2. A header with a diameter of 107 centimeters pressurized by five pumps drawing water from the 95-million-liter basin (primary).

3. Another header with a diameter of 107 centimeters pressurized by five additional pumps.

4. A line pressurized by the river station pumps. Because the water directly from the river can contain debris that could plug flow channels and orifices in the reactor components, this source is valved off from the ECS and would be used only if all other sources had failed (secondary).

<u>Airborne activity confinement system</u>

The L-Reactor is equipped with an airborne activity confinement system (see Figure G-1). In the event of an accident, an airborne fission product release could occur in the reactor room with the possibility of some release in the heat exchanger bay or pump room. The air from these areas would be exhausted through a set of confinement filters before release to the stack.

During normal operation, the process areas would be closed and maintained at a negative pressure with respect to atmosphere to ensure that all air from the process areas is exhausted through the activity confinement system. Three large centrifugal fans would exhaust the air from the process areas. Two of these fans normally would be online, but only one would be necessary to maintain the negative pressure. The fan motors could be powered by two independent sources of electricity:

- The normal building power, through at least two substations
- The diesel-generated emergency building power

In addition, each online fan has a backup motor; any two fans could be powered by the dedicated diesel generators.

Exhaust filters would remove moisture, particulates, and halogens. The filter banks are enclosed in five separate compartments; three to five of these compartments would be online during operation. Each compartment can be isolated for maintenance and testing; each contains the following filter banks, in the order of air-flow treatment:

- Moisture separators, designed to remove about 99 percent of entrained water (spherical particles measuring 1 to 5 microns) to protect against significant impairment of the particulate filters

- Particulate filters, designed to retain more than 99 percent of all particulates with diameters of 0.3 micron or larger

- Activated carbon beds that use an impregnated carbon to retain halogen activity

As shown in Figures 4-7 and 4-8, L-Reactor is completely surrounded by a massive concrete structure, which in combination with the confinement system forms a barrier of high reliability against the possible release of radioactive material. The confinement system has the capacity to accommodate unexpected gas or energy releases. Hydrogen formed during an accident would be swept from the building by the high ventilation flow before explosive concentrations could be reached. Even with steam or hydrogen explosions for the worst hypothetical accident, the integrity of the structure and confinement system (including filters) would not be breached by rupture. Durant and Brown (1970) present a detailed analysis of a most severe hypothetical accident affecting the confinement system; this analysis specifically addresses the impact of hydrogen and steam explosions. Durant et al. (1966) documents confinement system tests that confirm the confinement system can withstand the severe accident conditions described above with a large margin of safety.

For all reactor accidents, the airborne activity confinement system is assumed to operate. The three exhaust fans described above would provide a high degree of assurance that at least one would remain in operation to maintain the process-area exhaust through the filter system. The probability that all three fans would fail is estimated to be 10^{-4} per year. Such a fan failure happening at the same time as one of the described accidents would be extremely unlikely.

Reactor room spray system

A system of nozzles is provided in the reactor room to spray cooling water on an irradiated assembly accidentally dropped during unloading operations. The spray pattern from these nozzles covers the area traversed by the discharge machine.

Site features

The site feature that would most effectively mitigate the consequences of an accident at L-Reactor is the 9-kilometer distance to the nearest SRP boundary. Although South Carolina Highway 125 is only 5 kilometers from L-Reactor, there are existing procedures for stopping traffic and clearing all personnel off the highway within a short time of any incident on the Savannah River Plant. (For more detail concerning site features, see Section 3.1.)

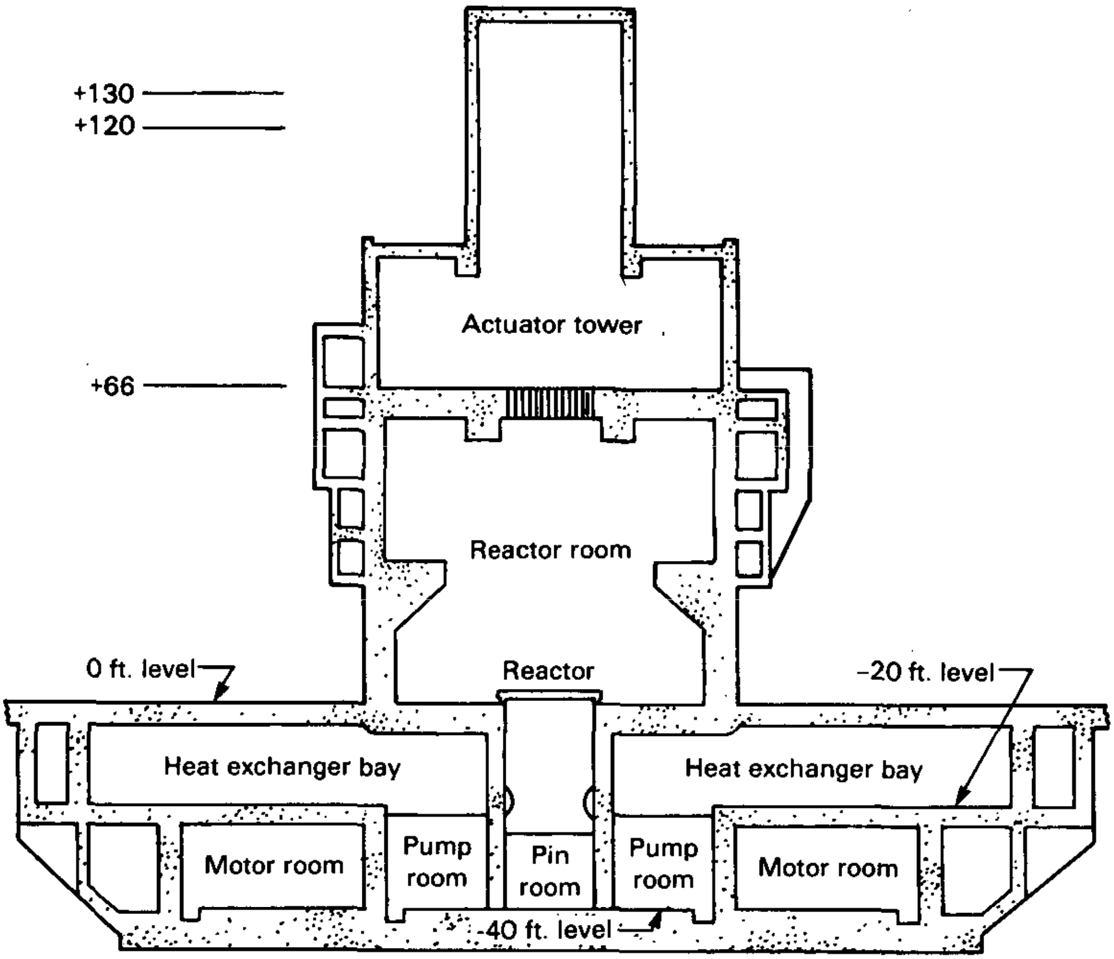

Figure 4-7. Schematic cross section of reactor process area.

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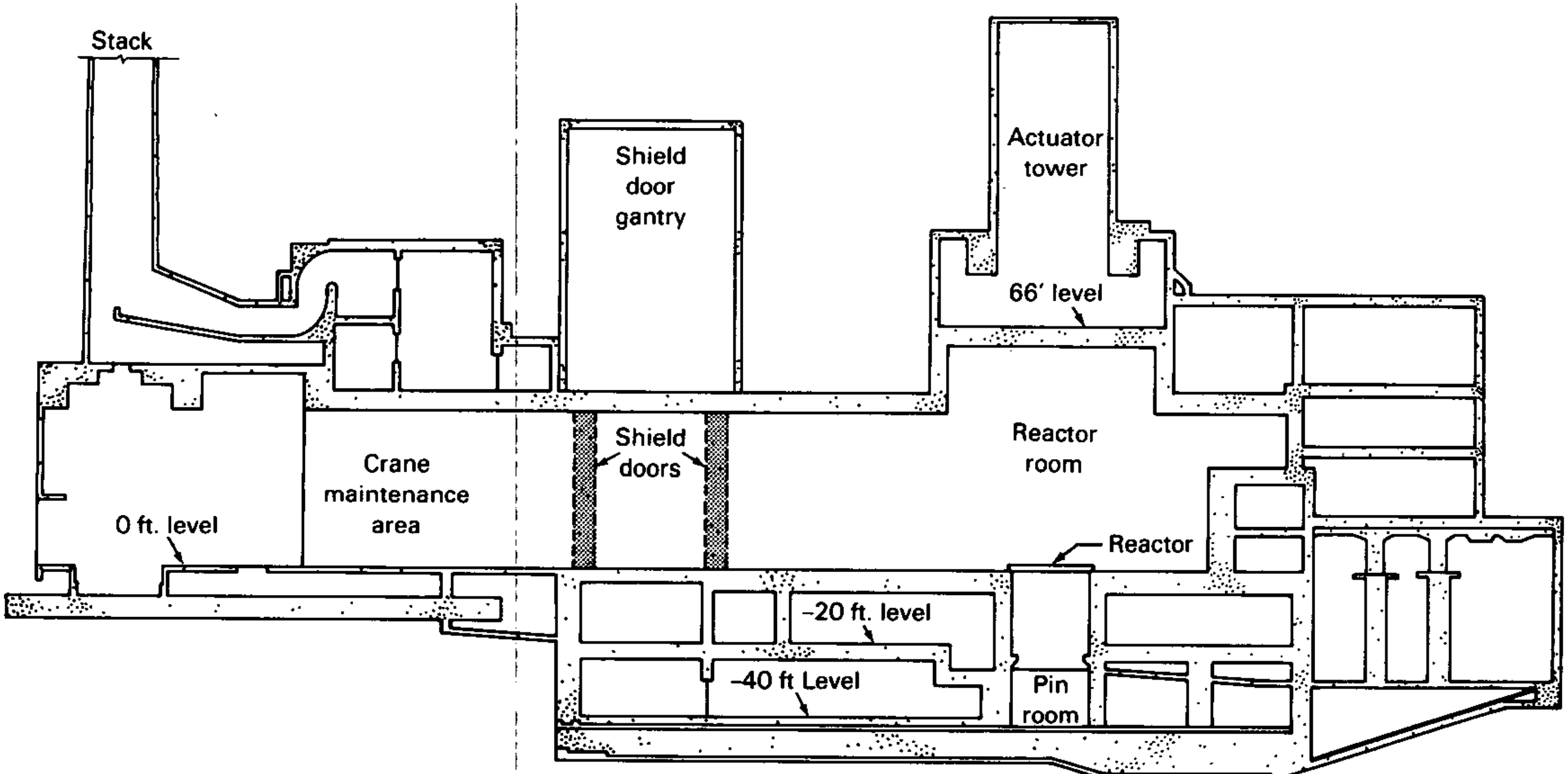

Figure 4-8. Schematic cross section of reactor.

Emergency planning

Onsite. The L-Reactor operating procedures include an Emergency Response Plan, which includes specific policies and procedures to minimize injuries and property damage caused by accidents, disasters, or deliberate damage in the reactor areas. The plan deals with sheltering or evacuation, nuclear incidents, civil defense readiness, missile or air attack, rescue plan, natural disasters and alerts, bomb threats, off-plant accidents, and forced entry or terrorist attack. (For more detail concerning Onsite Emergency Planning, see Appendix G.)

Offsite. DOE has various service agreements for assistance or special support with Fort Gordon and with Talmadge Hospital in Augusta, Georgia. DOE also has fire-fighting mutual aid agreements with the City of Aiken, South Carolina, and the South Carolina Forestry Commission. Memos of Understanding between DOE and the States of South Carolina and Georgia cover notification and emergency responsibility in the event of a potential or actual radiological emergency at the SRP. (For more detail concerning Offsite Emergency Planning, see Appendix H.) DOE continually reviews and updates its emergency planning procedures for consistency with applicable industrial and regulatory standards.

WIND system. The Weather Information and Display (WIND) System (Garrett et al., 1983) is an automated emergency response system for real-time predictions of the consequences of liquid and atmospheric releases from the Savannah River Plant. Site-specific features of the system include meteorological towers at each production area that are instrumented at the stack height, computer terminals at each production area that can be used to run emergency response codes remotely, codes that use empirical information on atmospheric diffusion and deposition gathered at the Savannah River Plant (Garrett, 1981; Carlson et al., 1982), and stream transport and diffusion codes that have been calibrated with dye tests in the SRP streams (Buckner et al., 1975). (For more detail concerning WIND, see Appendix G.)

4.2.1.4 Accident risk assessment

Accident description

Postulated events considered for safety evaluation of the L-Reactor are discussed in Appendix G and, more comprehensively, in the Safety Analysis Report (Du Pont, 1983a). Among these events are four postulated accidents that cover a spectrum of credible events with probabilities of greater than 10^{-6} per reactor-year that could release radioactive materials into the environment. Accidents with probabilities less than 10^{-6} per site-year are not considered credible.

Use of the probability of 10^{-6} per reactor-year as a threshold for credible reactor accidents has no absolute basis, but it is consistent with normal practice in the nuclear power industry. For example, this value can be derived from both an American National Standards Institute (ANSI) standard and the U.S. Nuclear Regulatory Commission Standard Review Plan. ANSI/ANS-212-1978, Appendix B, uses the value of 10^{-6} per site per year as a cutoff probability, TC below which combinations of events leading to accidents need not be considered for design purposes. The cutoff value does not include the probability of the consequences exceeding 10 CFR 100 dose guidelines, which is included in the NRC Standard Review Plan (NUREG-0800) acceptance criteria of 10^{-7} per year. The use of the 10^{-6} per site year value in the ANSI standard for accident probability is consistent with the NRC Standard Review Plan's value of 10^{-7} per site per year for accident plus consequence probability because the probability of the consequences exceeding 10 CFR 100 dose guidelines following an accident are conservatively estimated to be less than 10^{-1}. The SRP use of the 10^{-6} threshold is not for a so-called uncontrolled release, but for dividing "treated-as-credible" from "treated-as-noncredible" accidents. Even with estimates of accident probabilities beyond the 10^{-6} per reactor-year threshold, radioactive releases are limited by the performance of the reactor confinement system; they are not uncontrolled releases to the environment.

These four accidents are used for consequence and risk calculations. Other accidents or events are discussed in Appendix G, including the failure of an irradiated fuel or target component in the disassembly basin and various fuel-melt accidents. None of the accidents postulated would cause offsite doses that exceed either those adopted by DOE as safety limits for nuclear facilities (DOE Order 5480.1A) or those adopted by NRC as guidelines for siting for commercial power reactors (10 CFR 100). The four postulated accidents that cover the spectrum of credible events and risks are:

Moderator spill. Tritium in the moderator could become airborne and be partially released to the confinement system following ECS actuation or any loss-of-coolant accident. Tritium released into the confinement system is discharged from the stack, because the confinement system has no mechanism for tritium removal.

Five million curies of tritium are assumed to be present in the moderator of L-Reactor; this is the equilibrium value of tritium in the moderator and is 30 to 40 percent higher than present actual values for operating SRP reactors. The full moderator inventory of tritium is unlikely to evaporate and discharge to the atmosphere through the confinement system following any accident because ~~the moderator would flow first into the 225,000-liter tank and then to the~~ 1,900,000-liter tank of the liquid activity confinement system, unless the accident is a spill in the process room; in that case, most of the moderator would flow directly to the 1,900,000-liter tank. About 3 percent of the tritium is assumed to evaporate during the 2-hour period after the postulated accident and then to be released from the stack and dispersed during that period.

Discharge mishap. One irradiated fuel assembly could melt during a discharge operation under certain adverse (and improbable) conditions and release noble gases, iodine, and particulates. Fifty percent of the iodine and 100 percent of the noble gases available for release are assumed to escape the assembly and become airborne within the confinement system. More than 99 percent of that iodine reaching the carbon filter beds would be removed by the filter (a small fraction would desorb later and be released); 100 percent of the noble gases reaching the filters would pass through the filter. Half of the particulates released to the confinement system would reach the HEPA filters, where 99 percent of these particulates would be retained.

Reloading error leading to criticality. The highly localized damage postulated to occur following this accident would involve less than 3 percent of the core; melting would release iodine and fission products into the moderator. For this analysis, 50 percent of the iodine and all the noble gases were assumed to become airborne. Before the discharge operation began, the fission products would have decayed for a minimum of 14 hours. However, more fission products would be formed during the postulated criticality accident, and it was conservatively assumed that the fission product content of the core would be the equilibrium concentration at full power.

One-percent core melt due to a loss-of-coolant accident (LOCA). This accident is assumed to result from a double-ended pipe break in one of the six primary lines supplying heavy water to the reactor plenum. To compound this accident, the break is assumed to occur in one of the three primary lines having an emergency cooling-water injection line. Furthermore, a second emergency cooling-water addition system is assumed to be disabled. These assumptions of system operability are consistent with the single-failure criteria used on commercial power plants. SRP reactors are operated at power levels that limit core damage to 1 percent with only one of the three ECS operating. If the ECS operates as designed, no melting would occur. The amount of radioactivity available for release would be 1 percent of the noble gases and the iodine inventories in the core at the time of the accident. All released noble gases are assumed to become airborne. Fifty percent of the released iodine is assumed to become airborne. More than 99 percent of the released iodine would be trapped on the carbon filters; a small fraction would desorb later and be released from the stack.

Probability analysis

The following analyses are provided for each of the four hypothetical accidents:

Moderator spill. A 45,000-liter moderator spill (about 20 percent of the moderator inventory) occurred once at the Savannah River Plant during the early stages of operation. This spill was caused by a valving error while the reactor was shut down. Since then, unnecessary valves have been blanked, and moderator inventory procedures, level detection instrumentation, and leak detection instrumentation have been improved significantly. As a result, the Savannah River Plant has experienced more than 100 reactor-years of operation without a significant moderator spill. Today, the most probable scenario leading to a significant moderator spill is an unnecessary actuation of the ECS. The ECS has never activated; only once in 115 reactor-years of operation was there a spurious combination of reactor alarms and procedures that erroneously indicated the need to actuate the ECS. As a result, alarms and procedures were reanalyzed and AY-9 improved. If inadvertently actuated, the ECS would result in a significant moderator spill only if the reactor is shut down and contains heat generating assemblies with primary (AC) process water pumps shut down (during reactor operation, moderator pressure at ECS injection points exceeds ECS pressure; the ECS source is restrained by check valves), which occurs about 10 percent of the time. Because of extensive reactor instrumentation that provides a comprehensive status of reactor parameters, components, and systems, an estimated 90-percent probability exists that unnecessary actuation of the ECS will be terminated before the majority of the moderator has been expelled from the reactor. Thus, the estimated probability of spilling most of the moderator is equal to or less than 10^{-4} per reactor-year.

Discharge mishap. The melting of a fuel or target assembly during discharge would require at least two concurrent failures (for example, a failure of the assembly-holding mechanism on the discharge machine resulting in the dropping of a slug-type assembly plus a failure of the reactor room spray-cooling system, or a failure of the discharge machine drive mechanism resulting in the stalling of the machine plus a failure of four independent sources supplying cooling water to the discharge machine; in the latter case, melting would not necessarily result because the reactor room spray-cooling system could be used to provide cooling if the discharge machine stalls and its cooling-water supplies are lost).

In 115 years of reactor operation, no assembly has been dropped during discharge, indicating that the probability of this event is on the order of 0.01 or less per reactor-year. A review of approximately 250 tests of the reactor room spray system indicates four incidents in which less-than-designed flow was obtained. The system consists of 12 valves with 9 nozzles per valve. In each of the four incidents, the area of the process room receiving a less-than-designed flow was small, approximately 10 percent, indicating that the probability of failure to provide adequate spray cooling to a dropped assembly when called on to function is 0.0016.

More than 300,000 fuel and target assemblies have been discharged without a failure of the discharge machine cooling-water system. The probability of melting an assembly due to failures of both the discharge machine drive mechanism and the cooling system has been estimated to be approximately 7×10^{-5} (Nomm, 1977). Improvement to the discharge machine drive and control system that have
AY-9 been or are being implemented will substantially reduce this probability (by one or two orders of magnitude).

By combining the above probabilities, the estimated probability of melting a fuel or target assembly during discharge is estimated to be less than 10^{-4} per reactor-year.

Reloading error leading to criticality. This type of accident has not occurred at Savannah River Plant.

The reloading error most likely to occur that would lead to a large reactivity increase involves removing a target assembly, failing to replace that assembly with a fresh target, and then removing an adjacent target assembly. The probability of criticality occurring from the removal of so much absorbing material depends on three factors: (1) the probability that the reloading error occurs somewhere in the reactor; (2) the fraction of reactor positions for which the reloading error could produce extreme reactivity changes; and (3) the probability that the reactivity effect could be large enough to achieve criticality. (No damage would occur if the reactor were just critical. The reactivity addition would have to be large enough to achieve significant supercriticality. But to be conservative, this analysis only considers the probability of achieving criticality to be more likely than that of achieving supercriticality. The probability of actual damage would be less than that discussed here.)

Each reactor area has a charge/discharge computer system that monitors for target vacancies, checks the validity of steps in the charge and discharge sequence, and imposes interlocks that require extraordinary actions to bypass key steps. Prior to the installation of the charge/discharge computer system, the frequency of a double target vacancy was estimated to be about 0.1 per reactor year. Specific charge analyses indicate that about 4×10^{-5} of the postulated double vacancies could result in sufficient reactivity changes to achieve criticality. Thus, without taking credit for protection provided by the charge/discharge computer system, the probability of a double target vacancy resulting in a criticality is estimated to be 4×10^{-6} per reactor-year (Church, 1983).

Protection provided by the charge/discharge computer system has not been evaluated explicitly but should reduce the probability of occurrence by at least a factor of 10 to a value less than 4×10^{-7} (Church, 1983). This is below the probability considered credible. Until the protection provided by the computer system is evaluated explicitly, this accident is considered to define the spectrum of credible events and risks along with the other three accidents discussed in this section.

One-percent core melt due to a loss-of-coolant accident. This type of accident has not occurred at Savannah River Plant. The results of a literature search on pipe breaks in highly pressurized systems (L-Reactor is not a highly pressurized system) indicate probabilities on the order of 3×10^{-5} per year for massive piping failures. The probability of a partial failure of the Emergency Cooling System has been estimated to be 3×10^{-2}. Thus, the probability of the accident occurring with only one operable ECS is less than 1×10^{-6} per reactor-year. (If two ECS systems are operable, there is no damage.) AY-9

The assembly flow rates are computed for these extreme conditions using methods that are normalized to the results of reactor experiments simulating loss-of-coolant-accident conditions. Based on these flow rates, the damage to the reactor core is computed as a function of preincident reactor power. A maximum upper limit is then set on reactor power such that the reactor damage will not exceed 1 percent in the event of a maximum-leak-rate, loss-of-coolant accident coupled with losses of two of the three ECS systems.

Thus, the probability of a loss-of-coolant accident occurring and causing 1-percent core melting is estimated not to exceed 10^{-6} per reactor-year (Church, 1983).

Radiological consequences of reactor accidents

This section describes the techniques used to calculate offsite doses that result from reactor accidents. Appendix G provides a more detailed (NRC, 1979; Pendergast, 1982a,b) description. The calculations are consistent with NRC guidelines for accident analysis. The methods discussed were used for analysis of all accidents, including the moderator spill and fuel melting accidents.

Three parameters are necessary to compute the maximum offsite dose. First, the radioactive source term must be specified, including the release rate and isotope type. Second, the transport of the isotope by the wind must be computed based on appropriate calculational models and meteorological data. Third, the external and internal doses to an individual assumed to be located at the plant boundary are computed based on a standard man, breathing rates, and several parameters related to absorption of energy from a particular isotope.

The release from the stack is assumed to propagate as a Gaussian plume over a 2-hour period, and the exposure of an individual is treated as a time-integrated calculation. Two-hour duration of the meteorology is assumed, and this implies the subject is irradiated for a 2-hour period. This is very conservative because measurements at the SRP site show that the probability of wind persistence for a 2-hour period is, for some directions, only about 20 percent.

The 2-hour irradiation period begins when radioactive material reaches the plant boundary. Both the noble gas and iodine source terms are assumed to have decayed during transport. Decay during the exposure is not included in the calculation.

The source term for iodine is the amount that would penetrate and desorb from the filters in the first 2 hours following the incident. The average iodine retention efficiency assumed for the carbon is that for carbon aged 19 months. This is intended to be typical of normal operation. Carbon beds are replaced on a staggered schedule, so some beds have relatively fresh carbon, some have carbon of intermediate age, and some have carbon approaching its service limit of 30 months.

The downwind concentration of iodine, tritium, and noble gases was calculated according to an integral technique using the computer code NRC145-2. This code was developed at Savannah River Plant and uses a Gaussian plume model based on NRC Regulatory Guide 1.145 (Pendergast, 1982a).

The meteorological data used in the dose calculations were collected from January 1975 through December 1979. The data were obtained at towers near P-, K-, and C-Reactors. Calculations for L-Reactor used data from the closest tower (K-Area). The meteorological data from each tower were averaged for 2-hour periods and sorted into 16 direction sectors, six wind speeds, and seven stability classes. (Stability classes were based on the deviation of the mean wind direction.)

Median meteorological conditions (50th percentile) were assumed in these calculations. Relative doses could be higher under more extreme meteorological conditions, as indicated in Figure 4-9.

Corrections for the topography and jet rise of the released plume are also applied.

Interpolation between 2-hour doses and annual average doses was used to obtain the dose for an extended exposure period of 120 hours, using a method recommended in the NRC Guidelines, incorporated into NRC145-2 (Pendergast, 1982a), and independently verified.

The thyroid dose and the whole-body dose are composed of an inhalation component from iodine, tritium, and a shine component from the gamma emission of the noble gases. The inhalation component was computed by multiplying the isotopic relative concentration by the source strength and dose conversion factors. The shine component integrated the gamma dose from the entire (finite) radioactive plume.

The moderator spill accident considers the tritium dose when the moderator is displaced from the reactor (e.g., due to actuation of the Emergency Cooling

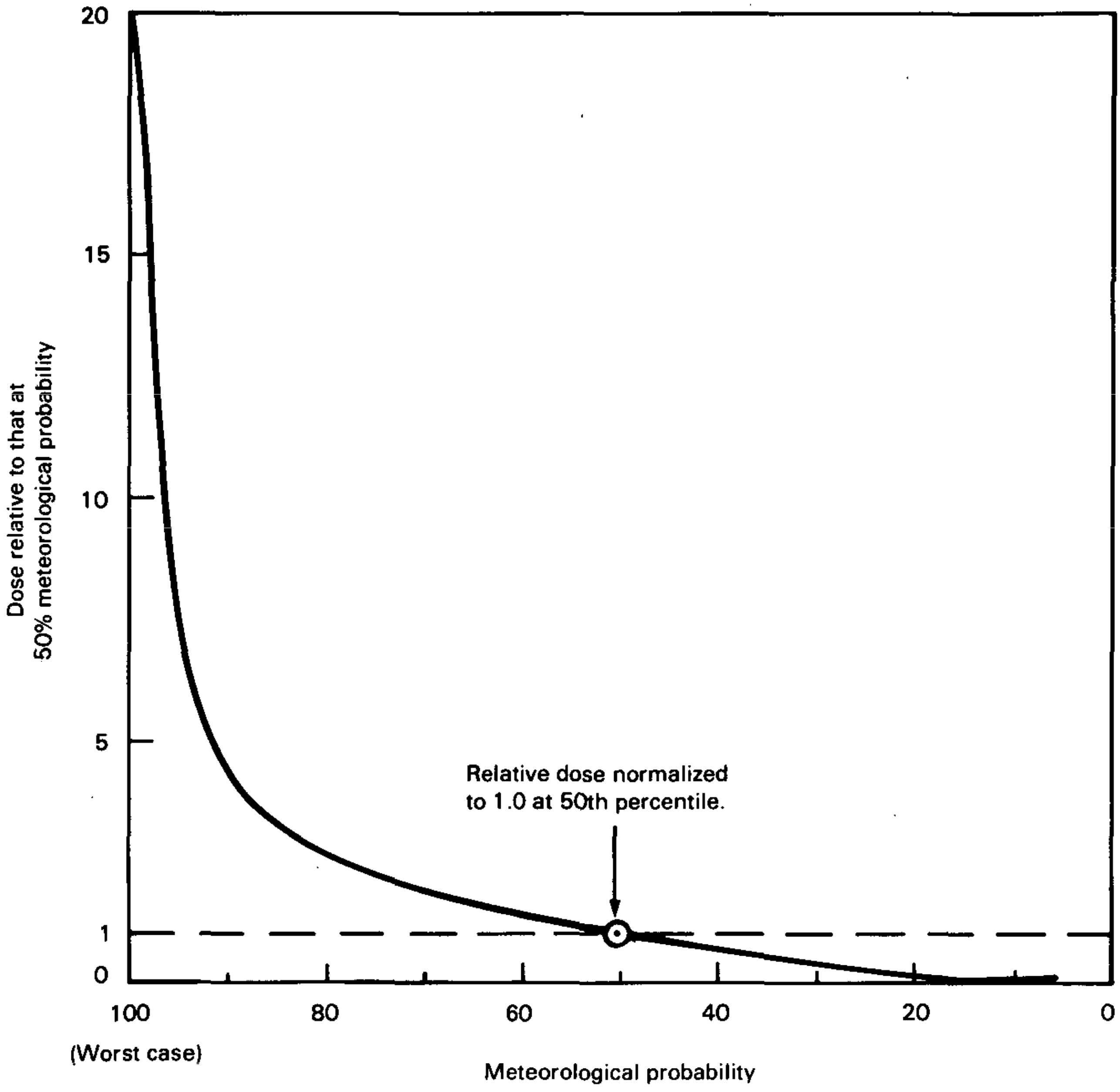

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Figure 4-9. Approximate effect of meteorology on boundary dose.

System). The calculation assumes a release of 0.15 megacurie (3 percent of the assumed 5 megacuries tritium inventory in the moderator) over a 2-hour period. The calculated dose to an individual at the plant boundary is shown in Table 4-20.

Table 4-20. Calculated radiation dose to a person at the SRP site boundary following four specific accidents (median meteorology)

Accident	Calculated dose (rem)		
	Whole-body (2 hr)[a]	Thyroid (2 hr)	Thyroid (120 hr)
D_2O spill	0.006	-	-
Discharge mishap (one fuel assembly melts)	0.003	0.004	0.01
Reloading error (3% core damage)	0.39	0.51	1.5
LOCA (1% core damage)	0.13	0.17	0.50

[a]The 2-hour whole-body dose is essentially the same as the accident-duration whole-body dose.

The discharge mishap accident assumes that an irradiated fuel assembly, having decayed for 14 hours after shutdown, melts while being discharged. The calculated dose to an individual at the plant boundary is shown in Table 4-20.

As discussed above, calculations indicate that the maximum hazard for a reloading accident would involve less than 3 percent of the core inventory of fission products. The fission product content of the core is assumed to be the equilibrium concentration that would be obtained at full power. Table 4-20 lists the calculated dose to an individual at the plant boundary.

The 1-percent core-melt accident assumes that a massive double-ended pipe break occurs. Thus, 1 percent of core fission product inventory as well as heavy-water coolant is released. Table 4-20 lists the calculated dose to an individual at the plant boundary.

In summary, these offsite doses from postulated accidents were calculated in accordance with accepted methods and assumptions. Appendix G describes offsite doses from particulates. These doses do not exceed DOE radiation protection standards (DOE 5480.1a.1, Chapter 11) for normal operation.

BF-9 Releases to ground water and surface water

No significant releases to ground water or surface water would be expected from reactor accidents. In the event of a loss-of-primary-coolant or a loss-of-pumping accident, the reactor scrams and the emergency cooling system forces as much as 53,000 liters of water per minute into the reactor to remove decay heat from the core. This water displaces the heavy water, then continues to flow through the reactor.

Overflow from the reactor is pumped to one of two holding tanks that are part of the confinement system. The first tank has a capacity of 225,000 liters and will retain essentially all of the displaced heavy water and its associated tritium. When this tank is full, any subsequent flow bypasses the tank at an upstream overflow point and flows to a 1.9-million-liter tank located in a 190-million-liter earthen basin.

If ECS flow has to continue until the larger tank is full (e.g., for a large primary coolant leak that cannot be isolated), subsequent flow bypasses the tank at an upstream overflow point and enters the earthen basin.

Air that is displaced as the tanks fill with water passes through vent lines and joins the ventilation air that is exhausted through the confinement filters to the 61-meter stack.

If core damage occurs during these severe accidents (less than 1-percent melting is calculated to occur for a large pipe break with only one of three ECS systems operable), fission products would be released to the emergency coolant flowing through the reactor. Any melting would occur in the first minutes of an accident while the decay heat is high and stable ECS flow is being established.

Volatile fission products would be released into the confinement ventilation system; the remainder of the fission products would be retained in the two tanks, which hold a total of more than 10 times the volume of the primary coolant. Any water flowing to the earthen basin after the tanks are full would have passed through a well-cooled, well-flushed core and would be essentially free of radioactivity. For the highly unlikely case of delayed melting after the tanks are full, the noble gases and radioiodine could be carried to the 190-million-liter basin where they could be released directly to the atmosphere. In this case, the iodine would cause increased offsite thyroid doses. Because of the extremely low probability of delayed core damage, no additional dose risk is attributed to this accident.

Risk considerations

The foregoing descriptions have dealt with both the frequency (or likelihood of occurrence) of accidents and their offsite dose impacts (or consequences). Because the ranges of both factors might be quite broad, it is useful to combine them to obtain average measures of environmental risk. Such averages can be particularly instructive as an aid to the comparison of radiological risks associated with accident releases and with natural sources of radiation.

A common way in which this combination of factors is used to estimate risk is to multiply the probabilities by the consequences. The resultant risk is then expressed as a magnitude of consequences expected per unit of time. Table 4-21 lists the estimated whole-body risks associated with the four postulated accidents described in this section. These risks were calculated by multiplying the calculated whole-body doses in Table 4-20 by the corresponding accident probabilities in Table 4-22; they range from 10^{-4} to 10^{-3} millirem per reactor-year. All risk values are much less than the risk that would be associated with a natural radiation dose of 93 millirem per year.

Table 4-21. Risk evaluation of postulated serious accidents

Accident	Consequence[a] (mrem)	Probability (y^{-1}) per reactor-year	Expected whole-body risk (mrem/reactor-year)
Moderator spill	6	10^{-4}	6×10^{-4}
Discharge mishap	3	10^{-4}	3×10^{-4}
Reloading error	390	4.0×10^{-7}	1.6×10^{-4}
LOCA, resulting in 1% core melt	130	10^{-6}	1.3×10^{-4}

[a]The 2-hour whole-body dose is essentially the same as the accident-duration whole-body dose.

4.2.1.5 Assessment of severe hypothetical accidents

Any accident that results in damage greater than the maximum calculated for the accidents described above (3-percent core melt) is highly improbable. As discussed in more detail in Appendix G and in the Safety Analysis Report (Du Pont, 1983a), analyses of hypothetical SRP reactor accidents indicate that the probability of an accident of a higher consequence than a 3-percent core melt is extremely low. The estimated probability of accident sequences that would result in melting as much as 100 percent of the reactor core is on the order of
TC 10^{-8} per reactor-year. For this analysis, the Airborne Activity Confinement System is expected to continue to function properly because it is already online before the accident, includes redundant primary components and diverse backup
TC power supplies, and has a high tolerance to severe accidents (Du Pont, 1983a). As an added safety measure, a Confinement Heat Removal System has been installed to reduce the possibility of confinement failure in the extremely unlikely event of a full core-melt accident. However, to assess the consequences of core melting for a highly improbable sequence of events, a 10-percent melt accident is postulated. Based on the discussion for the accidents with lesser consequences, the probability of a 10-percent core melt would be between 10^{-6} and 10^{-8} per reactor-year.

TC To analyze the consequences of accidents having very low probability, an evaluation independent of the SAR (Du Pont, 1983a) was performed using the computer model, CRAC2, employed by NRC to evaluate core-melt accident consequences in its Environmental Impact Statements (NUREG/CR-2901). This model considers the probability of occurrence of each of 29 meteorological conditions based on site data, population distributions as far as 800 kilometers from the site, and a number of options for mitigation of consequences that were not exercised in this evaluation. The model calculates exposures to individuals and populations from (1) direct radiation from the passing plume and material deposited on the ground, (2) inhalation, and (3) consumption of contaminated foods and milk. Finally, the model produces consequence-probability distribution curves (called complementary cumulative distribution functions, or CCDFs) for various doses, for prompt and delayed fatalities, and for economic costs (see Appendix G).

An examination of the results of these calculations must recognize that there are a number of differences between the CRAC2 methodology and the method that has been normalized to SRP conditions to arrive at the doses presented in Section 4.2.1.4. For example, mean doses determined by CRAC2 are not directly comparable to the median (or fiftieth percentile) meteorological condition employed for the doses in Section 4.2.1.4. Also, CRAC2 dose pathways include small doses from ground-deposited material, food pathways, and inhalation of resuspended radionuclides not considered in the other dose values. Other differences exist in the net effectiveness assumed for iodine retention by the charcoal filters, the duration of the releases, site boundary distances, meteorological data base, and the population data year chosen. Despite these differences in methodology and assumptions, the results are in good agreement.

