MIGRATION OF SAUGER PAST A THERMAL DISCHARGE IN MELTON HILL RESERVOIR

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Abstract: A total of 259 sauger (*Stizostedion canadense*) was tagged and released downstream of Bull Run Steam Plant during the winters of 1974-75 and 1976. Gill nets and electrofishing gear were used to recapture sauger that moved into the discharge basin or past the plant. Over the study period 7 sauger were recaptured upstream from the discharge; 3 of these had moved past the plant while it was continuously operating. Fourteen sauger were caught in the discharge. The thermal plume from Bull Run Steam Plant had no significant effect on the movement of sauger.

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The potential for thermal discharges, particularly from steam generating power plants, to impact adversely the fish populations in receiving waters has been intensively investigated in the past 10 years (e.g., see Coutant and Talmage 1975). There have been many hypothesized detrimental effects; one of the principal impacts envisioned was the blockage of spawning migrations by heated water (Craddock 1976). However, only a limited number of studies have attempted to evaluate interruption, delay, or complete blockage of spawning migrations of anadromous or potamodromous species by thermal effluents. One such study reported that high temperatures blocked the upstream migration of sockeye salmon (*Oncorhynchus nerka*) (Major and Mighell 1967).

It has been established by a number of researchers that sauger are eurythermal although considered a cool water species. At TVA's Colbert Steam Plant in northwest Alabama, Wrenn (1975) noted that from November to June sauger seemed to prefer the heated discharge zone when water temperature was below 30 C, possibly because of increased water flow and concentrations of prey species. Dryer and Benson (1956) observed large numbers of sauger feeding exclusively on shad during the winter in the discharge at TVA's Johnsonville Steam Plant. Walburg (1969) caught greater numbers of sauger when the water temperatures was between 4.4 and 15 C, and Dendy (1945) collected fewest fish when the temperatures were above 20 C. A thermal preference range was determined to be approximately 22.2-27.8 C for sauger from the Wabash River in Indiana (Gammon 1971).

Opitmum conditions for producing a thermal barrier to migratory fish would include a relatively high discharge volume with a large thermal rise (i.e., the difference between ambient and discharge temperatures) emptying into a narrow body of water so that the thermal plume occupied a large cross sectional area. Both of the previously mentioned TVA steam plants have a thermal rise of approximately 7.2 C, and the reservoirs (Pickwick and Kentucky, respectively) are broad, deep, and considered warm water systems. The thermal barrier criteria appear to be more closely met at TVA's Bull Run Steam Plant (Fig. 1) which has a thermal rise of approximately 10.5 C and discharges into Melton Hill Reservoir which at the plant site is relatively shallow, narrow, and cold.

Therefore, a fish movement study was conducted at this site to determine if migrating sauger were blocked by thermal discharges from the plant. This potamodromous, cool water species was selected because it is the most common migratory fish in the Clinch River. In the Tennessee Valley, sauger migrations typically occur from December through February. Gill netting and larval fish data in Melton Hill Reservoir suggest that spawning occurs during the months of April or May upstream of the plant.

MATERIALS AND METHODS

Sauger were collected below Melton Hill Dam, and tagged and released approximately 7.2 km below Bull Run Steam Plant. Gill nets and electrofishing gear were used to recapture tagged fish in the steam plant discharge basin and from a thermally unin-

