WSRC-RP-91-043

STUDY PLAN FOR CONDUCTING A SECTION 316(a) DEMONSTRATION: K-REACTOR COOLING TOWER, SAVANNAH RIVER SITE

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February 1991

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Savannah River Site
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DISCLAIMER

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INTRODUCTION

The K Reactor at the Savannah River Site (SRS) began operation in 1954. The K-Reactor pumped secondary cooling water from the Savannah River and discharged directly to the Indian Grave Branch, a tributary of Pen Branch which flows to the Savannah River. During earlier operations, the temperature and discharge rates of cooling water from the K-Reactor were up to approximately 70°C and 400 cfs, substantially altering the thermal and flow regimes of this stream. These discharges resulted in adverse impacts to the receiving stream and wetlands along the receiving stream. As a component of a Consent Order (84-4-W as amended) with the South Carolina Department of Health and Environmental Control (SCDHEC), the Department of Energy (DOE) evaluated the alternatives for cooling thermal effluents from K Reactor and concluded that a natural draft recirculating cooling tower should be constructed (DOE 1987).

The cooling tower will mitigate thermal and flow factors that resulted in the previous impacts to the Indian Grave/Pen Branch ecosystem. The gravity flow, natural draft, recirculating cooling tower system will be located approximately 1.3 km downstream from K-Reactor. Blowdown at approximately 45 cfs will be discharged from the cooling tower to Indian Grave Branch via the existing discharge canal (Figure 1). K-Reactor cooling tower blowdown will increase the average stream discharge in Indian Grave Branch from approximately 10 cfs to approximately 55 cfs (Paller et al. 1989).

A predictive 316(a) demonstration (USEPA 1977) that described the expected effects of the proposed cooling tower blowdown on aquatic life in Indian Grave/Pen Branch was completed in 1989 (Paller et al. 1989). Temperature modeling studies included in the demonstration indicated that cooling tower blowdown temperatures are not expected to exceed the 32.2°C maximum South Carolina Class B water quality criterion (USEPA 1977) but will sometimes result in temperature increases of more than 2.8 oC above the ambient stream temperature (Delta-T). Therefore, as required by SCDHEC under permit No. SC0044903, a variance to water quality standards must be obtained and a 316(a) Demonstration will be conducted after installation of the cooling tower to demonstrate that the temperature requirements in the Clean Water Act are more stringent than necessary to ensure the protection and propagation of balanced populations of indigenous aquatic life in Pen Branch and Indian Grave Branch.

