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PRELIMINARY REPORT OF FISH IMPINGEMENT MORTALITY AT THE VIRGIL C. SUMMER NUCLEAR STATION

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EXECUTIVE SUMMARY

Introduction

This report presents the findings of an impingement mortality characterization study (IMCS) conducted at the Virgil C. Summer Nuclear Station (Summer Station) to support South Carolina Electric & Gas Company (SCE&G) in complying with the U.S. Environmental Protection Agency's (EPA's) applicable regulations implementing Section 316(b) of the Clean Water Act. Summer Station is a 972.7-megawatt (MW) nuclear-fueled steam electric power generating facility located near Jenkinsville, Fairfield County, South Carolina. The objectives of this study were to: (1) characterize existing fish impingement at the Summer Station cooling water intake structure (CWIS) based on bi-weekly sampling from 12 July 2005 through 27 June 2006; and (2) develop a preliminary estimate of annual impingement mortality, referred to as the calculation baseline, providing a reference value for evaluating Section 316(b) compliance.

The study plan was designed, approved by South Carolina Department of Health and Environmental Control, and implemented in accordance with EPA's Phase II regulations published 9 July 2004 (69 Fed. Reg. 41576). Since completion of the study, the Second U.S. Circuit Court of Appeals remanded key provisions of the Phase II rule, and in response, EPA has suspended the rule. In the meantime, all 316(b) compliance decisions are to be based on Best Professional Judgment.

Study Site

Summer Station uses Monticello Reservoir, a 6,500-acre impoundment with average hydraulic retention time of about 24 days, as the source waterbody for once-through cooling. The reservoir also serves as the upper pool for SCE&G's Fairfield Pumped Storage Facility. Cooling water is withdrawn from Monticello Reservoir via a shoreline CWIS with a design intake capacity of 767.6 million gallons per day. Intake flow passes through steel trash racks beneath a skimmer wall extending 9.5 feet below the surface, followed by 3/8-inch conventional vertical traveling screens for removing impinged debris and organisms.

Impingement Sampling Results

Impingement samples were collected using the existing debris collection basket, modified with 3/8-inch wire mesh openings to match the traveling screens. Samples were collected over 24-hour periods split into 12-hour day and night sub-samples.

Thirteen fish taxa (12 species and one hybrid), crayfish, and freshwater grass shrimp were collected in 52 total impingement samples. Fish species included shad (two species), catfish and bullheads (five species), white perch, bass and sunfish (three species), and yellow perch. Threadfin shad numerically dominated the impingement samples, comprising 50.2 percent of the total number of fish. Other abundant species in impingement samples were blue catfish, channel catfish, white perch, and yellow perch. White perch dominated impingement biomass, comprising 36.6 percent of the catch. No rare, threatened, or endangered species were impinged during the study.

The majority of impinged fish were sub-adult or young-of-year fish less than 6.7 inches total length (TL). The most abundant impinged fish, threadfin shad, were observed in size classes ranging from less than 1.5 inches to 4.7 inches TL. Impingement rates peaked from late December through February, when threadfin shad were numerically dominant. Impingement rates were higher at night in 19 of the 26 sampling events.

Calculation Baseline

A calculation baseline estimate of annual impingement mortality was determined using Monte Carlo simulation techniques. After adjustments reflecting actual plant operations during the study, the 95-percent upper confidence limit of estimated annual impingement mortality (i.e., calculation baseline) was determined to be 9,154 organisms weighing 272 pounds. This calculation baseline is representative of the once-through cooling system at Summer Station in the absence of any structural or operational controls specifically intended to reduce impingement mortality.

Baseline Valuation

Using direct replacement costs published by the American Fisheries Society, the value of all fish and shellfish impinged annually at Summer Station totals approximately $2,336. Threadfin shad, the numerically dominant species impinged represents a total replacement value of $505. Recreationally important species represent a total replacement value of $1,786.

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1. INTRODUCTION

This report presents the results of an impingement mortality characterization study (IMCS) conducted at the Virgil C. Summer Nuclear Station (Summer Station) to support South Carolina Electric & Gas Company (SCE&G) in complying with the U.S. Environmental Protection Agency's (EPA's) applicable regulations implementing Section 316(b) of the Clean Water Act. Impingement refers to the entrapment of any life stages of fish and shellfish on the outer part of a cooling water intake structure (CWIS) or against a screening device during periods of intake water withdrawal. Summer Station is a 972.7-megawatt (MW) nuclear-fueled steam electric power generating facility located near Jenkinsville, Fairfield County, South Carolina. The facility uses Monticello Reservoir as the source waterbody for a once-through cooling water system. Section 316(b) requires the location, design, construction, and capacity of CWISs to reflect best technology available (BTA) for minimizing adverse environmental impact.

The principal objectives of this IMCS are to: (1) characterize existing impingement at the Summer Station CWIS based on bi-weekly sampling conducted from 12 July 2005 through 27 June 2006; and (2) develop a preliminary estimate of annual impingement mortality occurring at the site, representative of the once-through cooling system in the absence of any structural or operational controls specifically intended to reduce impingement mortality. The annual impingement mortality estimate, referred to as the calculation baseline for Summer Station, provides a reference value for evaluating compliance with applicable Section 316(b) regulations. This estimate is considered preliminary because of the recent suspension of EPA regulations and associated uncertainty regarding future compliance requirements.

1.1 Regulatory Background

Since completion of the sampling and data analysis for this IMCS, EPA's applicable Section 316(b) regulations and guidance for Phase II existing facilities (large steam electric generating power plants) have changed as a result of litigation. Although not affecting how the IMCS was approached, this change does affect how 316(b) compliance may be determined for Summer Station and what documentation SCE&G must submit with its next National Pollutant Discharge Elimination System (NPDES) permit application.

SCE&G's Proposal for Information Collection (the study plan) was designed, reviewed by the South Carolina Department of Health and Environmental Control (SCDHEC), and implemented to meet the requirements of EPA's final rule for Phase II existing facilities published 9 July 2004 (40 CFR Part 125 Subpart J; 69 Fed. Reg. 41576). The Phase II rule required the use of BTA, consisting of design and construction technologies, operational measures, and/or restoration measures, to meet national performance standards for reducing impingement mortality, and where applicable, entrainment at affected facilities. Based on the cooling source waterbody, Monticello Reservoir, meeting EPA's definition of a reservoir (§ 125.93), Summer Station was subject to complying with EPA's performance standard for reducing impingement mortality by 80 to 95 percent from the calculation baseline but was not subject to the entrainment performance standard (§ 125.94(b)(2)). The Phase II regulations required SCE&G to perform a Comprehensive Demonstration Study (CDS), of which the IMCS was to be a part, and submit it as part of the NPDES permit renewal process.

On 26 July 2004, Riverkeeper, Inc., leading a national coalition of environmental groups, filed a lawsuit against EPA challenging the Phase II rule. The Second U.S. Circuit Court of Appeals issued its decision in the case on 25 January 2007, remanding several key provisions of the rule, including those relating to determination of BTA; performance standard ranges; cost-cost and cost-benefit compliance alternatives; the Technology Installation and Operation Plan; the restoration option; and the "independent supplier" definition.

In response to the Court's decision, EPA suspended the Phase II regulations on 20 March 2007. Pending a Federal Register notice formally suspending the rule, EPA has directed that all permits for Phase II facilities should include 316(b) conditions developed on a Best Professional Judgment basis (see 40 CFR § 401.14) (Memorandum by Benjamin Grumbles, EPA, 20 March 2007).

The Court ruling and any forthcoming EPA appeal cast uncertainty on future determination of BTA and applicable performance standards for Phase II facilities. Nevertheless, the results of this IMCS stand on their own as providing data sufficient for characterizing existing impingement mortality at Summer Station and, therefore, are appropriate for applying Best Professional Judgment to Section 316(b) compliance decisions for NPDES permitting of the cooling water discharge.

1.2 Study Approach

This study was conducted in accordance with the sampling plan outlined in SCE&G's Proposal for Information Collection (PIC) submitted to SCDHEC in June 2005 and approved in April 2006 (SCE&G, 2006). The PIC provided:

- A description of the proposed technologies and/or supplemental restoration measures to be evaluated under the CDS;
- A list and description of historical studies characterizing the physical and biological conditions in the vicinity of the cooling water intake structures and their relevance to the Summer Station IMCS;
- A summary of consultations with Federal and State resource agencies that are relevant to the study; and
- An IMCS sampling plan for field studies to support development of a scientifically valid estimate of impingement mortality at Summer Station.

The suspended Phase II 316(b) rule required that the IMCS characterize fish susceptible to impingement "in the vicinity" of the CWIS and must include:

- Taxonomic identification of fish and their life stages;
- Description of abundance and temporal/spatial characteristics;
- Characterization of annual, seasonal, and diel variations in impingement mortality (e.g., related to climate/weather differences, spawning, feeding and water column migration);
- Documentation of current impingement mortality of all life stages of fish at the facility; and
- Identification of any Federal and/or State protected species.

