TENNESSEE VALLEY AUTHORITY

Biological Effects of Intake

BROWNS FERRY NUCLEAR PLANT

VOLUME 1: SUMMARY OF THE EVALUATION OF THE BROWNS FERRY NUCLEAR PLANT INTAKE STRUCTURE

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Continued

SUMMARY OF THE EVALUATION OF THE BROWNS FERRY NUCLEAR PLANT INTAKE STRUCTURE

I. Introduction

The National Pollutant Discharge Elimination System Permit for Browns Ferry Nuclear Plant (NPDES No. AL0022080) requires submission of a report summarizing entrainment and impingement studies evaluating the effects of the present cooling water intake with regard to section 316(b) of the 1972 Amendments of the Federal Water Pollution Control Act (FWPCA).

TVA has conducted extensive studies over the last year to assess the impact of the present operation of the cooling water system on the biological integrity of Wheeler Reservoir. The data resulting from these studies forms the basis for the evaluation which TVA believes shows that the continued operation of the present intake structure should not pose a serious threat to the aquatic communities of Wheeler Reservoir.

This document summarizes the interpretation and evaluation of the data obtained during the studies. As such, it constitutes Volume 1 of the four volume demonstration. The other volumes are identified as follows: Volume 2, "Analysis of Flow Patterns in the Vicinity of Browns Ferry Nuclear Plant Intake"; Volume 3, "Evaluation of Plankton Entrainment by the Intake of Browns Ferry Nuclear

Plant"; and Volume 4, "Effects of the Browns Ferry Nuclear Plant Cooling Water Intake on the Fish Populations of Wheeler Reservoir."

II. Plant Operating Data

The TVA Browns Ferry Nuclear Plant (BFNP) is situated on Wheeler Reservoir of the Tennessee River in north Alabama (Figure 1). This plant is a 3-unit, nuclear-fueled facility with a design capacity of 3,456 MW. The plant was originally designed for once through or "open mode" condenser cooling. In this mode, water is pumped from the river at 125 m^3/s (4410 ft^3/sec) and most flows through the steam condenser where the cooling water is heated before being discharged through submerged multiport diffusers in the river. To meet more stringent thermal water quality standards, the plant has been retrofitted with six mechanical draft cooling towers. The cooling towers may be operated in helper, or closed mode as needed to meet the thermal standards. With the towers in "helper mode" and operating at designed capacity, the plant withdraws 104 m^3/s (3675 ft^3/sec) of water from the river. When operating at designed capacity in the "closed mode" the plant uses between 5.7 and 8.5 m^3/s (200-300 ft^3/sec) water, most of which is "makeup" for the cooling system.

The intake for the condenser cooling water for the plant is situated at Tennessee River mile (TRM) 294 was shown in Figure 2.

The cooling water from the river flows to the plant through an intake channel which is approximately 150 meters (487.5 feet) long. The channel is separated from the Tennessee River by a 60 meter (200 feet) long skimmer wall which extends 2.8 meters (9.1 feet) below the water surface when the reservoir surface is at normal full pool (elevation 170 m, 556 ft msl). An approximately 7.3 meter (24 feet) high opening under the bottom of the wall permits withdrawal of cool water from the lower depths of the main channel. The underwater topography of the river near the skimmer wall (figure 3) reveals depths of about 10 meters (33 feet).

Water velocities in the intake channel have been measured when all nine circulating water pumps were in operation. Near the skimmer wall, the velocity averaged 0.25 m/sec (0.8 ft/sec) ranging from 0.50 m/sec (1.6 ft/sec) to 0.07 m/sec (0.2 ft/sec). Velocities across the intake channel recorded approximately 100 meters (325 feet) upstream of the pumping station ranged from 0.27 m/sec (0.9 ft/sec) to 0.48 m/sec (1.6 ft/sec) with an average of 0.39 m/sec (1.3 ft/sec). Velocities directly in front of the trashracks at the pumping station were measured when nine pumps were operating. These ranged from 0.24 m/sec (0.8 ft/sec) to 0.54 m/sec (1.8 ft/sec) with an average of 0.37 m/sec (1.2 ft/sec).

III. Physical Data

A. Physical Description of Wheeler Reservoir

Wheeler Reservoir was created in 1936 by the impoundment of the Tennessee River at Wheeler Dam (TRM 275). River flows in the vicinity of the plant are primarily dependent upon discharges

from Guntersville Dam (TRM 349), which is 80 km (55 miles) upstream, and from Wheeler Dam (TRM 275), which is 31 km (19 miles) downstream. The mean annual flow rate of the river at BFNP is 1,270 m^3/sec (45,000 ft^3/sec). Since discharges from these dams are normally used for hydroelectric generation during periods of daily peak power demand, flows in Wheeler Reservoir are often unsteady. As a result, flows past the plant are also unsteady and subject to change throughout the day.