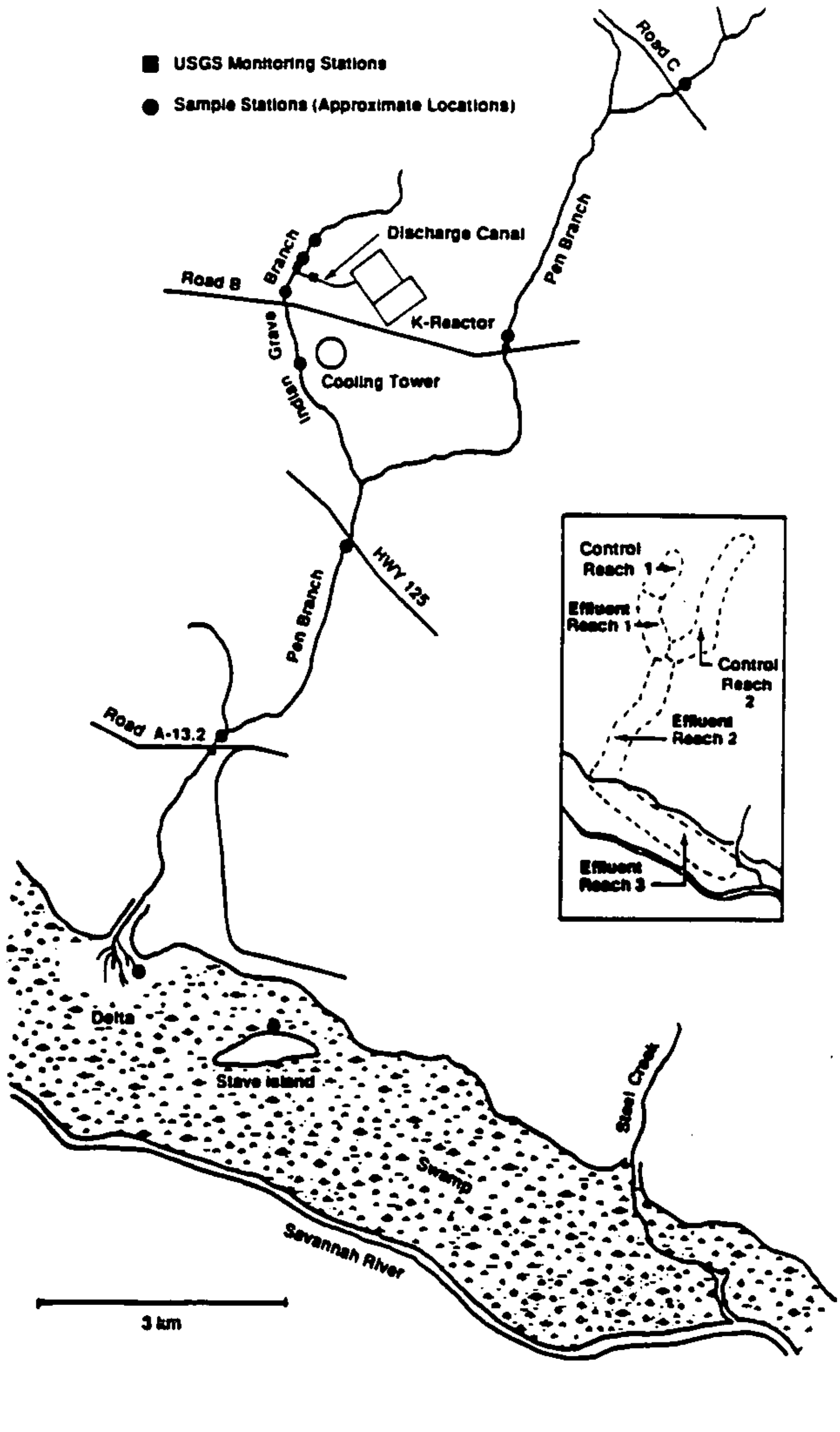

Figure 1. Proposed location of biological sampling stations on Indian Grave Branch and Pen Branch.

OBJECTIVES

The purpose of the proposed biological monitoring program is to provide information that will support a Section 316(a) Demonstration for Indian Grave Branch and Pen Branch when K-Reactor is operated with the recirculating cooling tower. The data will be used to determine that Indian Grave Branch and Pen Branch support Balanced Indigenous Communities when K-Reactor is operated with a recirculating cooling tower.

Balanced Indigenous Communities of aquatic organisms are communities that:

1) are not dominated by pollution tolerant organisms,

2) have diversity and productivity characteristic of streams of the region,

3) contain representatives of all trophic groups expected in a stream of this region, and

4) contain biotic communities that are self-maintaining (successfully reproducing).

The information collected during this study will be evaluated with respect to these four criteria to establish that a Balanced Indigenous Community of aquatic life exists, or is developing, in Indian Grave Branch and Pen Branch. It is notable that the portions of the Pen Branch drainage that previously received thermal discharges are undergoing post-thermal ecological succession and will be changing during the course of this study due to natural successional processes.

INITIATION AND DURATION OF SAMPLING

Field sampling will be initiated within 60 days after the K-Reactor recirculating cooling tower begins operating. The K-Reactor cooling tower is scheduled to begin operating no later than December 1992. Sampling will continue for two years. The results of this study will be reported to SCDHEC 10 (ten) months following completion of the two year field study.

GENERAL STUDY DESIGN

Water from the K-Reactor cooling tower will be discharged via outfall K-18 to Indian Grave Branch, which joins Pen Branch approximately 3 km downstream from the outfall (Figure 1). After the confluence, Pen Branch flows approximately 7 km before discharging into the Savannah River floodplain swamp where it has formed a delta. Pen Branch flow spreads over the delta and continues through the swamp until joining the flow of Steel Creek and discharging into the Savannah River, approximately 10 km from the Pen Branch delta. The area to be assessed for biological effects from the thermal effluents will only extend slightly beyond the Pen Branch delta, rather than to the Savannah River.