Dose and health impacts

Calculations using the CRAC2 code show that, for the hypothetical 10-percent core-melt accident, there are no cases of early fatalities, no cases where the whole-body dose exceeds 25 rem, and no cases where the thyroid dose exceeds 300 rem (10 CFR 100 siting criteria). The mean value for the site boundary whole-body dose is 0.35 rem and the expected peak value (i.e., for the most improbable meteorological condition sampled) is 1.7 rem. The mean value for the site boundary thyroid dose is 1.7 rem with a peak value of 11.7 rem.

Figure 4-10 displays the calculated CCDF for latent cancer fatalities. The mean number of cancer fatalities (including thyroid cancers) is 2.4 and the peak is 20 with a conditional probability (i.e., assuming the accident has occurred) of 1.4×10^{-4} per reactor-year. (Excluding thyroid cancers, the mean number of latent cancer fatalities is 1.0 and the peak number is 15.) When the probability of a 10-percent core-melt accident (10^{-6} to 10^{-8}) is taken into account, the mean number of latent fatalities is, conservatively, 2.4×10^{-6} per reactor-year or an average of one death per 400,000 reactor-years of operation.

Figure 4-11 displays the CCDFs for total population whole-body exposure in person-rem, that is, the conditional probability that the total population exposure will equal or exceed the values given. The peak population exposure is 2.4×10^5 person-rem with a conditional probability of 1.1×10^{-4} and the mean value is 1.6×10^4 person-rem for the population within 800 kilometers of the reactor site, and 7.7×10^3 person-rem for the population within 80 kilometers of the reactor site. Again, if the probability of an accident with a 10-percent core melt (10^{-6} to 10^{-8}) is taken into account, the mean value for total exposure for the population within 80 kilometers is, conservatively, 7.7×10^{-3} person-rem per reactor-year. For perspective, this can be compared to a whole-body dose from natural background radiation of 8×10^4 person-rem per year for the population in question.

Economic and social impacts

The offsite economic impact of a reactor accident is calculated as a probability distribution for the cost of offsite mitigating actions. The factors contributing to these estimated costs include the following:

- The value of crops contaminated and condemned
- The value of milk contaminated and condemned

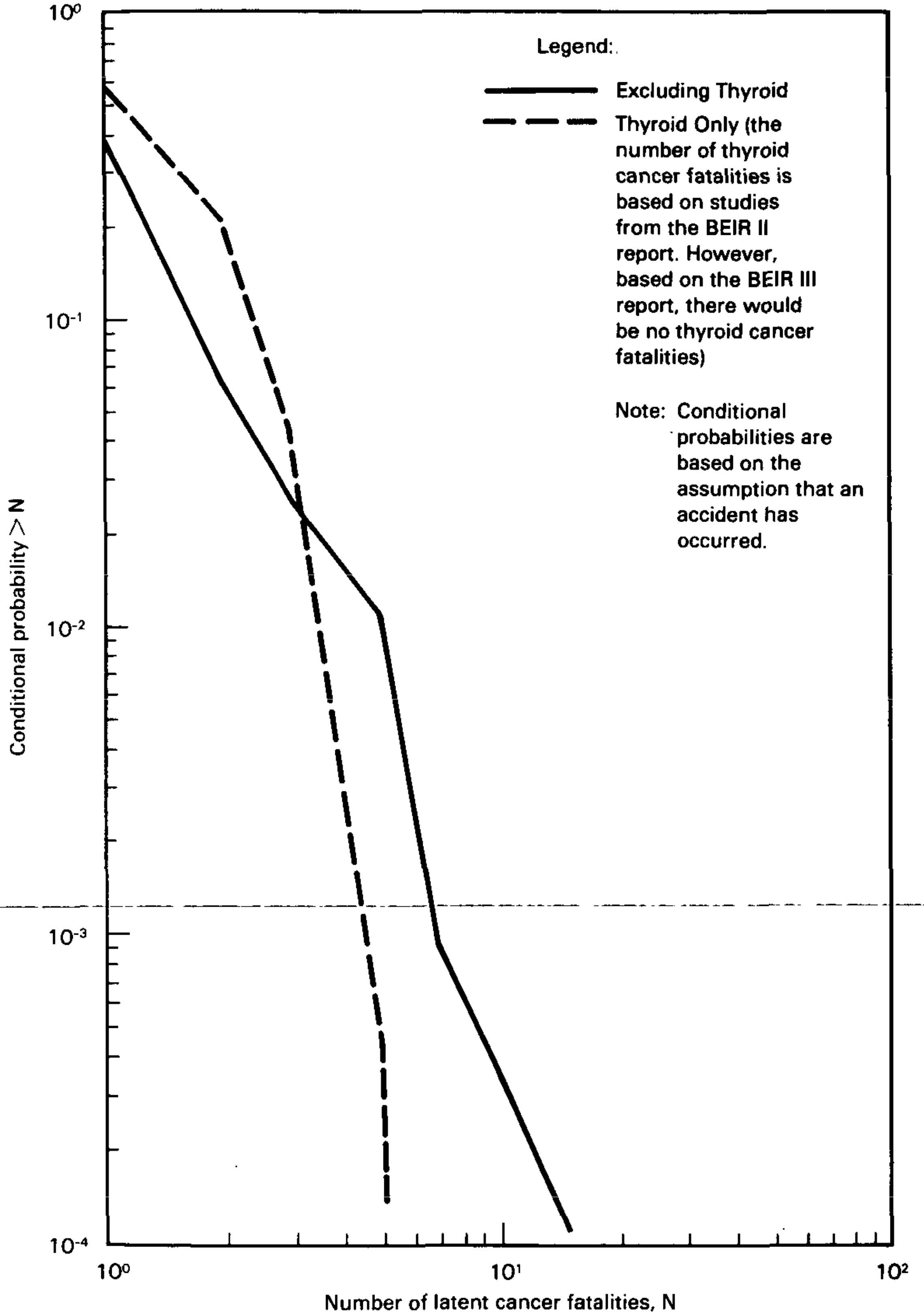


Figure 4-10. CCDFs for latent cancer fatalities in a hypothetical 10-percent core meltdown as calculated with the CRAC2 code.

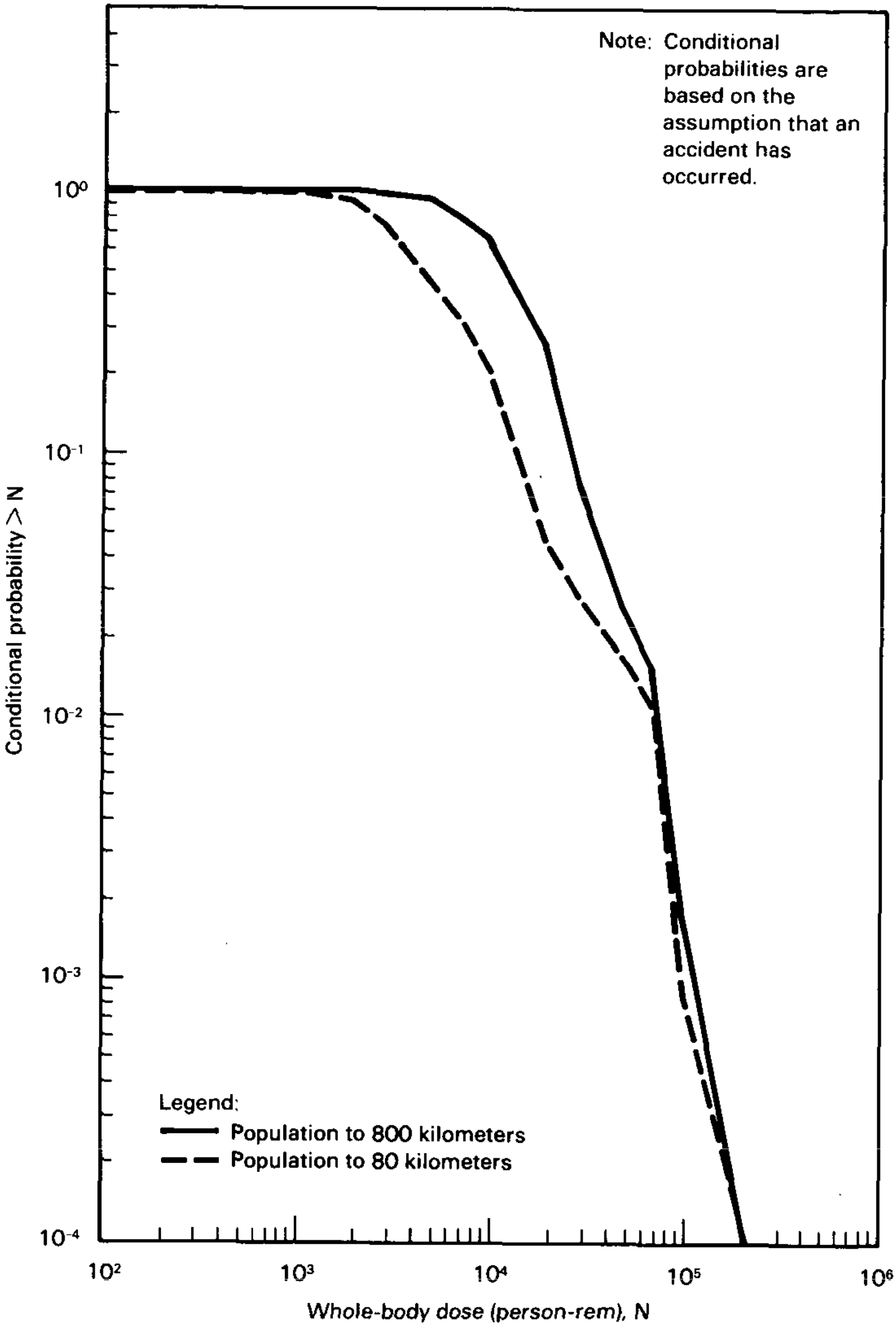


Figure 4-11. CCDF for whole-body person-rem doses in a hypothetical 10-percent core meltdown, as calculated with the CRAC2 code.

- Costs of decontamination of property where practical
- Indirect costs due to loss of use of property and incomes derived therefrom

The last cost would derive from the necessity for interdiction to prevent the use of property (i.e., farm crops, etc.) until it is either free of contamination or can be economically decontaminated.

The mean offsite economic risk from an accident where 10 percent of the core melts is $73,000 and the peak cost is $\$1.7 \times 10^6$ at a conditional probability of 2.4×10^{-4}. For comparison, the cost of property damage due to automobile accidents for the area of a circle with a radius of 80 kilometers is $\$1.3 \times 10^7$ per year and the property damage due to fires for the same area is $\$5.5 \times 10^6$ per year.

Table 4-22 summarizes all the consequences from a postulated 10-percent core-melt accident.

Table 4-22. Consequences from a postulated accident resulting in 10-percent core melt[a]

Consequence	Mean value	Peak value
Early fatalities	0	0
People with whole-body dose of 25 rem	0	0
People with thyroid dose of 300 rem	0	0
Latent-cancer fatalities (excluding thyroid)	1.0	14.9
Thyroid-cancer fatalities	1.4	5.2
Site boundary whole-body dose (rem)	0.35	1.7
Site boundary thyroid dose (rem)	1.7	11.7
Population whole-body dose (person-rem) (population to 80 kilometers)	7.7×10^3	2.4×10^5
Population whole body dose (person-rem) (population to 800 kilometers)	1.6×10^4	2.4×10^5
Population thyroid dose (person-rem) (population to 80 kilometers)	8.6×10^4	3.6×10^5
Population thyroid dose (person-rem) (population to 800 kilometers)	1.0×10^5	3.8×10^5

[a]Hypothetical 10-percent core melt as calculated with CRAC2 code.
TC| The probability of a 10-percent core melt is estimated to be less than 10^{-6}.

Table 4-23 shows average values of risk associated with population dose, early fatalities, latent fatalities, and costs for early evacuation and other protective actions, which have been calculated for a 10-percent core melt. These average values are obtained by summing the probabilities multiplied by the consequences over the entire range of the distributions. Because the probabilities are on a per-reactor-year basis, the averages shown are also on a per-reactor-year basis.

Table 4-23. Average values of environmental risks due to a 10-percent core melt, per reactor-year[a]

Offsite risk	Value
Population exposure	
Person-rem within 80 kilometers	7.7×10^{-3}
Person-rem total	1.6×10^{-2}
Early fatalities	0.0
Latent cancer fatalities	
All organs excluding thyroid	1.0×10^{-6}
Thyroid only	1.4×10^{-6}
Cost (dollars) of protective actions and decontamination	7.3×10^{4}

[a]Hypothetical 10-percent core melt as calculated by the CRAC2 code. The probability of a 10-percent core melt is estimated to be less than 10^{-6}.

4.2.1.6 Total risk from all postulated reactor accidents

To provide a perspective of the overall reactor accident risk on the Savannah River Plant and of L-Reactor operation, Figure 4-12 shows *preliminary* total probability curves that present the annual probability of a resident living at the SRP site boundary receiving more than a certain dose from postulated accidents (see Section G.5.7.3). These results are based on accident analyses presented in the Safety Analysis Report and a supporting document (Du Pont, 1983a; Church, 1983), including less severe accidents at the high end of the probability spectrum and an assumed hypothetical 100-percent core melt at the upper bound of the consequences spectrum (see also Section G.5.7.3). Six different accident initiators were considered. For all the accidents, the most probable outcome would be no reactor damage. For the six accidents, only 11 postulated, but highly improbable, sequences resulted in significant amounts of reactor core damage (ranging from 1 percent to 100 percent). For the postulated 100-percent core-damage accidents (sequences 2, 3, 4, and 6 below), Figure 4-12 also reflects the failure of the Confinement Heat Removal System. These accident sequences were as follows: TC TC

1. A loss-of-coolant accident with only one operable ECS.

2. A loss-of-coolant accident with a total failure of the ECS. EN-27

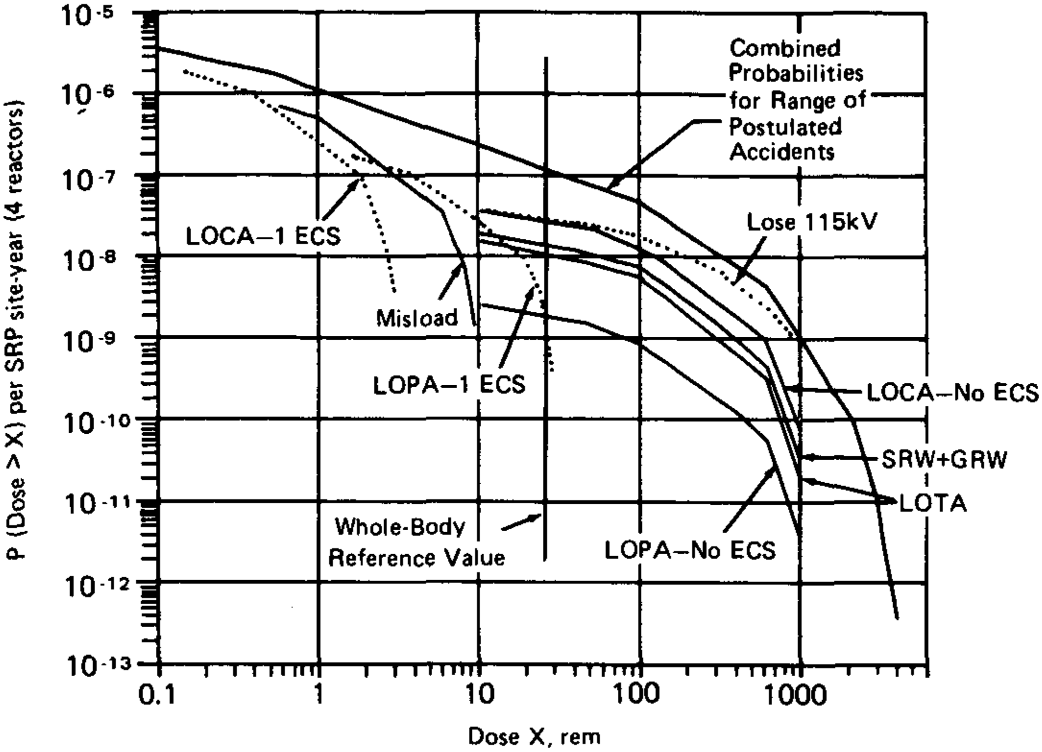
3. The withdrawal of a single control rod or a gang of control rods with a failure of both the safety-rod scram and the ABS-SC.

4. Loss of coolant to a single target assembly with a failure of both the safety-rod scram and the ABS-SC.

5. A loss-of-pumping accident with only one operable ECS.

6. A loss-of-pumping accident with a total failure of the ECS.

EN-27



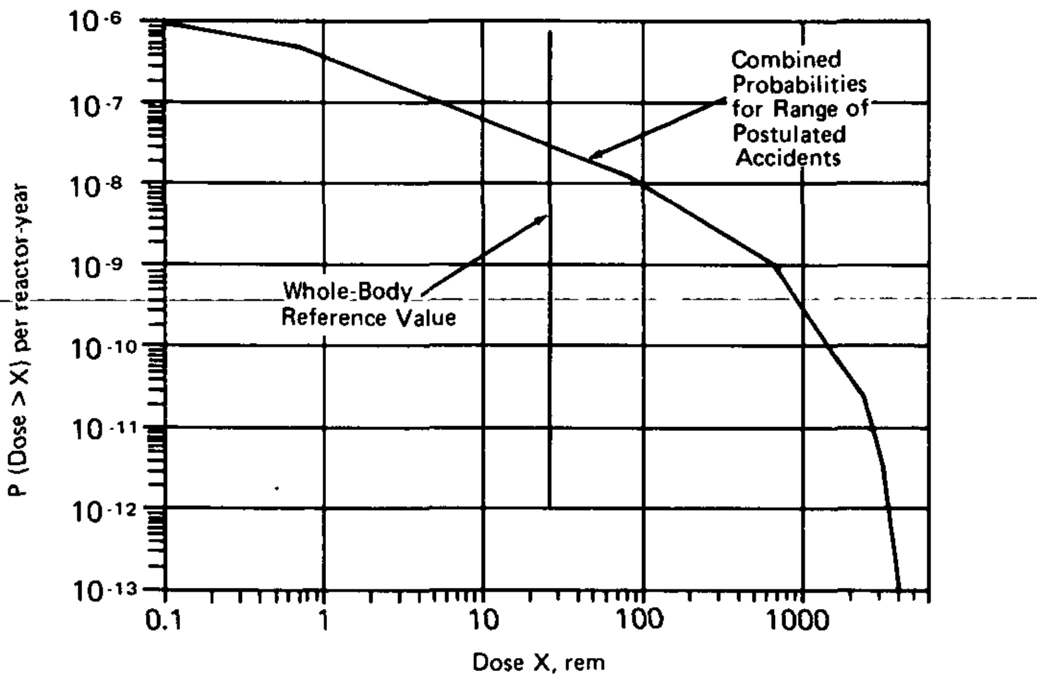


Figure 4-12. Total probability (P) per SRP site-year (upper) and reactor year (lower) that the whole body dose to a person on the plant boundary will exceed a specified value, X rem .

7. A reloading error during charge/discharge operations making the reactor supercritical.

8-11. Extended total loss of offsite (commercial) power together with extended loss of onsite generating capability. This sequence would affect all reactors and is postulated to result in core damage to 1, 2, 3, or 4 reactors.

The computed offsite doses for the loss-of-coolant accident with 1 percent core damage and the reloading error with 3-percent core damage are listed in Table 4-20 for median meteorology (conditions for which the more severe meteorological conditions are not exceeded 50 percent of the time). The relative doses for other meteorological frequencies are shown in Figure 4-9. Doses for postulated core damage greater than 1 percent would be proportional to the dose for 1-percent damage.

The probability of occurrence of an accident sequence was combined with the data for meteorological probability versus offsite dose for each of the above 11 sequences. Then, for a given dose rate, the occurrence probabilities were combined to obtain an overall probability per reactor-year of exceeding a given dose. This overall dose probability curve is shown in Figure 4-12. The results are consistent with (1) the decreasing frequency of meteorological conditions that give higher doses for any accident (Figure 4-9), and (2) the extremely low probability of accidents occurring with core damage exceeding 3 percent. EN-27

The implementation of reactor safety programs has reduced the probability of occurrence of accidents to extremely low levels. Figure 4-12 indicates that the probability of exceeding the Nuclear Regulatory Commission site whole-body dose criteria for commercial power reactors (10 CFR 100) of 25 rem at the site boundary in accident situations is extremely low (less than 10^{-7} per year), even in the most severe hypothetical accidents.

The traditional approach to SRP reactor safety analysis addressed the consequences for "worst-case credible" (and even some "noncredible") accidents based on the single-failure criterion. This criterion assumes that the initial accident is compounded by the failure of the single-most-important active component designed to mitigate the accident. (An active component is one that must change its state to perform its duty; e.g., a valve must be realigned.) The initiation of the accident and the failure of the component were considered without regard to the actual probability of their occurrence. Results from the preliminary risk evaluation of the accident sequences discussed above support earlier evaluations made for worst-case scenarios using single-failure criteria, which concluded that there is negligible risk to public health and safety.

4.2.2 Non-nuclear hazards and natural phenomena

4.2.2.1 Toxic-gas release

During prior reactor operations, the effects of toxic-gas releases were analyzed, and provisions were made for shutdown, building evacuation, and remote control of coolant flow pumps and valves. The two toxic gases considered were the chlorine used to prevent biofouling of reactor heat exchangers and the hydrogen sulfide used in the heavy-water production area. Two recent changes in plant operation have essentially eliminated any hazards from these gases:

1. L-Reactor would use sodium hypochlorite rather than chlorine as the cooling-water biocide. Sodium hypochlorite presents no toxic-gas health hazard to reactor operation and would provide the same biofouling inhibition as chlorine.

2. Heavy-water production at the Savannah River Plant has stopped. The large quantities of hydrogen-sulfide gas stored in the heavy-water production area have been removed.

4.2.2.2 Fire

The presence of flammable materials in the reactor building is strictly controlled, so the probability of a large fire is low. Because of redundancies in shutdown, a fire (e.g., in an electrical cable tray) will not prevent a safe shutdown. Analyses performed (Du Pont, 1983a) for L-Reactor startup did not find any credible fire hazard that would result in a release of radioactivity. The only fire-related incident deemed credible was the possibility of extended downtime and repair costs, but no specific cause for such a fire was identified.

In addition to normal operating personnel who are instructed in basic fire fighting, a fully trained and equipped fire department is maintained at Savannah River Plant.

A large cleared area surrounding the reactor building protects against hazards from a forest fire. Smoke from a forest fire could require temporary evacuation of L-Reactor. However, normal and emergency facilities are provided to maintain safe conditions, and the reactor could also be shut down and maintained in a safe shutdown condition from the remote control station.

4.2.2.3 Earthquakes

As noted in Section 3.3.2, there are no known capable faults within 300 kilometers of the L-Reactor site, except perhaps the geophysically inferred faults in the meizoseismal area of the 1886 Charleston earthquake (Du Pont, 1980; Georgia Power Company, 1982). No reservoir-induced seismicity is associated with Par Pond, which is located about 6.5 kilometers northeast of L-Reactor.

Probabilistic and deterministic analyses, commensurate with the criteria used by the NRC in 10 CFR 100, have determined that the maximum seismic hazard at the Savannah River Plant is due to a Modified Mercalli Intensity MMI; Langley and Marter, 1973) of VII (magnitude 5.0 to 5.5) earthquake in the immediate vicinity of Savannah River Plant or a postulated MMI = X (magnitude 6.6) earthquake near Bowman, South Carolina, 95 kilometers from Savannah River Plant. In both cases, the expected site MMI = VII corresponds to a peak horizontal free field acceleration of about 0.10g (Du Pont, 1982a). A design-basis earthquake acceleration of 0.20g has been established for design and analysis of key seismic-resistant buildings, systems, and components at Savannah River Plant. This design acceleration is predicted to be exceeded only once in 5000 years (Du Pont, 1982a).

Studies performed by Rutledge (1976) and D'Appolonia (Du Pont, 1980) show that earthquake ($\leq$0.20g)-induced liquefaction is not a potential problem for L-Reactor and other SRP facilities located on the Aiken Plateau (cf., Langley and Marter, 1973, and Figure F-1).

The foundation investigations for L-Reactor were performed by the U.S. Army Corps of Engineers (COE, 1952a). At their recommendation, a soil grouting program was undertaken to improve subsurface conditions (COE, 1952b). A number of earthquake-engineering investigations have been performed to establish earthquake-design criteria and to recommend modifications to component design (e.g., Du Pont, 1968; List, 1969; Rutledge, 1976; Geotechnical Engineers, Inc., 1979; URS/JAB, 1982a,b,c).

The reactor buildings are heavy, blast-resistant, concrete structures. Several earthquake-engineering improvements have been made at P-, C-, and K-Reactors to meet the seismic criteria for a design basis earthquake of 0.20g. These improvements were also made in the L-Reactor upgrade and include the following:

- Providing additional seismic bracing on the actuator tower to reduce its dynamic response to earthquake excitation
- Strengthening the 61-meter building exhaust stack
- Improving the lateral support for the emergency cooling-system piping and the supplementary safety system (neutron poison injection system) piping
- Improving the anchors on the 12 track-mounted process heat exchangers

An earthquake monitoring system will automatically alarm at 0.002g and shut down the reactor when the earthquake excitation reaches 0.02g (one-tenth the design-basis value). In more than 28 years of reactor operation there has never been a seismic alarm.

4.2.2.4 Tornado and hurricane effects

The SRP site lies within tornado risk region B (Twisdale and Dunn, 1981) with an occurrence rate of about 2.69 x 10^{-4} per square kilometer per year corrected for unreported tornadoes. Based on this study and on work by Reinhold and Ellingwood (1982), the probabilities of a tornado striking a point at Savannah River Plant are calculated for the midpoint characteristics of the Fujita-tornado intensity scale (F-scale); the results are presented in Table 4-24. In addition, this table provides the probability of striking a building as large as L-Reactor at the SRP site. Risks are extremely low. TC

Hurricanes that occur along the South Carolina coast generally will not subject the Savannah River Plant to winds in the whole-gale to hurricane range

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Table 4-24. Annual probabilities of a tornado strike at L-Reactor for midpoints of the Fujita tornado intensity scale

Fujita intensity scale	Wind speed[a] (m/sec)	Annual probability of a tornado strike at L-Reactor[b]
F-0	16.1	7.79×10^{-4}
F-1	41.4	3.52×10^{-4}
F-2	60.4	1.65×10^{-4}
F-3	81.4	5.35×10^{-5}
F-4	104.4	1.58×10^{-5}
F-5	129.4	2.61×10^{-6}
F-6	156.2	3.01×10^{-7}

[a]Wind speeds are reported for the midpoints of the Fujita tornado intensity categories.

[b]Based on an occurrence rate of 2.69×10^{-4} tornados per square kilometer per year (Reinhold and Ellingwood, 1982, Tables 16 and 17), and an L-Reactor building width of 170 meters.

because Savannah River Plant is approximately 160 kilometers inland, and the high winds associated with hurricanes tend to diminish as the storms move over land. Winds of 33.5 meters per second were measured once by anemometers mounted at the 61-meter level of the WJBF-TV tower during the history of Savannah River Plant, as Hurricane Gracie passed north of the plant site in September 1959. At Augusta, Georgia, the fastest 1-minute wind speed for the 1950-1978 period of record was 37.1 meters per second (corrected to an anemometer height of 10 meters). The return periods for 1-minute wind speeds at Augusta are reported in Table 4-25.

Table 4-25. Return of 1-minute wind speeds at Augusta, Georgia

Return period (years)	Wind speed (m/sec)
100	37.1
1,000	46.9
10,000	56.8
100,000	66.2

TC

The L-Reactor building is a concrete structure that is blast-resistant to a pressure of about 50,000 pascals. Its weakest structural area, the disassembly area, can withstand a tornado-induced pressure drop of 20,700 pascals (Yau and Zeh, 1976), twice that created by an intensity F-5 tornado (a very low probability event; see Table 4-24).

The 61-meter-tall ventilation exhaust stack at L-Reactor is designed to withstand a 1-in-10,000 year event (see Table 4-25) with winds of 56 meters per second. However, if the stack should fall, it would not strike a portion of the reactor that would impair the ability to shut down the reactor or maintain cooling capabilities.

The resistance of the L-Reactor building to wind-driven missiles was analyzed by Yau and Zeh (1976) as part of a study to determine the tornado resistance of the reactor building. The greatest penetration of the concrete reactor building was calculated to be caused by a 30-centimeter steel pipe; less than 40 percent of the wall thickness of the disassembly area wall was calculated to be penetrated by the pipe.

Because the disassembly area is structurally the weakest part of the reactor building, the rest of the building was also deemed safe from penetration by the postulated missiles. The probability of tornado missiles passing through exterior doors, ducts, vents, or other openings that are not tornado resistant is negligibly small.

Damage to the 61-meter-tall stack, confinement system filter compartments, and other parts of the building that are not resistant to tornados would not cause, directly or indirectly, a reactor accident. A tornado strike causing damage to the filter compartments or the stack after an independently caused reactor accident would increase offsite dose effects. Such multiple-series accidents are not considered in this analysis because of the extremely low probability of a tornado striking the reactor immediately following a reactor accident.

Emergency power capabilities at L-Reactor are sufficient to maintain the reactor in a safe shutdown condition if outside power is lost during a severe weather disturbance.

4.2.2.5 Floods

As noted in Section 3.4.1, L-Reactor (floor elevation of 76.5 meters) is situated well above (1) the maximum historical flood stage of 36 meters and (2) the flood stage of 43.6 meters calculated to result from the domino failure of Savannah River dams above the SRP. Flooding of these magnitudes could cause the loss of the river pumphouses supplying cooling water, and of external electrical power. However, onsite storage of cooling water (9.5×10^4 cubic meters) is, with partial recirculation, adequate to remove heat during shutdown, and onsite emergency power generation would maintain the reactor in a safe shutdown condition.

Because of the geographic location of the site, the formation of significant amounts of ice on streams and rivers occurs rarely. A review of Augusta, Georgia, newspaper accounts dating back to approximately 1800 indicates that the formation of ice jams on the Savannah River occurred in 1827 and 1886. Neither event resulted in reported flooding (Du Pont, 1980).

The L-Area is not subject to local flooding. Pen Branch to the west and north, and Steel Creek to the east and south provide adequate drainage. Opposite L-Reactor these streams are at least 15 meters below the reactor floor elevation under normal flow conditions.

4.3 TRANSPORTATION

4.3.1 Onsite and offsite shipments

Onsite

The proposed restart of L-Reactor would increase the total number of onsite shipments by an amount typical of the individual reactor areas now operating. Rail shipments of irradiated fuel from the reactor to the separations plants could be made with existing casks and equipment using current rail crews. Truck shipments involving unirradiated reactor fuel, deionizer casks, and wastes could also be made with existing equipment using the SRP traffic and transportation (T&T) crews currently assigned to these tasks. Higher volume shipments, such as scrap metal, waste dumpsters, and D_2O drums, would require purchase of additional equipment and a modest increase in T&T crews. Also, the operation of L-Area would require about the same number of nonradioactive shipments by T&T and vendor trucks as the other individual reactor areas. No significant impact on SRP transportation systems is expected from the operation of L-Area.

Shipments on the SRP rail system would include the following:

1. Empty casks to transport reactor fuel elements.

2. Intact irradiated fuel in 70-ton casks (CD casks) on flatbed railcars to 200-F or 200-H areas.

3. Any irradiated fuel with cladding defects in a special containment device ("harp") within a 55-ton failed fuel element cask to a 200-Area.

4. Occasional containers of helium or Polybor or other nonradioactive materials.

Onsite truck shipments for L-Area would include the following:

1. Unirradiated fuel in steel shipping boxes and other reactor lattice components from the 300-M area.

2. Irradiated lithium-aluminum control rods and blanket assemblies in a 45-ton cask on a flatbed trailer from the L-Area disassembly basin to 200-H area.

3. Irradiated scrap metal in a 15-ton cask or replacement cask from the L-Area disassembly basin to the SRP burial ground (about 80 shipments annually).

4. Moderator (D_2O) in stainless steel 55-gallon drums to and from other reactor areas and the 400-D area where contaminant removal and purification facilities are located (about 700 drums annually).

5. D_2O purification deionizers from 100-L area. After the resin is depleted, the deionizer would be shipped to 100-K area in a cask on a special flatbed trailer for dedeuterization before being shipped to the burial ground (about three annually). A replacement D_2O equilibrated purification deionizer would be shipped concurrently from 100-K to 100-L area.

6. Basin water deionizers mounted in casks on a special trailer to Building 245-H area for regeneration and return to L-Area service (about five annually).

7. Liquid and gas samples on a pickup truck to laboratories on each shift.

8. Dry wastes in collection pans on a daily basis and boxes of wastes intermittently generated during jobs such as replacing containment filters to the SRP burial ground.

9. Liquid light-water wastes to the underground storage tank in 100-C area (infrequently) or, when volumes are large, to F-Area waste management tanks, in an unshielded tank trailer.

10. Nonradioactive materials to L-Area on Savannah River Plant or vendor trucks.

Offsite

Shipments from off the site to support L-Area operation would include petroleum distillate products from major distribution terminals in Augusta, Georgia, and Aiken County, South Carolina; chemicals from normal distribution points; solid depleted uranium and 1.1-percent uranium-235 from the Feed Materials Production Center in Fernald, Ohio; and highly enriched uranium metal billets from the Y-12 plant in Oak Ridge, Tennessee. The latter shipments would be safeguarded (see Section 4.3.2.2). Operation of L-Reactor would increase the amount of plutonium metal shipped offsite from Savannah River Plant in special safeguarded Department of Energy (DOE) vehicles and also would increase the number of DOE-escorted shipments of uranyl nitrate hexahydrate solution shipments to the Y-12 plant in Oak Ridge, Tennessee.

These offsite shipments of nuclear and other hazardous materials would be subject to the same Department of Transportation (DOT) regulations (49 CFR 170-179) as other similar cargo already in commerce.

Primary reliance for safety in the transport of hazardous materials, including nuclear material, is placed on the packaging. The nuclear packaging standards are established by DOT, DOE Orders, and some of the states through which materials are transshipped. These standards are established according to the type and form of material for containment, shielding, nuclear criticality safety, and heat dissipation. The standards for nuclear materials provide that the packaging shall prevent the loss or dispersal of the radioactive contents, retain shielding efficiency, assure nuclear criticality safety, and provide adequate heat dissipation under normal conditions of transport and under specified accident damage test conditions (i.e., the design-basis accident). The quantity of material contained in packages not designed to withstand accidents is limited, thereby limiting the risk from releases that could occur in an accident. The quantity of material contained in a shipping package also must be limited so that the standards for external radiation levels, temperature, pressure, and containment are not exceeded.

Protection of the public from external radiation is provided by limitations on the radiation levels at the surface of, and at specified distances from, the outside of packages of nuclear materials and by storage and segregation provisions for such packages in transit. The number of packages in a single vehicle or area is limited to control the aggregate radiation level and to ensure nuclear criticality safety in the event of conceivable accidents. In addition, shipments of special nuclear materials such as plutonium and enriched uranium are safeguarded against theft or sabotage by use of DOE equipment and DOE couriers.

Nuclear materials shipped offsite are packaged by the operating contractor as required by DOT specifications with a DOE- or NRC-approved certificate of compliance for the packaging selected. The packaged material is transferred to the custody of DOE-SR, which becomes the consignor for the shipment.

Pollutant emissions

Pollutants would be released to the atmosphere from transportation operations associated with the L-Reactor operation. Table 4-26 lists the pollutant emissions from vehicles associated with L-Reactor operation that would occur both on and off the Savannah River Plant.

Table 4-26. Transportation-related nonradiological emission of pollutants associated with L-Reactor operation[a]

		Cars and light trucks	Trucks less than 10 tons	Trucks[b] off SRP site
	Fuel	gasoline	diesel	diesel
TC	Annual fuel consumption (liters)	147,600	64,300	199,900
TC	Kilometers traveled per year	643,600	290,000	491,000
	Annual emissions (kg)			
	Particulates	215	850	1,440
	Sulfur dioxide	160	310	530
	Nitrogen oxide	2,000	1,720	2,910
	Carbon monoxide	40,800	470	790
	Hydrocarbons	3,550	1,050	1,780
	Tire particulates	80	180	260

[a]Adapted from CRC Press (1972).
[b]Average 10-ton.

Transportation associated with L-Reactor operation at the Savannah River Plant is expected to consist of cars and light trucks for 643,700 kilometers burning 147,600 liters of gasoline and trucks weighing less than 10 tons for 241,000 to 491,000 kilometers burning 64,400 liters of diesel fuel each year. This would consist of an incremental transportation increase of 8 percent for the total Savannah River Plant. Neither the increased onsite or offsite transportation pollutant sources are expected to significantly impact ambient air quality.