1.3 Report Organization

The following sections provide a description of the Summer Station facility setting, CWIS hydraulic influence, and historical background (Section 2); the IMCS study methods (Section 3); summary of plant operations during the IMCS (Section 4); and impingement sampling results (Section 5), which provide the basis for the Summer Station CWIS preliminary calculation baseline estimate (Section 6).

2. STUDY AREA DESCRIPTION

Summer Station is located 26 miles northwest of Columbia, South Carolina, in a rural area in the Piedmont physiographic province of the Broad River system of the Santee-Cooper River basin (Figure 2-1). The facility uses Monticello Reservoir as the source water body for a once-through cooling water system.

2.1 Monticello Reservoir

Monticello Reservoir is a 2,630-hectare (ha) (6,500-acres (ac)) freshwater impoundment with 82.1 kilometers (km) (51 miles) of shoreline that was built in the Frees Creek valley in 1978 to serve both as the cooling water source for Summer Station (NRC, 2004; South Carolina Lakes, 2005) and the upper pool for the Fairfield Pumped Storage Facility (FPSF) (Figures 2-1 and 2-2). Monticello Reservoir has a storage volume of 431,050 acre-ft (SCWRC, 1991); inundating most of the Frees Creek watershed in Fairfield County, or approximately 17 square miles (44 square kilometers). Average depth of the reservoir is 18 m [59 ft]; maximum depth is 38 m [125 ft]), and upstream watershed area is only 445 ha (1,100 ac) with little natural surface water inflow. The reservoir is used for maintenance of water quality, hydroelectric power generation at FPSF, industrial water supply, and recreational opportunities, and serves as habitat for fish and wildlife.

Monticello Reservoir has an average hydraulic retention time of approximately 24 days (based on the period 2000-2004). Under the suspended Phase II regulations, Monticello Reservoir meets EPA's regulatory definition of a lake or reservoir because its hydraulic retention time exceeds 7 days.

The Federal Energy Regulatory Commission (FERC) regulates water levels in Monticello Reservoir through the hydropower license for SCE&G's Parr Shoals Hydroelectric Project (FERC No. 1894), of which FPSF is a part (Figures 2-1 and 2-2). The FERC license for Parr Shoals establishes water surface elevation guidelines for the reservoir of 425.0 ft MSL (high water level) and 420.5 MSL (low water level), an operating band of 4.5 ft. Reservoir levels may fluctuate daily within this range as a result of FPSF operation (see Section 2.3).

At the upper end of Monticello Reservoir is a 121-ha (299 ac) impoundment, known as the Monticello Sub-impoundment. Although hydraulically connected to the main reservoir by a conduit that passes under SC Highway 99, the water level in this sub-impoundment is minimally influenced by FPSF operations on Monticello Reservoir proper. The sub-impoundment is managed for fishing and recreation by SCE&G and the South Carolina Department of Natural Resources (SCDNR).

2.2 Summer Station

Summer Station is a single-unit nuclear-fueled electric power generating facility located near Jenkinsville, Fairfield County, South Carolina (Figure 2-1). The facility is rated by the Department of Energy, Energy Information Administration (DOE-EIA, 2005) at 966 MW in the summer and 975 MW in the winter. The total annual energy generated is approximately 7.2 million MW-hours with an estimated 10-year average plant capacity utilization rate of 85 percent.

The facility uses a once-through cooling water system that withdraws cooling water from Monticello Reservoir via a single shoreline-positioned CWIS located at the south end of the reservoir (Figure 2-2). Debris and fish are potentially subject to impingement on the CWIS's six vertical traveling screens. Impinged items are collected at a central location for ultimate disposal; thus, as currently configured, fish are subject to 100 percent mortality. After the cooling water leaves the condensers, the heated water is conveyed to a "discharge bay" and then through a 1,000 ft discharge canal leading into Monticello Reservoir.

The CWIS is designed to withdraw water from below a skimmer wall that extends from the water surface to a depth of 9.5 ft (415.5 ft above mean sea level (MSL) at normal high water (425 ft MSL). The skimmer wall is designed to exclude floating debris from entering the cooling water system and, combined with the pump house retainer walls, to optimize withdrawal of the coolest water from the water column at the pump house. Design intake flow totals approximately 533,100 gallons per minute (gpm) or 767.6 million gallons per day (MGD). The CWIS is comprised of three pump bays each with two entrances. Each entrance is 13 feet (ft) wide and 25.5 ft high, extending from the bottom of the pump house to the bottom of the skimmer wall. Each entrance is equipped with steel trash racks with 10-inch spacing to prevent large debris from entering the intake bay, and a vertical traveling screen (mesh size ~3/8-inch) for removing debris and impinged organisms.

Under normal operations, the traveling screens are activated by timer approximately every 12 hours (hrs) or more frequently if differential pressure across the screens becomes excessive. High pressure screen wash water is used to clean the screens of debris and impinged organisms and conveys removed items to a trash sump where they are accumulated in a collection basket. The screen wash water is then returned to the intake pumps downstream of the traveling screens. As the collection basket reaches capacity its contents are discarded (about every two weeks depending on debris load), thus resulting in 100 percent mortality of impinged organisms.

2.3 Operational Setting

FPSF pumps water from its lower reservoir, Parr Reservoir, a freshwater impoundment of the mainstem Broad River, into Monticello Reservoir. Parr Reservoir was enlarged in 1977 from 750 ha (1,853 ac) to 1,780 ha (4,398 ac) for added pumped storage exchange with Monticello Reservoir and to address evaporative losses from Monticello Reservoir due to Summer Station operations (SCE&G, 2002). Storage elevation of Monticello Reservoir is typically managed by FPSF at approximately 425 ft MSL. Monticello Reservoir can experience daily fluctuations in surface elevation of up to 1.4 m (4.5 ft) due to pumped storage activities.

Operations of FPSF vary, depending on the season and system power needs. In summer, the facility generally pumps water from Parr Reservoir to Monticello Reservoir between the hours of 11:00 pm and 8:00 am and generates power by releasing water between the hours of 10:00 am and 11:00 pm. In winter, FPSF generally pumps water daily from Parr Reservoir to Monticello Reservoir between 11:00 pm and 6:00 am and generates between the hours of 6:00 am and 1:00 pm. The level of generation varies from one generator up to the maximum output of eight, depending on demand. Maximum output may not be necessary on all days. Pumping into Monticello Reservoir is normally done at maximum capacity during off-peak periods.

The Nuclear Regulatory Commission (NRC) defines "cooling pond" as a manmade impoundment that does not impede the flow of a navigable system and that is used primarily to remove waste heat from condenser water (NRC, 1996). Under this definition, Monticello Reservoir is categorized by the NRC as a cooling pond. The NRC notes that nuclear power plants with cooling ponds represent a unique subset of closed-cycle systems in that they operate as once-through plants (with large condenser flow rates), but withdraw from relatively small bodies of water created for the plant (NRC, 1996). Because cooling water is withdrawn from Monticello Reservoir by Summer Station and discharged back to the reservoir, evaporative loss occurs.

The Federal Energy Regulatory Commission (FERC), which regulates the operations of FPSF as they relate to Monticello Reservoir, has established minimum water surface elevation guidelines for Monticello Reservoir of 425.0 ft MSL (high water level) and 420.5 ft MSL (low water level).

Based on generation data for FPSF for the years 2000-2004, average daily discharge from Monticello Reservoir back into Parr Reservoir is approximately 8,920 cubic ft per second (cfs). Considering the storage volume of the reservoir and the average volume of water (2000-2004) withdrawn from the reservoir each day by FPSF, the annual average retention time for Monticello Reservoir is approximately 24.4 days.

2.4 CWIS Hydraulic Influence

An Acoustic Doppler Current Profiler (ADCP) survey was conducted 20-21 April 2005. Based on pumping records provided by Summer Station, intake flow was during typical three-pump operation (flow rate = 738.7 MGD) throughout the survey period (Table 2-1). The survey included three hydraulic data collection events conducted over a 24-hour period with all three pumps running to monitor representative diel changes in lake elevations, which normally are managed near 425 ft MSL. Lake level elevation varied 3.9 ft during the survey (Table 2-1). Lake level changes occur daily due to operation of the FPSF. Survey events represented: (i) high water stage, (ii) declining water stage, and (iii) low water stage.

During each event, portions of the lake located on both sides and out from the CWIS were surveyed with the ADCP. Acoustic Doppler data were collected by navigating the boat and collecting ADCP data along parallel-shoreline transects each placed further away from the CWIS with each successive pass. Up to six transects and several roving data collection traverses were conducted during each survey to delineate the outer boundary of flow vectors (i.e., direction) associated with the CWIS.

Real time and post-processed acoustic Doppler data were used to detect and map the extent of the area of hydraulic influence and reservoir bathymetry in the vicinity of the CWIS. The boundary demarcating the area of greatest extent of hydraulic influence attributable to Summer Station was determined as the distance at which water velocities and flow vectors attenuated to the point of no longer being dominantly oriented toward the CWIS based on all survey events.