The assessment area (from the K-18 outfall to the Savannah River) will be divided into three cooling tower effluent influenced stream reaches on the basis of distinct stream gradients (Figure 1). Effluent Reach 1 (ER-1) will include the portion of Indian Grave Branch from the K-18 outfall to the confluence of Indian Grave Branch and Pen Branch), Effluent Reach 2 (ER-2) will include the mid-reaches of Pen Branch (from the confluence to the mouth of the delta), and Effluent Reach 3 (ER-3) will include the open canopy delta where Pen Branch enters the Savannah River floodplain swamp and the closed canopy swamp forest located between the delta and Steel Creek (Figure 1). The study will also include two control reaches that will not be directly impacted by cooling tower blowdown:

Control Reach 1 (CR-1), Indian Grave Branch above the K-18 outfall, and Control Reach 2 (CR-2), Pen Branch above the confluence of Pen Branch and Indian Grave Branch. Except where specified otherwise, there will be two sample stations in each of the five sample reaches and sufficient replication at each sample station to characterize within-station variability.

This study will follow the U.S. Environmental Protection Agency (USEPA 1977) draft guidelines for 316(a) demonstrations. A summary of the sampling plan is shown in Table 1. The data to be collected for each of the biological categories listed in the guidelines are described in the following sections.

PHYTOPLANKTON

Phytoplankton will not be sampled in Indian Grave Branch and Pen Branch because these streams are low potential impact areas for phytoplankton. Both Indian Grave Branch and Pen Branch (in its upper and mid-reaches) are relatively shallow and turbulent streams that offer little opportunity for phytoplankton growth. Further downstream, where Pen Branch enters the delta and swamp, the food base is primarily detrital material and periphyton rather than phytoplankton.

PERIPHYTON

While not included in the USEPA (1977) draft guidelines, periphyton will be monitored in the Pen Branch/Indian Grave Branch 316(a) demonstration. It is anticipated that periphyton may make a significant contribution to the productivity of open canopy reaches of Pen Branch and constitute a food source for some invertebrate species. In addition, there is precedent for using periphyton taxonomy to evaluate stream quality and environmental impact.

The complexity involved with sampling natural substrates for periphyton and ensuring adequate replication of samples has led to the use of artificial substrates for monitoring (APHA, 1985). While the species assemblage and abundance of periphyton on artificial substrates is not necessarily representative of that on natural substrates, artificial substrates provide a uniform and quantifiable surface on which periphyton may attach and make it possible to control important factors such as depth of substrate and orientation to light and current.

Periphyton Monitoring Program

Periphyton will be sampled quarterly with periphytometers. Each floating periphytometer will hold glass slides parallel to the flow of the water. Replicate periphytometers will be deployed at each sample station. The slides will be left in place for approximately 30 days before being collected and replaced with clean slides. The slides will subsequently be brought to the laboratory and analyzed for ash free dry mass, chlorophyll a, and taxonomic composition.

Variables to be determined

1. Mean (± Standard Error) ash free dry mass
2. Mean (± Standard Error) chlorophyll-a concentration
3. Identification and relative abundance (% based on number) of dominant taxa

Table 1. Sample methods, sample locations, and frequency of sampling proposed for Pen Branch 316 demonstration.

Sample Method	Sample Locations* Control 1	Control 2	Effluent 1	Effluent 2	Effluent 3	Frequency Continuous	Monthly	Quarterly	Semiannually
PERIPHYTON									
Periphytometer	x	x	x	x	x			x	
HABITAT HORMERS**									
Belt transect				x	x				x***
MACROINVERTRBRATES									
Hester-Dendy	x	x	x	x	x		x		
Kick net	x	x	x	x	x				x
FISHERIES									
Electrofishing	x	x	x	x				x	
WATER QUALITY									
Temperature	x	x	x	x	x	x			
Current velocity profile	x	x	x	x	x			x	
Stream morphometry	x	x	x	x	x			x	
Discharge (USGS)	x	x			x	x			
Temperature (grab) ****	x	x	x	x	x		x	x	
Oxygen concentration (grab) ***	x	x	x	x	x		x	x	
pH (grab) ****	x	x	x	x	x		x	x	
Conductivity (grab) ****	x	x	x	x	x		x	x	

* See Figure 1.
** Riparian and instream herbaceous and woody vegetation.
*** Sampled twice during growing season.
**** Grab samples taken concurrently with all biological samples.

Data Analysis

Periphyton community structure will be analyzed to determine if the periphyton community is dominated by thermally tolerant organisms. Ash free dry mass and chlorophyll-a concentration will be analyzed for patterns indicative of degradation (e.g., trends of decline). Seasonal patterns will be monitored and compared with normal seasonal changes (as indicated by data from the control reaches) to determine the influence of altered temperature regimes on periphyton.