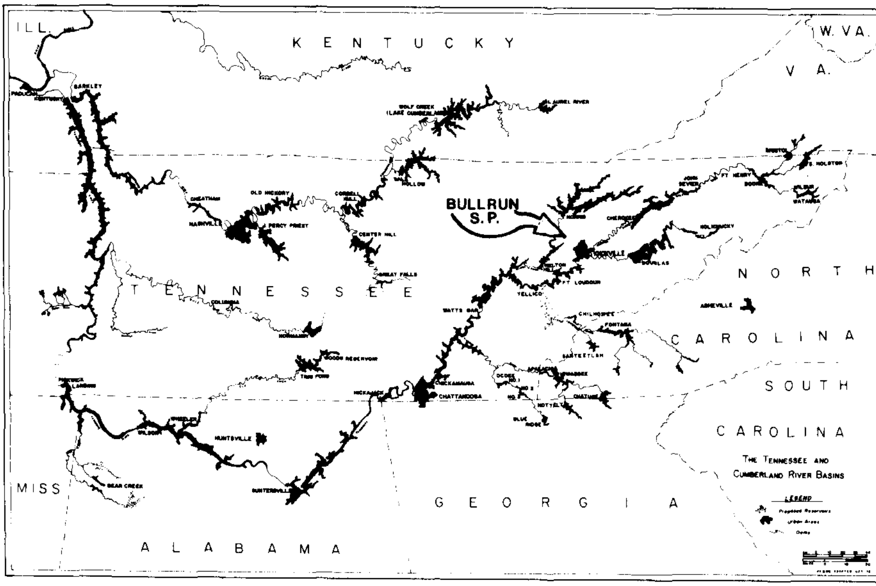

Fig. 1. The location of Bull Run Steam Plant on Melton Hill Reservoir (Clinch River Mile 48) within the Tennessee River Basin.

fluenced area upstream of the discharge. The investigation was conducted during December 1974 through April 1975 and January to March 1976.

Characteristics of the Bull Run Steam Plant and Discharge

Bull Run Steam Plant is located on the left bank of Melton Hill Reservoir in Anderson County, Tennessee, at Clinch River Mile (CRM) 48 (Fig. 2). It is a single unit fossil-fuel plant which began commercial operation in June 1967 with a total electrical generating capacity of 950 megawatts. Condenser water for the once-through cooling system is restricted to deep stratum withdrawal from the reservoir by underwater dams and a skimmer wall. Under full-load conditions, the steam plant uses 26 m^3s^{-1} of cooling water. This is heated to approximately 10.5 C above ambient during condenser passage and is discharged via a channel into Melton Hill Reservoir. This channel consists of an upper dredged section approximately 274 m long and a lower diked section approximately 305 m long which forms an embayment on the east shore of the reservoir. The dredged section has a surface width of 30.5 m with a depth of 4.9 m, and the lower section is approximately 76 m wide with depths to 7 m.

The topography of the reservoir in the vicinity of the discharge outlet is characterized by a main river channel approximately 152 m wide and 9 m deep on the plant (i.e., left) side and shallow area from 30.5-122 m in width extending from CRM 48.1 downstream to CRM 45.5 on the right bank (Fig. 2). There are several small, shallow embayments along this reach. Three km downstream from the plant the river turns westward and enters a wide, shallow valley inundated by the reservoir. Here the river channel runs through the center of the valley and is flanked on both sides by shallow areas which vary in depth from 0.6-1.5 m.

Melton Hill Reservoir Flows

The flow past the plant is primarily dependent upon the releases from Norris Dam located at CRM 79.7. The hypolimnetic discharge from Norris produces cold temperatures in Melton Hill from late spring until mid-autumn. The monthly average discharges from Norris Dam were usually lowest during April (71.9 m^3s^{-1}) and highest during January (194.7 m^3s^{-1}) with a 7 day, 10-yr low flow recurrence interval estimated to be 1.7 m^3s^{-1} (Waldrop and Johnson 1976, Part I). The maximum discharge is 1,110 m^3s^{-1} and the minimum is essentially zero.