The maximum extent of hydraulic influence from the Summer Station CWIS was associated with the lowest lake level (420.7 ft) observed during the study (Table 2-1). Integrating the results of all three surveys, the maximum areal extent of hydraulic influence in Monticello Reservoir adjacent to the CWIS structure was approximately 2.92 ac (Figure 2-3). The most distant boundary of the area of hydraulic influence (determined by locating the presence of vectors that were predominantly unrelated to the Summer Station CWIS) at the low lake stage extended out to a distance 555 ft away from the CWIS (Figure 2-3). Considering the average of the five closest water column profiles at this location, average water column velocity was measured at 0.09 ft per second (ft/s) with an average flow direction compass bearing of 205.80°N (compass bearing directly toward the center of the CWIS is 180° from magnetic north), thus indicating predominate flow direction away from the CWIS.

The bathymetry (i.e., depth contour) of the reservoir near the CWIS and the unconfined approach to the CWIS (i.e., absence of an intake canal) combined to provide rapid attenuation of the hydraulic influence of Summer Station withdrawals, thus resulting in a relatively small zone of hydraulic influence. Water depth along the face of the intake structure was 33.7 ft at the highest recorded lake elevation (424.6 ft). Water depth progresses to 48.8 ft deep within 392 linear ft of the CWIS (Figure 2-4). Where velocity alone is considered, the survey data indicates fish exposed to the immediate approach to the CWIS (survey Transects T1 and T2) would be the most susceptible to impingement on the face of the Summer Station vertical traveling screens.

2.5 Historical Impingement and Fish Community Data

Annual biological monitoring studies were conducted in Monticello Reservoir from 1978 through 1983 (Dames & Moore, 1983). Those studies showed that Monticello Reservoir fishery was composed largely of sunfish, bass, and crappie. Sixty-eight fish species had been identified from Monticello Reservoir and other areas of the Broad River watershed.

Impingement at the Summer Station CWIS was evaluated from October 1983 through September 1984 as part of a 316(b) demonstration (Dames and Moore, 1985).

Impinged fish were collected from the Summer Station vertical traveling screens for one 24-hour period every two weeks from October 1983 through September 1984. Seventeen impinged species representing six taxonomic families were collected. Additionally, two non-fish taxa (Asiatic clam [*Corbicula fluminea*] and crayfish [unidentified species]) were collected and reported. In the 1983-1984 study, 5,140 fish weighing 31 kilograms (kg) (68.2 pounds (lbs)) were impinged resulting in an extrapolated annual impingement estimate of 85,000 fish weighing 515 kg (1,133 lbs). Impingement was greatest during January 1984 when cold shock was implicated by the collection of high numbers (2,411) of young-of-the-year (YOY) gizzard shad (in the family Clupeidae - herrings), which are susceptible to swimming impairment induced by cold water temperatures. This single event comprised 47 percent of total study impingement) and was four times the number impinged during any other winter sampling event (December 1983 – February 1984). In total, gizzard shad comprised 83 percent by number and 51.8 percent by biomass of the organisms impinged in the 1983-84 study. No correlation was found between reservoir water level and fish impingement rate (Dames & Moore, 1985).

No other specific impingement studies at Summer Station have been conducted. However, relevant data on the source water fish community of Monticello Reservoir in the vicinity of the Summer Station CWIS is provided from the SCDNR studies conducted in 1987-1989 and 1995-1996, which were used to support the most recent renewal of the NRC operating license for Summer Station (NRC, 2004). Based on the standing stock data, the abundance of the primary species subject to impingement during the 1983-84 study generally increased between 1984 and 1996 (Table 2-2). Fish standing crop in 1984, approximately two years after Summer Station began operating, was dominated by bluegill (*Lepomis macrochirus*) and gizzard shad (*Dorosoma cepedianum*), with substantial populations of pumpkinseed (*Lepomis gibbosus*) and channel catfish (*Ictalurus punctatus*) (Table 2-2).

Dominant fish in 1986-1987 standing crop estimates included gizzard shad, bluegill, channel catfish, and white catfish (*Ameiurus catus*). In 1989 and 1995, respectively, blue catfish *(I. furcatus)* and white perch (*Morone americana*) were collected from Monticello Reservoir for the first time. By 1996, blue catfish was the most dominant species and white perch was the sixth most dominant species. Sub-dominant species included gizzard shad, bluegill, channel catfish, and white catfish. Other recently introduced and/or recently collected species included green sunfish (*L. cyanellus*), brook silversides (*Labidesthes sicculus*), and swallowtail shiner (*Notropis procne*).

Based on trends observed in standing crop data, the Monticello Reservoir fish community exhibited shifts in species composition and abundance from 1985 through 1996 as the result of the introduction of white perch and blue catfish. These species may have been introduced by fisherman or transferred into Monticello Reservoir from Parr Reservoir by pump-back operations (SCE&G, 2002). The blue catfish population in particular exhibited pronounced expansion in numbers as well as importance in the reservoir between 1995 and 1996 (SCE&G, 2002). At the time, SCDNR expressed concern about the rapid population growth of blue catfish in Monticello Reservoir, noting that Monticello Reservoir has a relatively low prey base and that the "unfortunate" introduction of blue catfish may lead to increased competition for forage between catfish and gamefish species (SCE&G, 2002).

Also, the white perch, a semi-anadromous species native to the southeastern coast, is considered a nuisance species by many inland fisheries managers (SCE&G, 2002). The species is known for a high reproductive capacity combined with slow growth rate and long lifespan (up to 17 years), which are characteristics that tend to create crowded populations of stunted white perch in reservoirs (SCE&G, 2002). Also, white perch are known to depress populations of other, more desirable gamefish species by competing for limited forage and by feeding heavily on their eggs.

A number of other fish species (brook silverside, swallowtail shiner, and green sunfish, *L. cyanellus*) appeared for the first time in SCDNR's Monticello Reservoir cove rotenone samples collected in 1995. These species were known to occur in other waterbodies in the Santee-Cooper drainage basin (which includes the Broad River), but had not been collected previously in Monticello Reservoir by SCDNR. They may have been introduced to Monticello Reservoir by bait-bucket releases and/or pump-back operations of FPSF. None of these species was expected to have a noticeable effect on the reservoir fisheries, beyond some minor contribution to the forage base.

Based on the historical fisheries monitoring data for Monticello reservoir and review of SCDNR natural heritage inventory records (see Section 3.4), no federally or state protected species of fish or shellfish, nor potentially suitable habitat for protected species, have been documented as occurring in the source waterbody.

3. STUDY METHODS

The IMCS documented impingement mortality at Summer Station and factored in existing fish community information from the vicinity of the CWIS. The resulting dataset provided information necessary to determine an appropriate calculation baseline estimate for evaluating Section 316(b) compliance, either in the context of the suspended Phase II regulations or by applying Best Professional Judgment.

3.1 Impingement Mortality Characterization

Impingement monitoring of the CWIS traveling screens was conducted during 12 July 2005 through 27 June 2006 on a pre-established (bi-weekly) schedule resulting in 26 sampling events. Impingement samples were collected using the existing collection basket, which was modified to incorporate 3/8-inch wire mesh openings matching the opening size of the traveling screens. Each impingement sampling event represented a 24-hr collection period split into two approximately equal 12-hr samples. The "day sample" was typically initiated at 0600 hours and extended until 1800 hours on day one and the "night sample" was taken from 1800 hours on day one until the following morning at 0600 hours on day two.

Operation of the traveling screens during impingement sampling events for the current study was modeled after the previous impingement study conducted at Summer Station by Dames and Moore (1985) to provide for appropriate comparison of results. The process involved cleaning the traveling screens prior to initiation of each sampling event by rotating the operable screens at least one full cycle to remove any accumulated debris and/or organisms. The screens were then stopped and left in a fixed position for each 12-hour sampling period. At the end of each 12-hr sampling period, operable screens were again rotated at least one full cycle allowing the spray wash system to convey impinged organisms and debris to the collection apparatus. Impingement samples were sorted by species and counted for each sample event yielding a total of 52 individual impingement samples.

Size distributions of impinged fish in each sample were determined by processing up to 100 representative individuals for each species. Fish were weighed (grams) and total length measured to the nearest millimeter (mm). When more than 100 fish were encountered, up to 300 additional individuals of a given species were weighed as a batch. When more than 400 individuals of a given species were collected, only a batch weight was recorded and the number estimated from the average weight of the individually processed fish and the enumerated batches.

Data collected during each impingement study were recorded on pre-printed data sheets for documenting species and size distributions during each sample, as well as the plant operating conditions. The data forms accommodated batch counts and/or batch weights as outlined above.

Plant operational parameters recorded at Summer Station for the entire study period included intake water flow rates, condenser inlet water temperature, Broad River water temperatures, and Monticello Reservoir water level elevations.

3.2 Calculation of Annual Impingement Mortality Estimate

In development of the calculation baseline estimate of annual impingement mortality for Summer Station, two estimates were determined: 1) using conventional spreadsheet calculation methods and; and 2) using Monte Carlo simulation techniques.