The water surface elevation in Wheeler Reservoir normally varies no more than six feet (1.8 m) throughout the year. From approximately April through July, the reservoir elevation fluctuates only slightly near the maximum level while during the remainder of the year it will be approximately five to six feet lower.

B. Hydrological Investigations

A relatively wide overbank area is situated immediately upstream of the intake of the BFNP. The quantity of flow along this overbank varies with reservoir stage and flow. Prior to spring filling of the reservoir, usually in April, the shallow depths will prohibit much flow over the overbank.

Hydrodynamic studies were conducted subsequent to spring reservoir filling (i.e., May through July) when the greater depths of the overbank region permitted more flow. These studies revealed that most of the flow over the overbank is being drawn into the BFNP intake when the plant is operating in open or helper

modes of condenser cooling. However, in the spring, when the reservoir is gradually warming, the large surface areas and shallow depths of the overbanks provide little thermal inertia; hence, the overbank areas are generally warmer than the main channel. Under these conditions, buoyancy of the warmer overbank water is sometimes sufficient to prevent water in the upper three feet (one meter) from being entrained into the plant intake. For the range of reservoir and plant operational conditions examined, between 53 and 63 percent of the BFNP intake flow came from the overbank when the plant was operating in open or helper modes.

IV. Biological Data

A. Evaluation and Interpretation of the Plankton Data

1. Description of the Sampling Program

Intensive nonfisheries biological studies were conducted in May, June, and July 1977, to determine the effects of the BFNP intake structure on the plankton of Wheeler Reservoir in the vicinity of the plant. Since the plankton is the biotic community most readily affected by entrainment into the condenser cooling water system of a power plant both phytoplankton (chlorophyll a and biomass as suspended solids and organic content) and zooplankton (biomass as mg/m^3) samples were included.

Studies were conducted on segments of water, designated as "water masses". Individual water masses were sampled both upstream of the intake structure, and opposite the intake skimmer wall. The upstream set of samples was

taken by four aligned boats, two positioned on the overbank, and two positioned in the channel. The second set of samples was taken in line with the skimmer wall, and included sampling by two boats in the navigation channel, by two boats in the intake approach (dredged channel to the intake), and by a fifth boat in the intake forebay of BFNP. Downstream progress of the water mass was observed by following movements of a subsurface drogue.

Water masses were usually sampled during daylight hours under varying conditions of plant operation and reservoir flow (Table 1). On July 20 and 21, 1977, a diel study was conducted to analyze possible diurnal and nocturnal fluctuations in entrainment of the plankton.

On three occasions (June 5, July 5, and July 28) the status of the plankton community of the reservoir upstream of BFNP at TRM 295.4, 296.9, and 298.4 was documented by collecting samples from the right (north) overbank and the channel. No attempt was made to follow water masses for these days.

2. Materials and Methods

a. Field Procedures

Triplicate water samples for phytopigments, suspended solids, and organic content were collected at surface, 1 m, 3 m, and 5 m depths at each sampling location using 2-liter Kemmerer or van Dorn samplers. A 500 ml subsample of each water sample was filtered through a glass fiber filter for later phytopigment

analysis. The remaining, unfiltered water was preserved for suspended solids and organic content analysis at a later time.

Five replicate samples for determination of zooplankton biomass were collected at each sampling location by bottom-to-surface vertical tows with a half-meter plankton net equipped with a digital flowmeter. Each zooplankton sample was preserved for later analysis.

b. Laboratory Procedures

Each phytopigment filter sample was placed in a centrifuge tube, extracted in 90% acetone, and analyzed with a recording spectrophotometer.

Replicate water samples were analyzed for suspended solids and organic content by filtering a 500 ml subsample through a preweighed glass fiber filter, oven dried at 100°C, and reweighed for suspended solids. Each subsample filter was then placed in a muffle furnace (575°C) for 20 minutes, cooled, and reweighed to determine organic content.

Zooplankton samples were washed and then subjected to sucrose density gradient centrifugation in order to separate phytoplankton and detritus from the zooplankton. Zooplankton samples were then washed and poured onto preweighed glass fiber filters. After filtration, the zooplankton samples were oven dried (100°C) and,

after cooling, weighed to determine zooplankton weight. Zooplankton weight was divided by the volume of water sampled and designated zooplankton biomass.

c. Data Analysis

Data were analyzed according to standard statistical methods. Mean values, variances, and coefficients of variation were calculated for all series of zooplankton, chlorophyll a, and organic content replicates. When four or five mean values were available, a Student-Newman-Keuls multiple range test was performed for mean values of chlorophyll a.