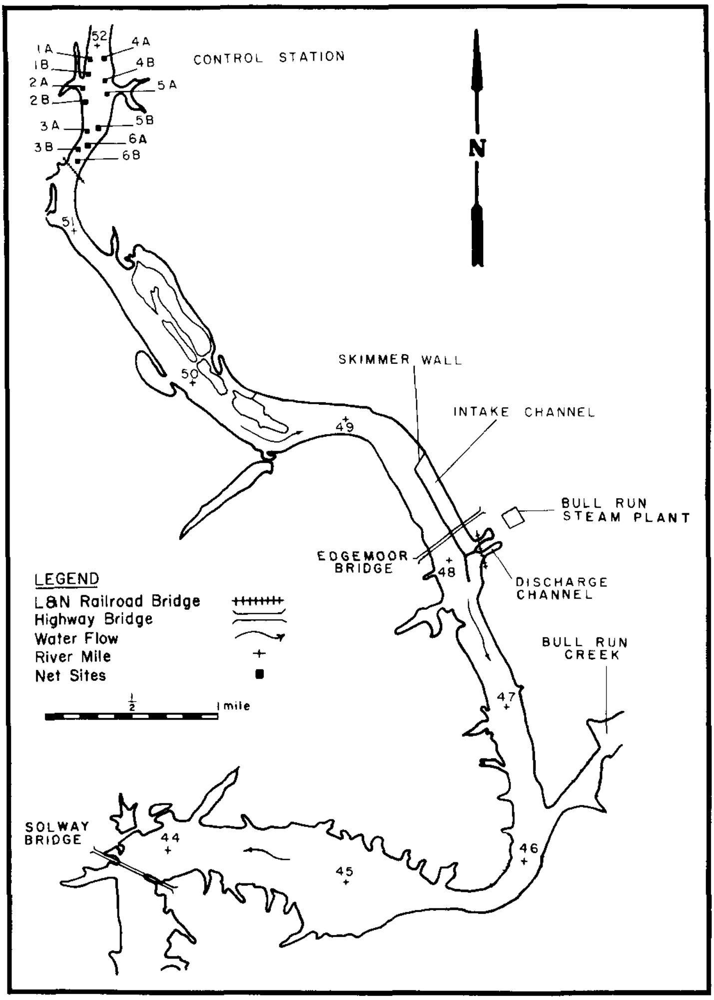

Fig. 2. The location of Bull Run Steam Plant in relation to Solway Bridge and gill net sites at the upstream sampling station on Melton Hill Reservoir.

Characteristics of the Thermal Plume

Under moderate conditions (the plant generating about 900 Mw and average flow past the plant approximately 254.9 m^3s^{-1}) the thermal plume emerges from the discharge channel near the surface and moves across the reservoir into the shallow overbank area where surface temperatures are about 7 C higher than ambient (*ibid.*). Under these conditions the plume migrates slightly upstream near the right bank where the flow is considerably lower than in the main channel. Temperatures in the discharge plume decline between the surface and 1.5 m depth and with increased distance downstream (Fig. 3). As a result, plant-induced temperatures at the 1.5 m depth drop to approximately 3C above ambient within about 550 m of the mouth of the discharge channel.

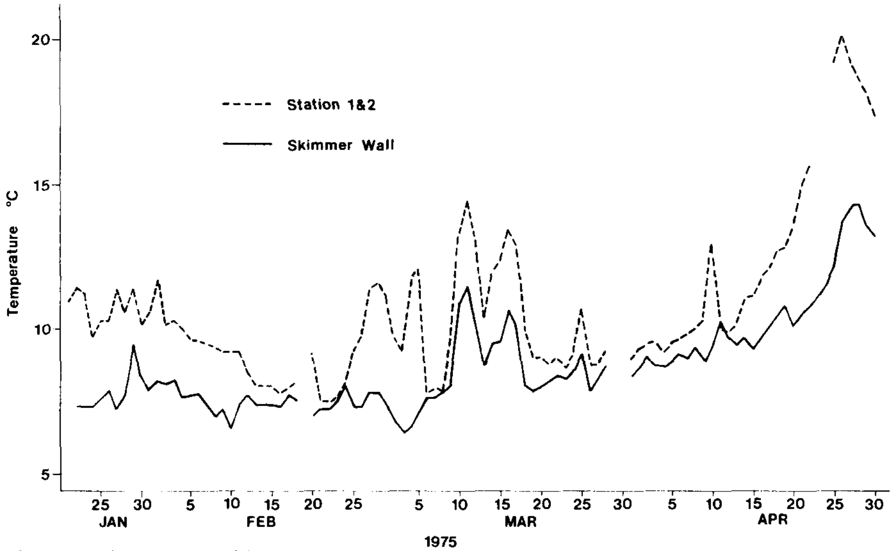

Fig. 3 Daily mean ambient temperatures upstream of the discharge and plume temperatures 1.9 km downstream of Bull Run Steam Plant in Melton Hill Reservoir (20 January through 30 April 1975).

During dry years the spring filling of Norris Reservoir results in no releases for several days or even weeks. When Norris is not discharging, the Bull Run thermal plume can migrate over 3.2 km upstream in 20 h (Waldrop and Johnson 1976, Part II). After 24 h, warm water can be approximately 6.4 km upstream, and the plume can reach to depths of aproximately 5.5 m, 183 m downstream (*ibid.*).

Sample Methods

Nets used to obtain sauger for tagging were fished at night and tended every 2 h to reduce the possibility of mortality. Throughout the study sinking nylon gill nets measuring 30.5 m by 2.4 m with 3.8 cm bar mesh were used. Most of the sauger tagged during this study were collected below Melton Hill Dam (CRM 23.3) and released at the Solway Bridge (CRM 43.8), approximately 6.7 km below the steam plant (Fig. 2). Early in the study sauger were also captured in an area immediately below Norris Dam (CRM 79.7) and released downstream immediately above Melton Hill Dam. Standard, serially numbered, Floy T-bar bags were used to mark the fish. Information including date, tag number, and location of initial capture and release was recorded. A message printed on each tag requested sport fishermen to return the tag and pertinent information to TVA.