In each case, fish impingement data were standardized to reflect density and mass of organisms per unit volume of cooling water pumped. Data collected over each twenty-four hour sampling period were normalized by dividing the number of fish impinged by the volume of cooling water pumped during the sampling event (expressed in number or mass per 100 cubic meters (100-m^3)) resulting in a "base density" impingement rate. The volume of cooling water withdrawn was determined from plant operation records.

Estimation of annual impingement at Summer Station was extrapolated using the equation:

$$\sum E_i = R_i \times V_i$$

where

E_i = estimated number of fish impinged for time period i
R_i = average impingement rate per 100-m^3 for time period i
V_i = volume of cooling water pumped for time period i

Linear interpolation was used to estimate impingement for un-sampled days by multiplying the associated base density impingement rates by the volume of cooling water withdrawn for each day of the half-month period associated with the sampling event (i.e., for the seven days preceding and following the sampling event). Daily impingement estimates were then summed to yield an annual estimate of impingement mortality associated with the Summer Station CWIS.

In the Monte Carlo simulation analysis, the base density impingement rates were grouped based on seasonality and then randomly drawn to estimate impingement rates for un-sampled days within a specified season. This was accomplished by multiplying randomly drawn base density impingement rates by the volume of cooling water withdrawn for each day of the half-month period associated with the sampling event. Daily estimates were then summed to yield an annual estimate of impingement mortality. This process was repeated 10,000 times to incorporate all possible outcomes from the available dataset and yield mean annual impingement mortality estimate for Summer Station. Additional detail is provided on the Monte Carlo simulation technique in Section 6.

For both annual impingement mortality estimation techniques, a 95-percent upper confidence limit was calculated for the resulting annual estimates to account for uncertainties associated with expected diel, seasonal, and operational variability. Confidence intervals for individual species were extrapolated based on the relative abundance of each species in the impingement sample.

3.3 Fish Community Characterization

The fish community occurring in the vicinity of the Summer Station CWIS and potentially susceptible to impingement was characterized through impingement sampling at the CWIS, and the use of historical data on the fish community found in the vicinity of Summer Station in Monticello Reservoir. Assessment of fish populations in the vicinity of the CWIS provide information necessary to characterize the species and associated life stages that are potentially susceptible to impingement on the vertical traveling screens at the Summer Station CWIS. Relevant data on the fish community of Monticello Reservoir in the vicinity of the Summer Station CWIS was provided from the SCDNR studies conducted in 1987-1989 and 1995-1996 as reported by NRC (2004). The new impingement data and historical data aided in identifying fish taxa most susceptible to impingement "in the vicinity" of the CWIS, provided the basis for estimating annual impingement mortality, and provided the data necessary for establishing the appropriate calculation baseline estimate of impingement mortality occurring at Summer Station against which compliance with the performance standard will be determined.

3.4 Threatened and Endangered Species

The potential for State or Federally listed threatened or endangered fish species to occur in Monticello Reservoir and/or in the vicinity of the Summer Station CWIS was evaluated based on habitat requirements of listed fish and freshwater mussel species known to occur in a four-county area surrounding the reservoir. Based on a desktop review of natural heritage inventory records (SCDNR 2001; 2005), there are no known threatened or endangered fish or shellfish species in Monticello Reservoir that could potentially be susceptible to impingement at the Summer Station CWIS (Table 3-1).

Further, NRC reported in 2004 that no endangered fish or freshwater mussels were known to occur in Monticello Reservoir (NRC, 2004). A review of the South Carolina lists for counties surrounding the reservoir suggests that potentially suitable habitat does not occur in Monticello Reservoir for any of the listed aquatic species known to occur in a four-county area. Listed mussels and fish species are also strongly associated with stream/river habitats that do not occur in Monticello Reservoir. Based on the known distribution of the listed species, it was anticipated before the current study began that it was unlikely that any protected species would be impinged at Summer Station.

3.5 Quality Assurance and Quality Control

Sample processing was conducted under South Carolina's "State Environmental Laboratory Certification Regulation 61-81" that assures data submitted to SCDHEC are scientifically valid and defensible. Geosyntec has been certified for taxonomic identification of freshwater fishes, marine/estuarine fishes, and ichthyoplankton (Laboratory I.D. 98022). Project quality assurance/quality control (QA/QC) for the IMCS followed Geosyntec's "Quality Assurance Project Plan" (QAPP) prepared for SCE&G that is applicable to the information and analyses required by the IMCS. Field personnel followed Geosyntec's "*Standard Operating Procedures for Collection, Processing, and Identification of Fish Samples*".

4. PLANT OPERATIONS DURING STUDY PERIOD

4.1 Cooling Water Flow

Daily once-through cooling water flows at Summer Station ranged from 492.5 to 738.7 MGD and averaged 671.0 MGD for the entire study period (Figure 4-1). Cooling water flows during the 12-month study averaged approximately 87.4 percent of the total rated capacity of the three circulating water pumps (i.e., 767.6 MGD).

Cooling water flows are affected by the same range of maintenance, operational, and demand factors as is annual generation, which is reflected in variable daily pumping rates. Reduced pumping flows occurred during two weeks in late July – early August 2005 and also during a three month period between mid-February and mid-May (Figure 4-1). Routine/scheduled maintenance on center-positioned circulating pump 'B' was responsible for the two week outage in 2005. However, the three month outage in 2006 was the result of circulating pump 'C' failure. The pump, located on the west side of the CWIS, had to be removed and shipped to the manufacturer for repair. Six of the 26 sampling events (27 percent) were conducted during periods of reduced flow (i.e., two pumps). The calculation baseline estimate of impingement mortality at Summer Station (Section 6) was developed in consideration of circulating water pump outages due to unscheduled maintenance.

4.2 Water Temperatures

Condenser inlet water temperatures were recorded hourly at Summer Station during the study period. Daily average condenser inlet temperatures were calculated and summarized graphically along with daily surface water temperatures from the Broad River near Jenkinsville (SCDNR, 2006) and mean water surface elevations for Monticello Reservoir to present a summary of major environmental variables occurring during the study (Figure 4-2). Daily average condenser inlet temperatures ranged from 9.6 to 29.8 degrees Celsius (°C). Hourly condenser inlet temperatures recorded during the 12-month impingement study ranged from 8.6 to 30.6 °C and reflected a typical seasonal temperature pattern when compared to Broad River surface water temperature data for the same period (Figure 4-2). A notable trend observed in the data indicated that water temperatures in Monticello Reservoir, as represented by the condenser inlet temperatures, lagged behind Broad River temperatures by approximately two weeks during seasonal temperature changes; from October 2005 to January 2006 and again from March to July 2006.

4.3 Water Level Fluctuations

Surface water elevations in Monticello Reservoir changed in response to daily pump-back operations of FPSF (Figure 4-2). Hourly reservoir levels ranged from 420.6 to 425.3 ft MSL. Daily average levels during the impingement study period ranged from 421.5 to 424.8 ft MSL. Daily fluctuations ranged from 0.2 to 4.6 ft, and the average daily fluctuation in reservoir water stage during the study was 2.8 ft.

5. IMPINGEMENT SAMPLING RESULTS

5.1 Species Composition

Thirteen fish taxa (twelve fish species and one hybrid Lepomis sunfish), plus crayfish, and a single freshwater grass shrimp were collected from 52 impingement samples from the Summer Station traveling screens during the 12-month study.[1] Impinged fish species represented five families including shad (Clupeidae; two species), catfish and bullheads (Ictaluridae; five species), temperate bass (Moronidae; one specie), bass and sunfish (Centrarchidae; three species plus the one hybrid), and perch (Percidae; one taxon) (Table 5-1).

Fewer species were impinged in the current study compared to the 1983-1984 impingement study at Summer Station when 18 fish species and two non-fish species (freshwater grass shrimp and Asiatic clam) were impinged (Table 5-1). Ten impinged taxa, including Asiatic clam, were common among impingement samples from both study periods. Source water fish community surveys conducted near the Summer Station CWIS in the 1983-1984 study yielded 28 aquatic species. Seventeen species collected in 1983-1984 impingement and ten species collected in the 2005 study were represented in the 1983-1984 source water checklist (Table 5-1).

As previously indicated in Section 3.4, fish or shellfish species listed as threatened or endangered are not known to occur in Monticello Reservoir and <u>none were collected during the current impingement study</u>.

5.2 Relative Abundance

A cumulative total of 574 organisms weighing 7.9 kg (17.4 lbs) were collected from the Summer Station CWIS during the 12-month impingement study. Fish taxa accounted for 569 of the 574 impinged organisms (Table 5-2). Threadfin shad (*D. petenense*) was the single most numerically dominant fish accounting for 50.2 percent of the total impingement sample (Table 5-2; Figure 5-1). Other relatively abundant impinged

[1] Asiatic clam (*Corbicula fluminea*), which accounted for 38 percent of the impinged organisms collected during this study, is widely considered an exotic/nuisance species with no recreational or commercial value. As such, Asiatic clams were excluded from the study results on the basis that they do not represent "shellfish" in the context of the Phase II rule.

species included blue catfish accounting for 12.2 percent of sample abundance followed by channel catfish (11.8 percent), white perch (9.4 percent), and yellow perch (*Perca flavescens*; 6.1 percent). No other species contributed to more than five percent of total impingement (Table 5-2 and Figure 5-1). The predominance of a few species in the impingement samples is typical as historical impingement studies have shown that five to 10 species often comprise 90 percent or more of annual impingement estimates (EPRI, 2004).