The potential for transportation accidents involving shipments of materials offsite is assumed to be comparable to that for general truck transportation in the United States. Based on accident rates and injury and fatality rates (AEC, 1972; Clarke et al., 1976), 0.4 injury and 0.02 fatality are expected annually from truck accidents associated with offsite shipments of L-Reactor materials.

The potential for transportation accidents onsite with resultant injury or fatality is much less than for public highways. Shipments onsite are almost never made during shift change and occur when traffic densities on the SRP highways are very low. Therefore, the risk of injury or fatality from operation of vehicles onsite is much less than one per year.

4.3.2 Radiological impacts

4.3.2.1 Routine radiation exposures

Onsite transportation

Nuclear materials moved onsite are packaged to contain the material during transit and shielded to minimize radiation exposures to drivers, riggers, and others near the material during transportation activities. The DOE contract permits the operating contractor to use procedural controls, escorts, and traffic controls to transport materials onsite.

The 70-ton railroad casks used to ship irradiated reactor fuel are separated from the locomotive by one or two spacer cars. The incremental exposure to the rail crew is estimated to be less than 10 millirem per year, based upon 1979 and 1980 exposure records.

The casks used to ship irradiated materials from reactor areas by truck are mounted on assigned trailers and do not require rigging. The annual radiation exposures, averaged over a 6-year period, were 330 millirem per year or less to the drivers who exclusively transport scrap metal and deionizer casks from the three operating reactors. Radiation exposure records show that cumulative exposures to T&T employees average about 2 to 3 person-rem per year per reactor area for all rigging and transportation activities.

Offsite transportation

The radiation levels from offsite shipments on exclusive-use vehicles to or from SRP are well below DOT radiation limits for transportation of nuclear materials. Typical measured radiation levels from these shipments are (1) depleted uranium shapes - less than 1 percent of DOT radiation limits, (2) uranyl nitrate uranium shapes - less than 1 percent of DOT radiation limits, (2) uranyl nitrate solutions in MC 311 cargo tanker - less than 2 percent of DOT radiation limits, and (3) safe secure transporter (SST) - about 10 percent of DOT radiation limits.

The radiological exposure from transportation of these nuclear materials from and to SRP is small, about 0.01 person-rem per year to the population along the shipping route; this subject was addressed in the NRC report, Final Environmental Statement on the Transportation of Radioactivity by Air and Other Modes (NRC, 1977a). Therefore, the consequences will not be examined in detail in this study.

4.3.2.2 Safeguards

Enriched uranium and plutonium resulting from L-Area operation would be TC shipped to and from Savannah River Plant in packages that meet the DOT Type A_2 requirements. These shipments would be safeguarded in the DOE's existing SST system with a courier escort. This transporter is essentially a mobile vault with built-in deterrent and disabling devices and special electronically coded locks set in vault-type doors; it is operated by carefully selected, specially trained personnel.

MC 311 or MC 312 cargo tankers are used to transport enriched uranyl nitrate hexahydrate solution. They are moved with SST tractors with a DOE escort.

4.3.2.3 Accident release risks

The cumulative risks from accidents during onsite transportation activities (in curies per year) for a single reactor are estimated to be about 2×10^{-3} curie beta-gamma per year, 2×10^{-5} curie alpha per year, and 3×10^{-2} curie tritium per year, as shown in Table 4-27. The radiological risks expressed as curie-per-year values were calculated using the GASPAR code defined in NRC Regulatory Guide 1.109 (NRC, 1977b), as modified for accidental releases.

The calculated total-body radiological risk to the offsite population from accidental release of nuclear materials in transport to and from L-Area operation would be 1.1 person-rem per year and, to the maximally exposed member of the population, would be 0.017 millirem per year (Table 4-28).

In the NRC analysis of radiological risks from radionuclide transport, several serious accidents were postulated and the release of radioactive material was assumed. However, the consequences of most events were determined to be not severe. The most serious postulated accident results in one early fatality and exposure of 60 persons to significant levels of radiation. The probability of such an event was estimated to be less than 3×10^{-9} per year for shipping rates in 1975 and is expected to decrease further due to more stringent shipping requirements that have been initiated or are planned (NRC, 1977a). Uranyl hexahydrate solution is shipped in DOT MC-311 or MC-312 cargo tanks that might, after an accident, release uranyl nitrate solution on or near a bridge and could contaminate a stream supplying a public water supply. In an extreme

Table 4-27. Annual onsite risk during transportation for L-Area

Shipping operation	Risk (Ci/yr)[a] Beta-gamma	Alpha	Tritium
Irradiated fuel	1×10^{-6}	1×10^{-9}	$\sim 2 \times 10^{-4}$
Unirradiated fuel		Very small	
100-Area sample trucks	--	--	$\sim 2 \times 10^{-2}$
Scrap metal		Extremely small	
Solid wastes	$<1 \times 10^{-6}$	$<1 \times 10^{-9}$	
Moderator shipments	--	--	$\sim 3 \times 10^{-3}$
Unshielded trailer shipments	2×10^{-3}	2×10^{-5}	
Deionizers			
Reactor basin	1×10^{-6}	1×10^{-9}	
Purification		Very small	
Total	2×10^{-3}	2×10^{-5}	$<3 \times 10^{-2}$

[a]Adapted from Du Pont (1982b).

Table 4-28. Annual radiological risk to the public from potential transportation accidents

Dose commitment	Risk: Maximum individual (mrem)	Population (person-rem)
Total body	1.66×10^{-2}	1.12
Bone	5.31×10^{-1}	3.55×10^{1}
Lung	5.29×10^{-2}	2.68
Liver	6.07×10^{-2}	3.96
Thyroid	8.29×10^{-5}	9.52×10^{-3}
Kidney	4.61×10^{-2}	3.01
GI-tract	7.33×10^{-4}	4.93×10^{-2}

accident scenario involving a major fire, some respirable particulates might be generated. The integrated radiological risk to the population along the route from these scenarios is about 2×10^{-6} person-rem per shipment.

4.4 L-REACTOR MITIGATION ALTERNATIVES

This section includes evaluations of the following mitigation alternatives: safety-system alternatives, cooling-water alternatives, and alternatives for the disposal of liquid waste and 186-Basin sludge. This section describes the effects of the possible implementation of each of these alternatives and its mitigation costs and schedules.

4.4.1 Safety-system alternatives

In part because of their low-temperature, low-pressure operation, SRP reactors have a low potential for an accidental widespread dispersion of radioactivity. Also, SRP reactors are equipped with instrumentation, computer controls, supplementary shutdown systems, and multiple cooling systems that provide a high degree of safety assurance against accidents that might cause fuel melting and releases of radionuclides to the environment. The following systems are being considered to mitigate potential accident consequences:

- Remote storage system
- Low-temperature adsorption system
- Tall stack
- Internal containment system
- Leaktight dome

After a brief description of each system the systems are compared using the following measures:

1. Technical feasibility
2. Capital cost
3. Cost of lost production
4. Total cost
5. Benefit in extra person-rem averted beyond existing confinement system performance
6. Cost/benefit ratio in dollars per extra person-rem averted, assuming an accident occurs
7. Timing

4.4.1.1 Existing confinement system (preferred alternative)

SRP reactors were built in the early 1950s, before containment systems became an accepted practice for nuclear reactors. In the 1960s, a variety of containment/confinement systems were considered for SRP reactors; the vented confinement system was selected as the optimum balance between cost and risk. The cost of a containment vessel over the large, sprawling SRP reactor buildings is considered to be impractical compared to the risk associated with improbable reactor accidents.

SRP reactors are designed and operated to make the melting of fuel or target material, with the consequent release of radioactivity to the environment, highly improbable. Nevertheless, these reactors are equipped with a confinement system, which consists of a series of filters through which air is exhausted from the reactor building. This system traps moisture and particulates and absorbs radioactive iodine on carbon filters. Noble gases and tritium would pass through the system and would be exhausted to the atmosphere from a 61-meter stack.

The confinement systems for the SRP reactors are not subject to overpressurization because the system is vented through filters and a stack. Furthermore, these reactors operate at a coolant temperature and pressure much lower than a commercial power reactor. The "stored energy" within an operating SRP reactor is much less than that within an operating power reactor; therefore, the risk of overpressurization is much less.

Calculated offsite doses for average meteorology with this system do not exceed 0.39 rem to the whole body and 1.5 rem to the thyroid of the individual receiving the maximum exposure for the range of postulated accidents. |TC

4.4.1.2 Remote storage system

Among several possible improvements to the confinement system is a remote storage system, as illustrated in Figure 4-13. In this system the reactor room exhaust is separated from other reactor-building exhausts and fed through a large online storage tank, as shown in Figure 4-13. Nearly 1 hour of normal reactor room exhaust flow could be contained in the long storage tank. One hour after an accident, the storage tank would be isolated so that the initial release of radioactive material would be trapped. Any further effluent from the reactor room would bypass the storage tank. Downstream of the storage tank, the reactor room exhaust flow joins flow from the purification and below-grade areas, such that all building exhaust flow (except from assembly and disassembly) passes through a large sand filter and underground carbon filters. Thus, releases of noble gases and tritium occurring during the first hour would be retained and radioactive iodine and airborne particulates would be captured regardless of the source or duration of the accident. |TC

Exhaust from either purification (e.g., blanket gas-venting) or below-grade areas (e.g., heavy-water spills) can be procedurally diverted into the storage tank (see Figure 4-13) to improve control of other minor incidents. A 300-meter stack would help mitigate the consequences of a possible upstream failure to contain the release. It is included as a part of this alternative.

4.4.1.3 Low-temperature adsorption system

Another possible improvement to the confinement system is a low-temperature solid-adsorption system using hydrogen mordenite as a noble gas adsorbent in addition to more conventional filters. Laboratory experiments have been conducted and a concept has been proposed for this multipurpose system. However, this concept would require much more development work before engineering feasibility

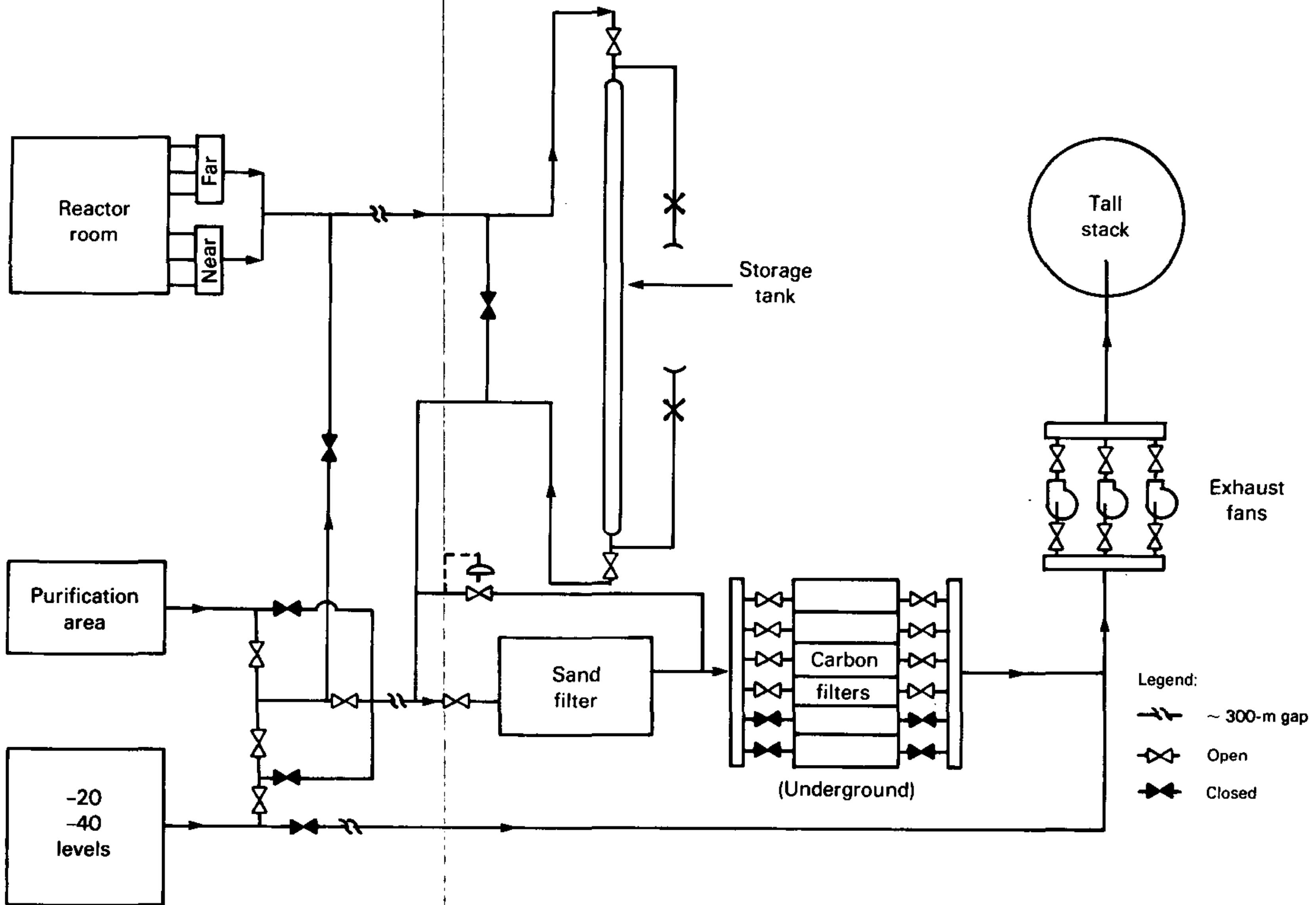

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Figure 4-13. Remote storage confinement system.

could be demonstrated. This system is schematically illustrated in Figure 4-14. The reactor-room air flow is separated from other process area exhaust flow. During normal operation, all of the exhaust air from the reactor room and the process areas passes through the filter compartments just as it does with the existing confinement system. Immediately following an accident the reactor room exhaust flow would be diverted through a separate filter train powered by a new 8500-cubic-meter-per-hour fan before it entered the normal operation filters. The noble gas adsorption train would have to be designed compact enough to be placed within the reactor room. The diverted reactor room exhaust air would first pass through a hydrogen recombiner, a high efficiency particulate filter, and a special iodine trap. The bulk moisture and tritium would then be removed in a combination chiller/molecular sieve trap before the air passes through multiple low-temperature (-40 to -60°C) adsorption beds of hydrogen mordenite. This system is expected to remove about 99 percent of the noble gases and tritium released in addition to providing much better iodine retention.

4.4.1.4 Tall stacks

Tall stacks for the reactor exhaust have been considered as a means of increasing the dispersion of reactor effluents. They can provide an appreciable reduction in exposure to the maximum individual onsite doses near the reactor and reduce site boundary doses. However, the tall stack concept does not reduce population dose as well as the other concepts.

4.4.1.5 Containment system

Commercial power reactors in the United States are built in large cylindrical buildings, which serve as containment vessels. They usually are built of heavy reinforced concrete with steel liners that are relatively leak-tight under moderate pressure. Such a containment is designed to withstand the pressure (about 0.34 megapascal) that would result if the reactor piping system suddenly burst and released the reactor coolant (steam and water at about 15.2 megapascals of pressure and 293°C) to the reactor building. The containment would retain most of the fission products, even in this improbable situation. A small amount of leakage of fission products from the containment system is permitted and has been accepted by NRC as having extremely small impacts.

The following paragraphs describe two variations of a containment system for SRP reactors.

<u>Internal containment structure</u>

In this concept, a leaktight containment zone would be created inside the existing building. A leakage rate below 1.7 cubic meters per hour might be achieved with this system, but continued maintenance to achieve this standard would be very difficult.

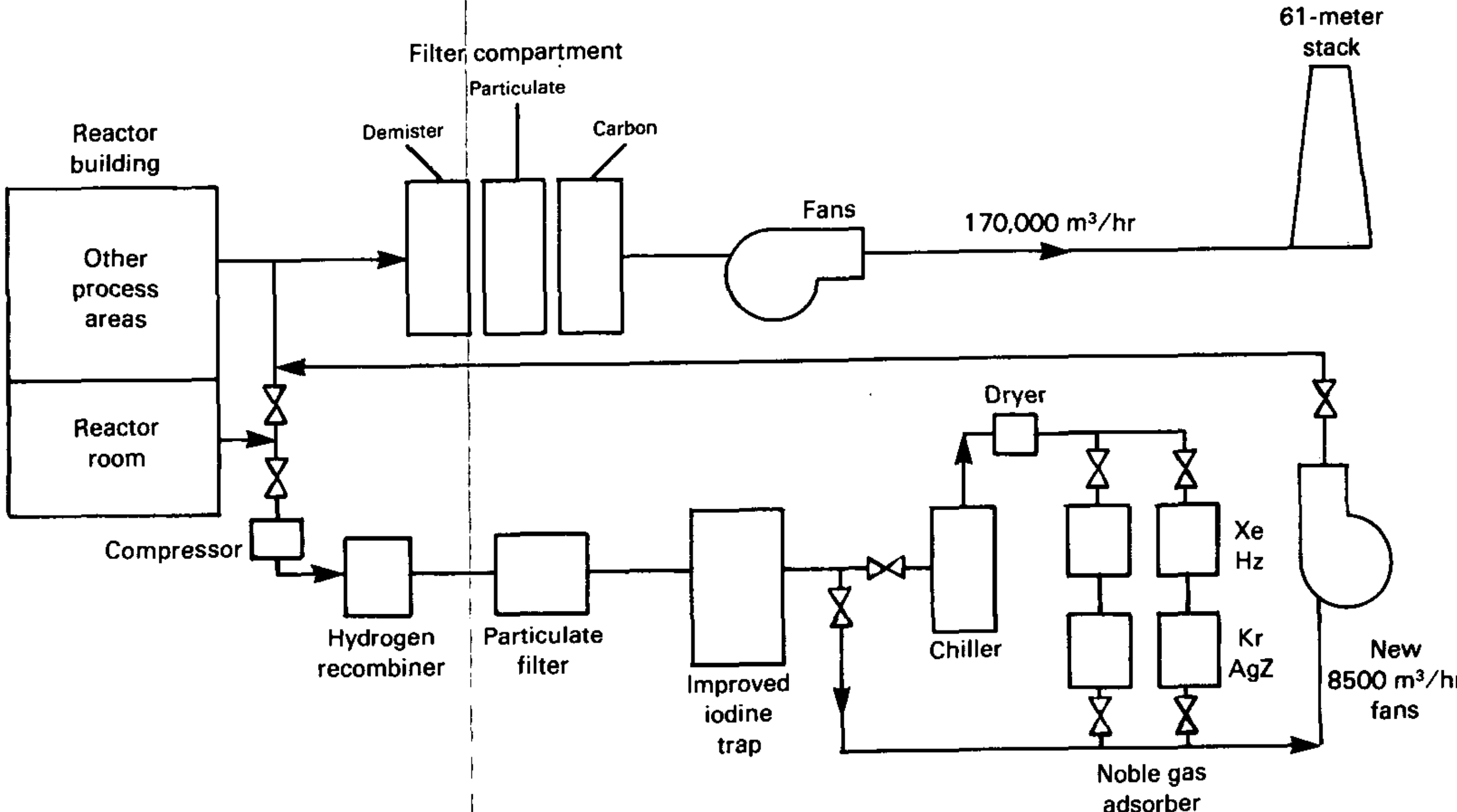

Figure 4-14. Low-temperature adsorption system.

The internal containment zone would consist primarily of the actuator tower, the reactor process room (extended out to include the charge and discharge machine service area and up to enclose the shield door gantry), the heat exchanger bay (beyond the cooling-water headers), and the main pump rooms. The entire containment zone would be lined with steel plate (Figures 4-15 and 4-16) backed by several concrete floor and wall thicknesses. Penetrations would be seal-welded in most cases and nonshrink grout would be used to seal the inside of conduits and cable trays. Special closures would be installed for the discharge and exit canal, presentation point, corridors, personnel doors, pump shaft penetrations, etc.

A heat-removal system would be provided to prevent pressurization from the heat released after a meltdown accident. A deluge spray system would cool the open volume inside the containment zone. After use of the initial supply of water from the disassembly basin and the 186-Basin, the water would be recycled from the -40 floor through a heat exchanger and back through the spray nozzles.

A new recirculating ventilation system would also be needed for the containment zone. This system would always be online except for purging during shutdowns. The existing once-through ventilation system (throttled appropriately) would serve the reactor building outside the containment zone. During normal operation, 10-percent outside makeup air would be admitted into the actuator tower and the crane service area to keep these areas accessible.

External containment structure

Another containment concept for the SRP reactors would be a leaktight dome structure over the entire reactor building complex (the stack would protrude). While theoretically possible, such a massive dome would be, at best, a formidable engineering challenge.

The dome itself would be a concrete structure semi-ellipsoidal in shape approximately 183 meters in diameter at the base and 61 meters high. The concrete would be lined with welded steel plating to achieve leaktightness (less than 0.1 percent leakage of the enclosed volume per day). The below-grade areas would also have to be sealed with steel plate to achieve the same standard of leaktightness. Extensive modifications to the existing ventilation system would be required to supply the new dome and to isolate and recirculate air inside the dome following an accident.

4.4.1.6 Comparison of alternatives

Table 4-29 provides the various measures of comparison outlined above for the alternative safety systems described. The existing confinement is the preferred alternative. The cost-benefit ratios per person-rem averted all appear extremely high for any of the alternatives compared to the present confinement system, particularly when the benefit includes the probability of the hypothesized accident occurring. By comparison, EPA (1976) has recognized a range from $250,000 to $500,000 per health effect averted as reasonable. (This range corresponds to a range from $30 to $60 per person-rem averted based on BEIR III estimates of cancer fatalities.) NRC has assigned a different (and larger) value of $1000 per person-rem as a basis for estimating the need for additional

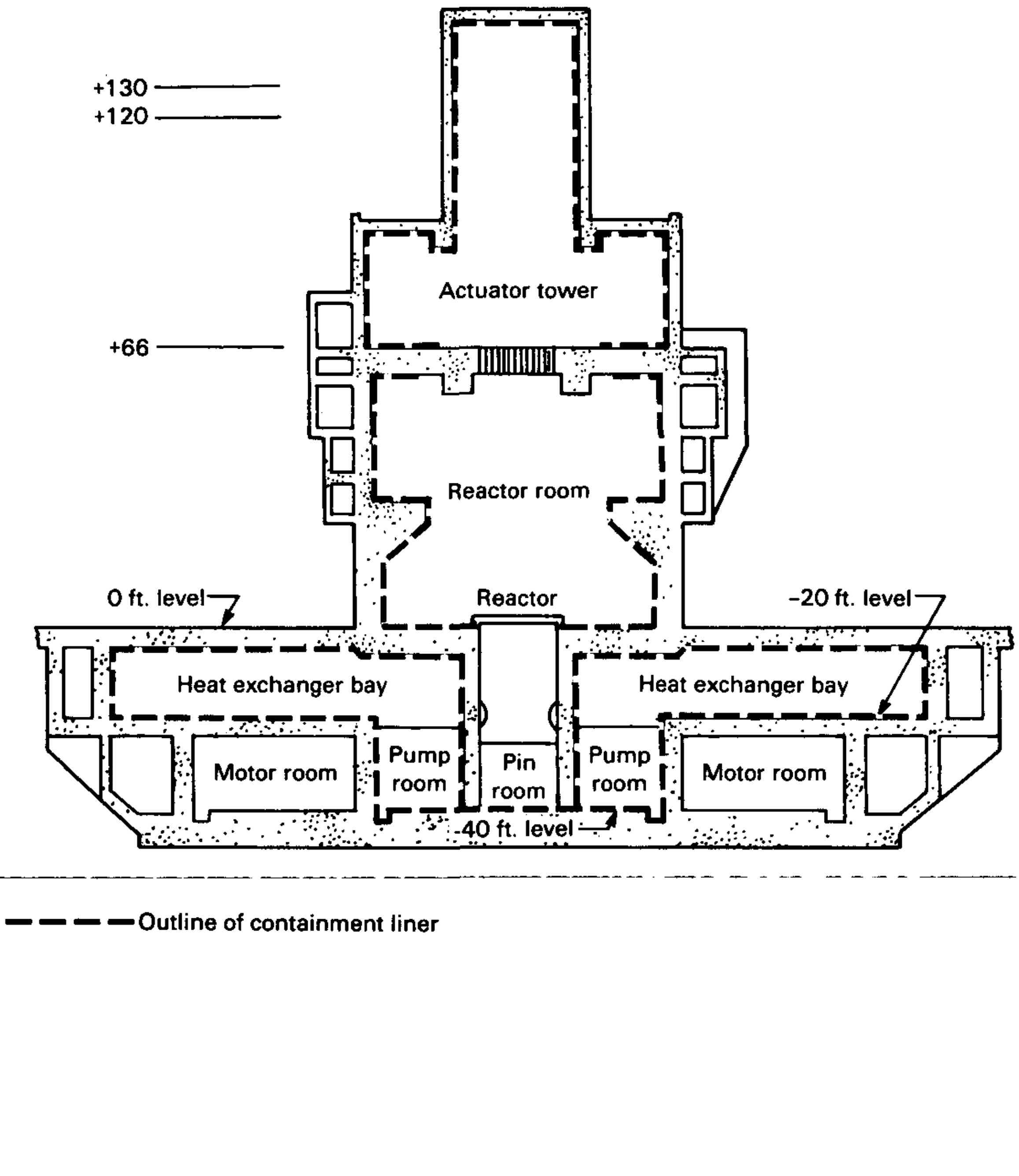

Figure 4-15. Vertical outline of containment liner, view 1.

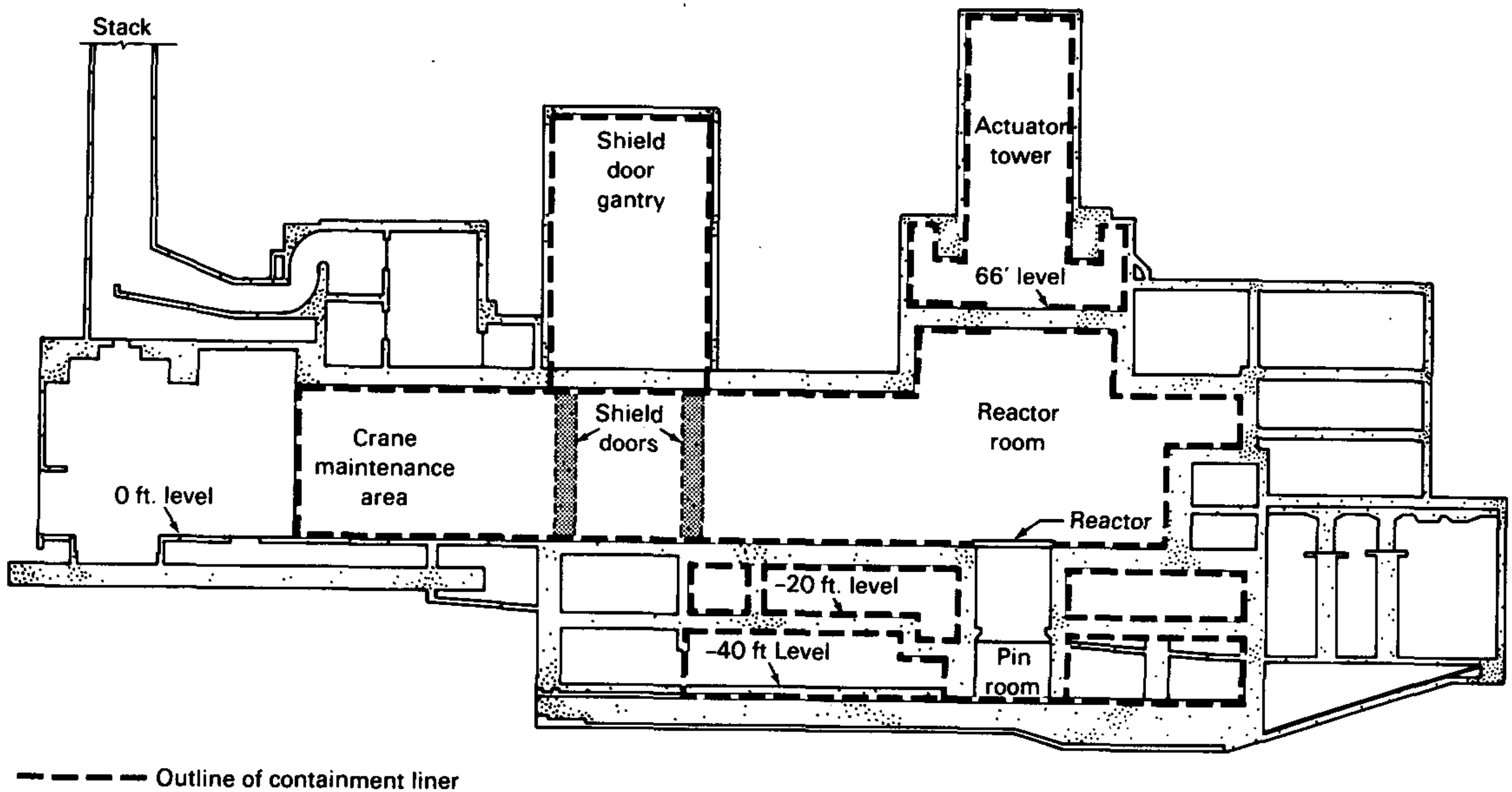

Figure 4-16. Vertical outline of containment liner, view 2.

Table 4-29. Comparison of safety system alternatives (primarily confinement/containment options)

System	Technical feasibility	Estimated costs ($MM)[a] Capital[b]	Production Loss[c]	Total	Benefit person-rem averted[d] (3% melt)	Cost/benefit[e] ($ per person-rem averted)	Timing (months to complete)
Existing confinement (ref) system	Demonstrated and proven	Installed	None	Installed	--	Reference	Installed
Remote storage system	Demonstrated	250	25	275	445	620,000	24
Low temperature adsorption system	Not demonstrated	90	50	140	460	300,000	36
Tall stack	Demonstrated	50	15	65	175	370,000	15
Internal containment	Questionable	250	150	400	455	880,000	48
Leaktight dome	Questionable	850	50	900	450	2,000,000	36

[a]MM - millions of dollars.

[b]Rough estimates escalated to 3Q FY 1988 construction midpoint.

[c]Rough cost of production lost during construction at $150,000 per reactor-day.

[d]Assumes hypothetical accident (3-percent melt) occurs. Dose within 80-kilometer radius from reactor (2500 megawatts accident). 50 percent meteorology. Benefit = (dose with existing confinement system - dose with alternative system) = person-rem averted.

[e]The expected cost benefit considering the probability of the accident is at least two million times greater than the values listed here.

equipment to reduce public exposures from radioactivity in effluents from nuclear power plants (10 CFR 50, Appendix I).

4.4.2 Cooling-water alternatives*

4.4.2.1 Introduction

The L-Reactor secondary coolant system would withdraw water from the Savannah River. This water would be pumped from the river through pipelines into the 95-million-liter 186-L cooling-water reservoir. From there it would flow through heat exchangers that transfer heat from the heavy-water primary coolant to the secondary cooling water. Under the reference case (direct discharge to Steel Creek), the heated river water would leave L-Reactor at a rate of about 11 cubic meters per second and at temperatures as high as 73°C; it would flow from the discharge canal into Steel Creek and then into the Savannah River.

The preferred cooling-water alternative of the Department of Energy is to construct a 1000-acre lake before L-Reactor resumes operation, to redesign the reactor outfall, and to operate L-Reactor in a way that assures a balanced biological community in the lake (i.e., to maintain 32.2°C or less for about 50 percent of the lake). The impacts of the 1000-acre cooling lake were bracketed in the Draft EIS by the 500-acre and 1300-acre cooling lakes. After L-Reactor is operating, DOE will conduct studies to determine the effectiveness of the cooling lake and to decide on the need for precooling devices to allow for greater operational flexibility. The preferred cooling-water alternative is discussed in detail in Appendix L.

This section describes possible thermal mitigation measures that could be implemented either before or after the restart of L-Reactor and their projected environmental effects, and assesses them with respect to meeting regulatory thermal criteria. Implementation of some of these alternative systems before direct discharge occurs would, to various degrees, reduce the environmental impacts to the Steel Creek system. If a cooling-water alternative is implemented after L-Reactor restart with direct discharge, the environmental impacts described in Section 4.1.1 would already have occurred. However, successional recovery of the Steel Creek system would begin after the mitigation alternative had been implemented. The extent of the successional recovery would depend on the thermal mitigation alternative implemented.

The evaluation of each alternative cooling system was based on its engineering feasibility, schedule, cost, L-Reactor production efficiency, and environmental effects. In general, the engineering costs presented in this section were based on limited design data. These costs can be used as a basis for a comparison of alternatives; however, they are not suitable for budgetary considerations. Schedules are based on normal construction work practices; some could be accelerated with increased costs. Estimates of construction personnel

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*Because of the extensive revisions to this section, vertical change bars have not been used.

requirements are also presented. Actual construction personnel requirements can vary based on the final construction design and schedule considerations. Both once-through and recirculating cooling-water measures have been considered to reduce the environmental impacts of the heated discharge. Alternative cooling systems include the following four categories: (1) once-through alternatives, including direct discharge (reference case); (2) cooling towers (including once-through, recirculation, and partial recirculation); (3) recirculation alternatives using lakes; and (4) other mitigation alternatives.

Steel Creek flows southwesterly from its headwaters near P-Area to the Savannah River swamp, where it is joined by flows from Pen Branch and Four Mile Creek. A delta has formed where Steel Creek adjoins the Savannah River swamp. After flowing through the swamp, Steel Creek discharges into the Savannah River. The length of Steel Creek from the L-Reactor outfall to the delta is about 11 kilometers. The distance from the delta to the confluence with the Savannah River is about 2 kilometers.

The average flow rate of Steel Creek is about 0.6 cubic meter per second at Road B; this includes natural flow (0.17 cubic meter per second) and some non-heated process water from P-Reactor (0.45 cubic meter per second) (Section 3.4.1.2). Table 4-30 lists ambient temperatures calculated for selected points along Steel Creek. Figure 4-17 shows monthly average ambient temperatures in Steel Creek at the L-Reactor outfall (calculated), at Road A (measured), and at the mouth of Steel Creek (calculated). Table 4-8 (Section 4.1.1.5) summarizes the water quality data for Steel Creek.

Table 4-30. Calculated ambient temperatures (°C) for selected locations along Steel Creek during summer, spring, and winter

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Near L-Reactor	33	29	22	8
Road A	33	29	22	8
Swamp at delta	33	29	22	8
Mid-swamp	29	26	19	6
Mouth of creek at river	30[c]	27[c]	21[c]	12[c]

[a]Based on worst 5-day meteorological conditions (July 11-15, 1980).
[b]Based on 30-year average values for meteorological conditions (1953-1982) and the actual power of an operating reactor.
[c]Temperature increase due to mixing with K-Reactor effluent.