The percentage of zooplankton entrainment was calculated by dividing the rate of passage of total zooplankton biomass transported past BFNP by the rate of zooplankton biomass entrained by the pumps of BFNP. The total rate of passage of transported zooplankton biomass was calculated by summing the rates of passage of zooplankton biomass in the channel and north and south overbanks at the initial sampling locations. The rates of passage of zooplankton biomass were determined by multiplying the calculated river velocity by the cross sectional area by the averaged zooplankton biomasses of the channel or the north overbank. In these calculations river velocities and zooplankton biomasses of the south overbank were assumed to equal those

of the north overbank. The total rate of zooplankton biomass entrainment was calculated by multiplying the zooplankton biomass in the intake forebay by the flow rate of water through the intake pumps into BFNP.

3. Results and Discussion

a. Phytoplankton

Significantly more chlorophyll *a* occurred in overbank samples than in channel samples immediately upstream of the intake of BFNP. Higher chlorophyll *a* concentrations were found in water nearest the north shore than in overbank water adjacent to the channel. Therefore, most of the phytoplankton immediately upstream of the intake of BFNP was located in overbank water.

Further upstream at TRM 298.4 very low concentration of chlorophyll *a* were found in both overbank and channel samples. As samples were obtained downstream, concentrations of chlorophyll *a* increased in both overbank and channel samples. The low values of chlorophyll *a* at TRM 298.4 cannot be explained with the data at hand.

Most of the phytoplankton entrained by BFNP originated on the overbank. Intake concentrations of chlorophyll *a* and pheophytin *a*, while lower than those on the overbank were closer to overbank than to channel concentrations. Patterns of phytoplankton entrainment under various conditions (i.e., a range of reservoir flows, three unit plant operation, and

open, helper, and mixed cooling modes) were similar in that almost all phytoplankton in water coming off of the north overbank in the vicinity of the plant was entrained. Exceptions to this entrainment pattern for phytoplankton were seen with May 18, 1977, samples in which phytoplankton in the top meter of overbank water passed by the intake of BFNP when warmer surface overbank water passed over cooler overbank and channel water entering the intake. Phytoplankton entrainment during mixed mode plant operation was similar to helper mode for the lower strata of intake forebay water (those strata not influenced by recirculation of heated water), and most phytoplankton in the lower strata was derived from overbank water. Under closed mode operation phytoplankton entrainment was minimal.

Most channel water (with its associated phytoplankton) entrained by BFNP was derived from lower channel strata. In most instances, only small amounts of chlorophyll _a_ (and phytoplankton) were located in channel waters at these depths, so these strata contributed only a small amount of phytoplankton to that entrained in the intake.

Positive concentrations of pheophytin were infrequently collected in replicate samples except for those from the second water mass on June 7, 1977, when it was present in most samples collected. The infrequent occurrence of pheophytin a indicates that the phytoplankton communities entrained into BFNP were physiologically healthy.

These studies show that almost all the phytoplankton in water coming off of the north overbank in the vicinity of the plant is entrained into BFNP, except when solar heating of overbank water creates thermally stratified conditions that result in surface to 1 meter overbank water bypassing BFNP. However, because of short phytoplankton generation times, the entrainment of almost all transported north overbank phytoplankton should not have a serious effect on the downstream phytoplankton community, unless community composition is affected.

b. Suspended Solids and Organic Content

Suspended solids and organic content showed no trends of increasing or decreasing with water mass movement as related to river flow rates and plant cooling modes. Suspended solids

in the intake or an anomaly of the sampling method.

Production of biomass in the intake forebay is not likely because the velocity does not provide sufficient retention time for reproduction. In addition, as indicated from dye studies there are no extensive "dead areas" within the forebay for such reproduction to occur.

The sampling method could have produced a lower biomass estimate in channel samples if the heavier zooplankton species (e.g., the crustaceans) were concentrated in the lower depths of the water column. The sampling device would integrate the more dense portions of the water column (i.e., the lower depths) with the less dense portions. However, even if there was a sampling anomaly the data should still provide a sound base for determining the percentage of the transported zooplankton biomass entrained into BFNP. The purpose of the sampling method was to provide an average zooplankton biomass for a water column in order to estimate the total transported biomass (i.e., biomass x cross-sectional area x velocity). Hence, the samples should provide valid data for deriving

the transported biomass and the resultant percentage of entrainment.