Although it ranked fourth in ranked abundance, white perch dominated in terms of biomass comprising 36.6 percent of impinged biomass (Table 5-2). In ranked order following white perch, blue catfish accounted for 16.1 percent of impinged biomass followed by gizzard shad (12.9 percent), channel catfish (12.5 percent), white catfish (7.4 percent), and threadfin shad (6.9 percent). No other single species accounted for more than four percent of impingement biomass. The impingement biomass result emphasizes the fact that most impinged fish were juvenile life stages recorded at small body sizes, especially for the abundant threadfin shad which dominated numerical abundance.

High relative abundance of clupeids such as threadfin shad is typical of impingement at other southeastern facilities, which has been consistently attributed to schooling behavior, distribution in the water column, negative reotaxis response to intake flows (i.e., swimming with the flow toward the CWIS), and their susceptibility to swimming impairment and/or mortality due to exposure to cold water temperatures (Loar et al., 1978). In contrast, typically lower abundance of sunfish species reflects their demersal position in the water column, association with cover, and relatively small home ranges that limit spatial movements.

A review of shad impingement at other southeastern facilities found that approximately 98 percent of fish impinged at 24 power plants were clupeids and that relative abundance exceeded 75 percent at 15 sites (Loar et al., 1978). Based on this current study and data available from historical studies at other facilities, the greater relative abundance of shad on the CWIS at Summer Station is consistent with early studies reported by Loar et al. (1978). However, based on absolute numbers and biomass, impingement at Summer Station is substantially less than that reported for other southeastern facilities.

5.3 Size Distribution

As mentioned in the previous section, fish impinged at Summer Station were typically small-bodied fishes (e.g., threadfin shad) or juvenile larger-bodied fish (e.g., gizzard shad, white perch, and blue catfish). Table 5-3 provides a summary of length ranges of minimum, maximum, and average lengths for fishes impinged at Summer Station. Based on 569 measured fish, total length averages by species ranged from 35 to 155 mm. Four of the 13 fish species including flier (*Centrarchus macropterus*), warmouth (*L. gulosus*), threadfin shad, and yellow perch, exhibited average lengths less than 100 mm (approximately 4 inches).

The length distribution of all impinged organisms represented size classes ranging from 38 to 349 mm total length (TL) (Figure 5-2). Figure 5-2 also compares length frequency distribution of impinged organisms between the 1983-1984 study (Dames and Moore, 1985) and the current study. Modal peaks occurring from 59 to 79 mm in 2005-2006 and from 79 to 109 mm in 1983-1984 reflect numerical dominance of clupeids during each study. Fish longer than 149 mm (~6 inches) in total length were infrequently impinged. Most impinged organisms were found in sizes < 129 mm.

Length-frequency distributions of the most commonly impinged fish species in 2005-2006 showed that the majority were less than 169 mm in total length (Table 5-4). As the most abundant impinged fish, threadfin shad were observed in size classes ranging from ≤ 39 to 119 mm with modal class abundance observed between 50 to 69 mm (Table 5-4). The majority of blue catfish were observed in sizes < 119 mm with multiple life stage modes observed throughout the range. Impinged channel catfish broadly represented most size classes between 49 and 239 mm and also in multiple life stages throughout the observed size range. White catfish were observed most abundantly in two modal size groups of 69 and 199 mm (Table 5-4). White perch, which contributed the highest impingement biomass component by species, was also broadly represented in most size classes to 250 mm and also with multiple life stage groups indicated. Impinged bluegill represented size classes ranging from 89 through 129 mm. Impinged gizzard shad represented size classes ranging from 59 to greater than 250 mm, with the modal size class occurring at 60 through 69 mm. Impinged yellow perch were collected in a narrow size range from 49 through 119 with peak abundance in the 99 through 109 mm size classes (Table 5-4). Overall, the size data indicates primarily juveniles and sub-adult fish were impinged at Summer Station during the 12-month study, which is consistent with impingement at other southeastern facilities (Dames & Moore, 1985; Edwards et al., 1978; Loar et al., 1978).

5.4 Seasonal Occurrence

Impingement rates were greatest during the winter months (late December through February). Impingement counts from three individual sampling events occurring on 27 December 2005, 24 January 2006, and 7 February 2006 accounted for approximately 43 percent of the annual total (Figure 5-3; Appendix A). Threadfin shad contributed to the majority of impingement on those dates. During the remainder of the sampling year, less than 31 organisms were impinged during any single event (Appendix A). Figure 5-4 illustrates how threadfin shad dominated impingement overall, and secondarily, the seasonal occurrence of threadfin shad throughout the study period.

The number of taxa impinged on the Summer Station traveling screens per event varied from one to seven during the 12-month study (Appendix A). The frequency of occurrence by species during the 12-month study varied from one (flier, hybrid Lepomid, warmouth, and freshwater grass shrimp) to 19 (channel catfish) (Figure 5-3). Although channel catfish occurred in 19 of 26 events, it was only the third most abundant species collected during the study. Channel catfish occurred most often during the latter part of December 2005 through June 2006. Four species including threadfin shad, blue catfish, channel catfish, and white perch occurred in at least 17 of the 26 impingement sampling events (Figure 5-3).

Impingement rate was examined in light of trends in surface water temperatures in Broad River and Monticello Reservoir (i.e., condenser inlet temperatures), and Monticello Reservoir water level elevations. Peaks in impingement abundance coincided with the coolest seasonal temperatures. The highest rates were observed in January and February 2006 when temperatures were lowest, approximately 10°C. As was reported by Dames and Moore (1985), no trends were apparent between impingement rates and reservoir water elevation in the current study.

Major impingement events of threadfin shad typical of other southeastern facilities were not exhibited at Summer Station during this study. Peak impingement of threadfin shad typically occurs during the winter, especially where the source waterbody is a reservoir (Loar et al., 1978; Edwards et al., 1978, and Dames & Moore, 1985). Swimming ability of fish in general and particularly for threadfin shad at lower water temperatures of winter, have a direct affect on increased impingement. Threadfin shad, observed mostly in December through February in this study, may have been more susceptible to impingement at Summer Station due to cold-induced swimming impairment; however, not in the large numbers observed for other southeastern facilities. In the previous impingement study conducted by Dames and Moore (1985), gizzard shad rather than threadfin shad were reported in large numbers during winter months (January – March) indicating their similar susceptibility to cold-induced effects.

5.5 Diel Distribution

Diel distribution of impingement at the Summer Station intake was determined through evaluation of the discrete 12-hr daytime and nighttime samples collected during each 24-hr sampling event. No organisms were impinged during three of the 26 daytime sampling events. Overall, 56 percent of the fish collected during the 12-month study occurred in the night samples, which were generally collected between 1800 and 0600 hours (Table 5-5). On an event by event basis there were statistically significant differences between the daytime and night samples. Impingement rates were higher during the night in 19 of the 26 sampling event resulting in a statistically different diel rate (paired-t test analysis; α=0.1).

6. CALCULATION BASELINE

The "calculation baseline" for Summer Station, as provided by § 125.93 of the suspended Phase II rule, is an estimate of impingement mortality that occurs on the basis that:

- the facility CWIS was designed as a once-through system;
- the opening of the cooling water intake structure is located at, and the face of the standard 3/8-inch mesh traveling screens are oriented parallel to, the shoreline near the surface of Monticello Reservoir; and
- current operational practices, procedures, and structural configuration at the facility are those that are maintained without structural or operational controls for the purposes of reducing impingement mortality.

The rule allows for the calculation baseline to be estimated using current biological and impingement mortality data collected in the vicinity of CWIS structure and/or through the use of data from other facilities with comparable design, operational, and environmental conditions. SCE&G has developed the calculation baseline for Summer Station based primarily on the July 2005 through June 2006 impingement sampling results with consideration of the historical fish community survey data in the vicinity of the CWIS.

The calculation baseline estimate for Summer Station was determined by using the results from the 26, 24-hour impingement sampling events.

6.1 Conventional Spreadsheet Calculation Method

6.1.1 Data Expansion

As presented previously, linear interpolation was used to estimate impingement for un-sampled days by multiplying the associated measured base density impingement rates by the volume of cooling water withdrawn for each day of the two week period surrounding each sampling event. Daily cooling water withdrawal rates vary somewhat, thereby resulting in variable estimates of daily impingement. This "expansion" process was repeated for each day of each two week period of the sampling year and summed to produce an annual estimate for impingement.