Predicted water temperatures are based on monthly average winter, spring, and summer meteorological conditions from 1953 to 1982; the extreme summer meteorological conditions are based on the most severe 5-day period from 1976 to 1980 (July 11 to 15, 1980). Five-day, worst-case meteorological conditions provide the basis for a conservatively high estimate of discharge and downstream temperatures that are likely to result from the implementation of a thermal mitigation alternative. The selection of 5-day worst-case meteorology is also based on a typical cycle of consecutive meteorological conditions; it is considered representative of extreme temperatures for which the maintenance of a

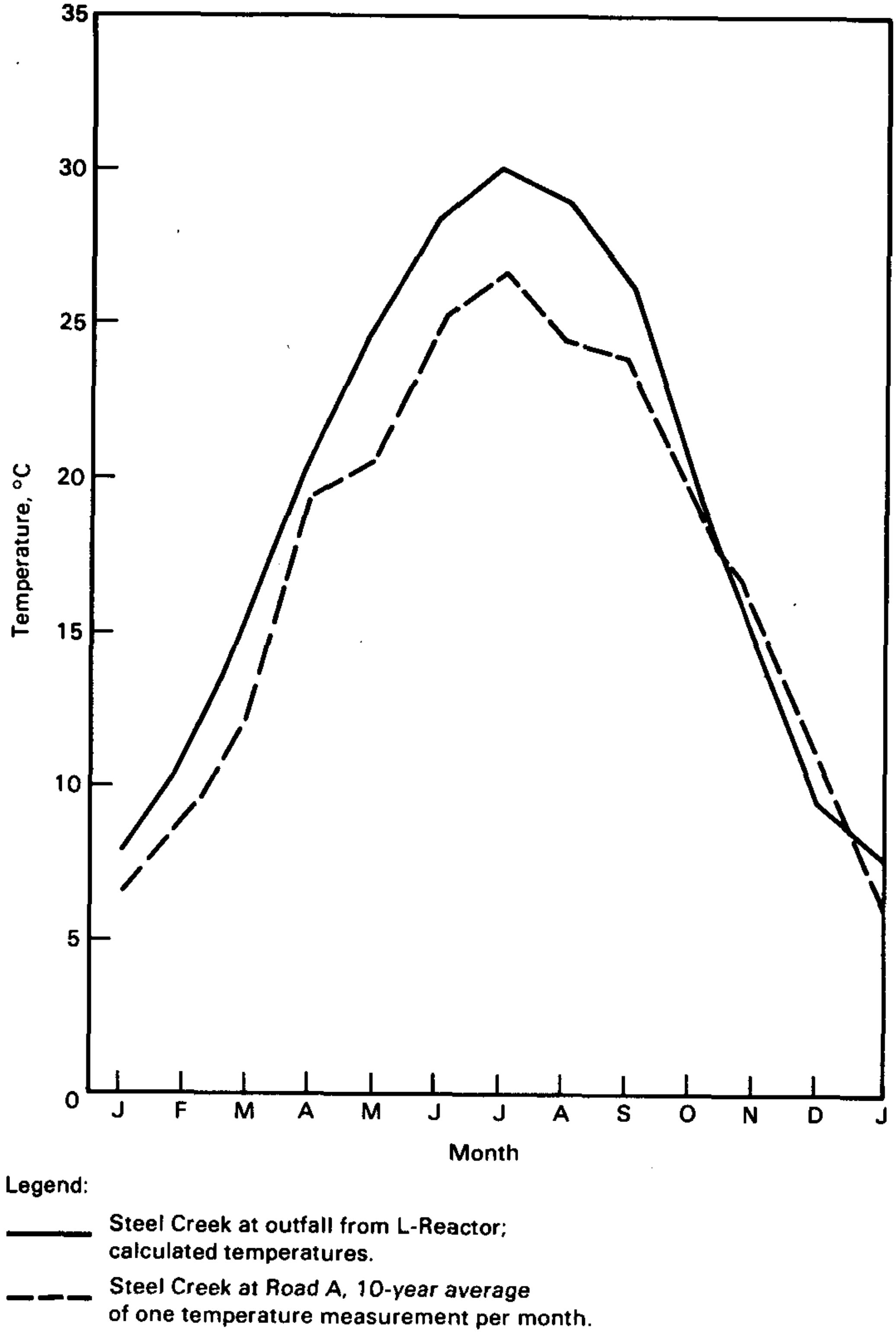


Figure 4-17. Monthly average ambient temperatures of Steel Creek.

balanced biological community can be measured under Section 316(a) of the Federal Water Pollution Control Act of 1972. 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.

Several of the cooling-water alternatives described in the following sections would require borrow pits or spoils piles, and could cause siltation. Borrow pits of suitable materials and similar quantities have been used in the past at the Savannah River Plant. For the alternatives described in the sections that follow, the most economically suitable pit would be identified and reclaimed.

Spoil piles of the size expected have also been developed for past construction activities at the Savannah River Plant and have met the necessary environmental control requirements. In this particular instance, spoil from any excavation in the former floodplain of Steel Creek would be monitored for radioactive species and would be disposed of in a suitable manner if such activity is found to be necessary.

Siltation would be controlled during all phases of construction.

Chapter 7 presents Federal and State environmental requirements applicable to the resumption of L-Reactor operation. These requirements emphasize air quality, water quality (including thermal discharge limits), the disposal of solid and hazardous wastes, the protection of fish and wildlife, and the preservation of cultural resources.

Appendix I describes floodplain and wetlands impacts associated with each alternative.

In recognition of the requirements for the discharge of dredged or fill material related to the potential construction of certain cooling alternatives discussed in this section, each alternative description contains information, as appropriate, on effects of such discharges pursuant to Section 404 of the Clean Water Act of 1977 and EPA regulations (40 CFR 230).

4.4.2.2 Once-through alternatives

Eleven alternative cooling systems that would receive direct discharge for L-Reactor have been evaluated. These include (1) the reference case (direct discharge), (2) a spray canal, (3) small lakes without sprays and with one or two sets of sprays, (4) a 500-acre lake without sprays and with one or two sets of sprays, and (5) a 1000-acre lake without sprays. Each would discharge heated effluent into Steel Creek at a rate of about 11 cubic meters per second. Two other alternatives would divert the discharge effluent into Pen Branch at about the same temperature and flow rate. The following sections describe and evaluate the environmental consequences of these various alternative cooling systems.

For once-through alternatives that require the use of a cooling lake, DOE will perform safety analyses for the design of the embankment to assure its 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. The purpose of these analyses will be to assure public safety, because a failure of the cooling-lake embankment could have adverse impacts on portions of the Seaboard Coast Line Railroad and South Carolina Highway 125 (SRC 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 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 Separation 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).

4.4.2.2.1 Direct discharge to Steel Creek (reference case)

During direct discharge, heated cooling water would enter Steel Creek at the end of the existing outfall canal (as shown on Figure 4-18); the water would cool gradually as it flows to the river through the lower reaches of Steel Creek and the Savannah River swamp (Figure 4-19). No construction would be required. Because reactor discharge and associated impacts would be similar to those that occurred during previous L-Reactor operation, this alternative is called the "reference case."

The reference case would require no new structures, equipment, or capital costs. The present worth (based on a discount rate of 10 percent and operating cost for a period of 20 years) would be $29 million, and the annualized cost (for this alternative, the same as the operating cost) would be $3.4 million. Operating costs would be associated primarily with pumping the secondary cooling water from the Savannah River to the 186-L basin and with pumping water through the reactor heat exchangers (Du Pont, 1983d).

This alternative would use about 11 cubic meters per second of water from the Savannah River. Water would be discharged at a rate of 10.9 cubic meters per second (minor evaporative losses). Direct discharge is the only option available that would allow L-Reactor operation to begin in 1984. As the reference case, it has a 100-percent production efficiency.

The temperature of the water discharge would vary by month; it would depend on the temperature of the supply water from the Savannah River and on the

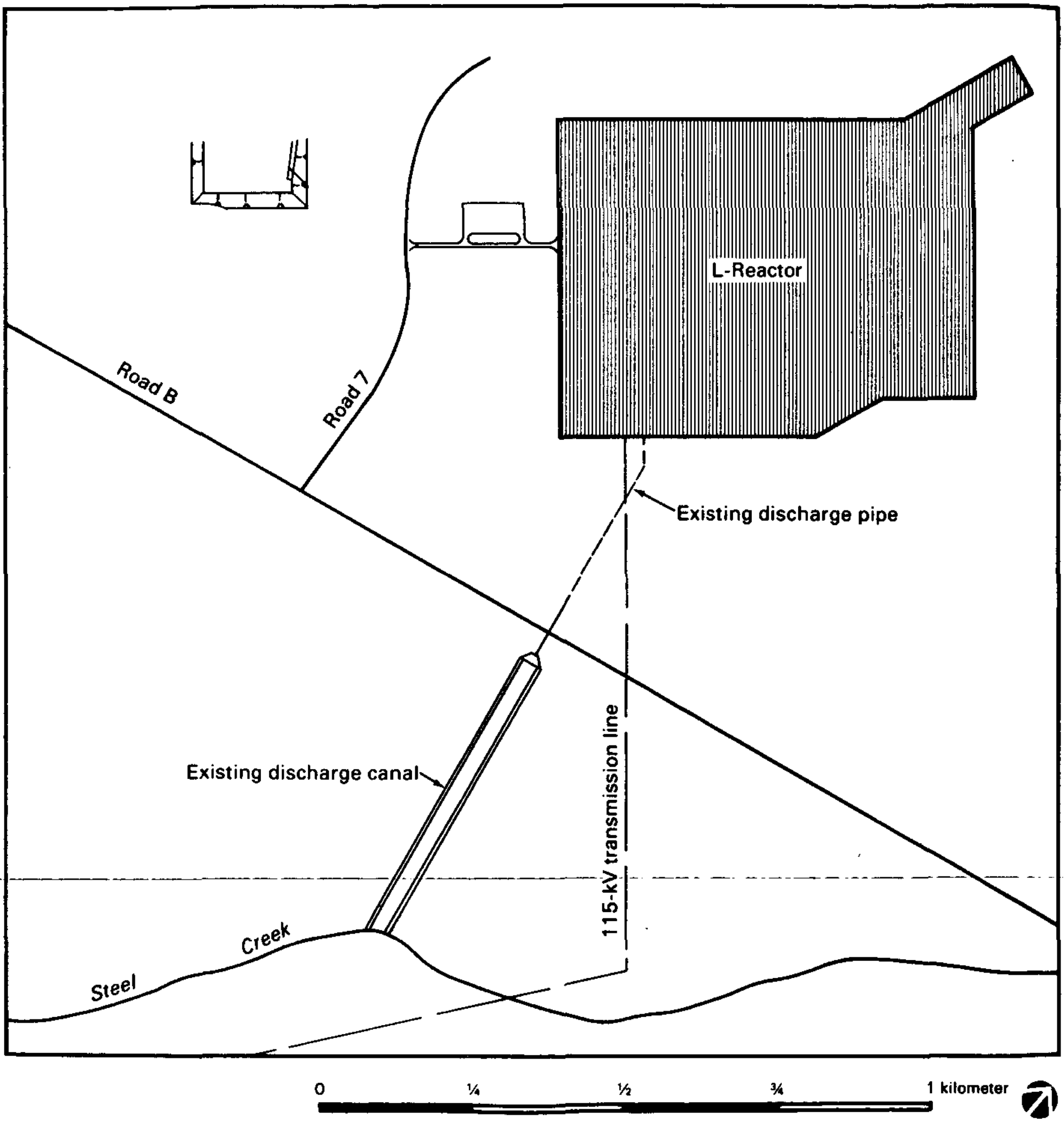


Figure 4-18. Direct discharge to Steel Creek at outfall.

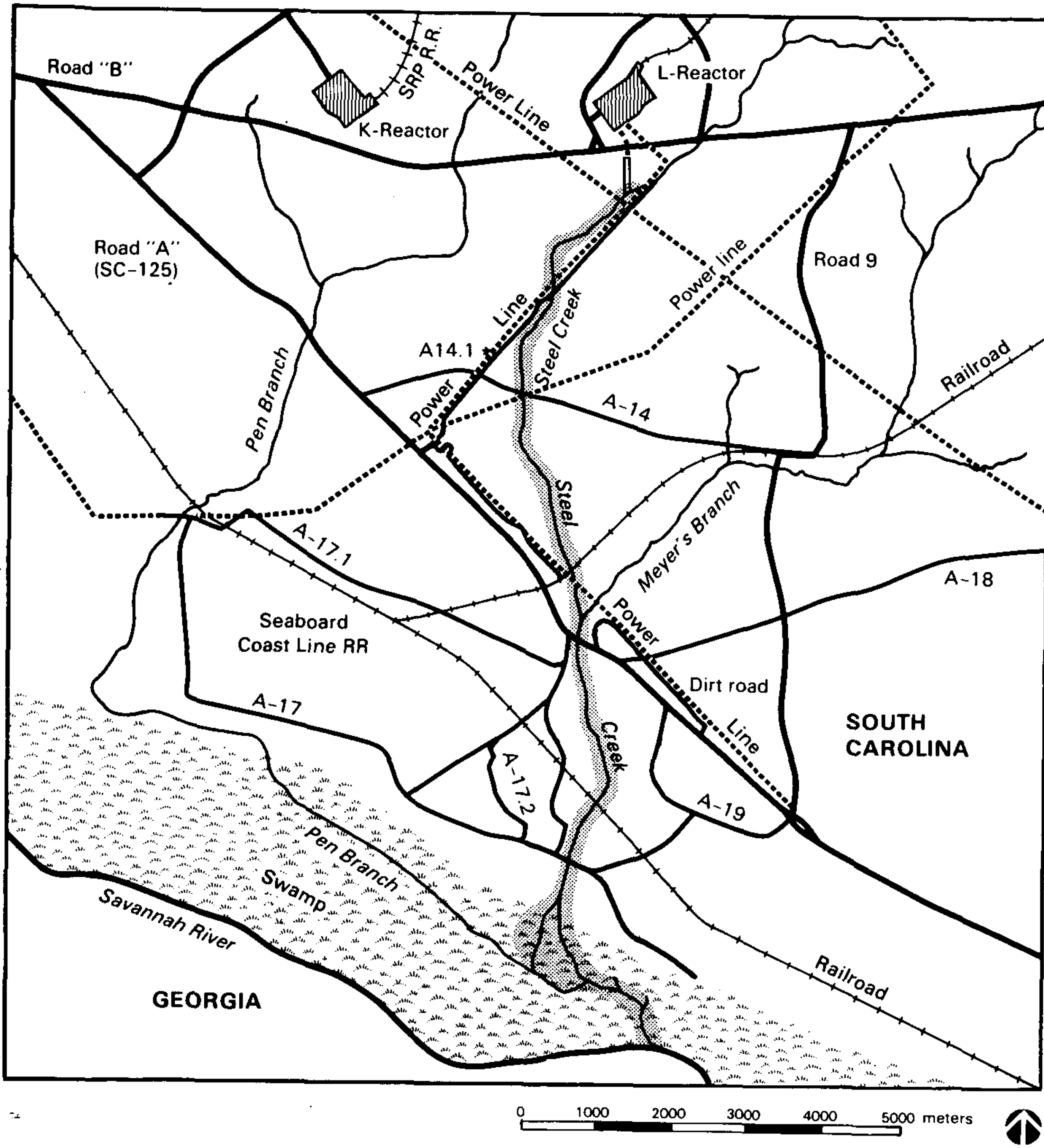


Figure 4-19. Steel Creek, showing area affected by direct discharge.

operating power of the reactor. The operating power would vary with the temperature of the water used for cooling. Figure 4-20 shows the estimated downstream temperatures in Steel Creek in the spring, summer, and winter. Table 4-31 lists downstream temperatures for this alternative.

Table 4-31. Temperatures (°C) downstream in Steel Creek with direct discharge

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	73[d]	71	69	66
Road A	54	53	50	46
Swamp at delta	46	45	41	36
Mid-swamp	37	35	31	25
Mouth of creek at river	34	33	28	21

[a]Based on worst 5-day meteorological conditions (July 11-13, 1980) and estimated operating power of reactor. Five-day worst-case meteorological conditions provide the basis for a conservatively high estimate of discharge and downstream temperatures that are likely to result from the implementation of a thermal mitigation alternative. The selection of 5-day worst-case meteorology is also based on a typical cycle of consecutive meteorological conditions; it is considered to be representative of extreme temperatures for which the maintenance of a balanced biological community can be measured under Section 316(a) of the Federal Water Pollution Control Act of 1972.

[b]Based on 30-year average values for meteorological conditions and 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]The temperature of the water entering Steel Creek.

[d]The secondary cooling-water discharge temperature during extreme summer meteorological conditions has been reduced to 73°C. This reduced discharge temperature reflects reduced reactor operating power to compensate for increased temperatures in the cooling-water supply drawn from the Savannah River during the warmest summer months.

Direct discharge would not provide thermal mitigation. The 73°C maximum discharge temperature from this alternative would be well above the 32.2°C discharge limit promulgated by the State of South Carolina. Because of the high discharge flow rates, Steel Creek temperatures would approach the cooling-water discharge temperature near the outfall. This alternative would result in year-round noncompliance with State discharge limits in Steel Creek, but could be in compliance in the Savannah River when a mixing zone is considered.

Initially, direct discharge will eliminate about 730 acres of wetlands in the Steel Creek corridor, the Steel Creek delta, and the Savannah River swamp. These wetlands, which have become established during the past 15 years through the process of natural succession, are structurally different from the closed

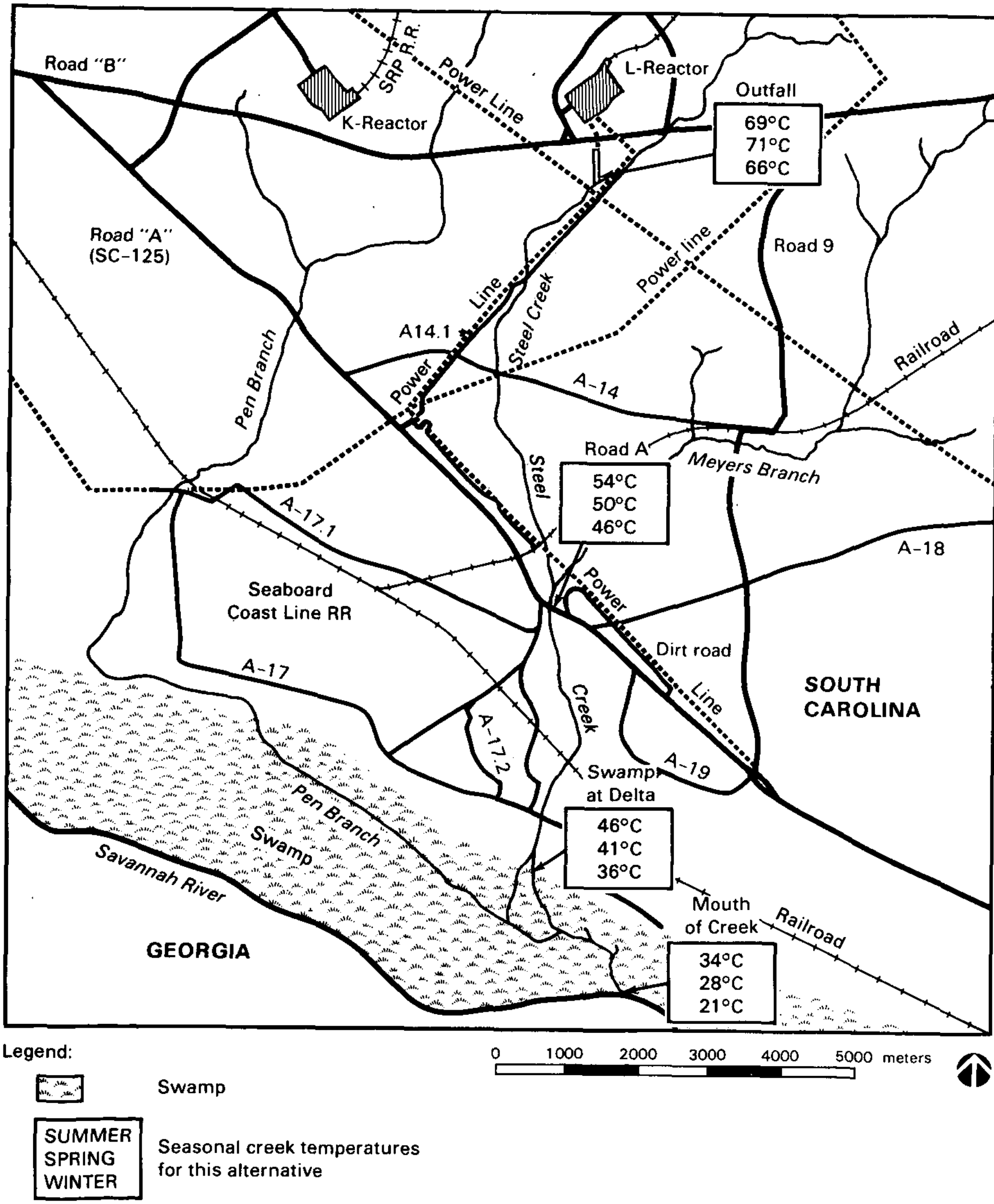


Figure 4-20. Steel Creek seasonal temperatures for direct discharge.

canopy of mature cypress and tupelo gum that existed before the SRP began operations (Sharitz, Irwin, and Christy, 1974). Furthermore, these wetlands 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). The vegetation of the corridor, which extends from the L-Reactor outfall to the delta, consists primarily of forested (73 percent) and scrub-shrub (24 percent) wetlands. The dominant flora of the forested wetland is alder, wax myrtle, and willow. Alder dominates the scrub-shrub wetland. Between 310 and 420 acres of the Steel Creek delta, which is dominated by forested (45 percent) and scrub-shrub (36 percent) wetland, would also be eliminated; this includes feeding and roosting habitat for 1200 mallards and 400 wood ducks.

Fish and other food sources would no longer inhabit the impacted Steel Creek or the delta-swamp area. Although 2280 acres of the wetlands along Steel Creek above L-Area and along Meyers Branch above its confluence with Steel Creek would not receive direct thermal discharges, access to these areas by fish from the Savannah River would be restricted. The entrance to Boggy Gut Creek, an offsite tributary immediately downriver of Steel Creek, could be blocked by the thermal plume at times and fish access would be limited. Wetland areas of Boggy Gut Creek total about 230 acres.

Thermal plumes in the Savannah River resulting from SRP operations (including L-Reactor), Vogtle Nuclear Power Plant (under construction), and the Urquhart Power Plant at Beech Island would not interact. A zone of passage for anadromous fish and other aquatic organisms would exist in the river near the Savannah River Plant.

The thermal plume in the Savannah River would increase the overall river temperature by less than 0.8°C about 2.4 kilometers downstream after total mixing; the calculated 1-week-in-10-year maximum increase resulting from SRP operations, including L-Reactor, would be 2.3° to 2.4°C. The expected thermal impacts of direct discharge in the river would be small, except near the mouth of Steel Creek, where temperatures could be high enough to exclude the creek and portions of the swamp as spawning areas for riverine and anadromous fish.

Before 1982, the endangered shortnose sturgeon had not been reported in the middle reaches of the Savannah River near the Savannah River Plant. In 1982, two shortnose sturgeon larvae were collected at River Mile 157.3, which is upstream from the 1G pumphouse. In 1983, seven shortnose sturgeon larvae were collected, five in the Savannah River adjacent to SRP (two from the canal and three from the river). Two larvae were also collected at River Miles 79.9 and 97.5, both of which are more than 60 miles downriver from SRP. Thus, impingement or entrainment could cause some larval mortality (ECS, 1983b). DOE included these factors and other data in the biological assessment and consultation process with the National Marine Fisheries Service, which concurred that this alternative would have no adverse effects on the shortnose sturgeon (Oravetz, 1983).

An estimated 23 to 35 individuals of the endangered American alligator inhabit parts of Steel Creek from the L-Reactor outfall to the cypress-tupelo forest adjacent to the Steel Creek delta; they also use areas lateral to Steel Creek, including Carolina bays, backwater lagoons, and beaver ponds. This species is described in greater detail in Section 4.1.1.4 and Appendix C. Direct discharge would eliminate feeding and breeding habitat in the Steel Creek corridor and portions of the swamp. The mobility of adult alligators should eliminate any mortality due to the direct impact of heated water. Juveniles would have greater difficulty avoiding thermal effluents, and would be exposed to greater predation. DOE included these factors and other data in the biological assessment and in continuing consultations with the U.S. Fish and Wildlife Service (Sires, 1983).

The wood stork is classified as threatened by the State of South Carolina, and as endangered by the U.S. Fish and Wildlife Service. A total of 478 observations was made in the Savannah River swamp in 1983, of which 102 were in the Steel Creek delta. Although roosting by the wood stork in the Steel Creek area is infrequent, the Steel Creek delta represents an important foraging site for breeding storks from the Birdsville rookery. This alternative would eliminate this foraging habitat. DOE will include these factors and other data in the biological assessment and consultation process with the U.S. Fish and Wildlife Service.

The fish egg and larvae entrainment produced by this alternative would result in 7.7×10^6 additional eggs and 11.9×10^6 additional larvae lost annually because of water requirements by L-Reactor. Based on 1982 and 1983 sampling data, these totals represent approximately 3 to 6 percent of the fish eggs and larvae in the Savannah River water passing the intake canal. This alternative would cause an estimated 16 additional fish per day to be impinged on the intake screens (5840 annually; average fish weight would be about 14 grams).

This alternative would remobilize and transport radiocesium from the Steel Creek system when cooling-water discharges resume. Approximately 4.4 ± 2.2 curies of radiocesium would be transported from the creek during the first year of resumed operations. Thereafter, radiocesium transport would decrease by an estimated 20 percent per year (Section D.4). Expected maximum concentrations in the Savannah River would average less than 0.5 picocurie per liter during average flow conditions. The Beaufort-Jasper County and Cherokee Hill (serving Port Wentworth, Georgia) water-treatment plants obtain their raw water from the Savannah River more than 100 river miles downstream from Steel Creek. Finished (potable) water from these plants is expected to contain no more than 0.09 picocurie of cesium-137 per liter, or 2200 times less than the EPA drinking-water standard (200 picocuries per liter).

In the tenth and subsequent years, L-Reactor would discharge about 14,600 curies of tritium each year to the environment via liquid effluent. About 75 percent of this total would be diverted to a low-level radioactive seepage basin; about 30 percent of the tritium discharged to the seepage basin is expected to evaporate. About 6000 curies per year would be discharged to Steel Creek via ground-water transport (assuming radioactive decay during the 4.4-year travel time to the outcrop, but neglecting dispersion effects). The remaining 25 percent (approximately 3600 curies per year) would be carried in the cooling water (Table 4-9).

Five archeological sites eligible for listing on the National Register would be subject to erosion and flooding from the implementation of this alternative. These include one prehistoric site and four historic sites. Cold water testing has indicated that erosion is occurring. A mitigation plan of rip-rapping is being designed whereby these sites will be protected in accordance with the Archeological Mitigation Plan. This plan has been approved by the South Carolina State Historic Preservation Officer (SHPO) and the Advisory Council on Historic Preservation (ACHP) (Lee, 1982). This mitigation is being designed by the Institute of Archeology and Anthropology of the University of South Carolina and will be completed prior to restart.

Steel Creek has received various reactor effluents since 1954, which have impacted its substrate accordingly. Increased flows that were sometimes an order of magnitude above normal altered the erosion-sedimentation patterns of the stream corridor (Smith et al., 1981). Upstream areas where stream gradients are high (7.8 meters per kilometer near L-Reactor) are severely eroded; downstream areas with low gradients (1.0 meter per kilometer near Cypress Bridge) receive sediments that drop from suspension as the water velocity decreases. Suspended solid loads in Steel Creek reached levels of 99 milligrams per liter during large rainfall storm events (Giesy and Briese, 1978) and declined from 80 milligrams per liter at Road A-14 to 14 milligrams per liter at the HP monitoring station at Cypress Bridge on Steel Creek during flows as high as 4 cubic meters per second in 1980.

This alternative would require no dredging and filling; thus, the substrate would not be affected by these activities. However, the combination of increased flow and temperatures would have adverse impacts on the substrate of Steel Creek. This substrate consists of Bibb sandy loam (Figure C-2); it is stabilized by macrophytic vegetation. The direct discharge of cooling-water effluent from L-Reactor would increase the flow rate at the outfall from about 0.6 (which includes the natural Steel Creek flow measured at Road B and some nonheated process water from P-Reactor) to about 11.4 cubic meters per second (1.36 for natural and P-Reactor discharges + 10.9 for L-Reactor cooling water - 0.85 consumptive use = 11.4) at Cypress Bridge, about 2.8 kilometers below Road A. The resulting erosion of upstream segments and the deposition downstream would alter the substrate elevation and contour of the Steel Creek corridor, scouring and burying vegetation. North of Road A, only vegetation rooted above the water level is expected to survive. The anticipated maximum delta growth rate at the swamp would be 3 surface acres per year from the deposition of sediments. No alteration of substrate elevation or contours of the Savannah River is expected.

In Steel Creek, reduced light penetration caused by turbidity from suspended particulates would lower the photosynthetic rates of those remaining thermotolerant and thermophilic algae, such as blue-greens. The reduction and elimination of submerged vegetation could create locally high oxygen demand due to decomposition.

Spawning and feeding success by the remaining fish species that move to avoid the heated effluent would be reduced due to siltation by suspended particulates from the initial restart of the reactor. This impact is expected to decrease as the turbidity decreases and sediments become more stable. As the effluent moves away from the reactor outfall and flow velocities decrease, turbidity would decline and more organisms would occur, beginning with those most tolerant to siltation effects. The expected total suspended and dissolved solid concentrations at Road A would be much less than the water-quality/drinking-water standard (Table 4-6). As discussed in Section 4.1, no significant impact on swamp-water quality is expected.

As listed in Table 3-6, Steel Creek has a varied history with regard to the release of reactor effluents. The release of thermal effluents into Steel Creek from L- and P-Reactors reached a peak of about 23 cubic meters per second in 1961. In 1963, P-Reactor effluents were diverted to Par Pond; thus, thermal discharges to Steel Creek were reduced to about 11 cubic meters per second, about 1.3 times the maximum flow expected after heavy rains. Since 1968, Steel Creek has received only infrequent and short-term inputs of thermal effluents (Smith, Sharitz, and Gladden, 1981, 1982; Du Pont, 1982b).

The flow of water in the swamp is altered when the Savannah River is in flood stage (about 27.7 meters) with a flow rate of about 440 cubic meters per second. Under flooding conditions, Four Mile Creek, Pen Branch, and Steel Creek discharge to the Savannah River at Little Hell Landing after they cross an off-site swamp (Creek Plantation Swamp). Data gathered from 1958 through 1980 indicate that, on the average, the Savannah River reaches flood stage at the Savannah River Plant 79 days (22 percent) of each year, predominantly from January through April (see Figure 3-6).

The direct discharge of cooling-water effluent into Steel Creek would require the following: (1) consultations with the FWS, (2) the preparation of a biological assessment for endangered species, (3) an NPDES permit, and (4) a 316(a) demonstration (see Chapter 7). An Army Corps of Engineers 404 permit would not be required.

4.4.2.2.2 Spray canal

A spray system would be added to the cooling-water outlet of L-Reactor to cool the discharged water by spraying it in the atmosphere before it enters Steel Creek. The spray canal (Figure 4-21) would utilize a gravity-power spray cooling system installed in the outfall canal. The system would operate in much the same manner as a conventional pumped spray system by dissipating a portion of cooling-water heat. Vegetation within 300 meters of the spray canal would have to be removed to enhance air circulation and increase cooling efficiency. The estimated time required to design and construct this alternative under normal construction practice is between 18 and 24 months. Penstock construction would not affect reactor operation if the L-Reactor startup occurs before this alternative is implemented. However, pipe header and nozzle installation would require reactor shutdown for 3 to 6 months. The valve chamber could be constructed during reactor operation except for cutting existing pipe and installing valves. These tasks could be performed during the same shutdown used for installing nozzles.

The estimated capital cost for constructing the spray canal is $9 million, with an annual operating cost of $3.5 million (Du Pont, 1983d). The present worth of this alternative would be $38 million and the annualized cost would be $4.5 million. An estimated 130 construction personnel would be required for the construction of the spray canal.

This alternative would use approximately 11 cubic meters of water per second from the Savannah River. Reactor production efficiency for this option

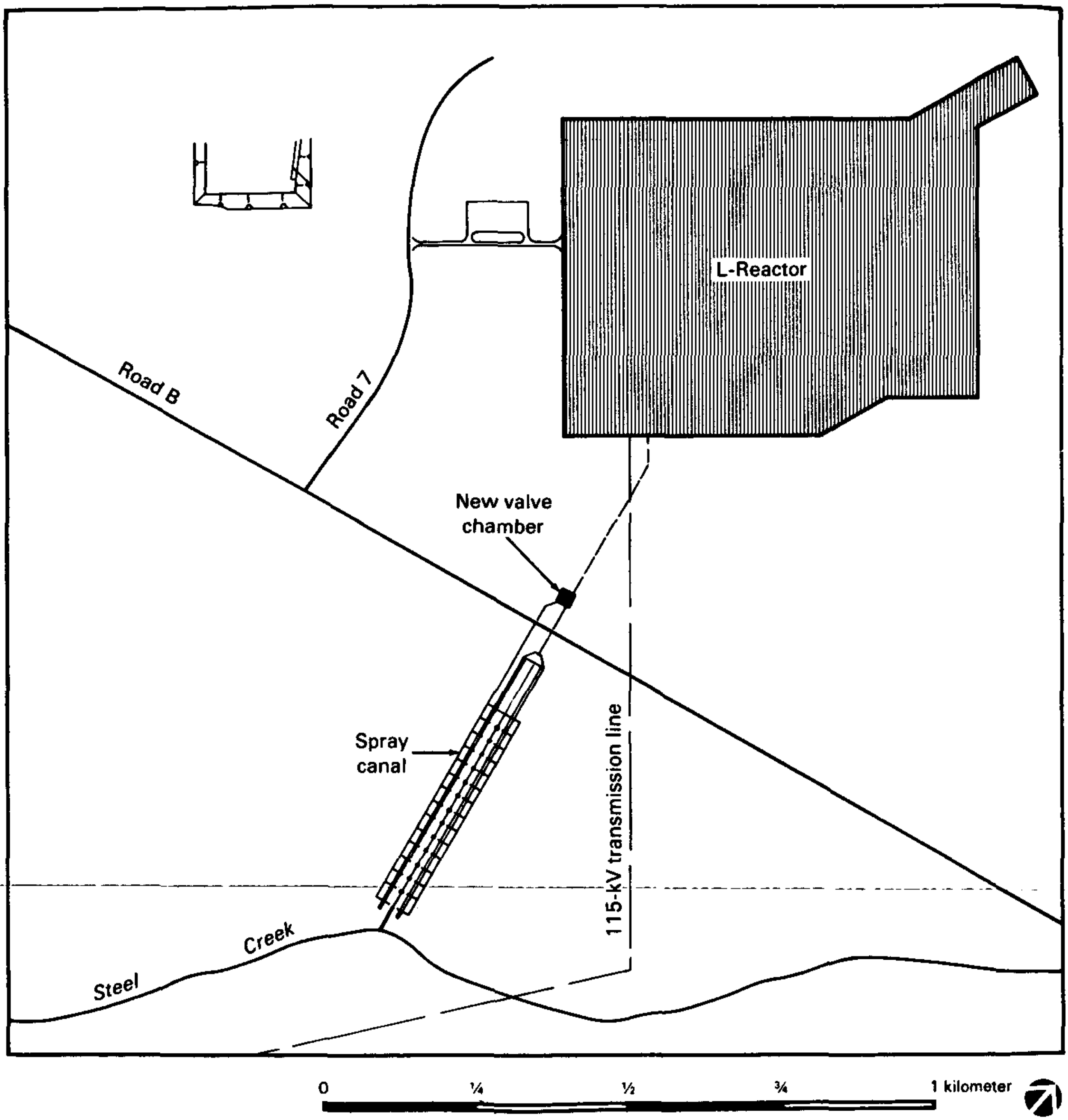


Figure 4-21. Conceptual layout of spray canal.

would be 100 percent. However, the use of reduced power would be necessary to meet State of South Carolina water-quality standards. Table 4-32 lists the estimated downstream temperatures in Steel Creek in the summer, spring, and winter without a reduction of power.

Table 4-32. Temperatures (°C) downstream in Steel Creek with once-through discharge using a spray canal

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	68	66	64	61
Road A	53	52	49	45
Swamp at delta	45	44	40	35
Mid-swamp	37	35	30	25
Mouth of creek at river	34	33	27	21

[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 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 entering Steel Creek.

Compared to direct discharge, the spray canal alternative would provide limited thermal mitigation. The 68°C maximum discharge temperature and the 66°C average summer temperature would both be well above the 32.2°C State discharge limit. Due to the large cooling-water discharge rate (about 10.6 cubic meters per second), Steel Creek temperatures would approach the cooling-water discharge temperature near the outfall, because mixing the discharge with natural flows would result in only a slight temperature reduction.

Implementation of this alternative would result in year-round noncompliance with the State discharge limits. This alternative would not meet discharge limits in Steel Creek but would be in compliance in the Savannah River when a mixing zone is considered.

The implementation of the spray canal alternative would discharge water at about the same rate as direct discharge and would achieve minimal cooling. Thus, the environmental impacts of this alternative would be slightly greater than those for direct discharge; they are summarized as follows:

- Between 730 and 1000 acres of wetlands would be eliminated, including habitat for the endangered American alligator, the endangered wood stork, and migratory waterfowl. These wetlands 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." In addition, about 2500 acres of wetlands could be isolated to aquatic biota by thermal temperatures.

- To achieve optional cooling performance using a spray system, vegetation within 300 meters of the unit would have to be removed. This would impact an additional 55 acres of wetlands and 55 acres of upland conifers. Thus, the total amount of impacted habitat would be 55 acres of uplands and between 785 and 1055 acres of wetlands.

- Approximately 16 fish per day (5840 fish annually) would be impinged; annual entrainment of fish eggs and larvae would be 7.7×10^6 and 11.9×10^6, respectively.

- Approximately 4.2 curies of radiocesium would be remobilized and transported into the Savannah River during the first year of resumed operations. Liquid releases of tritium from L-Reactor to the Savannah River would be reduced to about 9340 curies per year.

- Five archeological sites eligible for the National Register would be subject to erosion and flooding, including one prehistoric site and four historic sites.

- Increased flow would further erode the Steel Creek corridor, and delta growth would increase at approximately 3 surface acres per year.

No impact to the substrate, water quality, or naturally occurring turbidity levels would occur as a result of dredging and filling because construction activities would be confined to the existing discharge canal from L-Area during periods of reactor downtime.

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, (6) the preparation of a biological assessment for endangered species.

If the spray canal cooling system alternative is implemented before direct discharge occurs, the environmental impacts would be slightly greater than those attributable to direct discharge.