The percentage of the transported zooplankton biomass entrained ranged from 56 percent to 0.3 percent. Most data points fell within a range of 22 to 12 percent. Percentages out of this range were related to either closed cooling mode, low reservoir flows, or low zooplankton biomass. The closed cooling mode operation (July 5, water mass 2) resulted in an expected low percentage entrained (0.3%) because very little water was entrained. Low reservoir flows (July 19, water mass 1, 227 m^3/s resulted in an expected high percentage entrained (56%) because almost half the reservoir flow was entrained. Low zooplankton biomass value introduced more variability into the calculation as indicated by the larger range of percentages entrained (30 to 8 percent) if water masses (water mass 1, May 18, water masses 5 and 6, July 21) with a zooplankton biomass below approximately 30 mg/m^3 are included. The data in the 22 to 12 percent range were collected under varying conditions: reservoir flows (other than low flow) from 1,388 to 790 m^3/s; time of day from daylight, dusk, dark, to dawn; and mode of cooling tower

operation from open to helper to mixed (combination of helper and open). These results indicate that unless BFNP is in closed mode cooling, the reservoir flow is low, or zooplankton biomass is low, a relatively constant percentage of the transported zooplankton biomass will be entrained.

The high entrainment percentage under low reservoir flows would be of concern, if such flows existed for extended periods (24-12 hours). However, the low flow conditions for this study were established for specific study requirements. Under present operating guidelines for the upstream and downstream hydroelectric plants, low flows of this nature are not expected to occur for extended periods.

The entrainment of 22-12 percent of the transported zooplankton biomass under normal reservoir flows and plant operating conditions is of potential concern because zooplankton are an essential link in the aquatic food chain. Although there is potential for this loss (22-12 percent) to influence the zooplankton community downstream of the Browns Ferry Nuclear Plant intake, the loss should not represent an inpact to the aquatic community of Wheeler Reservoir.

B. Evaluation and Interpretation of Fisheries Data

1. Entrainment

a. Description of the Sampling Program

Estimation of taxa, numbers, and relative percentage of ichthyoplankton

entrained was performed by intensive sampling in the reservoir and in the intake during 1974 through 1977. Reservoir sampling consisted of replicate horizontal tows (5-minute duration) using a stern-towed, 1 m diameter conical net equipped with a flow meter. Samples were taken in the inshore (littoral) area and at the surface, and at 5 m depths in the pelagic area of the reservoir. Samples in the intake were taken with a 3x3 matrix (surface, mid-depth, bottom) of 0.5 m diameter stationary nets equipped with flow meters. Intake samples were taken during day and night periods and were of 2-hour duration each. Reservoir transect samples were taken simultaneously with intake samples.

Samples were sorted, identified to the lowest possible taxon and counted. Weighted transect densities were calculated and combined with reservoir flow data to obtain estimates of number of eggs and larvae transported past the plant for each sampling date. Intake densities were combined with plant operational data (number of pumps operating and pumping capacities) to yield estimates of number of eggs and larvae entrained. Estimates of percentages of transported eggs and larvae which were entrained were calculated for each sample date and integrated over time to yield annual estimates.

b. Results and Discussion

The ichthyoplankton was consistently dominated (80-98 percent) in both reservoir and intake samples by clupeids (shad). Other taxa contributing 1.0 or more percent of total numbers were catostomids (suckers), cyprinids (minnows and carp), sciaenids (drum) and percichthyids (white and yellow basses). Greatest densities of ichthyoplankton typically occurred in early to mid-June; in 1977, however, peak densities occurred approximately one month earlier.

Hydraulic entrainment (percent of river flow entrained annually) ranged from 3.0 to 12.0 percent from 1974 through 1977; entrainment of eggs ranged from 2.3 to 13.3 percent and larval entrainment ranged from 1.0 to 11.7 percent over the same period. Annual total entrainment percentages were less than hydraulic entrainment for all years except 1977, when the two values were virtually equal. The single high value for egg entrainment was probably the result of spawning activity in or near the intake.

Of the numerically important taxa, annual percent entrainment for 3-unit operation (1977) ranged from 4.5 percent (catostomids) to 15.6 percent (percichthyids). Of those taxa not numerically important, but of sport or commercial interest, annual entrainment was: centrarchids (sunfish and crappie) - 4.8 percent; percids (darters, sauger, walleye)- 14.6 percent and ictalurids (catfishes) - 29.0 percent.

Those taxa having an essentially pelagic, planktonic distribution (clupeids, cyprinids, percichthyids, and percids) were entrained in increasing percentages as intake demand increased; the lone exception to this pattern was exhibited by the sciaenids. Other taxa (ictalurids, centrarchids) which showed no consistent pattern are those taxa which have behavioral characteristics that preclude a pelagic, planktonic larval distribution. High entrainment percentages estimated for ictalurids are the result of ineffective sampling in the reservoir transect which resulted in underestimates of the transported population relative to intake densities. The highest entrainment percentage noted (90 percent for ictalurids in 1975) is the result of capture of 42 individuals in the intake and only one in the reservoir transect.

The total annual entrainment percentage estimated for 3-unit operation in 1977 was higher than expected, based on our experience at other plants. Because ichthyoplankton are not truly planktonic (beyond the first few days after hatching), entrainment percentages are expected to be less than corresponding hydraulic entrainment percentages; in 1977, however, the two values (12 percent hydraulic, 11.7 percent ichthyoplankton) were virtually identical. The reasons for this are not known.