ZOOPLANKTON

Zooplankton are functionally important in lentic and some slow flowing lotic systems where they provide the primary trophic link between phytoplankton and secondary consumers. They are not, however, expected to be functionally important in Indian Grave Branch and Pen Branch where detrital material comprises the food base and macroinvertebrates play a predominant role in nutrient cycling. In addition, current velocities are too high throughout most of the Indian Grave/Pen Branch system for substantial zooplankton populations to develop.

HABITAT FORMERS

Habitat formers in the study area include riparian and instream herbaceous and woody vegetation that determine the structure and productivity of the habitat used by aquatic organisms. Habitat former communities are best developed in Effluent Reach 3 and, to a lesser extent, Effluent Reach 2. Open canopy wetlands in these reaches support well developed communities of emergent and submerged macrophytes as well as woody plants such as buttonbush and willow, while closed canopy areas are generally dominated by a cypress-tupelo overstory. Habitat former communities in Effluent Reaches 2 and 3 have been impacted by previous reactor operations. Effluent Reach 1 and Control Reaches 1 and 2 are comparatively narrow and overshadowed by bottomland hardwoods. Because these three reaches support little riparian and aquatic vegetation, they will not be included in the habitat former surveys.

Habitat Formers Monitoring Program

Vegetation surveys will be conducted along multiple belt transects in Effluent Reaches 2 and 3 (Figure 1). Transect length and width and placement will be determined following pilot surveys but will be sufficient to characterize the vascular flora of the Pen Branch wetlands. The cover of the aquatic and wetland overstory, shrub, and herbaceous species will be determined in each transect. Transects will be sampled at least twice during the growing season (March-October).

Variables To Be Determined

1. Taxa lists during each sampling interval
2. Taxa specific areal coverage of overstory and shrub species (m2/ha)
3. Areal coverage of total herbaceous vegetation (m2/ha)
4. Taxa specific areal coverage of dominant herbaceous vegetation (m2/ha)
5. Percent cover of herbaceous vegetation, scrub, vegetation, overstory vegetation, open water, and mudflat

Data Analysis

Temporal changes in vegetation cover and species composition will be analyzed for trends indicative of successional changes or changes attributable to cooling tower effluents. Data from vegetation studies that are currently ongoing will be incorporated into these analysis to indicate preoperational conditions. Maps will be compared across time and correlated with discharge and temperature information to assess habitat changes resulting from increases in discharge or altered temperature regimes. Vegetation survey data will be correlated with fisheries and macroinvertebrate data to assess the effects of habitat changes on fish and macroinvertebrate communities.

Taxa lists, species composition and vegetation cover during cooling tower operation will be compared with historical data from Pen Branch to assess long term changes in habitat former communities.

MACROINVERTEBRATES

Macroinvertebrates will be sampled quantitatively with artificial substrates and qualitatively with kick nets. This combination of methods will provide quantitative data with adequate replication for statistical analysis and generate reasonably complete taxonomic lists.

Macroinvertebrate Monitoring Program

Macroinvertebrates will be sampled monthly at each station (Figure 1) using Hester-Dendy multiplate samplers. Replicate samplers will be placed at each station and allowed to colonize for approximately 30 days before collection. To supplement the species lists generated from the multiplate sampler data, qualitative macroinvertebrate samples will be collected semi-annually at each station using kick nets. All available natural substrates (macrophytes, sediments, snags, leaf packs, root mats, etc.) will be sampled when collecting kick net samples.

Variables To Be Determined

1. Taxa lists at each station
2. Mean densities (+SE) on artificial substrates (no./m2).
3. Relative abundance (%) of major taxonomic groups
4. Relative abundance (%) of functional feeding groups
5. Biomass as ash free dry mass (g/m2)
6. Biomass of functional feeding groups (g/m2).

Data Analysis

Macroinvertebrate data will be analyzed to determine if there are significant temporal trends that could indicate effluent related effects. Macroinvertebrate community structure in the effluent receiving reaches will be compared to community structure in other SRS streams of similar size and habitat type to determine if Indian Grave and Pen Branch support balanced indigenous macroinvertebrate communities. Macroinvertebrate data recorded during cooling tower operation will also be compared with historical data to assess long term changes in the macroinvertebrate communities.

FISH

Adult and juvenile life stages will be sampled to permit the assessment of recruitment, community structure, and persistence of adult populations.