4.4.2.2.3 Small lakes

This system, which would use several small dams (rubble dams) on Steel Creek to create small lakes (Figure 4-22), would provide some thermal mitigation to the lower portions of Steel Creek and the swamp compared to the reference case (direct discharge). A series of several rubble dams would create small lakes with a combined area of about 120 acres, which would pool water to provide an increased stream surface area and decreased stream velocity to enhance cooling. The dams would be created by dumping large stone or broken concrete in Steel Creek at accessible locations. The dams would be 1.5 to 2.4 meters high; they could be solid or porous, but better results could be expected with solid dams. Each small dam would consist of about 3500 cubic meters of material; the total volume for the seven dams would be about 24,500 cubic meters. Slightly contaminated spoil from the surface portion of the embankment foundations in the Steel Creek floodplain, estimated to contain a total of 0.2 curie of cesium-137

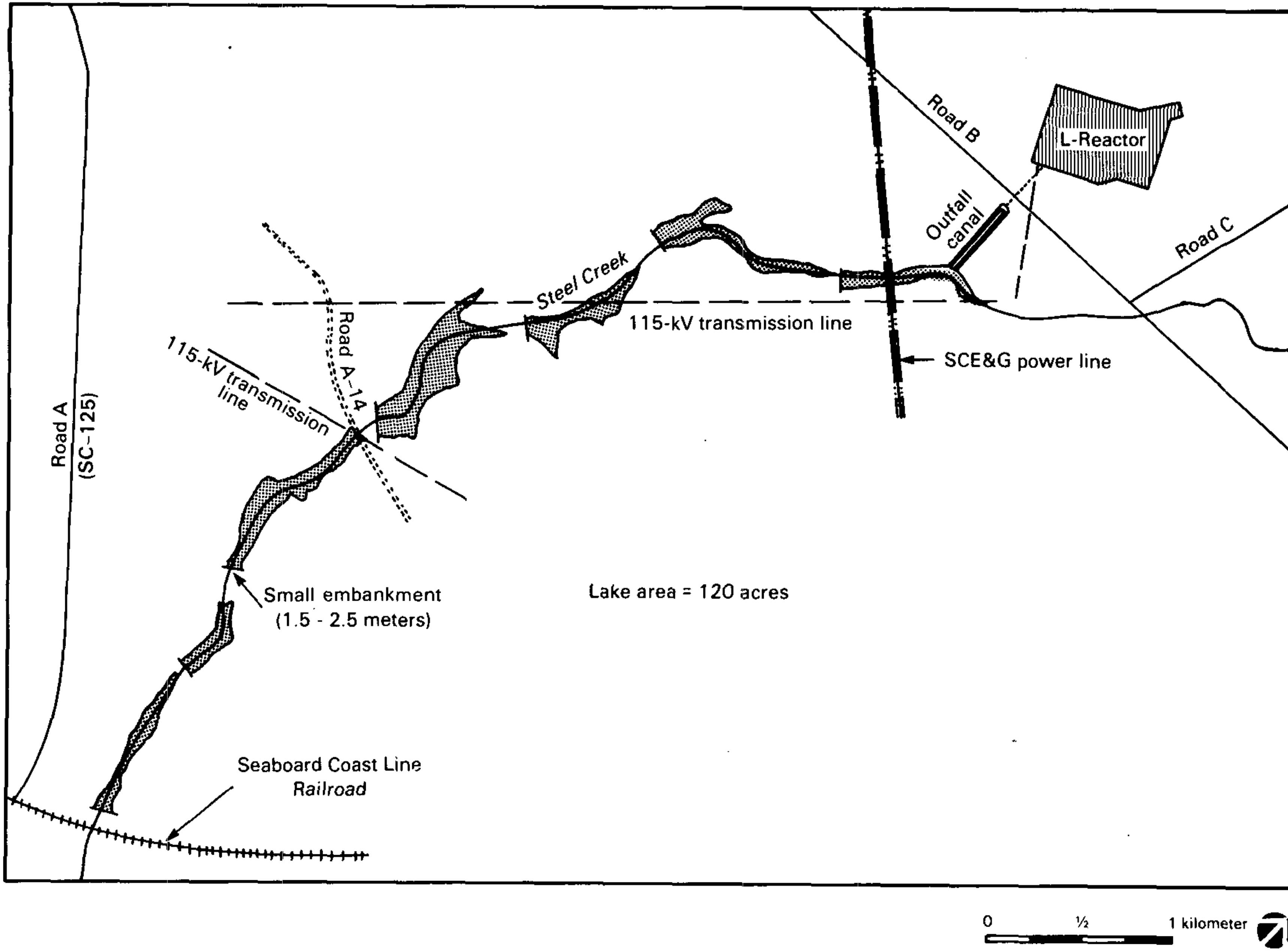


Figure 4-22. Conceptual design for a series of small lakes on Steel Creek.

and 0.02 curie of cobalt-60, would be separated, contained, replaced outside the wetlands upstream of the dam, and covered with subsurface spoil to prevent erosion during the construction period. This relocation would have no effect on net cesium transport estimates. All other material would be removed and used for backfill in the borrow areas. Sediment would collect upstream from each solid dam. Water spilling over the dams would increase the heat dissipation effectiveness of the system by increasing the exposure of the hot water to air.

Locations of the dams would be selected to minimize the relocation of existing roads, power lines, and cables and to maximize the potential for cooling in the upper reaches of the creek. Access roads would be minimized and their locations selected to prevent environmental impacts. The estimated time required to design and construct the small rubble dams, without an expedited schedule, is between 18 and 24 months (Du Pont, 1983d). On an expedited schedule, construction of this alternative would be possible in about 6 months. For the construction of these dams, diversion channels would be required around each dam site to reroute heated effluent. These could probably be constructed during a short (1-month) reactor shutdown. Another 1-month period would be required after dam construction is completed to reroute the water back over dams by filling the diversion channels.

The estimated capital costs for small rubble dams would be \$6 million. The annual operating cost would be \$3.4 million, and the present worth would be \$35 million. Annualized cost would be \$4.1 million (Du Pont, 1983d). An estimated 75 personnel would be required for construction of the rubble dams.

Water use for this alternative would be about 11 cubic meters per second. Production efficiency for this alternative would be 100 percent. However, water-quality standards could not be met without a reduction in power.

Small lakes could reduce the temperature at the entry to the swamp to about 40°C, or about 4°C cooler than that for direct discharge, under severe summer conditions. The water discharge temperature from L-Reactor would vary by month, depending on the temperature of the supply water from the Savannah River, meteorological conditions, and the reactor operating power. The temperature at the creek mouth would be about 33°C, or 1°C cooler than for a direct discharge (see Table 4-33).

Small lakes would provide limited thermal mitigation. The 43°C average summer discharge temperature would not comply with the State 32.2°C discharge limit. With the small lakes alternative, water temperatures in the mid-swamp and at the mouth of Steel Creek could be about 7°C above ambient during extreme summer conditions, but would be as much as 15°C above ambient in the winter. This could result in the concentration of fish in the heated areas during the colder months, which, in turn, could subject them to potential cold shock during any shutdown.

The small lakes would result in the loss of between 420 and 580 acres of wetlands in the Steel Creek corridor and between 310 and 420 acres in the delta-swamp area. In addition, about 2500 acres of wetlands could be isolated due to thermal temperatures. The wetlands that would be impacted by this alternative are classified as Resource Category 2 by the U.S. Fish and Wildlife Service.

Table 4-33. Temperatures (°C) downstream in Steel Creek with small lakes

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature (from downstream impoundment)	45	43	40	34
Road A	44	42	38	32
Swamp at delta	40	38	34	27
Mid-swamp	34	33	28	21
Mouth of creek at river	33	31	26	18

[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 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.

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).

This alternative would have about the same adverse impacts as direct discharge on habitat of the endangered American alligator, the endangered wood stork, and migratory waterfowl.

The impacts of impingement and entrainment would be the same as those for direct discharge--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.

The transport of radiocesium down Steel Creek from this alternative would be lower than that for direct discharge. Conservatively, no more than 4.4 ± 2.2 curies would be transported in the first year of operation (see Section L.4.1.2.2). Liquid releases of tritium from L-Reactor to the Savannah River would be reduced to about 7880 curies per year.

The area subject to impact by this alternative contains one prehistoric site and four historic sites eligible for the National Register. These sites would be subject to erosion and flooding due to the high water-flow conditions and the establishment of one or more small lakes. Erosion and transport of sediment are expected to be slightly reduced in relation to direct discharge. A delta growth rate of about 2 acres per year is anticipated.

No appreciable change is expected in the chemical characteristics of the effluent as the result of its passing through the impoundments, except about 6 percent of the suspended solids would be removed from the river water by the 186-Basin and the impoundments. The water quality of the impoundments should be somewhat similar to that of Par Pond; an ion-concentration ratio (impoundment-to-river-water) of less than 1.3 is expected (Tilly, 1974).

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 (i.e., loss of 730 to 1000 acres of wetlands, etc.). Any mitigative effects resulting from the small impoundments would not begin until the end of the 18- to 24-month construction period.

4.4.2.2.4 Small lakes with upstream spray cooling (one set)

This alternative is very similar to the alternative described in the previous section, except there would be a gravity spray module in the outfall canal. The final lake discharge water would flow at a rate of about 11 cubic meters per second and would be at a temperature of about 44°C under extreme summer conditions.

Small lakes with spray cooling (one set) could be designed and constructed in 18 to 24 months. During the construction (if L-Reactor operation is restarted before construction of the rubble dams), diversion channels would be required around each dam site to route heated effluent around construction areas. These could probably be built during a short (1-month) reactor shutdown. Another 1-month period would be required after construction to reroute water back over the dams by filling the diversion channels. 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 wetlands upstream of the dam, and covered with subsurface spoil to prevent erosion during the construction period. This relocation would have no effect on net cesium transport estimates. All other material would be removed and used for backfill in the borrow areas.

The estimated capital costs for the small lakes and single spray cooling system would be about $15 million. Annual operating and maintenance costs would be $3.5 million, the present worth would be $44 million, and the annualized cost would be $5.2 million (Du Pont, 1983e). An estimated 105 construction personnel would be required.

The flow rate for this alternative would be 11 cubic meters per second and the production efficiency would be 100 percent. Table 4-34 lists Steel Creek temperatures for various seasons without a reduction in power. However, the alternative could not meet water-quality standards without a reduction in power.

Discharge temperatures for this alternative would be above the 32.2°C State limit most of the year.

The use of small lakes with a single spray system would result in the loss of between 420 and 580 acres of wetlands in the Steel Creek corridor. The spray canal would also eliminate 55 acres of wetlands and 55 acres of upland habitat. Between 215 and 335 acres of wetlands in the delta and swamp would also be impacted, primarily due to flow. Thus, between 690 and 970 acres of wetlands and

Table 4-34. Temperatures (°C) downstream in Steel Creek with small lakes and one set of spray coolers

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	44	43	39	34
Road A	43	42	38	32
Swamp at delta	40	38	34	27
Mid-swamp	34	32	27	20
Mouth of creek at river	33	31	25	18

[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 leaving downstream impoundment.

55 acres of uplands would be effected by this alternative. 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." In addition, about 2280 acres of wetlands along Meyers Branch and along Steel Creek above the L-Reactor outfall would be isolated from riverine and anadromous fishes.

Effluent temperatures in the mid-swamp during summer and spring would be 7°C to 9°C above ambient. Winter temperatures in the mid-swamp and at the mouth of Steel Creek would be as high as 14°C above ambient. Thus, fishes might be attracted to the mouth of Steel Creek in winter.

The impacts of impingement and entrainment would be the same as those for direct discharge--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.

Conservatively, the transport of radiocesium down Steel Creek would be less than 4.4 ± 2.2 curies the first year of operation (see Section L.4.1.2.2). Liquid releases of tritium from L-Reactor to the Savannah River would be reduced to about 7800 curies per year.

The area subject to impact by these alternatives contains one prehistoric site and four historic sites eligible for the National Register. These sites would be subject to erosion and flooding due to the high water-flow conditions and the establishment of one or more small lakes. A mitigation plan would be developed and implemented prior to restart similar to that described for direct discharge.

Erosion and transport of sediment would increase because of the increased flow rate (about 10.5 cubic meters per second). A delta growth rate of about 2 acres per year is anticipated.

No appreciable change is expected in the chemical characteristics of the effluent as the result of its passing through the impoundments, except about 6 percent of the suspended solids would be removed from the river water by the 186-Basin and the impoundments. The water quality of the impoundments should be somewhat similar to that of Par Pond; an ion-concentration ratio (impoundment-to-river-water) of less than 1.3 is expected (Tilly, 1974).

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 effects would be as described above. If it is implemented after direct discharge occurs, the environmental effects 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.). The mitigative effects resulting from small lakes with one set of spray coolers would not begin until the end of the 18-to 24-month construction period.

4.4.2.2.5 Small lakes with upstream and downstream spray cooling (two sets)

Small lakes with two sets of spray cooling would also mitigate some of the environmental effects of a direct discharge system. The gravity spray canal system would be installed to obtain about 5°C of cooling before the water enters the first pond. The small dams would create pools that would slow the movement of the water and enhance cooling. The second spray system would be in the last shallow pond.

Small lakes with spray cooling (two sets) could be designed and constructed in 18 to 24 months. If L-Reactor operation is restarted before the construction of the rubble dams, the estimated reactor downtime would be between 3 and 4 months to accomplish the tasks. During the construction, diversion channels would be required around each dam site to route heated effluent around construction areas. These could probably be built during a short (1-month) reactor shutdown. Another 1-month period would be required after construction to re-route water back over the dams by filling the diversion channels. 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 wetlands upstream of the dam, and covered with subsurface spoil to prevent erosion during the construction period. This relocation would have no effect on net cesium transport estimates. All other material would be removed and used for backfill in the borrow areas.

The estimated capital costs for the small lakes with spray cooling (two sets) would be approximately $9 million for the spray canal system plus $5.5 million for the rubble dams plus as much as $14.5 million for the supplemental spray system; the total cost would be about $29 million.

Operating and maintenance costs would be higher than those for the direct discharge system because of the added costs of operating the spray modules in the ponds. Annual operating and maintenance costs for this alternative would be $3.5 million. The present worth of the alternative would be $60 million and the annualized cost would be $7.1 million (Du Pont, 1983d). An estimated 135 construction personnel would be required.

Production efficiency for this alternative would be 100 percent. However, State water-quality standards could not be met without a reduction in power. The flow rate would be 10.4 cubic meters per second.

During the passage through these ponds, the water would be cooled to about 43°C under extreme summer conditions. This cooling could be increased by the spray cooling modules in the final lake, where the water would be cooled to about 39°C before being released to Steel Creek above Road A. Table 4-35 lists Steel Creek temperatures for the various seasons without power reduction.

Table 4-35. Temperatures (°C) downstream in Steel Creek with small lakes and two sets of spray coolers

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	39	38	34	29
Road A	39	37	33	27
Swamp at delta	37	35	30	23
Mid-swamp	33	31	26	18
Mouth of creek at river	32	30	24	17

[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 actual power of an operating reactor (Du Pont, 1983d). 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 leaving downstream impoundment.

The use of small lakes with two spray systems would result in the loss of between 420 and 580 acres of wetlands in the Steel Creek corridor. These wetlands 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). In addition, about 55 acres of wetlands and 55 acres of uplands would be lost for the construction of the spray canal. Furthermore, 75 acres of uplands would be eliminated by the second spray pond. Between 215 and 335 acres of wetlands in the delta would also be eliminated, primarily by high flow. Thus, between 690 and 970 acres of wetlands and 70 acres of uplands would be eliminated by this alternative. In addition, about 2500 acres of wetlands along Steel Creek above the L-Reactor outfall and along Meyers Branch and Boggy Gut Creek will be isolated from riverine and anadromous fishes.

Effluent temperatures in summer in the mid-swamp and at the mouth of Steel Creek would be as high as 6°C above calculated ambient temperatures. Winter temperatures of 18°C and 17°C (which are 11° to 12°C above ambient) at the swamp and mouth of Steel Creek, respectively, might attract fish. Additional wetlands in the delta and swamp would be eliminated by high flow.

Discharge temperatures for small lakes with two sets of spray cooling are above the 32.2°C State limit. Discharge temperatures over the 32.2°C requirement would occur on most summer days; compliance could be expected during part of the spring and all of the winter months.

The impacts of impingement and entrainment would be the same as those for direct discharge--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.

Conservatively, the transport of radiocesium down Steel Creek would be no more than 4.4 ± 2.2 curies the first year of operation (see Section L.4.1.2.2). Liquid releases of tritium from L-Reactor to the Savannah River would be reduced to about 7770 curies per year.

The area subject to impact by these alternatives contains one prehistoric site and four historic sites eligible for the National Register. These sites would be subject to erosion and flooding due to the high water-flow conditions and the establishment of one or more small lakes. A mitigation plan would be developed and implemented prior to restart similar to that described for direct discharge.

Erosion and transport of sediment would increase because the flow rate would be about 10.4 cubic meters per second. A delta growth rate of about 2 acres per year is anticipated.

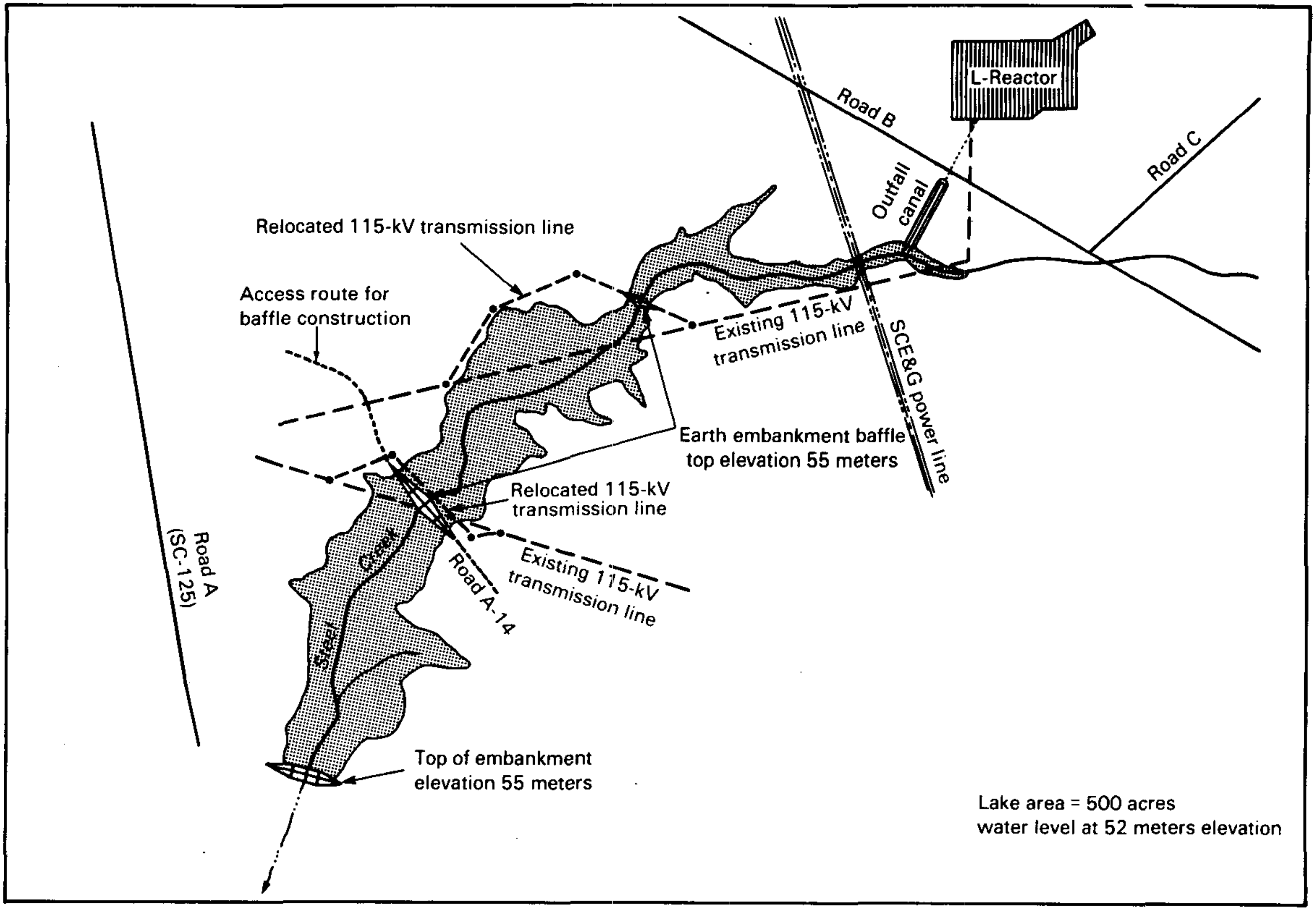
No appreciable change is expected in the chemical characteristics of the effluent as the result of its passing through the impoundments, except about 6 percent of the suspended solids would be removed from the river water by the 186-Basin and the impoundments. The water quality of the impoundments should be somewhat similar to that of the Savannah River.

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 small lakes with spray cooling (two sets) are implemented before direct discharge occurs, the environmental effects would be as described above. If this alternative is implemented after direct discharge starts, the environmental effects 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.). The mitigative effects resulting from rubble dams with sprays (two sets) would not begin until the end of the 18- to 24-month construction period.

4.4.2.2.6 500-acre lake

The topography along Steel Creek is suitable for the construction of a 500-acre lake (Figure 4-23). The lake would be separated physically into three



Note: The 500-acre lake configuration shown reflects actual land contours for a lake surface elevation of 170 meters above mean sea level

Figure 4-23. Conceptual design of a 500-acre lake on Steel Creek.

sections of about equal length with underflow baffles to enhance its cooling efficiency. The baffles would prevent short circuiting of hot water and would maximize the use of the surface area. The final (underflow) baffle would discharge water from several feet below the lake surface at a rate of about 10.7 cubic meters per second.

The estimated time to design and construct a 500-acre lake, without an expedited schedule, would be 31 months. With an expedited schedule, the lake could be completed in 6 months. If L-Reactor is restarted before this alternative is implemented, a discharge structure could be constructed away from the existing stream while reactor effluent flows continued. When this structure is complete, a short (1-month) shutdown might be required to divert flows through the structure. Also, clearing directly adjacent to the stream would be accomplished during this shutdown.

The construction of the embankment and clearing the 500 acres could be completed while flows are discharged through the structure. Gates in the structure would be closed to fill the 500-acre lake. The construction of the large earthen embankment and baffle structures required for the 500-acre lake would cause some temporary increases in suspended solids in the creek. The quantity of fill material required would be about 450,000 cubic meters. 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 wetlands upstream of the dam, and covered with subsurface spoil to prevent erosion during the construction period. This relocation would have no effect on net cesium transport estimates. All other material would be removed and used for backfill in the borrow areas. The embankment would be about 475 meters long; it would have a height of about 22 meters. The width at its base would be about 120 meters. Impacts to downstream areas can be minimized by the use of turbidity screens. During construction, the number of access roads would be minimized and their locations selected to prevent environmental impacts.

Water use from the Savannah River would be about 11 cubic meters per second and production efficiency would be 100 percent. The estimated capital cost for a single impoundment is $12 million; the capital cost would increase by $2 million if underflow baffles are included. The annual operating cost would be $3.4 million. The present worth of the lake would be $41 million, and the annualized cost is $4.8 million (Du Pont, 1983d). An estimated 345 construction personnel would be required for construction of the 500-acre lake.

Table 4-36 lists the estimated downstream temperatures in Steel Creek in the summer, spring, and winter without reduction in power. This arrangement would minimize diurnal temperature variations in the lake and provide additional cooling capacity during hot weather (about 5°C and 3°C cooler than the direct discharge at the mid-swamp and creek mouth, respectively).

A 500-acre lake would provide limited thermal mitigation. The 37°C discharge temperature from the lake would exceed the State 32.2°C discharge limit. Additionally, the temperature of Steel Creek would increase significantly more than the State temperature increase limit of 2.8°C. The temperatures could be lowered by reducing reactor power.

Table 4-36. Temperatures (°C) downstream in Steel Creek with a single 500-acre lake

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	37	36	31	24
Road A	37	35	30	24
Swamp at delta	36	34	28	20
Mid-swamp	32	30	24	16
Mouth of creek at river	31	29	23	15

[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 actual power of an operating reactor. Summer average temperatures that could be expected if significant temperature excursions above and below average did not occur.

[c]Temperature of water leaving lake.

The water temperature at mid-swamp would be 5°C, 6°C, and 10°C above ambient in summer, spring, and winter, respectively (Table 4-36). The water temperature at the mouth of Steel Creek would be 4°C above ambient in summer, 5°C above ambient in spring, and 9°C above ambient in winter. Cold shock to fishes is possible.

The 500-acre lake would impact between 435 and 595 acres of wetlands in the Steel Creek corridor. Approximately 360 acres of uplands would be inundated by the lake. Impacts to wetlands in the delta and swamp due primarily to flow would range between 215 and 335 acres. Thus, this alternative would affect between 650 and 930 acres of wetlands and 360 acres of uplands. Furthermore, approximately 2280 acres of wetlands along Meyers Branch and above L-Reactor would be thermally or physically isolated from riverine and anadromous fishes. Because the lake would achieve an average water temperature of 37°C, it would be biologically devoid of life except for thermophilic flora. 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).

This alternative would have about the same adverse impacts as direct discharge on habitat of the endangered American alligator, the endangered wood stork, and migratory waterfowl.

The impacts of impingement and entrainment would be the same as those for direct discharge--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.

The transport of radiocesium down Steel Creek from this alternative would be about the same as that for direct discharge. Conservatively, about 4.4 ± 2.2 curies would be released during the first year of operation (see Section

L.4.1.2.2). Liquid releases of tritium from L-Reactor to the Savannah River would be reduced to about 7880 curies per year.

The area subject to impact by this alternative contains one prehistoric site and four historic sites eligible for the National Register. These sites would be subject to erosion and flooding due to the high water-flow conditions and the establishment of one or more small lakes. Mitigation would be similar to that discussed for direct discharge.

Erosion and transport of sediment are expected to be slightly reduced in relation to direct discharge. A delta growth rate of about 2 acres per year is anticipated.

No appreciable change is expected in the chemical characteristics of the effluent as the result of its passing through the lake, except about 6 percent of the suspended solids would be removed from the river water by the 186-Basin and the impoundments. The water quality of the lake should be somewhat similar to that of the Savannah River.

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 (i.e., loss of 730 to 1000 acres of wetlands, etc.). Any mitigative effects resulting from the 500-acre-lake alternative would not begin until the end of the 18- to 31-month construction period.

4.4.2.2.7 500-acre lake with spray cooling (one set)

The cooling efficiency of the 500-acre lake (Figure 4-23) could be enhanced through the addition of a spray module. The gravity-power spray cooling system (Figure 4-21 and Section 4.4.2.2.2) would operate in much the same manner as a conventional pumped spray system by dissipating a portion of cooling-water heat into the atmosphere.

The estimated time required to design and construct the lake is a total of 31 months without expediting. On an expedited basis, the lake could be constructed in 6 months. Assuming that the permit process for the lake begins when the design of the spray canal is initiated, then the lake construction would be completed about 19 months after the spray canal. This schedule assumes that there would be no major permitting delays. Before the implementation of this alternative could begin, a budget proposal would have to be submitted to the U.S. Congress to seek funding appropriations.

The construction of the spray system would begin after permits have been obtained from the appropriate State and Federal agencies. The estimated time required to design and construct the spray system is about 12 months (on an expedited basis). A new valve chamber (shown in Figure 4-21) and a penstock would be installed as part of the spray canal system, along with pipe headers and nozzles. L-Reactor operation would begin at the same time the construction of the spray canal and the lake get underway.

Provisions would be made for the diversion or controlled channeling of more than 11 cubic meters per second of increased water flow that would occur when L-Reactor begins operation. The water flow would include L-Reactor cooling water, storm runoff, and natural Steel Creek flows. This water would be diverted around active construction areas.

Depending on when the diversion around the construction area first occurs, a short shutdown (about 1 month) might be required to implement the diversion. Clearing the vegetation directly adjacent to the stream could be accomplished during this shutdown. When the embankment is completed and the land is cleared, the control gates in the diversion structure would be closed to fill the lake.

The construction of the earthen embankment, baffle structures, and water diversion system for the lake would cause some temporary increases in suspended solids in the creek. Suitable precautions would be taken (1) during the construction operations necessary to establish a foundation for the impoundment, (2) during any necessary diversion of Steel Creek, and (3) during emplacement of the fill to ensure that undue silt and debris loads do not move downstream from the construction site. Turbidity screens could minimize impacts to downstream areas. About 450,000 cubic meters of fill material would be required for the dam and baffles.

Borrow pits of suitable materials and similar quantities have been used in the past for similar construction at the Savannah River Plant. For this alternative, the most economically suitable pit would be identified and controlled. Spoil piles of the size expected for this alternative have been developed for past construction activities at the Savannah River Plant and have met necessary environmental control requirements.

During construction, the location and number of access roads would be minimized to reduce environmental impacts. 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 wetlands upstream of the dam, and covered with subsurface spoil to prevent erosion during the construction period. This relocation would have no effect on net cesium transport estimates. All other material would be removed and used for backfill in the borrow areas.

Capital costs for the combined lake-and-spray system would be approximately the $9-million cost of the spray canal system plus the $12-million cost of the 500-acre lake, a total cost of about $21 million. Underflow baffles would increase the capital cost by about $2 million. Operating and maintenance costs would be about the same as those for direct discharge if a gravity spray system is utilized ($3.5 million). The present worth of this alternative would be $50 million and the annualized cost would be $5.9 million (Du Pont, 1983d). An estimated 375 construction personnel would be required.

Approximately 11 cubic meters per second would be withdrawn from the Savannah River and used as the secondary cooling-water supply. Production efficiency would be 100 percent. However, reactor operation would be limited in the summer by the ambient temperature of the Savannah River.

Table 4-37 lists the estimated downstream temperatures in Steel Creek for the summer, spring, and winter without a reduction in power. Ambient temperatures in Steel Creek at Road A are about 25°C in summer, 20°C in spring, and 7°C in winter; this is based on 10 years of measurements (Du Pont, 1983d).

Table 4-37. Temperatures (°C) downstream in Steel Creek with a 500-acre lake with spray cooling (one set of sprays)

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	37	35	30	23
Road A	37	35	30	23
Swamp at delta	36	33	28	20
Mid-swamp	32	30	24	16
Mouth of creek at river	31	29	23	15

[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 (Du Pont, 1983d). Summer average temperatures have been included to show the discharge and Steel Creek temperatures that could be expected if significant temperature excursions above conditions and below average did not occur.

[c]Temperature of water leaving lake.

The gravity spray canal system would provide about 5°C cooling in the summer before the water entered the 500-acre lake. This water (at 73°C) would be cooled to about 37°C during its travel through the lake (under worst-case meteorological conditions). As shown in Table 4-37, this alternative would exceed the 32°C discharge temperature limit on extreme summer days but would be in compliance on average summer days. These temperatures could be reduced by a reduction in power.

The environmental consequences of using a cooling system with one set of sprays until a 500-acre lake became operational would include impacts from the elevated water temperature and the increased rate of flow.

The construction of the spray canal (Section 4.4.2.2.2) would necessitate the removal of vegetation within 300 meters of the unit to achieve the best cooling performance, causing a slightly greater impact on wetlands than direct discharge. These impacts from the spray canal alone (until the lake is constructed), which would result from high water temperatures (i.e., delta-T = 8°C at the swamp in summer) and flow rate (about 10.6 cubic meters per second) include:

- Between 705 and 985 acres of wetlands would be eliminated, including habitat for the endangered American alligator, the endangered wood stork, and migratory waterfowl. These wetlands 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). In addition, about 2500 acres of wetlands would be isolated to aquatic biota by thermal temperatures, and 415 acres of uplands would be inundated.

- Approximately 16 fish per day (5840 fish annually) would be impinged; annual entrainment of fish eggs and larvae would be 7.7×10^6 and 11.9×10^6, respectively.

- Conservatively, no more than 4.4 ± 2.2 curies of radiocesium would be remobilized and transported into the Savannah River during the first year of resumed operations (see Section L.4.1.2.2). Liquid releases of tritium from L-Reactor to the Savannah River would be reduced to about 9340 curies per year.

- Five archeological sites eligible for the National Register would be subject to erosion and flooding, including one prehistoric site and four historic sites. A mitigation plan would be designed by the Institute of Archeology and Anthropology of the University of South Carolina and would be completed prior to restart.

- Increased flow would further erode the Steel Creek corridor, and delta growth would increase at approximately 3 surface acres per year.

No impact to the substrate, water quality, or naturally occurring turbidity levels would occur as a result of dredging and filling because construction activities would be confined to the existing discharge canal from L-Area during periods of reactor downtime.

The construction of the 500-acre lake would cause short-term impacts to the substrate, water quality, and naturally occurring turbidity levels of Steel Creek as a result of dredging and filling.

The lake would impound about 6 kilometers of Steel Creek from the L-Reactor outfall to its dam near Road A (SC Route 125). Biota would have already been eliminated in this portion of the creek from the operation of the spray cooling system. Because the lake would achieve an average water temperature of 37°C, it would be biologically devoid of life except for thermophilic flora. It could also thermally isolate Meyers Branch and physically isolate the upper reaches of Steel Creek (about 2280 acres of wetlands) from fishes and other aquatic and semiaquatic biota. Access to wetlands associated with Boggy Gut Creek (about 230 acres) will be unaffected.

The rate of flow of the effluent discharged below the dam for this once-through alternative would be about 10.5 cubic meters per second. The temperature of the effluent in summer would be 37°C.

In spring, water temperatures in the mid-swamp and at the mouth of Steel Creek would be within 6°C of calculated ambient temperatures (Table 4-37). Thus, anadromous and riverine fishes would have access to the swamp for spawning and foraging. Winter temperatures in the swamp and at the mouth of Steel Creek would be about 10°C and 9°C above ambient, respectively. Although there is a potential for fishes to concentrate in these warmer waters during the winter, no adverse impacts to the Savannah River due to effluent discharge are expected. Although this option would achieve thermally viable water temperatures in the swamp and at the mouth of Steel Creek, the discharge rate below the dam would have adverse impacts on the Steel Creek delta and portions of the swamp. The flow and scouring effect of the effluent would uproot most of the existing vegetation almost immediately; the remaining vegetation would eventually succumb to high flow. Other wetland vegetation would experience elevated water levels, and their root systems would be inundated. Mortality, especially after continuous inundation, would occur to even the most water-tolerant species (i.e., willow and alder).

An estimated 215 to 335 acres of wetlands would be eliminated in the Savannah River swamp and Steel Creek delta. This would include important foraging habitat for the endangered wood stork. In addition, important roosting and feeding habitat for as many as 1200 mallard ducks and 400 wood ducks would be lost. There would be negligible impact to the American alligator below the Steel Creek delta.

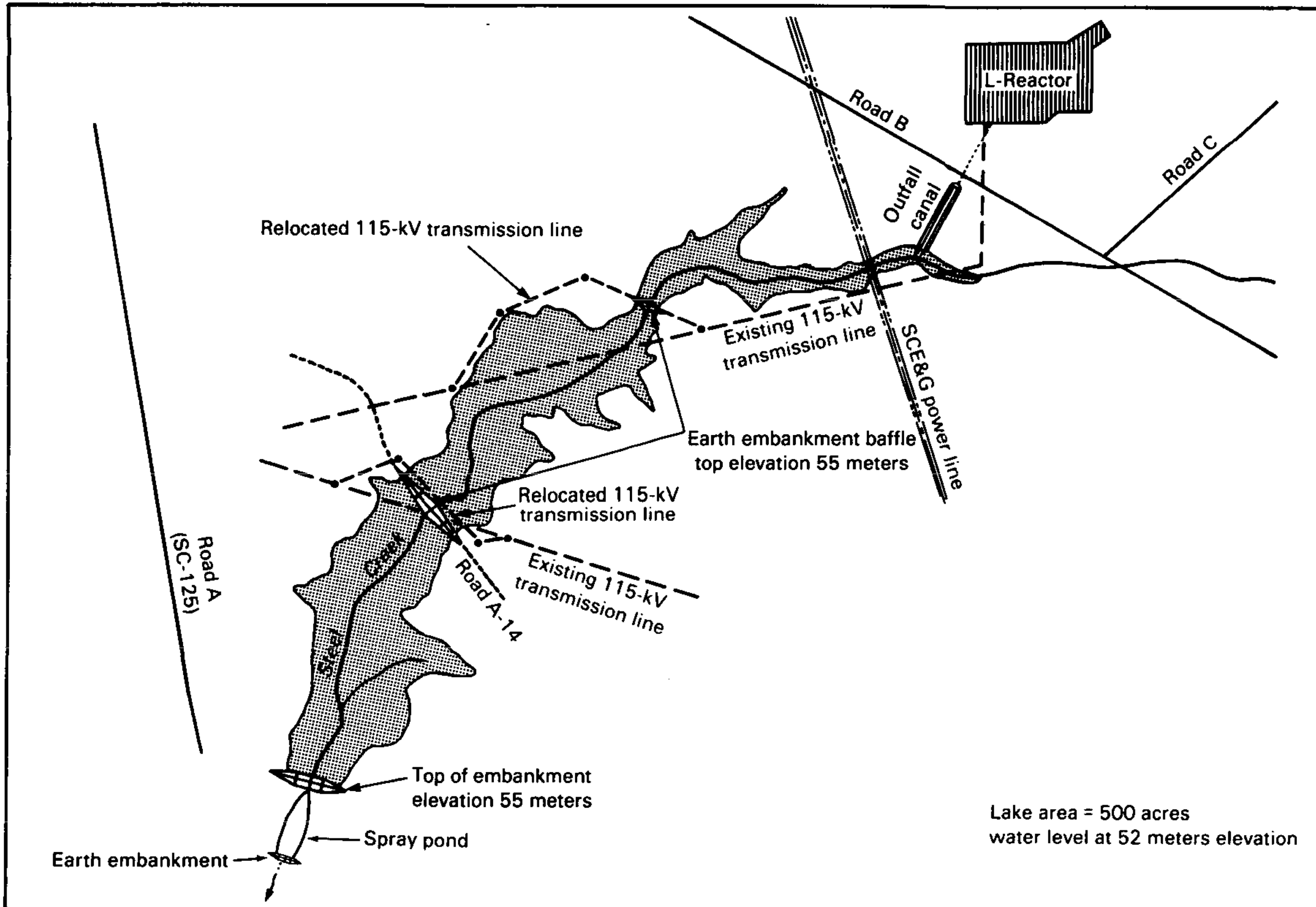
This alternative would require the following permits or processes: (1) a U.S. Army COE 404 permit, (2) an SCDHEC 401 certification, (3) an NPDES permit, (4) a 316(a) demonstration, (5) consultations with the FWS, and (6) the preparation of a biological assessment for endangered species.