Because of system and methodology variability, and the fact that 1977 was an uncharacteristic year in terms of the timing of peak densities of ichthyoplankton, an additional year of improved and intensified sampling and analysis will be carried out to better define fish entrainment estimates, and assess the potential impacts of plant entrainment on the fisheries resources of Wheeler Reservoir.

2. Impingement

a. Description of the Sampling Program.

Two sampling procedures were employed. From March 1974 through July 1976, one screen was sampled three times per week; fish were removed, identified and counted. Expansion of the data to provide estimates for all operating screens was performed using results of bimonthly studies in which all screens were sampled during four consecutive 12-hour periods. Beginning September 1976, all screens were sampled during one 24-hour period each week; data collection was expanded to include the measurement of biomass while retaining species and enumeration data.

Under both sampling regimes, screens to be sampled were rotated and washed to remove impinged fish and debris; screens were then stopped for the 24-hour test period. Each screen was then idividually washed, the fish collected and the data recorded. Subsampling within a species was employed when large numbers of that species precluded efficient counting and weighing

Three 1-year periods, each extending from March through March were used to examine impingement under a variety of conditions: 1-and 2-unit operation, no units operating and minimal pump operation, and 3-unit operation.

b. Results and Discussion

During the entire period of study (March 1974-August 1977) 72 species were collected from the screens. Of these, four (threadfin shad, gizzard shad, freshwater drum and skipjack herring) accounted for approximately 95 percent of total numbers impinged; threadfin (76.5%) and gizzard shad (12.3%) accounted for nearly 89% of all fish impinged. No species other

than these four represented greater than 1 percent of total observed impingement and no species classified as threatened or endangered was noted.

Estimated total annual impingement was 5.26×10^6 fish for 1 and 2 unit operation, 2.69×10^6 fish for minimal pump operation and 6.67×10^6 fish for 3-unit operation. Estimated total biomass impinged annually for 3-unit operation was 63 metric tons.

Impingement was usually lowest in May and June and highest in winter (December through March) except in 1976-1977 when impingement peaked in September and October. Impingement of clupeids was reduced in late 1977 owing to severe winter die offs of threadfin shad during 1976.

Of 15 species examined for diel differences in impingement, all but one (longear sunfish) exhibited a significantly greater proportion of individuals impinged at night.

Except for sauger and freshwater drum, approximately 80 percent of the individuals of species impinged were less than 150 mm total length; impinged sauger were generally larger than 175 mm but still were considered young-of-year fish and sauger never exceeded 1 percent of impinged fish.

Thirty species which were impinged at a rate of at least 1 per day were selected for comparison of numbers lost through impingement versus standing stock in Wheeler Reservoir. Impingement of 17 of these species exceeded 1 percent of their estimated standing stock for at least one of the three annual study periods. For the three of these dominant

species (skipjack herring, channel catfish and drum) which exhibited high impingement levels relative to standing stock, relative and total impingement for 3-unit operation was similar to or less than that noted for 1 or 2 unit operation, thereby suggesting that impingement was independent of intake demand and was not related to variations in standing stock. Of other species which exhibited increasing rates of impingement over the three study periods, no instances of a causal relationship between impingement losses and standing stock were shown.

Of 72 species impinged, 42 were impinged at rates of less than one fish per day (365 per year); the potential for adverse impacts on these species is very low. Thirteen of the remaining 30 species were impinged in numbers representing less than 1 percent of their reservoir standing stocks and therefore for these species no significant adverse impact is judged to exist as the result of impingement. Five of the remaining 17 species were impinged at rates exceeding 1 percent of their standing stock for at least one of the three study periods. Rates of impingement for these were less than 3 individuals per day. These species (mooneye, blue catfish, black and brown bullheads and black crappie) although common in Tennessee River impoundments are not commonly collected in cove samples; standing stocks are therefore likely to be underestimated. Based on these considerations, no potential for adverse impact appears to exist.

Of the remaining 12 species, no consistent trends in terms of impingement rates versus plant operational regime; numbers impinged versus resulting standing stocks; or trends in standing stock versus plant operation were noted. Therefore, impingement of fish at Browns Ferry Nuclear Plant does not represent an adverse impact upon the fisheries resources of Wheeler Reservoir.

V. Conclusion and Summary

The purpose of the studies discussed herein was to determine the environmental impact of the Browns Ferry Nuclear Plant intake on the reservoir aquatic communities.

Phytoplankton and zooplankton studies were conducted during spring and summer 1977 with all three generating units in operation. These studies documented localized effects to the plankton. However, these effects should not represent an adverse impact on the plankton community of Wheeler Reservoir.