Recapture of tagged fish was also accomplished with the use of gill nets and a boat-mounted electrofishing unit. During the winter of 1974-75, gill nets were set in the lower section of the discharge basin at Bull Run Steam Plant and in a thermally uninfluenced area (CRM 51.4 to 52.1) above the plant (Fig. 2). Six nets were set at each station for a 1 wk period each month. These nets were tended once each day during the 5 day sample period.

Up to 6 additional gill nets were used for the recapture of tagged sauger during 1976. These were fished in the main channel (CRM 48.6) near the skimmer wall intake of the steam plant (Fig. 2). Gill nets located in this area were tended once each day and left in the water for a period of 15 days. Continuous recording underwater thermometers located near these net sites allowed us to determine that upstream migration of the thermal plume did not occur during the 15 day sample period.

The electrofishing unit used to collect sauger consisted of a portable 230 volt, 3.5 kw, AC generator, and a rectifier which converted the current to pulsed (180-360 Hz) DC. Current entered the water through electrodes suspended from booms attached to the fiont of the boat. Electrofishing samples were collected 2 days a week on a biweekly schedule when gill nets were not being fished. Electrofishing samples were collected from the Bull Run discharge and from a thermally uninfluenced area (CRM 50.5 to 51.5) immediately below the upstream gill netting station.

Water temperature data used during the study were collected at permanently located stations in the reservoir. Two of these stations on each bank) were located at CRM 46.8 (approximately 1.6 km below the discharge outflow). A third station was located on the skimmer wall for the purpose of recording ambient temperature. Data from these thermistors were transmitted electronically to a computer where the information was compiled. Temperatures were recorded hourly and minimum, maximum, and average daily temperatures were computed for each 24 h period.

We wish to express our gratitude to Tennessee Valley Authority's Division of Water Management, Water Systems Developmnt Branch, Norris, Tennessee, for their assistance in collecting and compiling the temperature and flow data; in particular, thanks is expressed to B. J. Clift for his help in obtaining the data and photograph.

RESULTS AND DISCUSSION

During the first tagging period (December 1974 to February 1975) 203 sauger were tagged and released below Bull Run Steam Plant. It appeared that the peak sauger migration occurred during 23-30 January (Table 1). After 4 mo of sampling, 30 sauger

Table 1. Number of sauger tagged and recaptured in Melton Hill Reservoir near Bull Run Steam Plant (December 1974 through February 1975 and January 1976).

Dates of Release	*Number Tagged*	*Number and (Percent) Recaptured*	*Number and (Percent) Recaptured above Plant*	*Range Days Out*	*Mean Days Out*
1974-75					
12/16/74	3	1 (33)	—	—	—
12/17-19/74	1	1 (100)	1 (100)	58	58
1/ 9-10/75	1	—	—	—	—
1/23/75	25	1 (4)	—	—	—
1/27/75	42	9 (21)	4 (44)	10- 56	35.3
1/28/75	58	13 (22)	8 (61)	—	44.3
1/29/75	37	2 (5)	1 (50)	15	15
1/30/75	18	3 (16)	1 (33)	54	54
2/26/75	10	—	—	—	—
2/27/75	8	—	—	—	—
Subtotal	203	30 (14)	15 (50)	8-127	41.5
1976					
1/ 6/76	25	5 (20)	3 (60)	7- 22	13.8
1/12/76	7	—	—	—	—
1/14/76	13	—	—	—	—
1/15/76	11	—	—	—	—
Subtotal	56	5 (9)	3 (60)	7- 22	13.8

(14.8%) were recaptured. Eleven of these sauger had moved 6.7 km upstream into the plant's discharge basin, and 4 were recaptured upstream of the plant in ambient temperature water. The other 15 sauger either moved downstream or were caught before reaching the steam plant. The time period between release and recapture ranged from 9 to 92 days with a mean of 40.7 days.

None of the 4 recaptured sauger were taken upstream of the plant before it experienced a shutdown, but 6 of the 11 sauger which moved into the discharge basin were caught while the plant was operating (Fig. 4). Effluent temperatures during the 24 day liberty period (20 January to 13 February 1975) for these 6 fish averaged 9.8 C above ambient, and an average river flow past the plant of 236.9 m^3s^{-1} (Table 2) allowed the thermal plume to reach the opposite shore of the reservoir.