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 mitigative effects would be that riverine and anadromous aquatic biota would have access to the Savannah River swamp.

4.4.2.2.5 500-acre lake with spray cooling (two sets)

Another alternative system would combine the 500-acre lake with two spray cooling systems. The gravity spray canal system described in Section 4.4.2.2.2 would be installed to obtain about 5°C of cooling in the summer before the water enters the 500-acre lake. This water would be cooled to about 37°C during its travel through the lake under extreme summer conditions. A spray system below the dam would cool the water to about 32°C before discharging it to Steel Creek (Figure 4-24). To reduce energy requirements (and, thus, operating and maintenance costs), the hydraulic head created by the lake would be used to power a gravity spray system below the dam.

The combined lake-and-spray system could be designed and constructed on a normal schedule within the same 31-month timespan that the lake alone would require. The 31-month schedule would assume that construction permits could be obtained with no major delays. An accelerated schedule could shorten this time. Implementation would also be contingent on funding. The three components could be built simultaneously; the embankment construction would be the limiting feature of the schedule. The reactor downtime would be from 3 to 6 months. 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 wetlands upstream of the dam, and covered with subsurface spoil to prevent erosion during



Note: The 500-acre lake configuration shown reflects actual land contours for a lake surface elevation of 170 meters above mean sea level

0 ½ 1 kilometer

Figure 4-24. Conceptual design of a 500-acre lake (two spray systems) on Steel Creek.

the construction period. This relocation would have no effect on net cesium transport estimates. All other material would be removed and used for backfill in the borrow areas.

Capital costs for the combined lake-and-spray system would be approximately the $9-million cost of the spray canal system plus the $12-million cost of the 500-acre lake plus about $15 million for the additional spray system; the total cost would be about $36 million. If underflow baffles are included, capital costs would increase by $2 million. Operating and maintenance costs would be about the same as those for direct discharge ($3.5 million) if gravity spray systems are utilized. The present worth of this alternative would be $65 million and the annualized cost would be $7.6 million (Du Pont, 1983d). An estimated 405 construction personnel would be required.

Approximately 11 cubic meters per second would be withdrawn from the Savannah River and used as the secondary cooling-water supply. Production efficiency would be 100 percent. However, reactor operation would be limited in the summer by the ambient temperature of the Savannah River.

Table 4-38 lists the estimated downstream temperatures in Steel Creek for the summer, spring, and winter without reduction in reactor power. The 500-acre lake with two sets of spray coolers would normally comply with the maximum discharge temperature of 32.2°C during extreme meteorological conditions.

Table 4-38. Temperatures (°C) downstream in Steel Creek with a 500-acre lake with spray cooling (two sprays)

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	32	30	25	18
Road A	32	30	25	18
Swamp at delta	32	30	24	16
Mid-swamp	30	28	22	13
Mouth of creek at river	30	28	22	13

[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 leaving lake.

The environmental impacts of this alternative are summarized as follows:

- This alternative would significantly reduce thermal impacts. Summer and spring temperatures in the mid-swamp and at the mouth of Steel Creek would be within 4°C of ambient. Water temperatures in the swamp and at the mouth of Steel Creek in winter would be as high as 7°C above ambient. Thus, temperatures in the winter could cause fish to concentrate near the mouth of Steel Creek, and also subject them to cold shock.

- Approximately 705 to 985 acres of wetlands would be affected, including habitat of the endangered American alligator, the endangered wood stork, and migratory waterfowl. 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). In addition, 490 acres of upland habitat would be inundated. About 100 acres of wetlands would be isolated by this alternative.

- Approximately 16 fish per day (5840 fish annually) would be impinged; the annual entrainment of fish eggs and larvae will be 7.7×10^6 and 11.9×10^6, respectively.

- Conservatively, no more than 4.4 ± 2.2 curies of radiocesium would be remobilized and transported to the Savannah River during the first year of resumed L-Reactor operation (see Section L.4.1.2.2). Liquid releases of tritium would be about 7670 curies per year.

- Five archeological sites eligible for the National Register would be subject to erosion and flooding, including one prehistoric site and four historic sites. A mitigation plan would be developed and implemented prior to restart similar to that described for direct discharge.

- The increased flow (to about 10.4 cubic meters per second) would further erode the Steel Creek corridor, and delta growth will increase at a rate of approximately 2 surface acres per year.

- Short-term impacts to the substrate, water quality, and naturally occurring turbidity levels would occur as a result of dredging for the construction of dams and spray systems. These impacts are discussed in Section 4.4.2.2.3.

- Local ground-water levels would be raised due to the reservoir.

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 the 500-acre lake with two spray cooling systems 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 be the same as those described in Section 4.2.2.2.1 (i.e., loss of 730 to 1000 acres of wetlands, etc.). The primary mitigative effect resulting from this alternative would be that riverine and anadromous aquatic biota could inhabit the Savannah River swamp system, Meyers Branch, and Boggy Gut Creek.

4.4.2.2.9 1000-acre lake

This alternative consists of a 1000-acre once-through cooling lake on Steel Creek (Figure 4-25). The normal water surface elevation would be 58 meters above mean sea level. The embankment for this cooling lake would be at the same location as that for the 500-acre lake described in Section 4.4.2.2.6. This alternative would require the relocation of two 115-kilovolt electric transmission lines and buried supervisor control and relay cable lines that cross Steel Creek near Road A-14. Roads A-14, A-14.1, and B-5 would have to be abandoned.

The lake would have a length of about 7000 meters including about 1500 meters of tailwater upstream of the outfall canal. The embankment would be about 750 meters long, 28 meters high, and 210 meters wide at its base. The water would be discharged several meters below the top of the embankment. Several small earthen berms would be required to prevent high water from overflowing natural saddles into adjacent watersheds. One of these points could be controlled for use as an emergency spillway to prevent unusually large storm flows from overtopping the embankment.

The construction of the 1000-acre lake would begin after permits had been obtained from the appropriate State and Federal agencies. The estimated time for the design and construction of this alternative would be about 36 months without an expedited schedule. This schedule assumes there would be no major permitting delays. With an expedited schedule, this alternative could be completed in 6 months, as discussed in Section 4.5 and Appendix L.

The construction of the earthen embankment, baffle structures, and water diversion system for the lake would cause some temporary increases in suspended solids in the creek. Suitable precautions would be taken (1) during the construction operations necessary to establish a foundation for the impoundment, and (2) during emplacement of the fill to ensure that undue silt and debris loads do not move downstream from the construction site. Turbidity screens could minimize impacts to downstream areas. About 1.2 million cubic meters of fill material would be required for the embankment.

Borrow pits of suitable materials and similar quantities have been identified in the past for similar construction at the Savannah River Plant, and have been controlled in an environmentally acceptable manner. For this alternative, the most economically suitable pit would be identified and similarly controlled.

Spoil piles of the size expected for this alternative have been developed for past construction activities at the Savannah River Plant and have met necessary environmental control requirements. In one case, special precautions were taken to protect a Thermal Effects Laboratory operated for environmental purposes on Upper Three Runs Creek. These measures were completely successful. Spoil from any excavation in the former floodplain of Steel Creek would be monitored for radioactive species; contaminated spoil would be disposed of in a suitable manner. During construction, the location and number of access roads would be minimized to reduce environmental impacts. 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 wetlands upstream of the dam, and

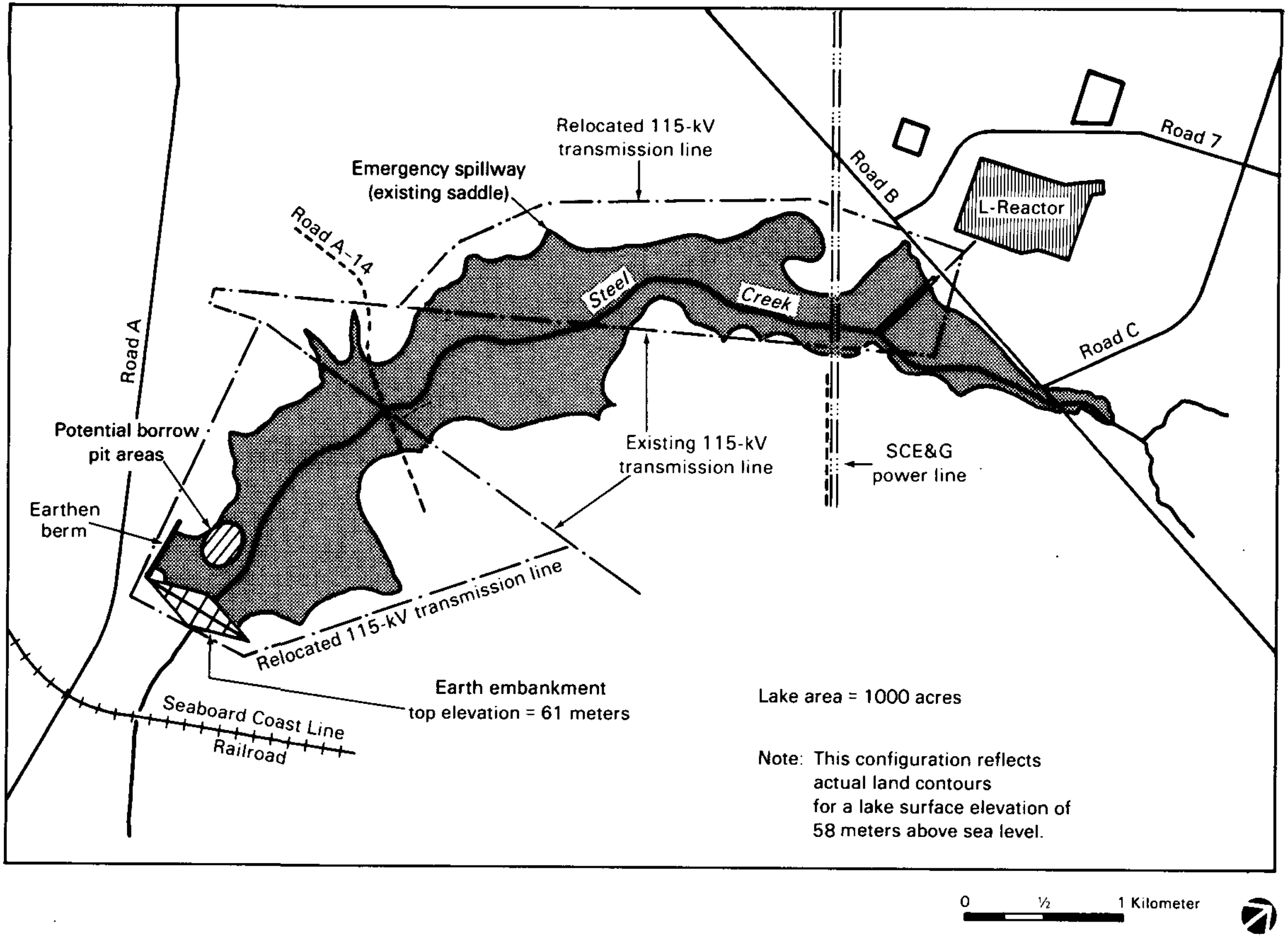


Figure 4-25. Conceptual design for 1000-acre lake on Steel Creek.

covered with subsurface spoil to prevent erosion during the construction period. This relocation would have no effect on net cesium transport estimates. All other material would be removed and used for backfill in the borrow areas.

Capital costs for the 1000-acre lake would be approximately $25 million. Operating and maintenance costs would be about $3.4 million. The present worth of this alternative would be $56 million and the annualized cost would be $6.6 million (Du Pont, 1983d). An estimated 550 workers would be required for the construction of the lake.

Approximately 11 cubic meters per second would be withdrawn from the Savannah River and used as the secondary cooling-water supply. Production efficiency would be 100 percent. However, reactor operation would be limited in the summer by the ambient temperature of the Savannah River.

Table 4-39 lists the estimated downstream temperatures in Steel Creek for the summer, spring, and winter without reduction in power (Du Pont, 1983d). These temperatures could be lowered by a reduction in reactor power, as discussed in Section 4.5 and Appendix L. The 1000-acre lake without power reductions would probably be uninhabitable to aquatic and semiaquatic biota. A depauperate biological community could exist in the lower reaches of the impoundment near the embankment. Projected water temperatures in the summer (5-day worst-case) at the Steel Creek delta, the mid-swamp, and the mouth of Steel Creek would be within 2°C of ambient. In the spring, water temperatures at Steel Creek delta would be 3°C above ambient. Water temperatures would be near ambient at the mouth of Steel Creek. These conditions do not pose any adverse impacts to aquatic and semiaquatic biota. In the winter, however, projected temperatures at Road A and points downstream would be 7° to 9°C above ambient. These warmer conditions could concentrate fish at the mouth of Steel Creek, and also cause the phenomenon of cold shock. This alternative would not adversely impact access and spawning of riverine and anadromous fishes in the Savannah River swamp below the Steel Creek delta.

Table 4-39. Temperatures (°C) downstream in Steel Creek with a 1000-acre lake

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	34	32	26	17
Road A	34	32	26	17
Swamp at delta	34	31	25	15
Mid-swamp	31	29	22	13
Month of creek at river	31	28	22	13

[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.

[c]Temperature of water leaving lake.

The habitat impacted by the 1000-acre lake alternative would include between 520 and 680 acres of wetlands in the Steel Creek corridor. The lake would also inundate 775 acres of uplands. An additional 100 acres of uplands would be impacted due to the relocation of electric and cable rights-of-way. The flow rate would adversely impact between 215 and 335 acres of wetlands in the Steel Creek delta and swamp that provide foraging habitat for the endangered wood stork and the endangered American alligator. These wetlands also represent important feeding and roosting habitat for as many as 1200 mallard and 400 wood duck. It could also prevent access by riverine and anadromous fish in summer to about 2280 acres of wetlands along Steel Creek above L-Reactor and along Meyers Branch. These wetlands are classified as Resource Category 2 by the U.S. Fish and Wildlife Service. This resource category and its 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).

Because this alternative would require approximately 11 cubic meters per second of Savannah River water, the impacts of impingement and entrainment would be the same as those for direct discharge--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.

Conservatively, the transport of radiocesium down Steel Creek from this alternative would be no more than 4.4 ± 2.2 curies the first year of operation (see Section L.4.1.2.2). Liquid releases of tritium from L-Reactor to the Savannah River would be reduced to about 7880 curies per year.

Four historic sites and one prehistoric site in the Steel Creek terrace and floodplain system have been determined to be eligible for inclusion in the National Register of Historic Places. No direct impacts are expected to the prehistoric site or to three of the historic sites because they would be below the embankment and outside the area affected by high-water flow conditions. One historic site area would be inundated when the lake was filled. In March 1984, an intensive survey of the proposed excavation areas (embankment and borrow pit areas) was made (Brooks, 1984). This survey identified seven sites described as of ephemeral quality and not eligible for nomination to the National Register. Archeological surveying and testing are presently being conducted in the proposed lake area by the University of South Carolina Institute of Archeology and Anthropology. It is anticipated that several sites associated with the Ashley Plantation will be affected. The schedule for completion of the requirements under the National Historic Preservation Act, including data recovery, is consistent with the construction schedule for the embankment, and all mitigation will be completed prior to restart (Hanson, 1984). The study results, determination eligibility of potential sites, and the development of a mitigation plan are being coordinated with the SHPO and ACHP.

Erosion and transport of sediment are expected to be slightly reduced in relation to direct discharge. A delta growth of about 1 to 2 acres per year is anticipated.

No appreciable change is expected in the chemical characteristics of the effluent as the result of its passing through the lake, except about 6 percent of the suspended solids would be removed from the river water by the 186-Basin and the impoundments. The ground-water level would be altered in the vicinity of the lake.

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, (6) the preparation of a biological assessment for endangered species, and (7) consultation with the SHPO for archeological resources.

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 (i.e., loss of 730 to 1000 acres of wetlands, etc.). Any mitigative effects resulting from the 1000-acre-lake alternative would not begin until the end of the construction period.

4.4.2.2.10 Penstock diversion to Pen Branch/lake-canal diversion to Pen Branch

Heated secondary coolant leaving L-Reactor could be diverted to Pen Branch, which presently carries heated effluent from K-Reactor back to the Savannah River. Because of physical location, the input to Pen Branch from L-Reactor would occur a few kilometers upstream of the point at which Indian Grave Branch, which receives K-Reactor discharges, joins Pen Branch.

Two possible methods of water diversion to Pen Branch have been evaluated. They are (1) by penstock and canal (Figure 4-26) and (2) by lake and canal (Figure 4-27).

Under the first option, cooling effluent from L-Reactor would be diverted through an underground pipe that would begin at the 904-L sump, which is where secondary cooling water from L-Reactor accumulates after passing through the reactor heat exchangers. The pipe would convey the flow to the northwest, about 1200 meters to the north side of SRP Road 7, where it would discharge into an open canal. The water would flow through the canal about 1000 meters to Pen Branch. No pumping would be required in either the pipe or the canal. Structural improvements to bridges crossing Pen Branch might be required because of increased flows.

The estimated minimum time required to design and construct this alternative is 38 months (Du Pont, 1983d). All construction would take place away from Steel Creek. Therefore, L-Reactor shutdown would be required for approximately 1 to 2 months for the installation of a pipe connection and valves.

For the penstock-and-canal diversion to Pen Branch, the estimated capital cost would be $7 million. The annual operating cost would be $3.4 million and the present worth would be $36 million. The annualized cost would be $4.2 million. An estimated 120 construction personnel would be required.

Water requirements for the penstock-and-canal diversion to Pen Branch would be 11 cubic meters per second. Production efficiencies would be 100 percent. During summer periods of high river temperatures, reactor operating power would be reduced, though the same flow rate would be maintained.

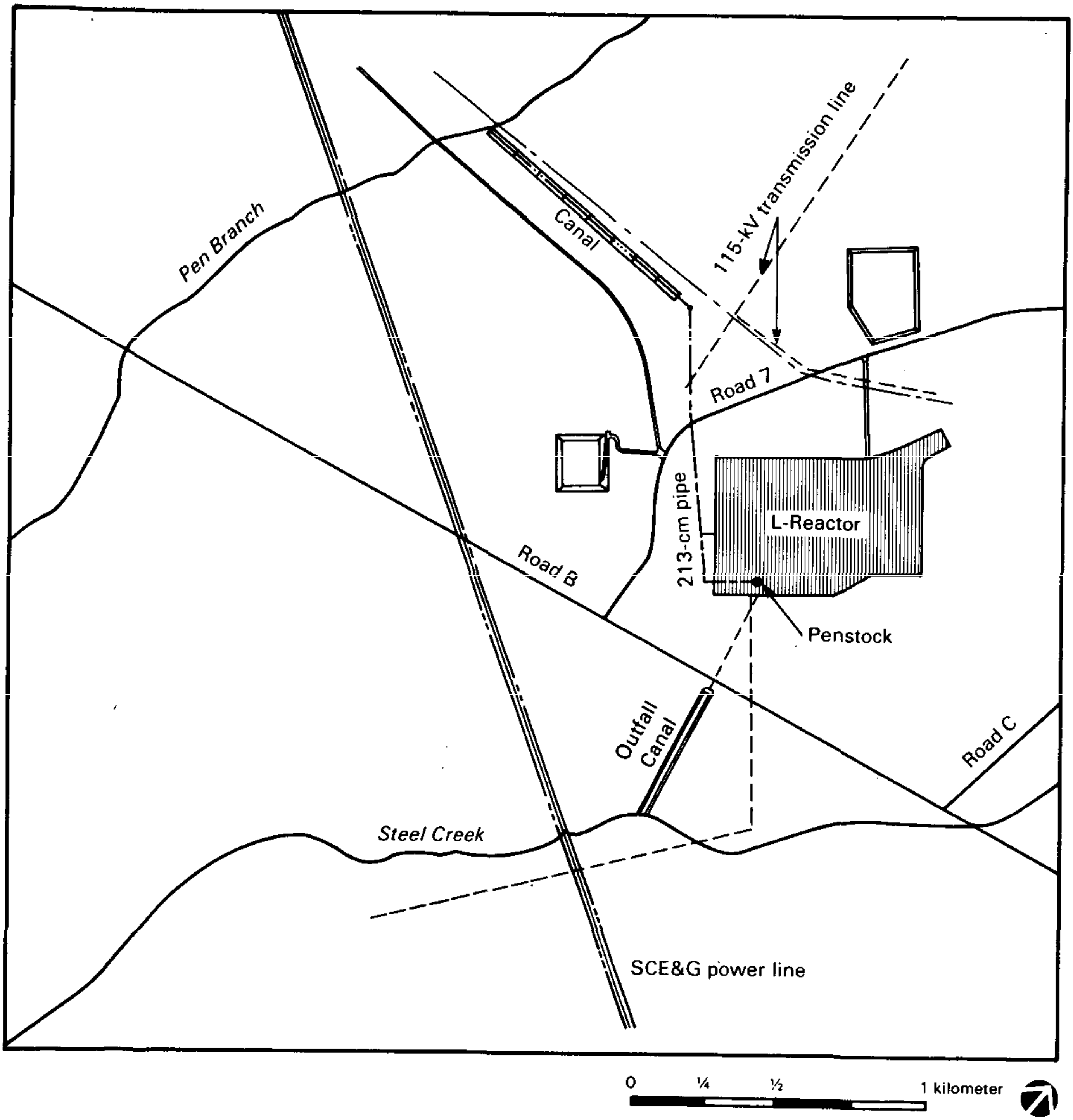


Figure 4-26. Discharge of cooling water to Pen Branch by penstock and canal.

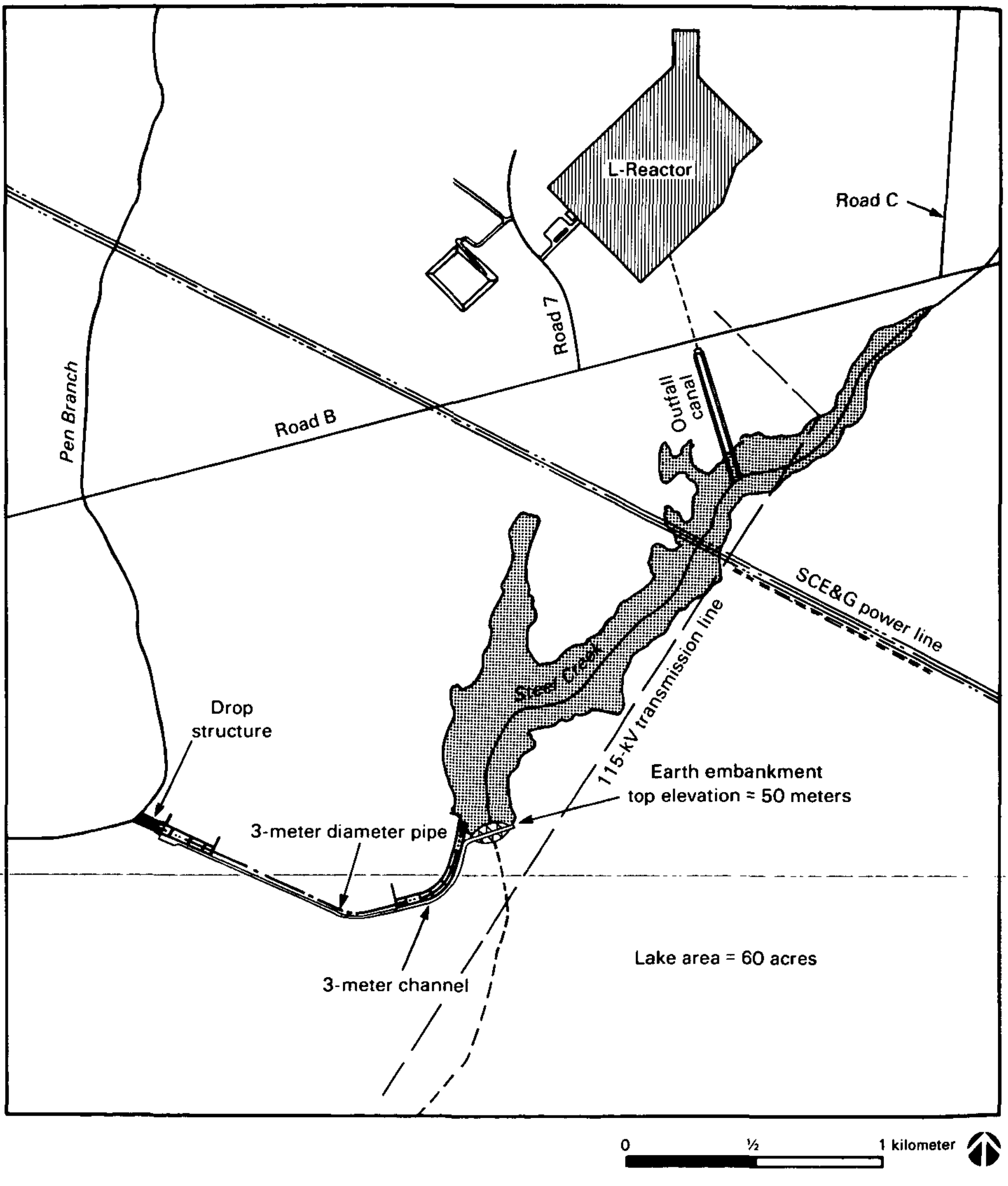


Figure 4-27. Diversion of cooling water to Pen Branch by lake and canal.

Although Steel Creek temperatures would not be increased above ambient, Pen Branch would receive about 11 cubic meters per second of water at 73°C, which exceeds the State limit of 32.2°C. The reported temperature (73°C) is for extreme summer meteorological conditions and reflects reduced reactor operating power due to elevated Savannah River temperatures. A previously unaffected 5-kilometer portion of Pen Branch would experience increased temperatures well above ambient.

The second diversion option would require an earthen embankment in Steel Creek about 1500 meters downstream from the L-Reactor effluent canal discharge. The embankment would require 17,000 cubic meters of material. Truck access roads for embankment construction would be routed to minimize environmental impacts. The embankment would form a small (60-acre) lake (Figure 4-27) to provide additional cooling. A canal and a pipe with a combined length of about 1400 meters would divert the flow from the lake to Pen Branch. Just north of Road A, the diversion from Steel Creek would join Pen Branch, which carries the effluent stream discharged from K-Reactor. No pumping would be required.

A diversion of L-Reactor effluent would cause extensive additional impacts to the Pen Branch system. The penstock-and-canal alternative would impact approximately 5 kilometers of the stream, or 55 acres of wetland that have not been impacted by earlier reactor operations. In addition, about 210 acres of the Pen Branch delta and 960 acres of the Savannah River swamp would be affected. 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). Construction of the canal would affect 10 acres of upland habitat. No wetlands (i.e., Steel Creek above L-Reactor, Meyers Branch, or Boggy Gut Creek) would be isolated by this alternative.

With a lake and canal, a discharge structure could be constructed away from the existing stream to carry reactor effluent. The diversion pipe, canal, and drop structure could be constructed and most clearing completed during this time. The estimated time required to design and construct this alternative would be 33 months.

For the lake-and-canal diversion to Pen Branch, the estimated capital cost would be $4 million. The annual operating cost would be $3.4 million, and the present worth would be $33 million. Annualized costs would be $3.9 million. An estimated 315 construction personnel would be required.

Water use from the Savannah River for the lake-and-canal diversion would be 11 cubic meters per second. The production efficiency would be 100 percent.

Thermal impacts are not expected in Steel Creek below the 60-acre lake and embankment. The lake-and-canal alternative would cause approximately 4 kilometers of unimpacted stream and floodplain along Pen Branch to receive heated effluent at about 73°C during extreme summer meteorological conditions. A total of about 1280 acres of wetlands would be impacted by the lake-and-canal alternative, including (1) Pen Branch (50 acres), (2) Steel Creek (60 acres), (3) Pen Branch delta (210 acres), and (4) the Savannah River swamp (960 acres). These wetlands are also classified as Resource Category 2 by the FWS (USDOI, 1981).

About 10 acres of uplands would be affected by the construction of the canal. This alternative would isolate about 100 acres of wetlands above the embankment. The temperature at the Pen Branch entry to the swamp would be about 58°C and the temperature at the mouth of Steel Creek would be 30°C in summer. The lake-and-canal diversion to Pen Branch would result in discharge water temperatures well above the 32.2°C State discharge limit.

A reactor shutdown of about 1 month would allow the diversion of stream flows through the discharge structure and the clearing of land adjacent to the stream. The dam would be constructed and the discharge stopped to fill the lake and divert flows to Pen Branch.

Any alternative involving a diversion to Pen Branch would result in average water temperatures at the mouth of Steel Creek of 29°C in summer, 23°C in spring, and 18°C in winter without power reduction. This would be about 2°C above ambient in summer, and spring, and 6°C above ambient in winter.

The penstock-and-canal alternative would not have a direct impact on aquatic habitat in Steel Creek upstream from the swamp. However, the lake-and-canal alternative, in addition to diverting L-Reactor effluent to Pen Branch, would convert the upper reach of Steel Creek into a tributary of Pen Branch, which is much less productive biologically due to long-term thermal impacts from the operation of K-Reactor. The thermal effluent discharging into this modified stream would eliminate any access to the upper reach of Steel Creek during the operation of either K- or L-Reactor. Aquatic organisms in the upper reach that survive these modified conditions would become isolated unless neither reactor were operational.

Either alternative would result in a loss of habitat in the lower reaches of Pen Branch due to increased flows of heated water. This would occur primarily in backwater areas that have not been impacted directly by the main thermal stream.

The occurrence of resident alligators above the Pen Branch delta is unlikely (Murphy, 1981), although the 7800-acre swamp bordering the Savannah River might support a small population. The impact of this option on endangered and threatened species is considered to be insignificant.

The impacts of impingement and entrainment would be the same as those for direct discharge--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.

Radiocesium transport would consist of about 0.25 curie per year from Steel Creek plus a component from Pen Branch. About 0.15 curie would be remobilized and transported in Pen Branch to Steel Creek during the first year of resumed L-Reactor operation. The total transport from Steel Creek is estimated to be 0.4 curie per year. Liquid releases of tritium from L-Reactor would be about 9600 curies per year.

An estimated seven or eight archeological sites are assumed to be impacted by this alternative as the result of the construction of the diversion canal and the increased flow down Pen Branch. A mitigation plan would be developed and implemented prior to restart similar to that described for direct discharge.

Additional impacts to existing aquatic habitat in Pen Branch would result from erosion and sedimentation effects. The stream flow would increase to about ten times normal in the upper reach between the points of entry into the stream of the L-Reactor and K-Reactor discharges. The increased erosion, downcutting, widening, and straightening of the stream would result in the loss of existing aquatic habitat. In addition, erosion would be expected in the lower reach where, with either option, the stream flow would be twice the present flow. Changes in sedimentation due to either alternative would result in the Pen Branch delta growth rate reaching about 18 acres per year.

The chemical characteristics of the L-Reactor liquid effluent are estimated to be similar to those of Steel Creek and the Savannah River, and not unlike those presently being discharged by K-Reactor to Pen Branch. No appreciable change is expected in the characteristics of the effluent as it flows through the lake-and-canal system, except about 4 percent of the suspended sediment load would be lost. About 100 metric tons of silt and clay would be deposited in the lake each year.

Additional impacts would be caused by changes in existing stream flow patterns. The diversion of flows from upper Steel Creek would reduce flows in the lower reaches of this stream, thereby modifying or eliminating some existing aquatic habitat, particularly in backwater areas.

These alternatives 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 either of the Pen Branch diversion alternatives is implemented before the restart of L-Reactor, the environmental impacts would be as described above. If it is implemented after direct discharge begins, the environmental impacts would be the same as those described in Section 4.2.2.2.1 (i.e., loss of 730 to 1000 acres of wetlands, etc.). The mitigative effects resulting from the penstock/canal diversion alternative would include no impacts to wetlands of the Steel Creek corridor (i.e., 420 to 580 acres); the lake/canal alternative would cause no impacts to wetlands below the dam. Between 1225 and 1280 acres of wetlands associated with Pen Branch and the Savannah River swamp, however, would be impacted. Mitigative effects would not begin until the end of the 18-month construction period.

4.4.2.3 Cooling towers

The following sections describe three types of cooling towers--once-through, recirculation, and partial-recirculation. Figure 4-28 shows the estimated discharge-water temperatures for cooling towers with 2.8°C, 5.6°C, and 8.4°C approach temperature designs, which are based on recorded average wet-bulb temperatures at the SRP. The approach temperature is the number of degrees over the ambient wet-bulb temperature to which the reactor secondary cooling water can be reduced by the cooling tower. The curves on Figure 4-28 show the resultant cooled/cooling-water temperatures for the three approach temperatures. If the 1-percent worst-case meteorological condition (the 1-percent design wet-bulb temperature is 26.7°C) had been used to develop the curves, the resulting

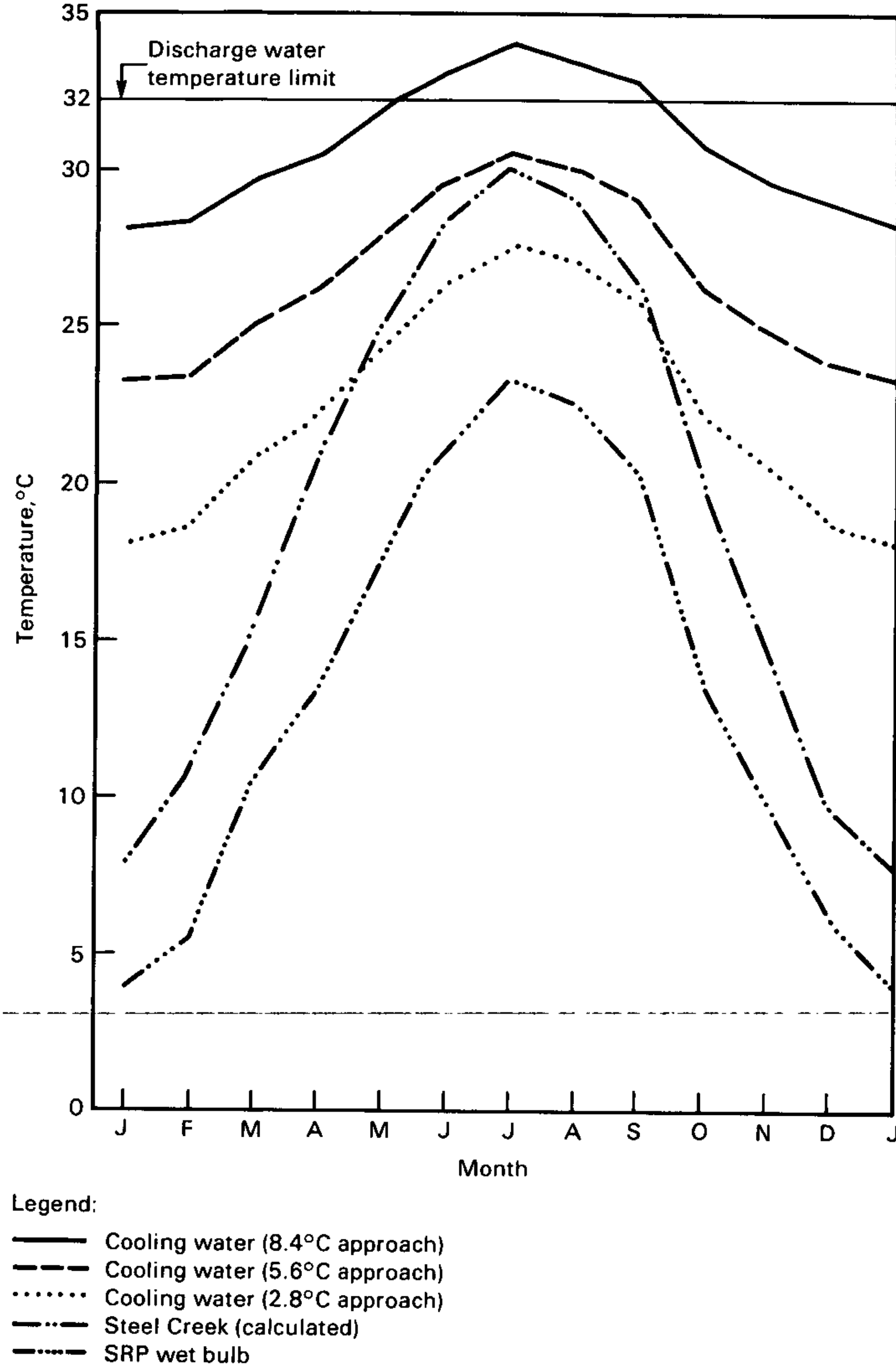


Figure 4-28. Average monthly wet-bulb temperature responses at SRP and cooling-tower water discharge temperatures.

cooling-tower discharge-water temperatures would have been higher by about 3.5°C than those shown. With the 1-percent design wet-bulb temperature, both the 5.6°C and the 8.4°C approach temperature towers would exceed the State of South Carolina water-discharge temperature limit of 32.2°C part of the time.