Fish impingement and entrainment studies were conducted during 1974-1977 with one, two, and three unit operation. Impingement studies indicate that even though the number of fish impinged increased as the number of operating units increased, the overall impingement of fish at Browns Ferry Nuclear Plant does not represent an adverse environmental impact on the Wheeler Reservoir fish community. Entrainment studies showed that the percentage of transported populations entrained also increased as the number of operating units increased. For both one and two unit operation a low percentage of entrainment occurred, however, the percentage increased considerably under three unit operation.

However, for the reasons indicated herein, quantification of fish entrainment and evaluation of potential associated environmental impacts are not conclusive and further studies will be carried out to better define entrainment and to better assess the potential impact of plant entrainment.

Table 1. Reservoir and Condenser Flow Rates, BFNP Cooling Modes, and Water Mass Sampling Times for Plankton Sampling

Date	Q_R[a]		Q_C[b]		Cooling Mode	Sampling Time	Water Mass
	ft^3/s	m^3/s	ft^3/s	m^3/s			
May 18, 1977	38,000	1,076	4,410	125	open	0900-1100	1
	38,000	1,076	3,550	101	helper	1300-1500	2
June 7, 1977	36,000	1,019	3,550	101	helper	0900-1100	1
	36,000	1,019	3,550	101	helper	1300-1500	2
June 8, 1977	49,000	1,387	3,550	101	helper	1300-1500	1
	49,000	1,387	4,410	125	open	1800-2000	2
June 9, 1977	5,550	157	4,410	125	open	0900-1000	1
	7,400	210	4,410	125	open	1100-1200	2
July 5, 1977	18,000	510	1,200	34	mixed[c]	0900-1100	1
	37,000	1,048	220	6	closed	1400-1600	2
July 19, 1977	8,000	227	3,550	101	mixed[d]	0900-1100	1
July 20, 1977	45,000	1,274	3,550	101	mixed[d]	1900-2100	1
	33,000	934	3,550	101	mixed[d]	2300-0100	2
July 21, 1977	28,000	793	3,560	101	mixed[d]	0300-0500	3
	38,000	1,076	3,550	101	mixed[d]	0700-0900	4
	36,000	1,019	3,550	101	mixed[d]	1100-1300	5
	36,000	1,019	3,550	101	mixed[d]	1600-1800	6

a - Reservoir flow rate
b - Condenser cooling flow rate
c - Combination of helper and closed cooling modes (Q_c estimated)
d - Combination of open and helper cooling modes