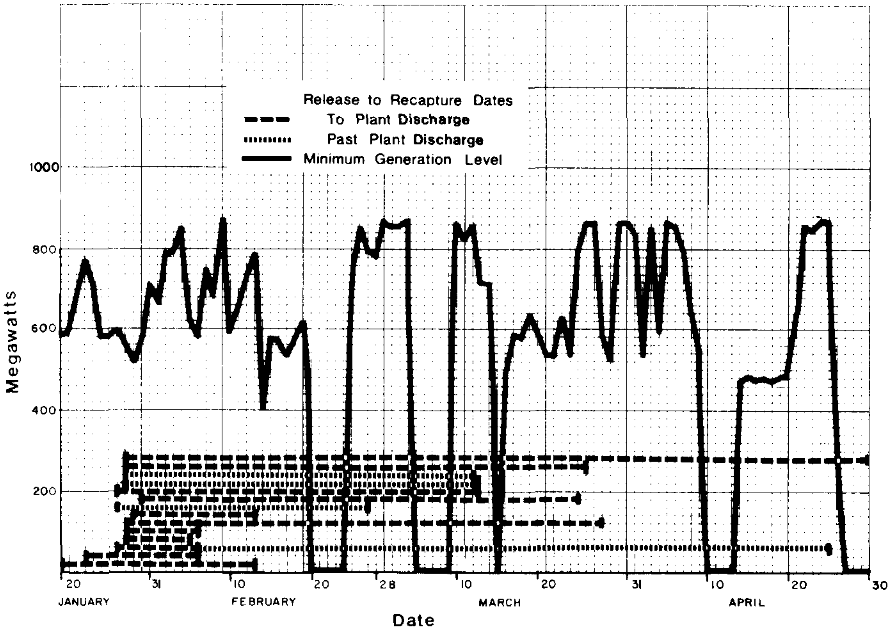

Fig. 4. Bull Run Steam Plant minimum generation levels versus sauger movements to or past the plant from 20 January through 30 April 1975.

Because none of the recaptured fish had moved upstream into ambient temperature water while the plant was continuously operating, it was felt that further study was needed. Therefore, during January 1976, 56 additional sauger were tagged and released below Bull Run Steam Plant. The peak spawning migration could not be determined during this phase because the effort was concentrated over a short period of time. Three of the sauger (5.4%) were later recaptured upstream of the plant before a shutdown occurred (Fig. 5). The distance moved by the these 3 fish was 13 km, and it took a mean of 8.7 days. Water temperature at the discharge over the 12 day period (6-17 January 1976) averaged 10.3 C above ambient while 1.9 km below the plant there was a 2.4 C increase on the left bank and 2.1 C increase on the right bank. The average river flow during this period was 150.5 m^3s^{-1}.

During sampling in the discharge station, 4 sauger (1 on 27 January 1976 and 3 on 28 January 1976) were tagged and released. Each of these was recaptured the following day in the discharge, and one sauger was released and recaptured on 2 successive days (Fig. 5). This may have been the result of fish drifting back into the nets shortly after release, or it may suggest that sauger seek thermally enriched water at certain times and remain in it, probably to feed on shad, for an undetermined period. The steam plant was in operation over the entire 4 day period, and the average temperature at the point of discharge was 9.7 C above ambient.

One sauger moved from the upstream uninfluenced area downstream past the plant while a thermal effluent was being discharged. This fish was tagged on 29 January 1976, and it was recaptured on 17 March 1977, at CRM 46.3 in the thermally enriched left bank section at the mouth of Bull Run Creek (Fig 2). This recapture indicates that there was no permanent barrier to movement downstream past the discharge. The steam plant was operating continuously during this time, and the temperature increase at the monitoring station on the left bank just upstream from the recapture point ranged from 1.1 to 6.1 C and averaged 4.2 C.

SUMMARY

It was apparent from this 2 yr study that the heated discharge from Bull Run Steam Plant posed no significant problem to sauger migrations in Melton Hill Reservoir. Data

Table 2. Daily average water flows in Melton Hill Reservoir near Bull Run Steam Plant (20 January 1975, through 30 April 1975).