For commercial power plants, recirculating cooling towers have been constructed as fast as 18 months from award of contract. The temperature of the L-Reactor cooling water would be higher than that of commercial power plants, which would require special consideration in the engineering design of the cooling towers and pumps. Although the time period required for the design, procurement, construction, and testing of recirculating cooling towers and pumps for L-Reactor could be expedited, DOE does not believe that the 27-month schedule could be greatly shortened without sacrificing proper consideration of the operability and reliability of the recirculating cooling tower system.

4.4.2.3.1 Cooling towers--once through

4.4.2.3.1.1 Once-through--discharge to Steel Creek

Cooling towers could be added to L-Area that treat the heated effluent and discharge it directly to Steel Creek. Such towers could be constructed adjacent to the existing reactor discharge canal, as shown in Figure 4-29. A diversion valve box would be built onto the 904-L sump to route the reactor discharge water through 750 meters of new 2.5-meter diameter pipe to the new cooling towers. The tower location would be a relatively flat area just north of Steel Creek along the west side of the discharge canal. This location is about 21 meters lower than the L-Reactor area and 12 meters lower than the outlet of the 904-L sump. The discharge from the cooling towers would run through short pipes to the existing discharge canal and then into Steel Creek at the original discharge point.

The differences in elevation between the diversion valve box and the cooling-tower sprays would be sufficient to eliminate the need for pumps. This would result in a capital cost and time savings, an energy savings, and less dependence on the operation of mechanical equipment.

This alternative could meet the 32.2°C temperature criterion for water discharged to State waters. River water would be passed through the reactor heat exchangers and cooling towers and diverted to the outfall. Water withdrawal from the river would be about 11 cubic meters per second, the same quantity as that for the direct discharge case.

About 27 months would be required to design and construct this alternative. On an expedited schedule this alternative could be constructed in a little more than 1 year. If L-Reactor operation starts before the alternative is implemented, a shutdown of about 1 month would be required while the new cooling system is connected into existing facilities.

The capital cost for the 2.8°C approach tower would be approximately $55 million; the cost of the 5.6°C approach tower would be $50 million. Annual operating costs for the 2.8°C and 5.6°C approach tower designs would be $5.5 million and $5.4 million, respectively. The present worth of this alternative would be $102 million for the 2.8°C approach tower and $96 million for the 5.6°C approach tower. The annualized costs would be $12 million and $11.3 million,

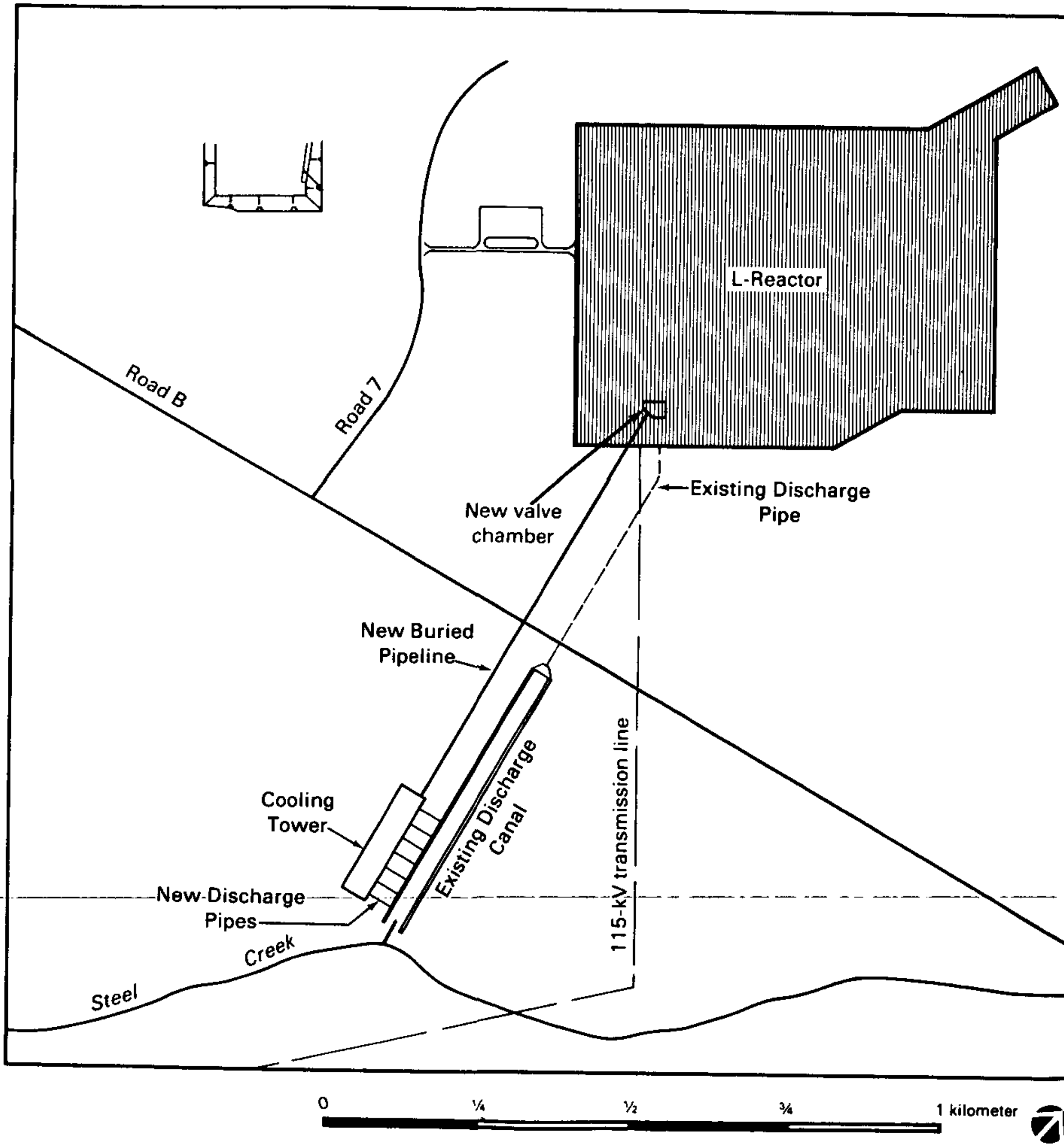


Figure 4-29. Conceptual layout of once-through cooling tower system.

respectively. An estimated 135 construction personnel would be required for either tower.

The production efficiency would be the same as that for the direct discharge alternative, 100 percent. The reactor would have a volume flow rate of about 11 cubic meters per second from the Savannah River. This alternative would discharge cooling effluent into Steel Creek at a flow of about 10.2 cubic meters per second.

The temperature of the effluent would be lower than that from the direct discharge alternative due to the cooling by the towers, and would vary according to the cooling tower approach temperature (i.e., 2.8° or 5.6°C).

With a 2.8°C approach temperature tower, the average effluent temperature entering Steel Creek would range from about 18°C in January to 28°C in July (Du Pont, 1983d). A preliminary analysis of SRP wet bulb data (Du Pont, 1983f) indicates the 32.2°C temperature maximum at the outfall would be exceeded once every 4.5 years. If the 5.6°C approach tower were used in this once-through system, the 32.2°C maximum at the outfall would be exceeded about five times a year. Downstream temperatures are listed in Tables 4-40 and 4-41, and shown (for the 2.8°C approach) in Figure 4-30. These temperatures assume no power reduction. Average ambient Steel Creek temperatures measured over a 30-year period at Road A are about 29°C in summer, 22°C in spring, and 8°C in winter.

Table 4-40. Temperatures (°C) downstream in Steel Creek with once-through cooling towers (2.8°C approach)

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	28	27	23	18
Road A	29	28	23	17
Swamp at delta	30	28	23	15
Mid-swamp	29	27	21	13
Mouth of creek at river	29	27	21	13

[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 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.

Once-through cooling towers (either the 2.8°C or the 5.6°C approach temperature) with a discharge to Steel Creek would provide normal compliance with the 32.2°C maximum discharge temperature during average meteorological conditions.

The towers would substantially mitigate the thermal effects associated with direct discharge; the environmental impacts of this alternative would be

Table 4-41. Temperatures (°C) downstream in Steel Creek with once-through cooling towers (5.6°C approach)

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	31	30	28	24
Road A	32	30	26	21
Swamp at delta	32	30	26	19
Mid-swamp	30	28	23	15
Mouth of creek at river	30	28	22	14

[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 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.

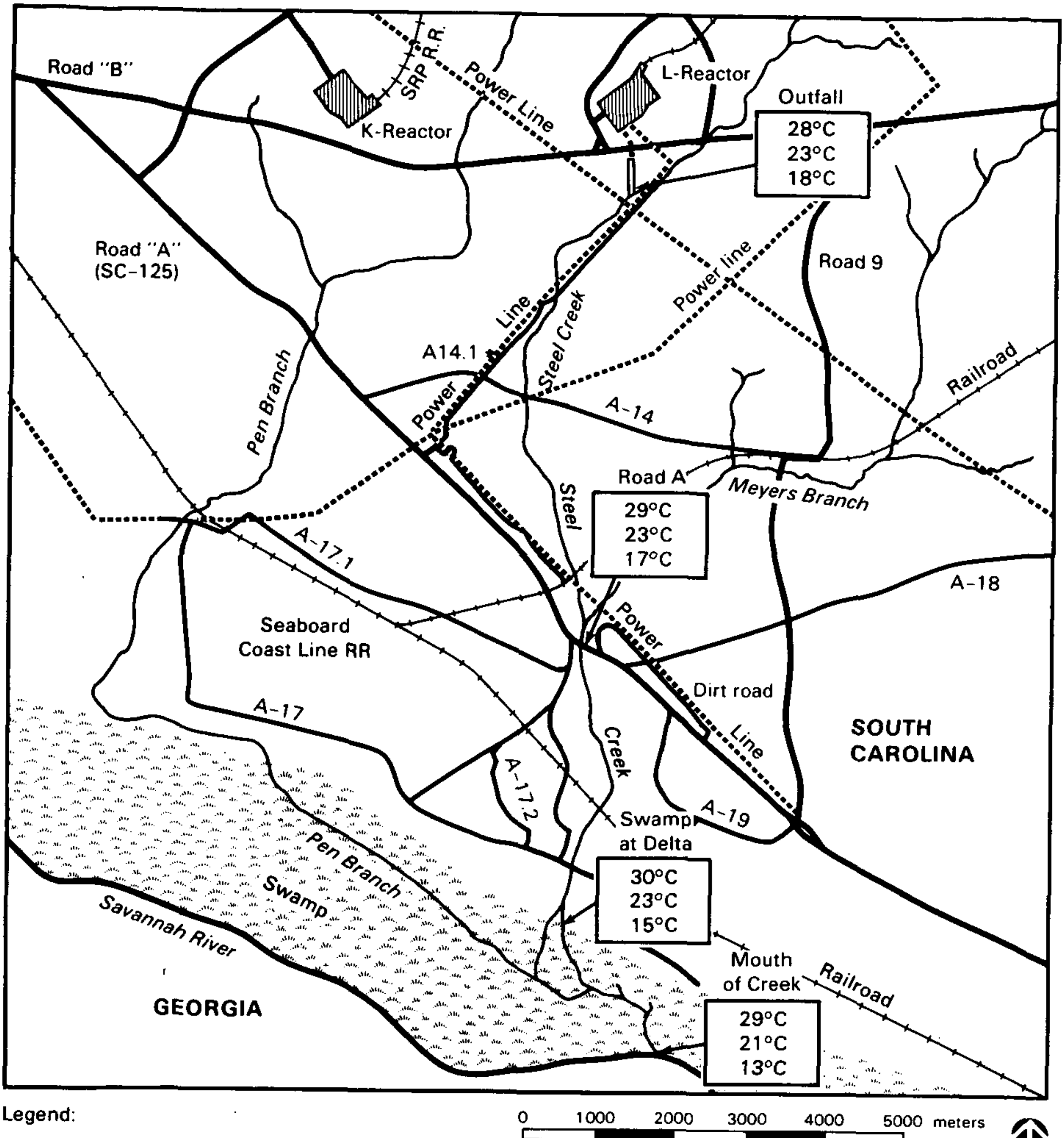
somewhat less than those for direct discharge because of flow rate; they are summarized as follows:

- The high flow rate would eliminate between 420 and 580 acres of wetlands in the Steel Creek corridor. In addition, about 30 acres of uplands would be impacted by the construction of the cooling towers. Because the effluent would not have markedly elevated temperatures, the high flow rate would impact between 70 and 80 percent of the area predicted for direct discharge. Thus, between 215 and 335 acres of wetlands would be eliminated in the delta and swamp. The total amount of wetlands that would be impacted by this alternative is between 635 and 915 acres. 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).

- The spring water temperatures in mid-swamp would be within 4°C of ambient for the 5.6°C approach, and within 2°C of ambient for the 2.8°C approach. Thus, approximately 2500 acres of wetlands and aquatic habitat would be available to spawning riverine and anadromous fishes and other aquatic and semiaquatic biota.

- 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.

- The remobilization and transport of 3.2 curies (2.8°C approach) or 3.3 curies (5.6°C approach) of radiocesium (first year). Liquid releases of tritium to the Savannah River would be about 8850 curies per year. These values would be about the same for both the 2.8°C and 5.6°C approach.



Legend:

Swamp

SUMMER
SPRING
WINTER

Seasonal creek temperatures for this alternative

Figure 4-30. Steel Creek seasonal temperatures for cooling towers (2.8°C approach) once through.

- Fogging conditions (i.e., visibility is reduced to less than 1000 meters) would occur about 5 hours per year within 1.0 kilometer of the towers. Icing to an average thickness of 1.0 millimeter on horizontal surfaces within 0.5 kilometer of the towers would occur 55 hours per year. Salt drift deposition within 1 kilometer is estimated to be 0.37 kilogram per acre per month.

- 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 and filling.

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.

If this alternative is implemented before direct discharge occurs, environmental impacts would be as described above (i.e., loss of about 635 to 915 acres of wetlands due to flow effects). 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.

4.4.2.3.1.2 Once through--canal to swamp

Under this alternative, 2.8°C, 5.6°C, or 8.4°C approach cooling towers would be constructed on the south side of Road B, approximately 1000 meters southwest of L-Reactor, as shown in Figure 4-29. The cooling-water effluent would be pumped to the towers through a buried pipeline from a new sump constructed over the existing cooling-water discharge pipe. The sump, approximately 9 meters square and 11 meters deep with pumps, would be built over the existing outfall pipe.

As shown in Figure 4-31, the discharge from the cooling tower would flow into a new excavated and lined canal, which would be constructed along or near the top of the west bank of Steel Creek. The canal would be routed adjacent to Steel Creek above the floodplain and extend for approximately 10.4 kilometers before discharging at the delta. This canal, which would be similar to those constructed with Par Pond, would cross under two railroad tracks, roads A-14, A, A-17.1, and A-17.2, and several 115-kilovolt and super control and relay cable lines. The canal would have to feed into a pile-supported aerial pipeline or viaduct where it crosses a low area about 1200 meters below Road A. This pipe or viaduct would discharge back into a canal and continue to the edge of the swamp. A discharge structure would be constructed in the Savannah River swamp west of the Steel Creek delta with diffusers to control erosion and to mix the cooling-water discharge.

About 27 months would be required to design, construct, and permit this alternative. If L-Reactor is started operating before this alternative is constructed, a shutdown of about 1 month would be required while all new facilities

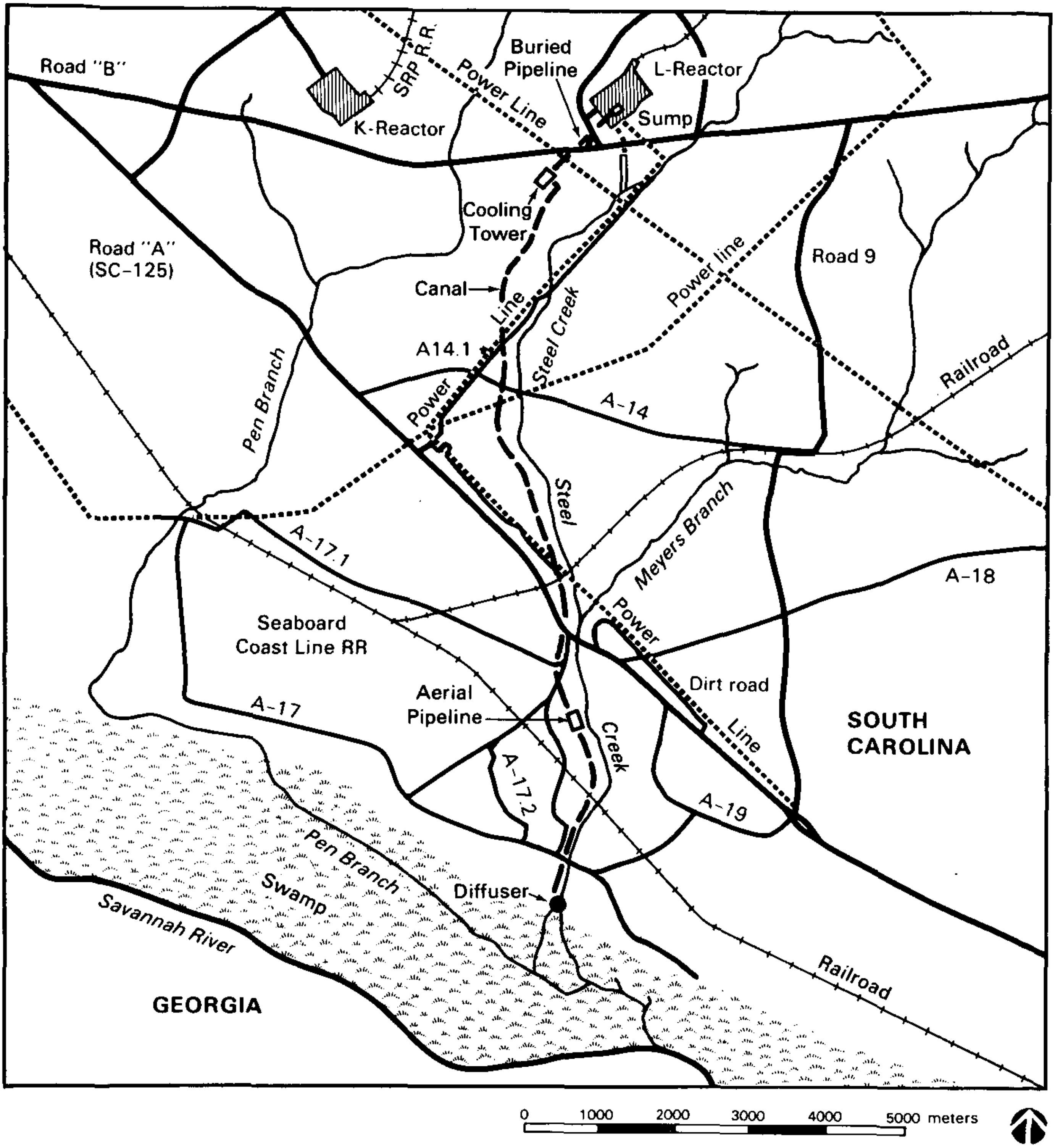


Figure 4-31. Conceptual layout of cooling tower with canal to swamp.

are completed to cut the existing pipe and install a valve to retain water in the sump.

Dredge material from the canal and the area in the swamp around the diffuser will be handled and monitored to meet applicable regulatory requirements. Thus, no significant changes in water quality, suspended particulates, or turbidity are expected to occur in the swamp or Savannah River due to dredge and fill activities. Access roads to construction areas would be selected to minimize impacts.

Capital costs for the pumping station, cooling towers, canal/pipeline, and other related items would be an estimated $68 million to $89 million, depending on cooling-tower efficiency. Annual operating costs would be an estimated $5.2 million to $5.6 million. The present worth of this alternative would be from about $112 million to $136 million, and the annualized cost would be $13.2 million to $16 million. An estimated 300 construction personnel would be required.

Production efficiency is estimated to be 100 percent of that for the direct discharge case. About 11 cubic meters per second of water would be required from the Savannah River. This alternative would discharge cooling-water effluent directly at the Steel Creek delta at a rate of flow of about 10.1 cubic meters per second.

These towers could be 2.8°C, 5.6°C, or 8.4°C approach temperature towers designed for about a 27°C wet bulb; however, only the cooling-water temperature from the 2.8°C tower would be near ambient when the water is discharged to the delta. Tables 4-42, 4-43, and 4-44 list seasonal temperatures for these three approach temperatures. Ambient temperatures (30-year average) in Steel Creek measured at Road A are 29°C in summer, 22°C in spring, and 8°C in winter.

Table 4-42. Temperatures (°C) downstream in Steel Creek with once-through cooling towers (2.8°C approach)--canal-to-swamp

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	28	27	23	18
Swamp at delta	28	27	23	18
Mid-swamp	29	27	21	13
Mouth of creek at river	29	27	21	13

[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 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 swamp.

Table 4-43. Temperatures (°C) downstream in Steel Creek with once-through cooling towers (5.6°C approach)--canal to swamp

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	31	30	28	24
Swamp at delta	31	30	28	24
Mid-swamp	30	26	23	15
Mouth of creek at river	30	25	22	14

[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 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 swamp.

Table 4-44. Temperatures (°C) downstream in Steel Creek with once-through cooling towers (8.4°C approach)--canal to swamp

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	34	34	31	28
Swamp at delta	34	32	28	21
Mid-swamp	31	29	24	17
Mouth of creek at river	31	29	23	16

[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 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 swamp.

The discharge at the swamp from the 2.8°C approach cooling tower would exceed State discharge temperature limits only infrequently. The 5.6°C and 8.4°C towers would be in compliance under average summer conditions. Under some conditions, power reduction would be necessary.

This alternative (all approach temperatures) would avoid Steel Creek to its delta, allowing approximately 420 to 580 acres of wetland to continue successional recovery in the Steel Creek corridor, including habitat for the endangered American alligator. About 30 acres of uplands would be impacted by construction of the towers. The effluent would reach the swamp via the canal parallel to Steel Creek and would enter the swamp through a diffuser at temperatures between 28° and 31°C during the summer; this would allow riverine and anadromous fish and other aquatic biota to have access to the swamp during the spawning season and partial access during the summer for the 2.8°C and 5.6°C approaches. However, the impacts on the swamp (i.e., loss of 215 to 335 acres of wetlands) from the 10.1-cubic-meter-per-second flow would be almost the same as those described for direct discharge. 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). The canal would impact about 120 acres of upland pine forest and open fields, and require the disposal of approximately 850,000 cubic meters of spoil. Dredged material would be monitored and handled to meet applicable regulatory requirements.

This alternative would have no impact on endangered and threatened species that inhabit Steel Creek above its delta because the creek corridor would not receive thermal effluent. The discharge of 10.3 cubic meters per second through a diffuser located at the Steel Creek delta could channelize portions of the existing wetlands. However, the discharge temperatures (28°C and 31°C for 2.8°C and 5.6°C approaches in summer, respectively) would not have adverse impacts on the American alligator. The greatest potential impact would result from elevated water levels, which could eliminate foraging habitat for the endangered wood stork, and foraging and roosting habitat for migratory waterfowl. The shortnose sturgeon would be unaffected by this alternative.

The impacts of impingement and entrainment would be the same as those for direct discharge--impingement of 16 fish per day (5840 fish per year) and annual entrainment of 7.7×10^6 fish eggs and 11.9×10^6 fish larvae.

Under this alternative, there would be no remobilization or transport of radionuclides from the substrate of the Steel Creek corridor. Approximately 1.4 curies of radiocesium from the delta and swamp would be remobilized and discharged to the Savannah River. Liquid releases of tritium to the Savannah River would be about 8900 curies per year.

Approximately 5 hours per year of fogging would occur within 1.0 kilometer of the towers. The estimated frequency of ice accumulation on horizontal surfaces will be 55 hours per year. Drift deposition of salts is predicted to be about 0.37 kilogram per acre per month.

Several archeological sites occur near or along the canal route and could receive adverse impacts from construction activities. A mitigation plan would be developed and implemented prior to restart similar to that described under direct discharge.

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 (successional recovery of 420 to 580 acres of wetland in Steel Creek corridor and losses of 215 to 335 acres in the swamp). 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.

4.4.2.3.1.3 Once through--spray canal and canal to swamp

A variation on the previously described once-through, canal-to-swamp alternative using 2.8°C or 5.6°C approach cooling towers would be to add a spray system to the canal; this would reduce the cooling-tower discharge temperature of the water by about 3°C in the summer. The discharge would comply with State discharge criteria for the 2.8°C and 5.6°C towers. The spray canal location and configuration would be as shown in Figure 4-21.

About 27 months would be required to design and construct this alternative. A shutdown of about 1 month would be required while all new facilities are completed and connected to the cooling-water discharge of the reactor. Truck routes to construction areas would be selected to minimize environmental impacts. If a 5.6°C approach tower were used for this alternative, most of the discharge water temperature reduction that was caused by the spray canal would be lost due to the less efficient cooling tower.

Capital costs for the 2.8°C approach cooling towers, spray canal, and canal or pipeline to the Steel Creek delta would be about $98 million; annual maintenance and operating costs would be about $5.5 million. The present worth of this alternative would be $146 million, and the annualized cost would be $17.1 million (Du Pont, 1983d).

The capital cost for a 5.6°C approach cooling tower with a spray canal and canal to the swamp would be about $93 million. With annual maintenance and operating costs similar to those of the 2.8°C approach tower, the present worth would be $139 million and the annualized cost would be $16.4 million. An estimated 330 construction personnel would be required.

The production efficiency for this alternative would be the same as that for the direct discharge alternative, 100 percent. Production efficiency (reactor power) would be reduced in the summer when cooling-water temperatures from the Savannah River are elevated. This alternative would discharge cooling-water effluent into the swamp via a canal at a somewhat lower rate of flow (10.0 cubic meters per second) than direct discharge due to evaporation losses.

Downstream temperatures for this alternative are presented in Tables 4-45 and 4-46. Ambient temperatures in Steel Creek at the delta (30-year average) would be summer--33°C, spring--22°C, and winter--8°C.

Table 4-45. Temperatures (°C) downstream in Steel Creek with a once-through cooling tower (2.8°C approach)--spray canal and canal to swamp

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Swamp at delta	30	28	23	12
Mid-swamp	29	27	21	10
Mouth of creek at river	29	27	21	11

[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 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.

Table 4-46. Temperatures (°C) downstream in Steel Creek with once-through cooling towers (5.6°C approach) with a spray canal and canal to the swamp.

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Swamp at delta	32	30	24	15
Mid-swamp	30	28	22	13
Mouth of creek at river	30	28	22	13

[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 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.

This alternative would include complete avoidance of Steel Creek down to the swamp, allowing approximately 450 to 580 acres of wetland to continue successional recovery in the Steel Creek corridor, including habitat for the endangered American alligator. The effluent would reach the swamp via a canal near Steel Creek and enter the swamp through a diffuser at a temperature of 23°C in spring (2.8°C approach). This would allow access to the swamp and Steel Creek by spawning riverine and anadromous fish and other aquatic biota. However, the impacts on the swamp from the 10.0-cubic-meter-per-second flow would be somewhat less than those described for direct discharge.

Both the 2.8°C and the 5.6°C approach-temperature cooling towers would result in full-time compliance with the 32.2°C State discharge temperature limit as the cooling water enters the swamp.

The environmental impacts of this alternative would be similar to those for cooling towers with a once-through discharge via a canal to the swamp. These impacts are summarized as follows:

- About 55 acres of wetlands and 55 acres of uplands would be impacted by construction of the spray canal. No impacts to wetlands would occur within the Steel Creek corridor, but the increased flow rate would eliminate between 215 and 335 acres of wetlands in the swamp. 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).

- Approximately 120 acres of upland pine forest and open fields would be disturbed for construction of the canal; the towers would displace 30 acres of uplands. About 850,000 cubic meters of spoil would have to be removed and stored or utilized. Any dredged material would be monitored and handled to meet applicable regulatory standards.

- No impact to the American alligator and shortnose sturgeon would occur; foraging habitat of the endangered wood stork and roosting habitat for migratory waterfowl would receive adverse impacts from increased water levels.

- Approximately 16 fish per day (5480 fish per year) would be impinged, and 7.7×10^6 fish eggs and 11.9×10^6 fish larvae would be entrained annually.

- No remobilization or transport of radionuclides from the Steel Creek corridor would occur. About 1.0 curie of radiocesium would be remobilized and transported to the Savannah River by either approach. Liquid releases of tritium to the river would be about 8640 curies per year.

- Approximately 5 hours of fogging and 55 hours of horizontal icing would occur, and 0.37 kilogram per acre per month of salt drift would be deposited.

- Several archeological sites near or along the canal route could receive adverse impacts from construction activities. A mitigation plan would be developed and implemented prior to restart similar to that described for direct discharge.

- The bottom contour of the swamp near the diffuser would be modified.

- No impacts to water quality or increased suspended particulates and turbidity would result from the dredging of the canal. Short-term impacts could be associated with the installation of the diffuser.

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 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.

4.4.2.3.1.4 Once through--canal to swamp; pipe to river

Another variation of the once-through cooling-tower alternative would use the same canal to the swamp as that described previously, except it would not discharge near the Steel Creek delta. Instead, it would discharge into a pile-supported pipeline extending approximately 2500 meters across the swamp to a new discharge structure with diffusers to be constructed in the Savannah River below the mouth of Steel Creek. This alternative is shown in Figure 4-32. The effluent completely bypasses the Steel Creek corridor and swamp.

For this design, K-Reactor would still discharge through the mouth of Steel Creek, but L-Reactor would discharge downstream into the K-Reactor plume.

The canal would be parallel to the Steel Creek floodplain. It would be constructed by using material from cuts as fill material where needed. The pipeline across the swamp would be supported on pilings to prevent the pipe from acting as a water barrier when the swamp is flooded. Because a pile-driver would be used, no material would have to be dredged for the pilings. Barges would be floated in during periods of high water and tied together to form a working platform or temporary causeway. Equipment for building the pipeline would work from the barges. Vegetation adjacent to the pipeline would be removed to provide room for the barges. Some dredging and fill at the river would be needed to place the diffuser. The dredged material would be monitored and handled to meet applicable regulatory standards.

About 27 months would be required to design, construct, and permit this alternative. All construction would take place away from Steel Creek. A shutdown of about 1 month would be required while the new facilities are completed and connected to the cooling-water discharge if L-Reactor operation starts before this alternative is implemented.

Temporary, limited impact to wetlands from this alternative would result from the construction of the pipeline. This raised structure would extend from a point near the Steel Creek delta to the Savannah River, a distance of 2500 meters. Pipeline construction could have adverse impacts on the Savannah River swamp because of: (1) piles driven into the substrate to support the pipeline, (2) the use of heavy equipment affecting wetlands by compacting the substrate, and (3) increased erosion and sedimentation due to disturbances of the substrate.

Capital costs for the cooling towers, the canal to the swamp, and the pipeline over the swamp to the river would be about $103 million for the 8.4°C approach tower or $112 million for the system with the 5.6°C approach tower. Yearly maintenance and operating costs would be $5.2 million to $5.4 million and the present worth would be $140 million to $158 million. Annualized cost would be $16.5 million to $18.6 million (Du Pont, 1983d). An estimated 375 construction personnel would be required.

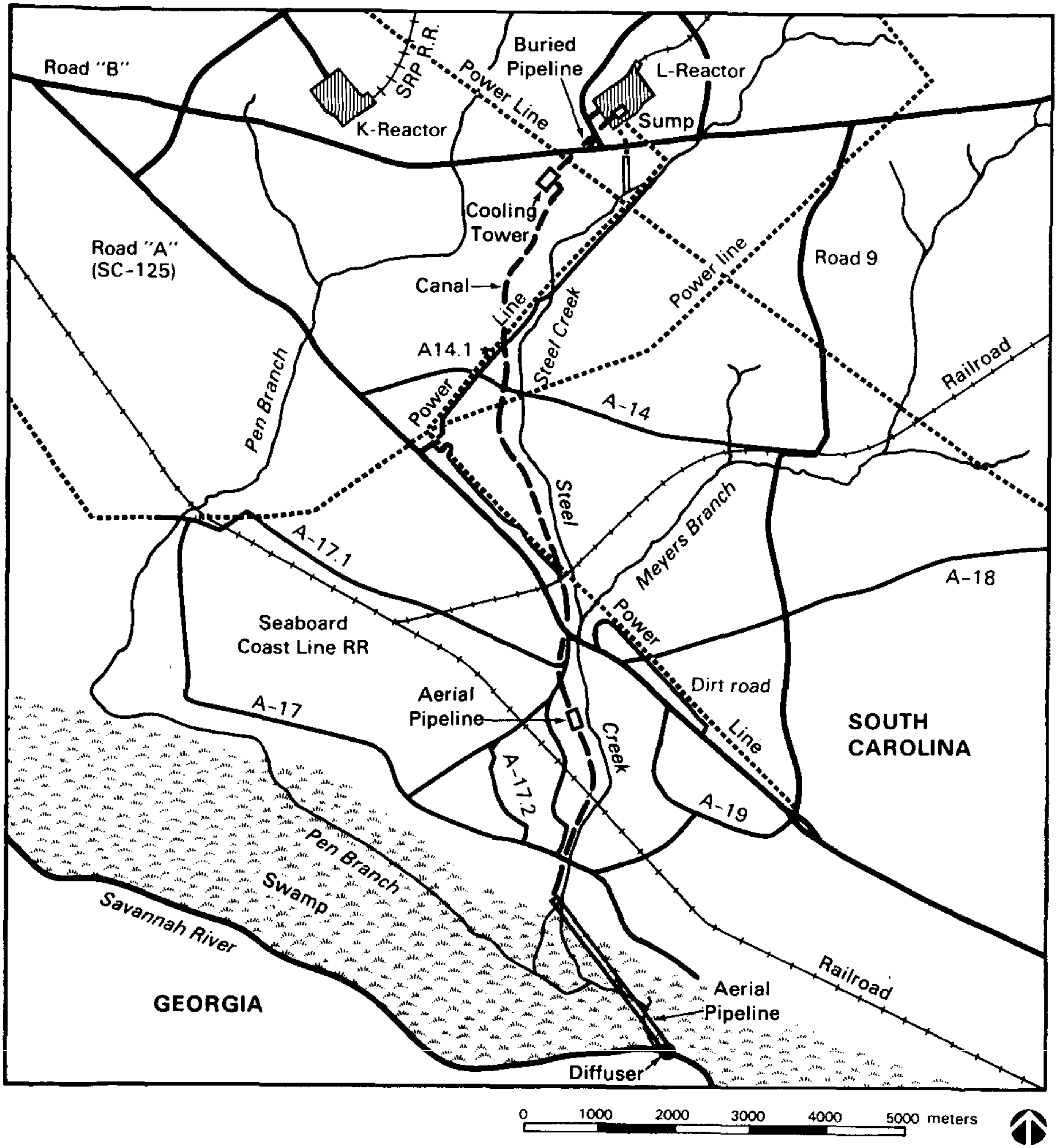


Figure 4-32. Conceptual layout of cooling tower with canal to swamp and pipeline to river.

The production efficiency for this alternative would be 100 percent, the same as that for the direct discharge alternative. Water withdrawal from the river would be the same as for direct discharge. The only environmental impact to the swamp would be due to the pipeline construction.

The water discharge flow rate to the Savannah River would be about 10.1 cubic meters per second for this alternative. No discharges would be released to Steel Creek.

Because this alternative would completely avoid Steel Creek and the swamp, approximately 730 to 1000 acres of wetland would continue to undergo successional recovery; fish would have full access to Steel Creek and the swamp. However, the access of fish to Boggy Gut Creek would be limited, especially during the spring and summer.