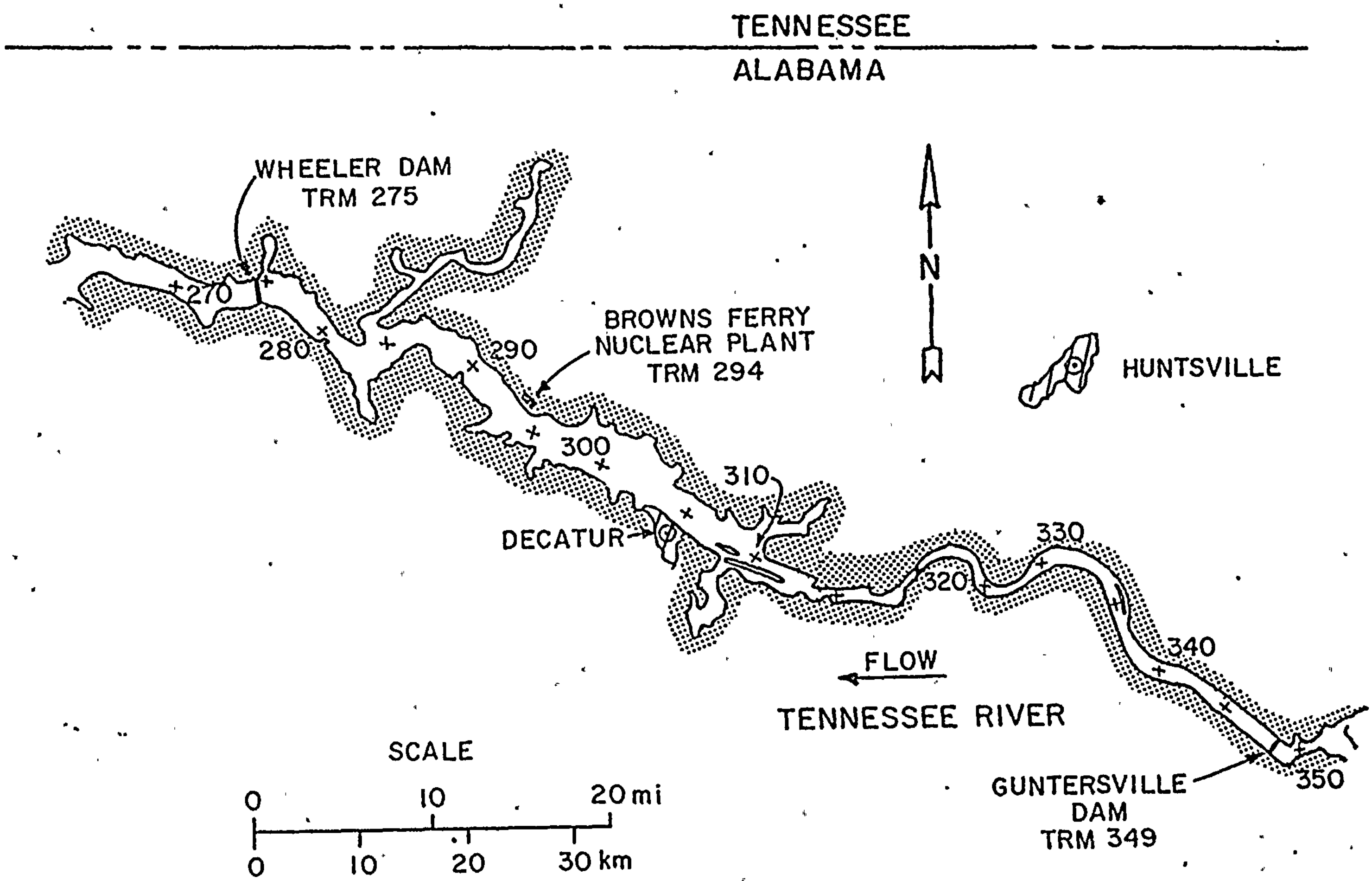

Figure 1: Location Map of Browns Ferry Nuclear Plant

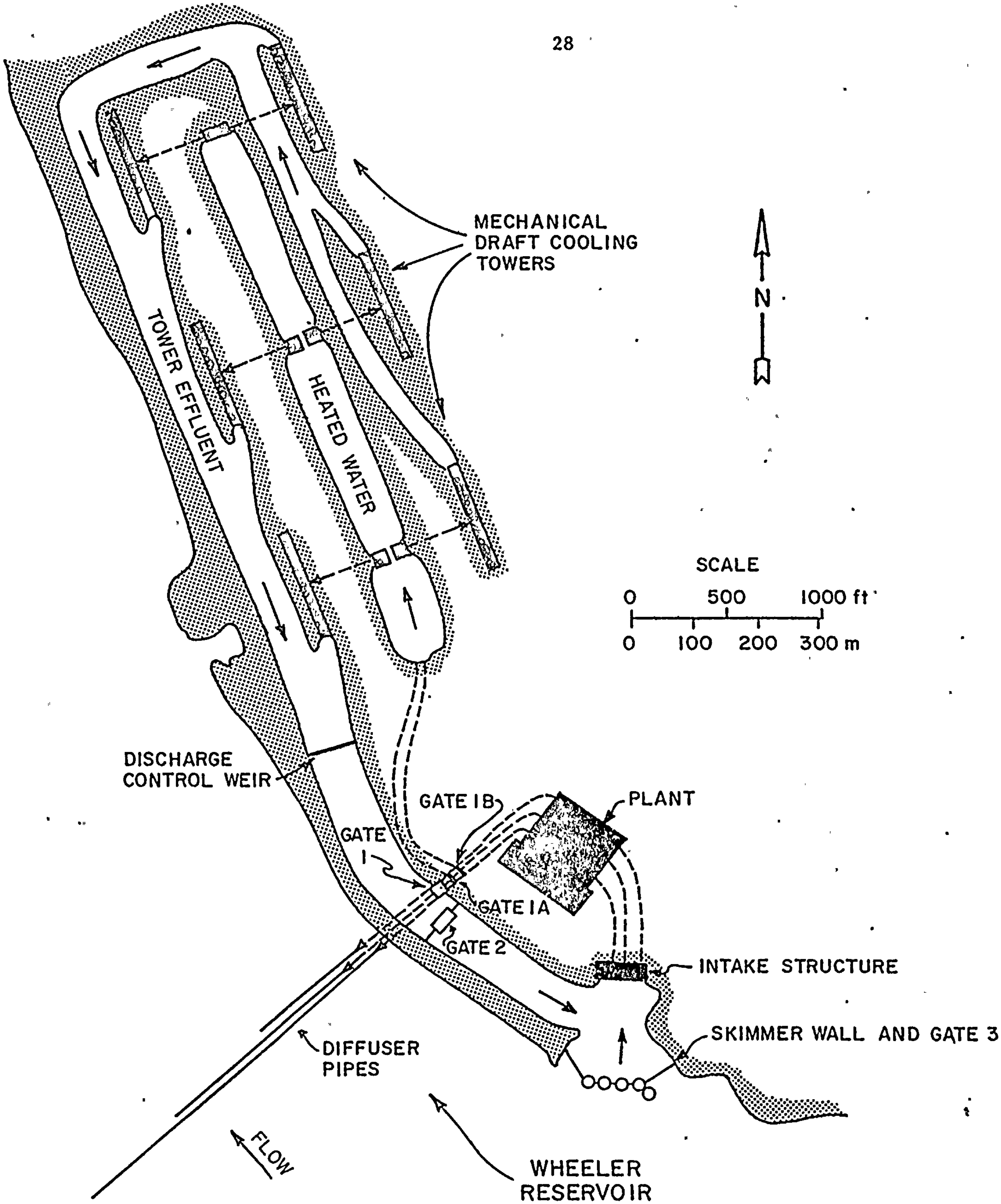