Date	*River Flow* (m^3s^{-1})	*Date*	*River Flow* (m^3s^{-1})	*Date*	*River Flow* (m^3s^{-1})
1975					
Jan. 20	190.3	Feb. 23	234.2	Mar. 29	492.8
21	170.8	24	261.9	30	623.0
22	165.4	25	250.3	31	484.3
23	204.2	26	248.1		
24	200.5	27	190.0	Apr. 1	552.2
25	229.9	28	189.5	2	591.9
26	150.9			3	586.2
27	158.0	Mar. 1	179.5	4	523.9
28	184.4	2	156.6	5	467.3
29	237.0	3	154.6	6	464.4
30	239.0	4	145.8	7	407.8
31	236.5	5	154.6	8	348.3
		6	134.8	9	294.5
Feb. 1	235.3	7	72.8	10	264.5
2	264.5	8	156.3	11	258.6
3	253.2	9	8.2	12	218.1
4	254.9	10	13.2	13	218.1
5	267.3	11	16.3	14	216.6
6	256.6	12	123.8	15	215.2
7	249.2	13	205.9	16	214.1
8	248.6	14	203.1	17	214.4
9	247.5	15	56.1	18	218.6
10	245.5	16	27.1	19	217.5
11	279.8	17	283.2	20	216.4
12	354.0	18	305.9	21	139.9
13	399.3	19	305.9	22	108.2
14	424.8	20	376.6	23	108.2
15	424.8	21	433.3	24	107.9
16	421.9	22	421.9	25	77.9
17	430.5	23	436.1	26	77.3
18	376.7	24	354.0	27	76.5
19	281.8	25	393.6	28	108.5
20	246.1	26	506.9	29	108.7
21	245.3	27	586.2	30	107.6
22	243.8	28	572.1		
1976					
Jan. 5	113.1	14	—	23	199.7
6	101.8	15	214.8	24	158.2
7	48.6	16	151.0	25	148.3
8	130.1	17	133.6	26	137.7
9	197.3	18	121.2	27	40.2
10	—	19	146.9	28	45.0
11	129.8	20	158.8	29	51.5
12	199.3	21	151.8	30	4.0
13	199.1	22	196.5	31	14.4

collected during 1975 indicated that sauger moved into and remained in the discharge while the plant was operating. Studies conducted during 1976 indicated that the tagged fish had little difficulty continuing their movement past the thermal plume to the colder upper reaches of the reservoir and then returning downstream. It remains unclear whether the heated effluent was a temporary hindrance and could have caused some delay in movement, and whether sauger move under, around, or through the thermal plume.

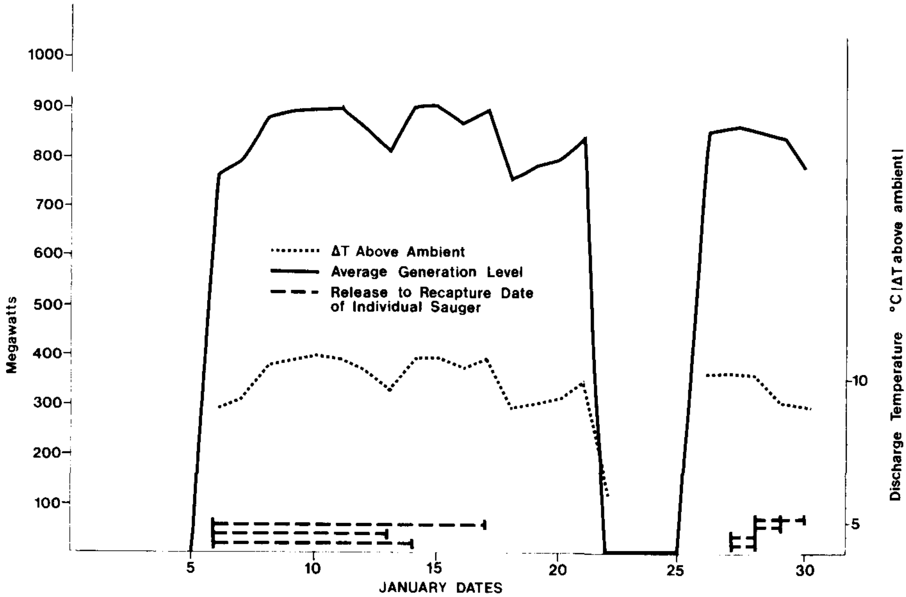

Fig. 5. Bull Run Steam Plant average generation levels, ΔT of intake and discharge water temperatures and sauger movements past the plant and into the discharge basin (5 January through 30 January 1976).

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