For example, 24 fish were impinged in the 12 July 2005 sample. During the 24-hour sampling period, the three circulating water pumps collectively withdrew approximately 738.7 million gallons (~2.8 million m^3) of cooling water on that day translating to 0.000858 fish impinged per 100-m^3. This calculated daily impingement rate was then multiplied by the actual volume of water pumped for the seven un-sampled days preceding and following the 12th of July resulting in an estimated 536 organisms impinged for that period. This method was applied to each of the 26 impingement samples yielding an annual impingement estimate of 8,042 organisms.

6.1.2 Statistical Analysis

To help account for the annual, seasonal, and diel variability expected in impingement rates, the base density impingement rates were used to calculate an upper bound (i.e., 95 percent [%] upper confidence limit [UCL]) for the annual impingement mortality estimate (for number and biomass). The 95% UCL estimates the 95^{th} percentile of the sampling distribution of the sample average. For example, given 100 sets of measurements, each set selected at random from the same population having a known mean, then 95 of the computed mean values would be expected to be above the true mean and 5 would be expected to be below the true mean. This attribute represents the desired UCL "coverage" of the mean (i.e., 95%). Any method used to calculate 95% UCL should have this property; while at the same time, not substantially overestimate the true mean.

Base density impingement rates for Summer Station were plotted. The Shapiro-Wilk's test for normality indicating the dataset was consistent with a log-normal distribution ($p < 0.05$). Therefore, log-transformed data were used to calculate the 95% UCL on the mean base density impingement rates (See Appendix B for probability plot and related statistics).

The 95% H-UCL (i.e., the H-statistic) method was selected as the most statistically appropriate method for calculating the conventional 95% UCL for the Summer Station impingement data[2]. The H-statistic derived 95% UCL extrapolates to an estimated adjusted annual impingement rate of 11,850 organisms.

The same statistical analysis was used for biomass impinged at Summer Station. Organism biomass impingement rates from the 26 sampling events, resulted in an annual impingement biomass estimate of 110.8 kg (244.3 lbs) with a 95% UCL of 158.2 kg (348.8 lbs). The most appropriate 95% UCL methodology for biomass was the non-parametric Chebyshev.

In summary, based on the 95% UCLs the conventional estimate of annual impingement mortality for Summer Station during the study period was 11,850 organisms weighing 158.2 kg (348.8 lbs).

6.2 Monte Carlo Simulation

Because the impingement rate is, for the most part, a random event, particularly within any given season, assigning a measured fixed value (i.e., impingement rate) to simulate values for pumping rates on days when no samples were taken does not adequately account for this randomness. Consequently, a more robust simulation method, the Monte Carlo technique, was applied to the impingement data.[3]

Monte Carlo simulation is a proven and widely accepted statistical technique by which a quantity is calculated repeatedly (e.g., estimate of annual impingement rate), as many as thousands of times, using randomly selected parameter values (e.g., measured impingement rates) for each calculation. The results approximate the full range of possible outcomes, and the likelihood of each. This simulation technique was developed during World War II and is named after the casinos in Monte Carlo, Monaco, where the primary attractions are games of chance. The random occurrence in games of chance is similar to how Monte Carlo simulation selects variable values at random to simulate a particular modeling scenario. In rolling a die, it is intuitive that one of six numbers will come up, but it is not known *a priori* which value it will be for any particular roll. It is

[2] The Florida Department of Environmental Protections "FLUCL" tool was used to determine which of many available calculation methods for the 95% UCL was the most appropriate (i.e., best "coverage" of the mean without overestimating it) for this dataset (FDEP, 2005).
[3] In development of the final Phase II 316(b) rule, EPA employed similar Monte Carlo analysis to address uncertainty in fish yield estimates used in evaluating economic impacts (EPA, 2004).

the same with variables that have a known range of values, such as for impingement data, but an uncertain value for any particular time or event.

In applying Monte Carlo simulation to the Summer Station impingement dataset consideration was given to the seasonality in impingement rates as reflective of seasonal abundance of fish in Monticello Reservoir. In addition to variability of pumping rates, the temporal presence and abundance of fish and other organisms, and their individual susceptibility to impingement on the CWIS traveling screens were the primary implicating factors affecting variability in measured impingement rates. Therefore, "seasons" were assigned to the impingement rates to correspond to times of the year when impingement rates were "high" or "low". This partitioning of the dataset allowed the Monte Carlo simulation to only draw from the "high" rates measured in the "high" season during that period of the year. Conversely, only low rates were drawn upon during the "low" season. This strategy prevented selection of measured impingement rates from times of the year when rates where seasonally "high" to simulate impingement rates at times when rates were seasonally "low", and vice versa.

The highest impingement rates were recorded at Summer Station during the winter season (late December 2005 through February 2006) and were due primarily to threadfin shad. Instances of very low impingement rate (2 to 8 organisms per event) occurred sporadically in other seasons of the year (Appendix A, Table A-1). Thus, in developing an estimate of annual impingement for Summer Station, the Monte Carlo simulation randomly drew from seasonally representative pools of data (Figure 6-1). The simulation procedure for estimating impingement during the study period followed this sequence:

1. For each day of the yearlong study period (July 2005 through June 2006), a measured impingement rate (number or biomass per 100-m^3) was randomly drawn by the computer from the existing pool of data for the five and half-month period representing either high impingement or from the period representing low impingement depending on the calendar date of the un-sampled day for which the estimate of impingement was to be generated.

2. The randomly drawn measured impingement rate was multiplied by the volume of cooling water pumped specific to an operable day, thereby

generating a daily estimate of impingement. This process was repeated until a daily estimate of impingement was calculated for each day.

3. Daily impingement estimates were then summed to derive an annual estimate of impingement and this value stored by the computer.

4. The above process was repeated 10,000 times, thus resulting in 10,000 possible outcomes for the estimate of annual impingement based on the available data as seasonally partitioned.

5. Descriptive statistics (i.e., mean and 95% UCL) were performed on the resulting output data distribution (Appendix B).

6. The same process was repeated for estimating the biomass impinged.

The table below presents the results of the conventional and Monte Carlo simulation methods for calculating annual impingement mortality estimates for Summer Station.

Summer Station Annual Impingement Estimates

		Annual Estimate	95% UCL
Conventional	Number	8,042	11,850
	Biomass (kg)	110.8	158.2
Monte Carlo	Number	7,996	8,395
	Biomass (kg)	106.5	114.0

The Monte Carlo derived values provide the best estimate of impingement for Summer Station because:

- The uncertainty associated with impingement being a random event is better integrated into the estimate of annual impingement.
- Impingement rates for sampled days are randomly drawn from actual measurements and assigned to un-sampled days rather than assigned arbitrarily.

- The resulting annual estimate of impingement is based on a conservative estimate of the mean drawn from thousands of possible outcomes, not on a single estimate.

- The high number of simulation trials captures a wide array of potential impingement outcomes based on actual sampling data and provides a robust and unbiased estimate of the mean impingement.

Specific to actual plant operations (i.e., cooling water flows) during the study period, the 95% UCL estimate of annual impingement mortality documented for Summer Station is 8,395 organisms with a biomass of 114.0 kg (251.3 lbs) (Tables 6-1 and 6-2).

However, in development of the calculation baseline estimate of impingement, consideration was given to the failure of circulating water pump 'C' which resulted in reduced flows, and likely impingement rates, for a three month period between mid-February and mid-May (see Section 4.1). In order to account for this flow reduction, the Monte Carlo simulation was repeated using the typical three-pump flow rate (738.7 MGD) that would have normally occurred for the specified three month period.

The resulting adjusted 95% UCL estimate of annual impingement mortality documented for Summer Station is 9,154 organisms with a biomass of 123.4 kg (272.0 lbs). Species relative abundance in the "sampled" dataset was used to estimate the annual expanded 95th percentile UCL for number of each species (Table 6-3) and the biomass of each species (Table 6-4). These estimates are presented as the calculation baseline of impingement mortality at the Summer Station CWIS and represent conditions under approximate maximum design flow for a 12-month period of continuous operation. It is important to note that Summer Station schedules 30-40 day outages approximately every 18 months for maintenance and re-fueling. As such, annual impingement mortality at the facility within some calendar years is reduced accordingly.

6.3 Perspective

Based on total number and biomass, impingement of aquatic organisms on the Summer Station CWIS in 2005-2006 was relatively minor compared to impingement reported in the previous study and when compared to other facilities in the southeast. The following text provides overall perspective on the number, biomass, and composition of organisms impinged at Summer Station as determined in the current study.

6.3.1 Comparison with the 1983-1984 Impingement Study

In the 1983-1984 study, 5,140 organisms were collected in the impingement samples and annual impingement was estimated to be 85,000 organisms weighing 515 kg (1,133 lbs). A summary and comparison of organism impingement from the 1983-1984 and 2005 IMCS studies are shown in Table 6-5. In the 2005 study, a total of 574 organisms weighing 7.9 kg (17.4 lbs) were collected in the impingement samples from a comparable number of samples. Annual impingement extrapolation for the 2005 study at the 95% UCL was 9,154 fish weighing 123.4 kg (272.0 lbs). A statistical upper confidence level was not reported for 1983-1984 estimate of annual impingement. Difference in impingement rates between the two study periods stems in part from high impingement rates for YOY gizzard reported during January of the 1983-1984 study when cold-induced swimming impairment was implicated.