In summer, considering extreme meteorological conditions, this alternative would discharge effluent into the Savannah River at temperatures of 5°C and 7°C above ambient for the 5.6°C and 8.4°C approaches, respectively. In the spring, temperatures at the mouth of Steel Creek would be 5° to 7°C above ambient. Effluent temperatures in winter at this discharge point would be 19° to 21°C. These temperatures would be 7° to 9°C above ambient temperature. The 5.6°C approach alternative would comply with maximum discharge temperature criteria; the 8.4°C approach alternative would not comply.

The diffuser would be constructed to mix the effluent rapidly with the river. Based on seasonal outfall temperatures, a zone of passage would be maintained to allow movement of anadromous fish past SRP; the mouth of Steel Creek would not be blocked by temperatures high enough to exclude riverine and anadromous fish from entering and spawning in the Steel Creek swamp system (for both 5.6°C and 8.4°C approach temperatures). Discharge temperatures could attract some fish species into the thermal plume during the winter; however, insignificant impacts are expected on riverine species due to overwintering stress.

The pipeline would be constructed above the high-flood mark (about 7 to 9 meters), so it could not act as a dam and impede water flow during flooding.

Proper buffers would be installed during construction to prevent movement of suspended particulates, which could cause turbidity impacts. Discharge water quality would be the same as that described for direct discharge. No significant changes in water quality, suspended particulates, or turbidity are expected to occur in the swamp or the Savannah River.

Other environmental consequences of this alternative would be as follows:

- Construction of the canal would impact about 120 acres of upland pine forest and open fields, and would require the disposal of approximately 850,000 cubic meters of spoil material. The construction of the towers would impact 30 acres of upland pine forest.

- Construction of the pipeline would impact foraging habitat of the endangered wood stork.

- 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.

- No remobilization and transport of radionuclides in sediments of Steel Creek and the swamp would occur. About 0.25 curie of radiocesium would be released annually from Steel Creek as the result of P-Area discharges and natural flow. Liquid releases of tritium to the Savannah River would be about 8900 curies per year.

- Atmospheric discharges from the canal and cooling towers would result in approximately 5 hours of increased fogging, 55 hours of icing on horizontal surfaces, and salt drift deposition of 0.37 kilogram per acre per month.

- Several archeological sites occur near or along the canal route and could receive adverse impacts from construction activities. A mitigation plan would be developed and implemented prior to restart similar to that described for direct discharge.

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 (successional recovery of about 730 to 1000 acres of wetland). 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.

4.4.2.3.2 <u>Cooling towers--recirculation</u>

4.4.2.3.2.1 Total recirculation--blowdown to Steel Creek

Cooling towers that completely recirculate the cooling water could be added to the L-Reactor site. The towers would be designed for a 2.8°C or 8.4°C approach temperature at a 27°C wet bulb. The secondary cooling water would be discharged from the reactor heat exchanger, cooled by the cooling towers, and returned to the 186-L reservoir for recirculation. Makeup water would be required to replace evaporative and blowdown losses.

This option would require the construction of cooling towers adjacent to the reactor (Figure 4-33). A reinforced concrete sump, approximately 9 meters square and 11 meters deep with pumps, would be built over the existing outfall pipe. The sump pit could be constructed around the existing outfall pipe while reactor flows continue. Discharge pipes from the pumps would run above ground to connections with an underground pipe that would convey the heated water to the top of the cooling towers. The flow would proceed by gravity to reinforced concrete basins beneath the towers and then to the 186-L reservoir. About 27 months would be required to design and construct this option (Du Pont, 1983f).

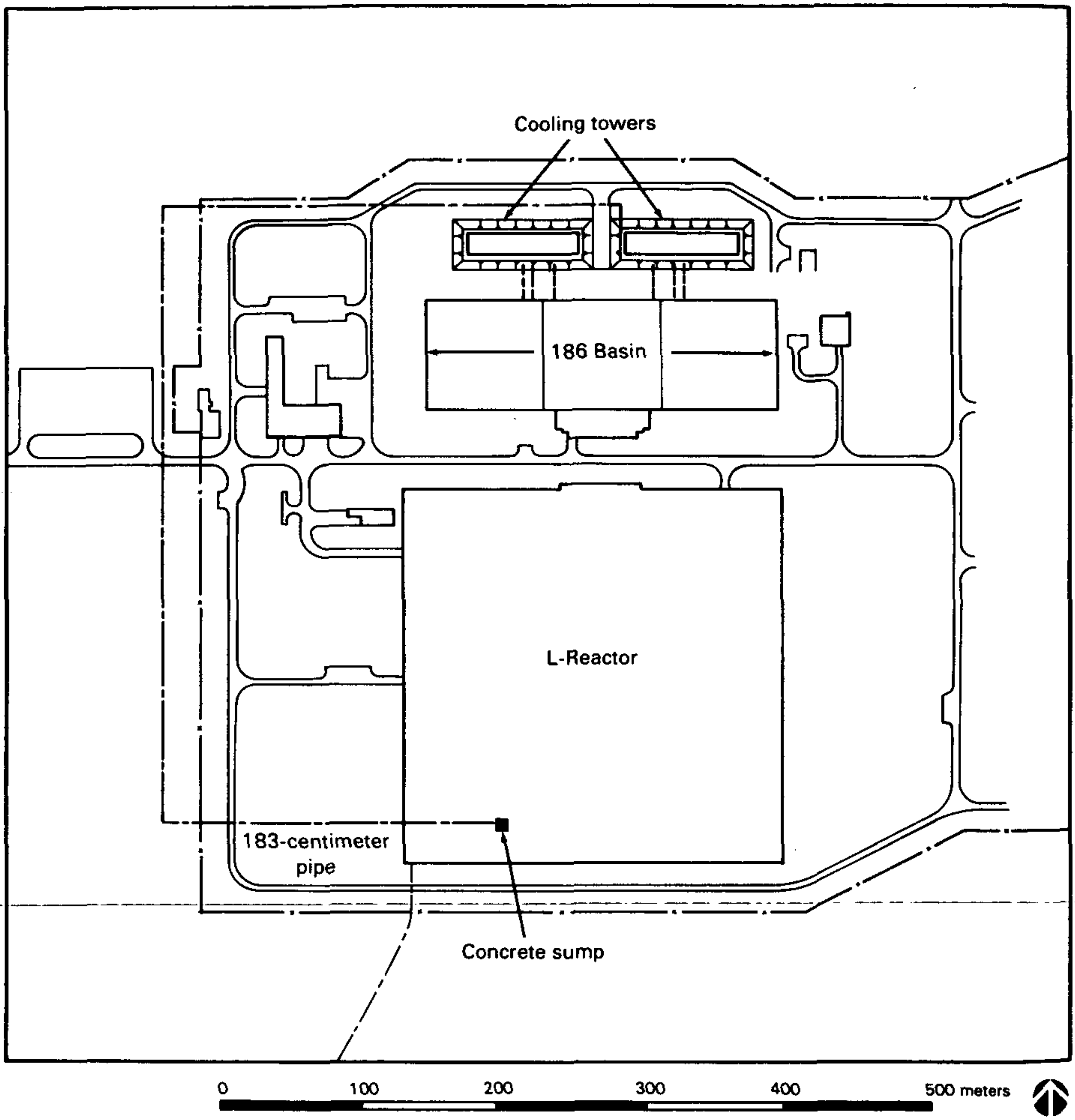


Figure 4-33. Conceptual design and location of mechanical draft cooling towers for L-Reactor.

All construction would take place away from Steel Creek. If L-Reactor is restarted before this alternative is implemented, a shutdown of about 1 month would be required to cut the existing pipe and install a valve to retain water in the sump.

Approximately 300 meters of the north perimeter fence and road would have to be relocated around the north side of the new cooling towers to provide space for the structures and the connecting pipes to the reservoir. A control building (approximately 8 by 15 meters) for miscellaneous electrical and mechanical items would also be required. Power could be run from existing sources in the L-Reactor complex to both new areas. Construction roads would be located to minimize environmental impacts.

Capital costs for the 2.8°C approach towers are estimated to be $60 million. Annual operating and maintenance costs for the cooling towers would be $2.5 million. The present worth would be $142 million, and the annualized cost would be $16.7 million. Towers designed for a 8.4°C approach temperature at a 27°C wet bulb would have a capital cost of about $39 million, which is somewhat less than that for the 2.8°C approach temperature towers. Operating and maintenance costs would be $2.2 million; the present worth would be $198 million; and the annualized cost would be $23.3 million (Du Pont, 1983d). An estimated 150 construction personnel would be required. The overall configuration of the cooling-tower water recirculation system would be similar to that shown for the more efficient towers in Figure 4-33.

Production efficiency for the 2.8°C approach towers is estimated to be 94 percent (derived from Du Pont, 1983d) of that for the direct discharge case. Production efficiency for the 8.4°C approach towers is estimated to be 85 percent (derived from Du Pont, 1983d). The makeup-water requirement for a 2.8°C or 8.4°C approach cooling tower is estimated to be approximately 1.4 cubic meters per second, of which about 0.6 cubic meter per second would be due to blowdown and about 0.8 cubic meter per second would be due to evaporation.

Under extreme meteorological conditions, the cooling-tower blowdown (0.6 cubic meter per second) to Steel Creek would have summer exit temperatures of 28°C (2.8°C approach) and 34°C (8.4°C approach).

The blowdown water discharge temperature from the cooling towers would vary depending on existing meteorological conditions and reactor operating power. Downstream temperatures are listed in Tables 4-47 and 4-48 and shown in Figures 4-34 and 4-35. The 30-year-average ambient Steel Creek temperatures measured at Road A are 29°C in summer, 22°C in spring, and 8°C in winter.

Under extreme summer meteorological conditions, the cooling-tower blowdown to Steel Creek would have an exit temperature of about 34°C (8.4°C approach). Near-ambient temperatures would be reached at the Steel Creek delta in the summer and spring for the 2.8°C approach. Temperatures at the delta in winter would be about ambient with the 2.8°C and 8.4°C approaches. Winter temperatures at the mouth of Steel Creek would be at ambient for both designs.

The 2.8°C approach tower would comply with the 32°C maximum discharge temperature except under extreme summer meteorological conditions. The 8.4°C approach system could be expected to regularly exceed the 32°C maximum temperature in summer.

Table 4-47. Temperatures (°C) downstream in Steel Creek with total recirculation cooling towers (2.8°C approach)

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	28	27	23	18
Road A	32	29	23	10
Swamp at delta	33	29	22	9
Mid-swamp	29	26	19	7
Mouth of creek at river[d]	30	27	21	12

[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 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.

[d]Temperature increase due to mixing with K-Reactor effluent.

Table 4-48. Temperatures (°C) downstream in Steel Creek with total recirculation cooling towers (8.4°C approach)

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	34	34	31	28
Road A	33	30	24	12
Swamp at delta	33	29	23	10
Mid-swamp	29	26	19	7
Mouth of creek at river[d]	30	27	21	12

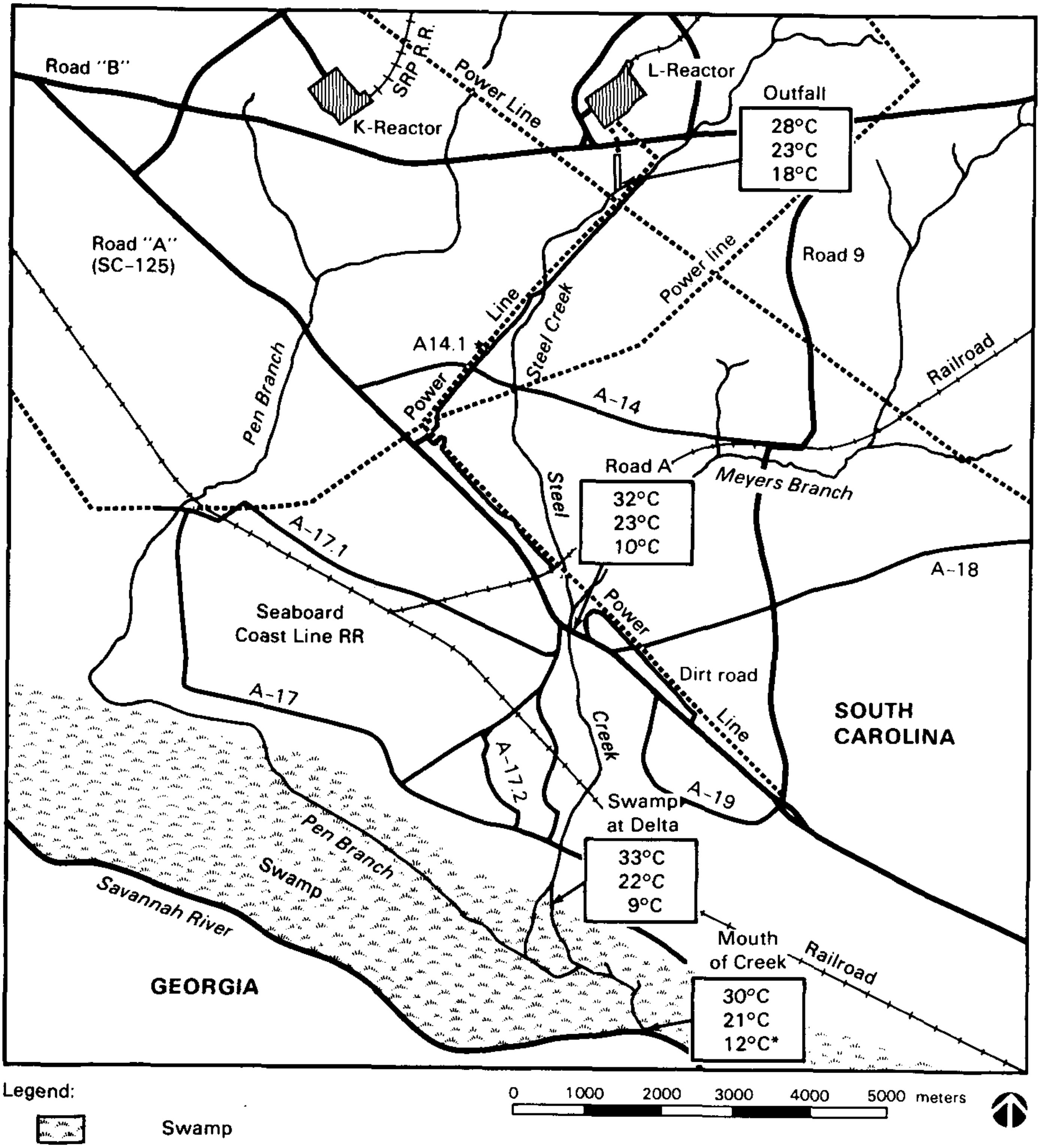
[a]Based on worst 5-day meteorological conditions (July 11-15, 1980) and estimated operating power of the reactor.

[b]Based on 30-year average values for meteorological conditions (1953-1982) and 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.

[d]Temperature increase due to mixing with K-Reactor effluent.

The 2.8°C and 8.4°C approach recirculation alternatives would substantially reduce thermal discharge to Steel Creek, and would result in minimal impacts to the biota of the creek, its delta, the floodplain, and the Savannah River in comparison to the effects caused by direct discharge. This alternative would have low discharge rates, and impacts due to flow would be minimal.



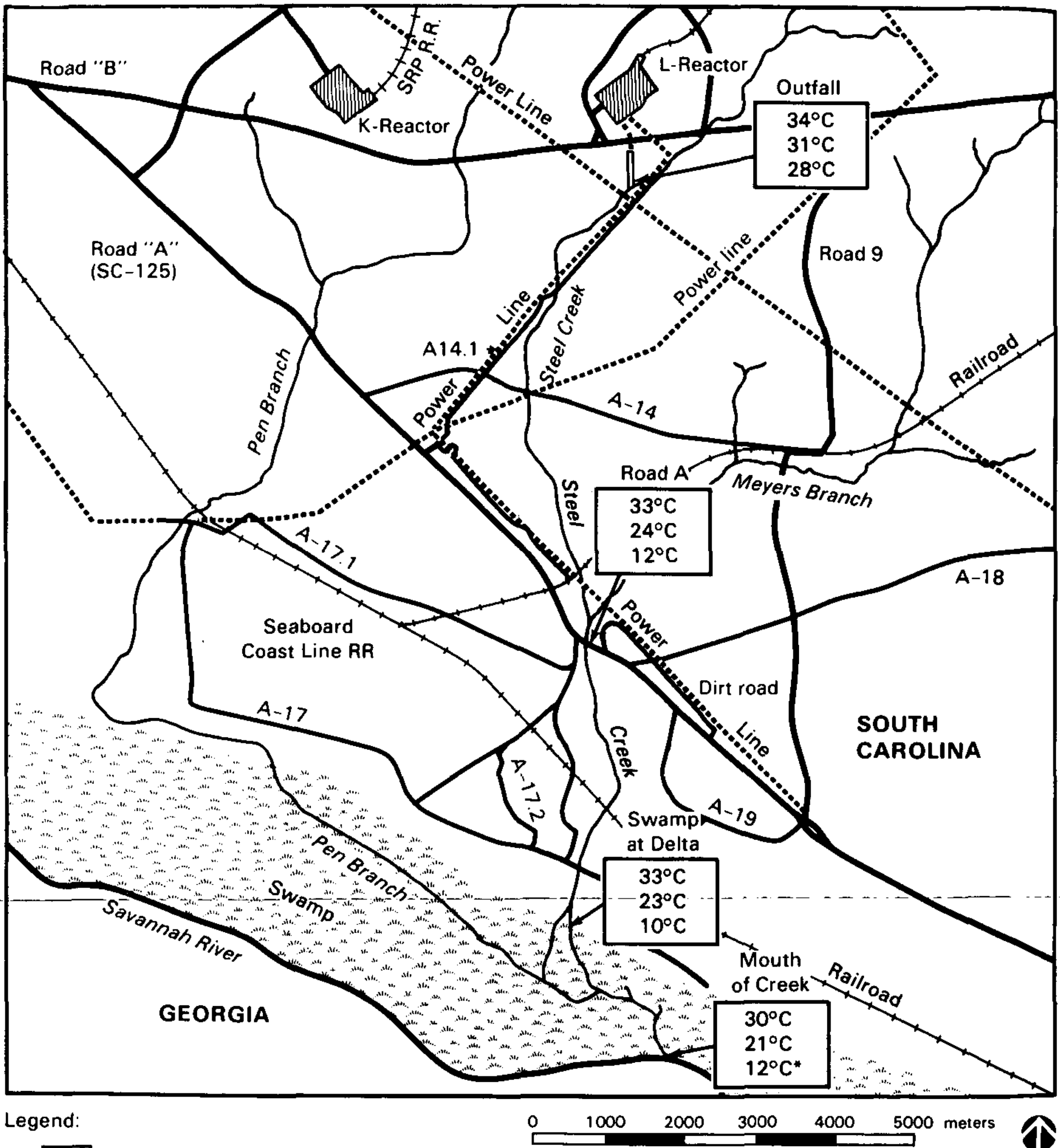
Legend:

Swamp

SUMMER SPRING WINTER	Seasonal creek temperatures *for this alternative*

*Increase due to mixing with K-Reactor effluent.

Figure 4-34. Steel Creek seasonal temperatures for cooling towers (2.8°C approach) with total recirculation.



Legend:

Swamp

SUMMER
SPRING
WINTER

Seasonal creek temperatures for this alternative

*Increase due to mixing with K-Reactor effluent.

Figure 4-35. Steel Creek seasonal temperatures for cooling towers (8.4°C approach) with total recirculation.

The construction of the towers would affect approximately 30 acres of upland pine forest. This area is contiguous with the L-Reactor facility and does not provide habitat for endangered or threatened species or other important wildlife.

Based on an estimated requirement of 7 percent makeup or 1.4 cubic meters per second of Savannah River water usage for the cooling towers, there would be approximately 743 fish impinged per year, and 9.8×10^5 fish eggs and 1.5×10^6 fish larvae entrained per year as the result of L-Reactor operation with cooling towers.

Radiocesium transport down Steel Creek would be about 0.8 curie per year by either approach. Liquid releases of tritium from L-Reactor to the Savannah River would be about 8900 curies per year.

Nonradioactive atmospheric releases would result in (1) a maximum of 5 hours per year of fogging (i.e., the visibility reduced to less than 1000 meters) within about 1 kilometer, 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 deposited from tower drift within about 1 kilometer of the tower.

No archeological sites are expected to be impacted by this alternative.

The ion-concentration ratio in the blowdown to Steel Creek is expected to be about 3. Thus, the chemical constituents in the creek water near the L-Reactor outfall would be about 1.7 times their normal concentration without the blowdown. At Road A, the increases in concentration would be only about 1.4 times normal. The blowdown is not expected to have an appreciable impact on the water quality of Steel Creek, the swamp, or the Savannah River.

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 wetland). 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 construction period.

4.4.2.3.2.2 Total recirculation--blowdown treatment

As indicated in Table 4-47 in Section 4.4.2.3.2.1, the resultant temperature rise in Steel Creek could exceed the State discharge criteria of 2.8°C above ambient due to reactor secondary cooling-water discharge temperatures during certain months of the year. Winter compliance would be the most difficult. Measures could be taken to ensure that the State requirements would always be met by additional blowdown treatment. Such measures could include one of the following: (1) refrigerating the blowdown before discharge to Steel Creek, (2) piping all the blowdown to Par Pond or K-Reactor and thereby eliminating the blowdown discharge to Steel Creek, (3) using a small cooling tower to further reduce the blowdown temperature before discharge, or (4) using a holding pond for the blowdown with or without a spray system.

The application of a large refrigeration system (estimated 10,000 tons refrigeration capacity--see Figure 4-36) to cool the blowdown flow would guarantee full-time compliance with State discharge requirements, because the blowdown would always be discharged at near-ambient stream temperature. This alternative represents the "Best Technology Available" for minimizing thermal discharge impacts. Piping the blowdown to Par Pond or K-Reactor is being considered at this time with regard to its practical application. The small cooling tower or holding ponds could significantly reduce the discharge temperature, but possibly not enough to meet the 2.8°C criterion in the winter. Cost estimates are available at this time only for the refrigeration blowdown treatment.

Construction time and reactor downtime for this alternative have been estimated to be about the same as those for the total recirculation system without blowdown treatment (Section 4.4.2.3.2.1).

The capital cost of the total-recirculation 2.8°C approach cooling-tower system with blowdown refrigeration is estimated to be $75 million. Yearly operating and maintenance costs for this alternative would be $3.2 million. Present worth would be $163 million and annualized cost would be $19.1 million. An estimated 170 construction personnel would be required.

Although the refrigeration system would ensure compliance with State requirements, it would represent a significantly increased capital cost and annual operating cost over a cooling-tower system without blowdown treatment. Production efficiency would be 93.5 percent for this alternative with refrigeration.

This cooling-system alternative would discharge 0.6 cubic meter per second of blowdown effluent at the same temperatures in summer and spring as those achieved by cooling towers having total recirculation (2.8°C approach). In summer, winter, and spring, near-ambient temperatures (calculated) would be achieved from the outfall to the Savannah River. Winter temperatures at the mouth of Steel Creek would be 11°C. This slightly over-ambient-temperature water could attract and concentrate fish near the mouth of Steel Creek.

Table 4-49 lists Steel Creek temperatures for various seasons with this alternative. Ambient temperatures in Steel Creek at Road A are 29°C in the summer, 22°C in the spring, and 8°C in the winter.

The total-recirculation cooling towers with blowdown refrigeration would be in continuous compliance with the maximum 32°C discharge temperature except during extreme summer meteorological conditions. If less efficient cooling towers were used, additional refrigeration could be used to meet State requirements; cost, however, would increase accordingly. The refrigeration unit would be operated for a longer time period over the year if less efficient towers were used.

This alternative would have essentially the same environmental impacts as those resulting from the implementation of cooling towers having total recirculation (2.8°C approach) without blowdown cooling during the spring and summer

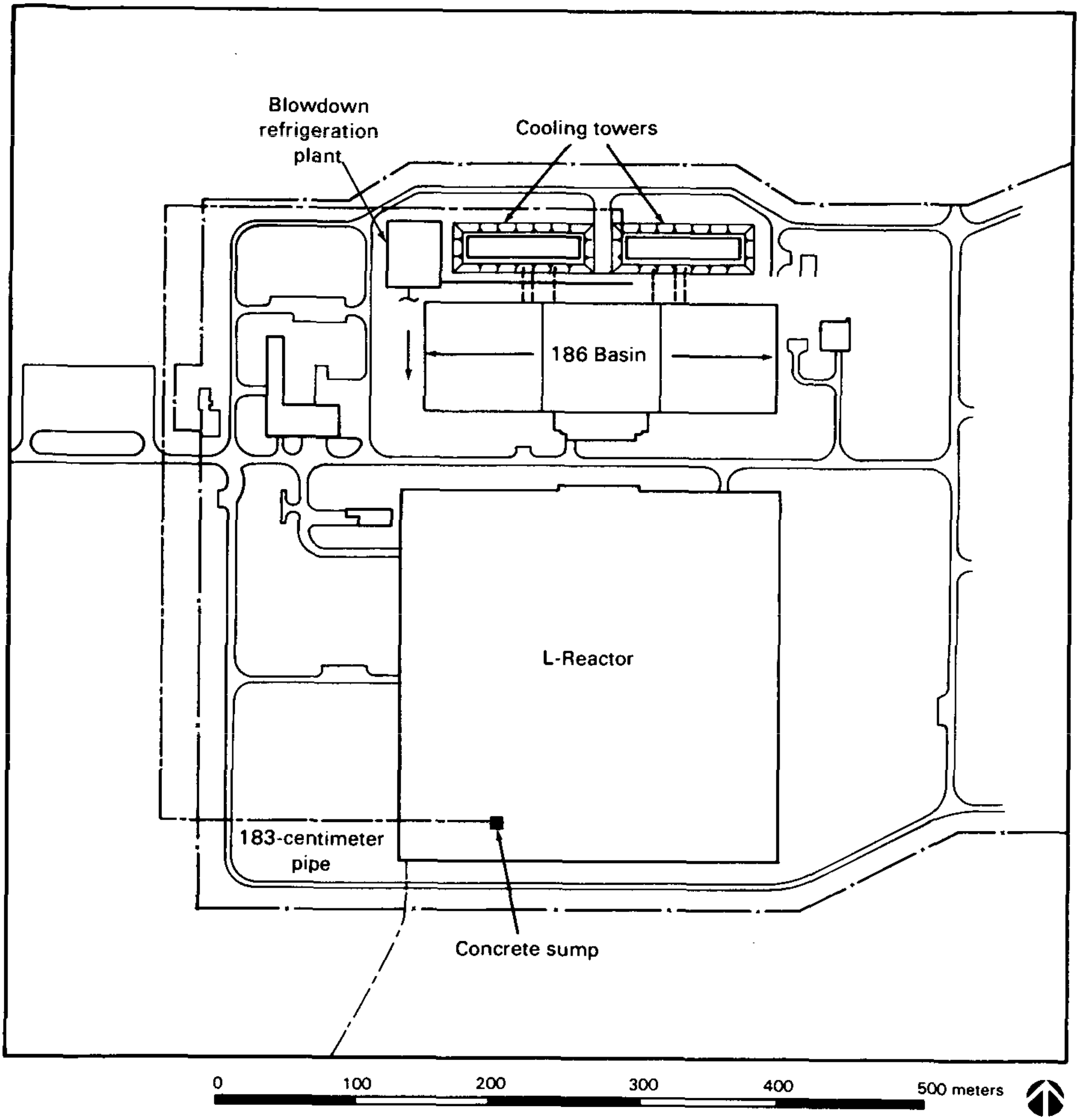


Figure 4-36. Conceptual design and location of recirculating cooling towers with blowdown refrigeration.

Table 4-49. Temperatures (°C) downstream in Steel Creek with a total-recirculation cooling tower (2.8°C approach) with blowdown treatment (refrigeration)

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	28	27	23	11
Road A	32	29	23	9
Swamp at delta	33	29	22	9
Mid-swamp	29	26	19	7
Mouth of creek at river[d]	30	27	21	11

[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 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.

[d]Temperature increase due to mixing with K-Reactor effluent.

because the blowdown would meet criteria without treatment. During the winter the impacts would be less with treatment because the blowdown would be treated to meet criteria. These impacts are summarized as follows:

- Construction of the towers would affect approximately 30 acres of upland pine forest. There would be no impact to wetlands or the biota that inhabit the Steel Creek ecosystem and swamp.

- There would be no impact to endangered and threatened species.

- The makeup requirement would be about 1.4 cubic meters per second. Approximately 743 fish would be impinged annually; annual entrainment of fish eggs and larvae would be 9.8×10^5 and 1.5×10^6, respectively.

- Transport of radiocesium would be maintained at its normal level, about 0.8 curie per year. Tritium discharges in liquid effluents would be about 8900 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 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.

- No archeological sites would be impacted.

Because of the low discharge rate, little or no change in present erosion or sedimentation patterns is expected. There would be no impacts to aquatic substrate or water quality from dredging and filling activities, because they are not required.

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

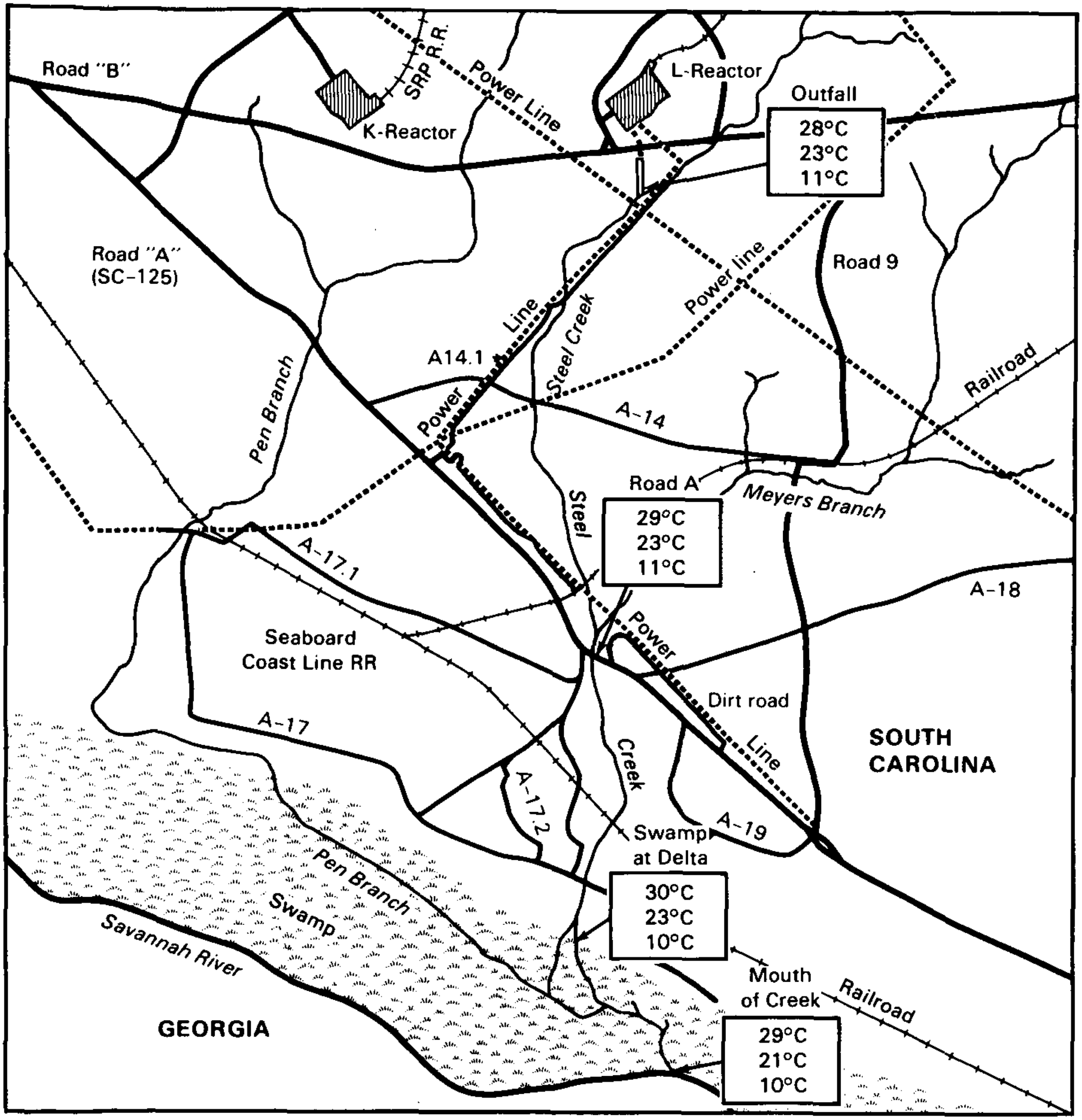
[a]Based on worst 5-day meteorological conditions (July 11-15, 1980) and estimated operating power of the reactor.

[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.



Legend:

0 1000 2000 3000 4000 5000 meters

Swamp

SUMMER
SPRING
WINTER

Seasonal creek temperatures for this alternative

Figure 4-37. Steel Creek seasonal temperatures for cooling towers (2.8°C approach) with partial recirculation.

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

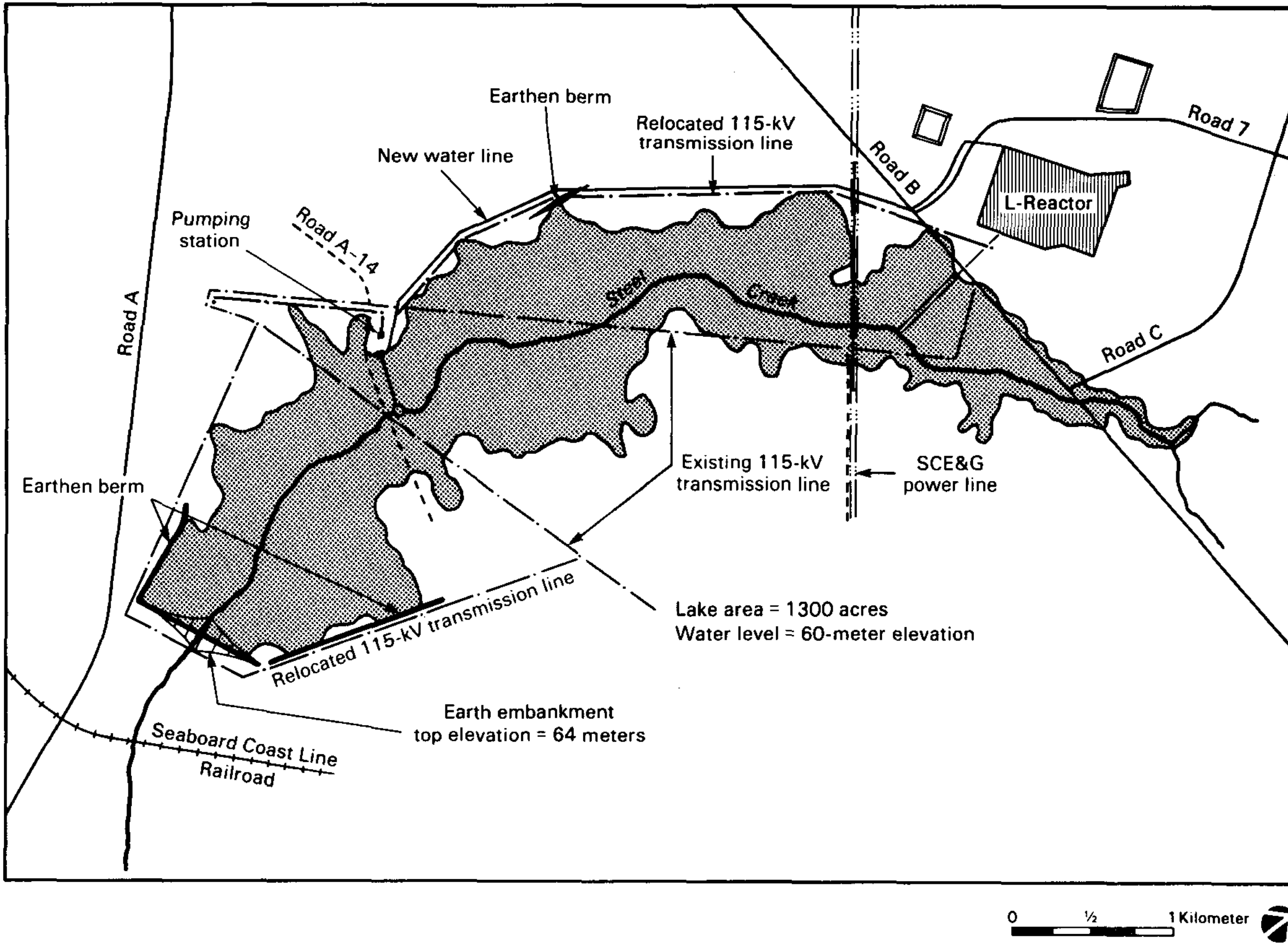


Figure 4-38. Conceptual design for L-Pond.

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