Juvenile/Adult Fish Monitoring Program

Electrofishing will be used to collect adult and juvenile fish from each sample station. Because of large differences in stream size and depth among sample stations, it will be necessary to use both backpack and boat electrofishing to sample Indian Grave Branch and Pen Branch. Backpack electrofishing will be used to sample the smaller headwater sample stations and barge or boat electrofishing will be used to sample deeper and wider sample stations. Each sample station will include at least two stream segments. Multiple passes will be made at each stream segment to obtain accurate assessments of community structure. Electrofishing samples will be collected quarterly to provide information on seasonal changes in community structure. More frequent sampling could result in progressive habitat degradation and community disturbance at the sample stations. Captured fish will be measured, weighed, examined for abnormalities and disease, and a limited number will be sacrificed to provide data on food habits and age.

Variables to be determined

1. Electrofishing mean (± Standard Error) catch per unit effort (no./100 m)
2. Species lists of adult and juvenile fish
3. Species richness of adult and juvenile fish
4. Relative abundance (%) of adult and juvenile fish
5. Length-frequency distributions of dominant species
6. Age structure of dominant species (derived from scale and otolith analysis)
7. Mean (± Standard Error) condition factors (K) of dominant species.
8. Mean stomach fullness (± Standard Error) and frequency of occurrence of food items for dominant species

Data Analysis

Fish community structure in the effluent influenced reaches will be compared to community structure in relatively unimpacted SRS streams of similar size and habitat type to determine if Indian Grave and Pen Branch support balanced indigenous fish communities (data from unimpacted streams is currently being collected). Temporal trends in various community and population metrics will be analyzed for evidence of effects related to effluent discharge. Recruitment success will be evaluated on the basis of length-frequency distributions and age structure. Temporal trends in juvenile fish abundance at control and effluent influenced sites will be compared to determine if the timing and success of recruitment have been altered by reactor operations. Community structure will be analyzed with respect to the temperature requirements of southeastern stream fishes and in relation to measured temperature levels in the receiving stream reaches. Habitat suitability for key species will be analyzed by comparing published current velocity and substrate requirements with current velocities and substrate types within the receiving stream.

WATER QUALITY

Water quality measurements associated with the biological monitoring program will focus on three objectives:

1) collection of temperature data needed to satisfy 316(a) demonstration requirements and evaluate potential thermal effects on stream communities,
2) collection of current velocity, discharge, and stream morphometry data needed to evaluate potential effects of increased flow resulting from the addition of cooling tower blowdown to Indian Grave Branch and Pen Branch, and
3) collection of basic water quality data (pH, dissolved oxygen concentration, etc.) needed to support the interpretation of biological data.

Additional water quality data will be collected as specified in the draft NPDES permit (SC0044903).

Temperature Monitoring

Instream temperatures will be monitored at a minimum of one location in each of the five sampling reaches and in the K-Reactor effluent canal by continuous recording devices. This continuously recorded data will be obtained from USGS monitoring stations and/or from continuous recording devices monitored by SRS. In addition, grab temperature data will be collected concurrently with fisheries and macroinvertebrate sampling.

Stream Discharge Monitoring And Stream Morphometry

Instream flow data will include the continuously recorded discharge data collected from USGS stations in Pen Branch, Indian Grave Branch, and the K-Reactor discharge canal (Figure 1), plus the current velocity and stream morphometry data collected by SRS field personnel. Current velocity profiles, stream depth profiles, stream width, and substrate type will be obtained at each sample station.

Basic Water Quality Monitoring

Several water quality parameters (dissolved oxygen concentration, pH, and conductivity) will be measured concurrently with fisheries and macroinvertebrate sampling.

Variables To Be Determined

1. Average daily, maximum and minimum temperatures in each of the five stream reaches Temperature differences between control and effluent influenced reaches
2. Pre- and post-cooling tower differences in stream temperature
3. Current velocity profiles, depth profiles, stream discharge, and usable habitat area at different stream discharge levels during cooling tower operation
4. Mean (± Standard Error, max, min) dissolved oxygen concentration, pH, and conductivity at each sample station

Data Analysis

Average and maximum temperatures will be determined in all stream reaches and average and maximum Delta-Ts will be determined in stream reaches 1, 2, and 3. Temperature, flow, and basic water quality data will be compared with various community attributes (such as species richness, abundance, and species composition) and with published limits of tolerance for stream organisms to evaluate potential influences of temperature and flow changes resulting from cooling tower operation.

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