Figure 2: Layout of Browns Ferry Nuclear Plant

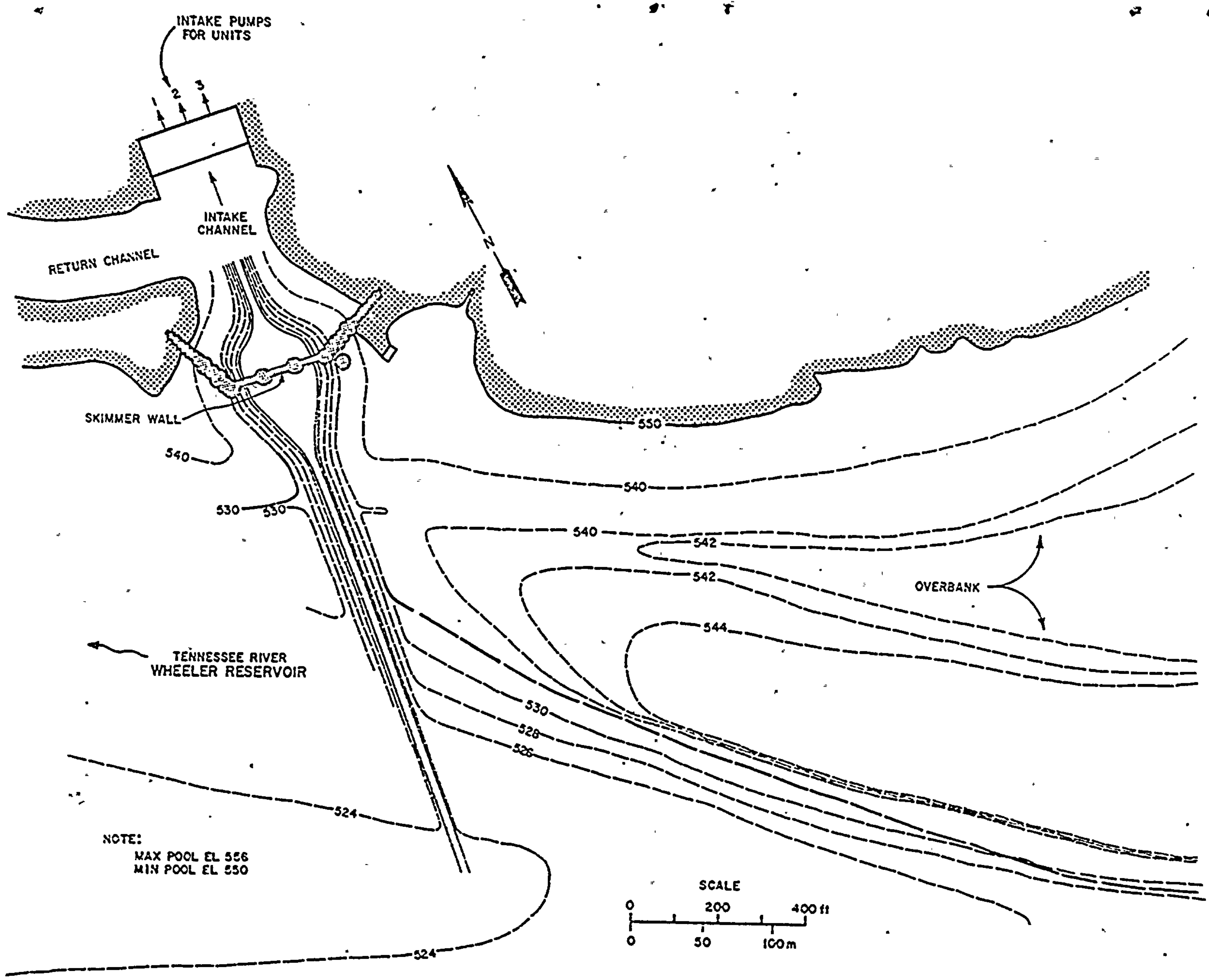

Figure 3: Underwater Topography Near the BFNP Intake