Approximately 50 percent fewer sportfish species were impinged at Summer Station in 2005 than in the 1983-84 study. Species including black crappie (*Pomoxis nigromaculatus*), white crappie (*P. annularis*), largemouth bass (*Micropterus salmoides*), pumpkinseed, redear sunfish (*L. microlophus*), and white bass (*M. chrysops*) were impinged in the early study period but were not observed in the 2005 study (Table 6-5). Although the current study does not specifically address this point, rationally assuming that impingement data are largely representative of the reservoir fishery, the 2005 impingement data may point to a decline in sunfish diversity from the mid-1980's due to the successful establishment of blue catfish and white perch in the reservoir. Regardless of the diversity of sportfishes present in the source waters, historical impingement studies demonstrate that it is typical for impingement rates of sportfish to be low (Edwards et al., 1978; Dames & Moore, 1985). It is also typical for a few species (5 to 10) to account for over 90 percent of annual impingement at power plants in general (EPRI, 2004) as observed at Summer Station in both study periods.

Impingement data collected in the 1983-1984 study showed high abundance of gizzard shad (83 percent) followed by yellow perch (7.6 percent) and sunfish (4.8 percent) (Table 6-5). Accounting for impinged biomass in the early study, gizzard shad dominated with 51.8 percent followed by white catfish (17.6 percent), and white bass (5.2 percent). By comparison, the most frequently impinged fish in the 2005 study was threadfin shad at 50.2 percent followed by blue catfish (12.2 percent), and channel catfish (11.8 percent). As for impinged biomass in the 2005 study, white perch accounted for 36.6 percent while blue catfish and gizzard shad accounted for 16.1 and 12.9 percent, respectively.

Either gizzard shad or threadfin shad have historically represented the primary forage base in Monticello Reservoir. Shad are typically one of the most abundant species in southeastern impoundments. Historically, threadfin shad were shown to represent approximately 90 percent of the fish impinged at 15 southeastern power plants (Loar et al., 1978). As indicated by the results observed in the 1983-1984 study, impingement at Summer Station may not be unlike other facilities where notable episodic impingement events of clupeids (especially threadfin shad) can occur with weather extremes. Even though a severe cold shock event was not observed in the current study, impingement samples indicate that collectively, shad and catfishes continue to dominate the fishery of Monticello Reservoir with threadfin shad in particular, representing the most vulnerable limnetic forage species subject to impingement at Summer Station.

6.3.2 Historical Perspective - SCDNR Standing Crop Studies

The 2005 impingement study result lends evidence in addition to early standing stock study results by SCDNR that fish community composition in Monticello Reservoir has shifted since the 1983-1984 studies. The introduction of white perch and blue catfish marked a shift in fishery assemblage of Monticello Reservoir beginning in the mid-1980's. White perch, not present in the previous impingement study, accounted for a substantial component of impinged biomass in the 2005 study (36.6 percent). Blue catfish evidently remain prevalent in Monticello Reservoir as they accounted for 12.2 percent of the impingement sample abundance and 16.1 percent of impingement biomass in 2005.

The comparative low numbers of organisms impinged at Summer Station in 2005 likely reflect the trophic condition of Monticello Reservoir which was characterized by SCDNR, based on long-term eutrophication studies (1984–1996), as one of the least eutrophic reservoirs in South Carolina marked by low nutrient concentrations (SCE&G, 2002). These attributes favor a condition of low productivity for the aquatic community of Monticello Reservoir compared to other older reservoirs in the region. By comparison in terms of productivity, Parr Reservoir which is integral to daily pump-storage operations for water supply in Monticello Reservoir as a cooling water source maintains an intermediate trophic state among reservoirs in South Carolina.

Somewhat in contradiction to the documented low productivity of Monticello Reservoir, historical standing crop estimates indicated general biomass increase between 1984 and 1996. As an explanation, it can be reasonably assumed that the introduction and population expansion of blue catfish (as well as white perch) during that period contributed to the apparent increase in standing crop biomass and resultant fish community shift in Monticello Reservoir. Standing crop studies have not been performed by SCDNR in Monticello Reservoir since the mid-1990's to provide a more current status of fish standing crop. As a matter of relatively recent occurrence, Monticello Reservoir has become known regionally among anglers for producing good fishing specifically for larger-sized blue catfish (personal communications – Mr. Robert Stroud and Mr. Gene Hayes, SCDNR Fisheries Biologists, 2006).

6.3.3 Examination of Cold Weather Induced Impingement

The 1983-1984 impingement study indicated that the high number of impinged fish (primarily clupeids – shads) was probably attributable to cold shock leading to moribund fish captured in the CWIS (Dames and Moore, 1985). During the first sampling event in January 1984, 2,411 gizzard shad (47 percent of total study impingement) were impinged, four times the number impinged during any other winter sampling event (December 1983–February 1984). Although threadfin shad were collected at Summer Station in higher numbers during winter months of the current study, there was no indication that a cold shock event had occurred based on the expected abundance of threadfin shad in the reservoir and number actually impinged at the CWIS. To compare environmental conditions of the two studies, plant condenser inlet water temperatures for the winter months of each study were plotted along with sampling event impingement data (Figure 6-2). Interestingly, inlet temperatures exhibited a similar pattern of rapidly dropping temperatures in January of both study years. However, water temperatures were colder in January of the 1983-1984 study when the high numbers of shad were collected in the impingement samples.

As a means to experimentally explore the effect of episodic cold shock events on impingement rate and compare to the current study, raw impingement data from the 1983-1984 study were re-analyzed by excluding the single excessively high January impingement event. In this way, the data were normalized to simulate a 12-month impingement study without episodic severe cold weather events as was the case during the 2005 IMCS. Assuming that the surrounding sampling events in winter months yielded impingement rates for gizzard shad that were representative of typical cold season temperatures, an adjusted per-event impingement rate was derived and substituted for the January cold shock event based on the per-event average winter impingement rate (300 organisms). This exercise resulted in the downward adjustment of the number of organisms actually impinged during the 1983-1984 study from 5,140 to 3,029; a reduction of approximately 41 percent. Assuming linearity, the revised annual estimate of impingement is reduced to 50,150 from the originally estimated 85,000 organisms.

Even accounting for episodic cold weather events in this way, impingement in 2004-2005 was substantially lower than observed 23 years ago in the previous 316(b) study at Summer Station. This exercise also highlights the impact that episodic cold weather-related shad impingement events can have on baseline calculation estimates of annual impingement.

6.3.4 Comparison with Other Southeastern Facilities

Another means for gaining perspective for the 2005 Summer Station IMCS results is by way of comparison to impingement results from other once-through facilities located on regional freshwater reservoirs as presented in Table 6-6. Annual impingement rates for several southeastern power plants, standardized to the estimated number of number of organisms impinged per million gallons (org/mg) of cooling water pumped, ranged from 0.03 to 4.41 org/mg. The Summer Station rate of 0.03 org/mg represented the lowest impingement rate of the facilities evaluated. Among the example plants shown, Duke Power Company's Oconee Nuclear Station is the closest facility geographically to Summer Station and similarly withdraws cooling water from a waterbody (Lake Keowee, SC) where eutrophication assessments have indicated notably low nutrient concentrations. In fact, Lake Keowee was reported as the least eutrophic large lake in South Carolina (NRC, 1999). The flow-normalized impingement rate for Oconee Nuclear Station was approximately 0.30 org/mg, or ten times higher than the impingement rate observed at Summer Station in the current study (Table 6-6).

Clearly, the scale of impingement at Summer Station as determined from the current study is small compared to other facilities in the region. A number of factors could be implicated as possible reasons for the low impingement rates at Summer Station, including but not limited to:

1. Rapid attenuation of the hydraulic zone of influence with increasing distance from the CWIS;

2. Possible beneficial effects of the existing CWIS skimmer wall which limits cooling water withdrawals to depths greater than 9.5 ft, thereby minimizing impingement of surface oriented fish species;

3. "Natural" aging of Monticello Reservoir following trophic upsurge commonly associated with new reservoirs (Kimmel and Groeger, 1986), leading to reduced biological productivity since construction;

4. Lack of significant allochthonous nutrient input to the reservoir due to limited natural inflow from its relatively small watershed (~1,100 ac); and/or

5. Up to 4.6-ft daily fluctuations in reservoir water level negatively affecting fish spawning success.

6.4 Baseline Valuation

In order to establish some initial perspective on matters of costs associated with impingement mortality at Summer Station, direct valuation of fish replacement costs was determined based on methods published in the American Fisheries Society publication entitled: *Investigation and Monetary Values of Fish and Freshwater Mussel Kills* (Southwick and Loftus, 2003). Where replacement costs for species where not available or could not be appropriately obtained from this source (e.g., crayfish), wholesale prices were obtained from the Fisheries Statistics Division of National Marine Fisheries Service (NMFS, 2006).

As previously presented, the 95% UCL estimate of the impingement mortality calculation baseline (i.e., calculation baseline) documented for Summer Station is 9,154 organisms weighing 123.4 kg (272.0 lbs). Using the referenced source materials and simple analysis indicates that <u>direct replacement costs collectively for all fish and shellfish impinged at Summer Station totals approximately $2,336</u>. Threadfin shad, the dominant species impinged at Summer Station have a total replacement cost of $505. The value of impinged recreationally important species represents 76 percent of the total value or $1,786 (Table 6-7).

Because a large proportion of impinged fish are juveniles that would otherwise experience high rates of naturally mortality, the replacement value of adult-equivalent organisms would be even lower. However, this may be offset by other use and non-use values attributable to the lost resource not captured by direct replacement costs. Thus, assignment of direct replacement costs for juvenile life stages impinged at Summer Station represents a reasonably conservative approach for estimating the value of aquatic resources lost to impingement at the facility.

Consideration of the monetary value of juvenile and/or adult equivalents of fish and other organisms subject to impingement mortality at Summer Station will be helpful in informing decisions on Section 316(b) compliance. SCE&G will seek a compliance approach for Summer Station that returns the greatest net benefits to the aquatic resources of Monticello Reservoir at a cost commensurate with the numbers and species of fish and shellfish impinged and their associated resource value.

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TABLES

TABLE 2-1. SUMMARY OF THE HYDRAULIC INFLUENCE OF THE SUMMER STATION CWIS BASED ON ACOUSTIC DOPPLER CURRENT PROFILE (ADCP) SURVEY RESULTS, 20-21 APRIL 2005

Date	5/20/2005									5/21/05								
Time	1200	1300	1400	1500	1600	1700	2100	2200	2300	0000	0100	0200	0300	0400	0500	0600	0700	0800
Summer CWIS[1]																		
Lake Elevation (ft)[2]	424.3	424.1	423.9	423.4	422.9	422.4	420.9	420.7	420.8	421.1	421.7	422.2	422.9	423.5	424.0	424.5	424.6	424.5
ADCP Survey	Survey 1 (declining stage)							Survey 2 (low stage)								Survey 3 (high stage)		
(survey time)	1300 to 1430 hrs							2231 to 2342 hrs								0648 to 0823 hrs		
Avg. Flow Direction at CWIS (degrees mag. N)[3]	180.14							166.18								182.90		
Avg. Flow Vel. (ft/s) at CWIS Intake[4]	0.35							0.45								0.36		
Areal Extent (ac) of CWIS Influence	2.01							2.44								1.71		

Notes:
1 = three (3) circulator pumps running at 738.7 MGD (million gallons per day) during the survey.
2 = lake elevations as feet above mean sea level, provided by SCE&G.
3 = for general reference, the compass bearing directly toward the center of the CWIS is ~180 degrees from Magnetic N.
4 = based on cross-sectional transect in front of the CWIS.

TABLE 2-2. STANDING STOCK OF DOMINANT FISHES OF MONTICELLO RESERVOIR [1,2]

Species	1984	1987	1988	1989	1995	1996
Gizzard shad	13.69	84.4	37	25.2	46.8	103
Threadfin shad	0.14	16.5	10.6	10.4	1.71	2.8
Channel catfish	2.78	62.7	75.9	31.5	36.1	98.7
White catfish	0.7	25.7	55.6	30.5	0.38	48.3
Blue catfish	--	--	--	4.9	7.67	123.7
White perch	--	--	--	--	0.5	24.6
White bass	present	0.7	0.3	1	30	0.2
Bluegill	14.69	57.3	70.9	70.9	18.5	56
Pumpkinseed	3.48	3.5	5.49	4.6	0.86	3.1
Black crappie	0.03	8.7	6.16	0.3	0.01	0.5
Largemouth bass	1.04	6.4	6.4	3.9	4.19	6.5
Yellow perch	0.59	10	9.7	9.7	--	4.4
Total	40.13	306.3	204.5	204.5	154.3	482.3

(1) Source: NRC. 2004.

(2) Standing crop expressed as kilograms per hectare (kg/ha).

TABLE 3-1. ENDANGERED AQUATIC SPECIES LISTED AS OCCURRING OR POTENTIALLY OCCURRING BY THE USFWS OR THE STATE OF SOUTH CAROLINA IN THE VICINITY OF SUMMER STATION

Scientific Name	Common Name	Federal Status	State Staus
Plants			
Myriophyllum laxum	Piedmont watermilfoil	–	SC
Potamogeton confervoides	algae-like pondweed	–	SC
Crustaceans			
Distocambarus youngineri	Saluda crayfish	–	SC
Mollusks			
Elimia catenaria	gravel elimia	–	SC
Elliptio lanceolata	yellow lance	–	SC
Lasmigona decorata	Carolina heelsplitter	E	SC
Pyganodon cataracta	Eastern floater	–	SC
Strophitus undulatus	squawfoot	–	SC
Villosa delumbis	Eastern creekshell	–	SC
Fish			
Acipenser brevirostrum	shortnose sturgeon	E	–
Etheostoma collis	Carolina darter	–	SC
Fundulus diaphanus	banded killifish	–	SC
Notropis chiliticus	redlip shiner	–	SC
Rhinichthys atratulus	blacknose dace	–	SC

Notes:

E = endangered

SC = South Carolina species of special concern

– = no listing

TABLE 5-1. FISH SPECIES COLLECTED DURING THE 2005 AND 1984 IMCS AT SUMMER STATION

Scientific Name	Common Name	Impinged Species 2005 IMCS	Impinged Species 1984 IMCS (1)	Source Water Community Survey 1984 IMCS (1)
Lepisosteus osseus	longnose gar		X	X
Dorosoma cepedianum	gizzard shad	X	X	X
Dorosoma petenense	threadfin shad	X	X	X
Cyprinella nivea	whitefin shiner			X
Cyprinus carpio	common carp			X
Hybognathus regius	Eastern silvery minnow			X
Catostomus commersoni	white sucker			X
Carpiodes cyprinus	quillback			X
Moxostoma macrolepidotum	shorthead redhorse			X
Moxostoma anisurum	silver redhorse			X
Moxostoma rupiscartes	striped jumprock			X
Ameiurus brunneus	snail bullhead	X		X
Ameiurus catus	white catfish	X	X	X
Ameiurus natalis	yellow bullhead		X	X
Ameiurus nebulosus	brown bullhead		X	X
Ameiurus platycephalus	flat bullhead	X	X	X
Ictalurus furcatus	blue catfish	X		
Ictalurus punctatus	channel catfish	X	X	X
Morone americana	white perch	X		
Morone chrysops	white bass		X	X
Centrarchus macropterus	flier	X	X	
Lepomis auritus	redbreast sunfish			X
Lepomis gibbosus	pumpkinseed		X	X
Lepomis gulosus	warmouth	X	X	X
Lepomis macrochirus	bluegill	X	X	X
Lepomis microlophus	redear sunfish		X	X
Lepomis spp.	hybrid sunfish	X		X
Micropterus salmoides	largemouth bass		X	X
Pomoxis annularis	white crappie		X	X
Pomoxis nigromaculatus	black crappie		X	X
Perca flavescens	yellow perch	X	X	X
Corbicula fluminea	Asiatic clam		X	
Palaemonetes spp.	freshwater grass shrimp	X	X	
unidentified	crayfish, unidentified	X		
Total Number of Taxa		**15**	**20**	**28**

Note:

(1) Dames and Moore, 1985.

TABLE 5-2. RELATIVE ABUNDANCE AND BIOMASS OF ORGANISMS COLLECTED DURING THE SUMMER STATION IMPINGEMENT STUDY, JULY 2005-JUNE 2006

Common Name	Number of organisms		Biomass of organisms	
	Number	Percent	kg	Percent
gizzard shad	25	4.4%	1.022	12.9%
threadfin shad	288	50.2%	0.549	6.9%
snail bullhead	2	0.3%	0.050	0.6%
white catfish	15	2.6%	0.589	7.4%
flat bullhead	3	0.5%	0.084	1.1%
blue catfish	70	12.2%	1.272	16.1%
channel catfish	68	11.8%	0.985	12.5%
white perch	54	9.4%	2.893	36.6%
flier	1	0.2%	0.001	0.0%
warmouth	1	0.2%	0.005	0.1%
bluegill	6	1.0%	0.116	1.5%
hybrid sunfish	1	0.2%	0.052	0.7%
yellow perch	35	6.1%	0.271	3.4%
grass shrimp	1	0.2%	0.001	0.0%
crayfish	4	0.7%	0.017	0.2%
TOTAL	**574**		**7.9**	

TABLE 5-3. SIZE RANGE OF FISH IMPINGED AT SUMMER STATION JULY 2005 – JUNE 2006

Species	Number of fish measured (1)	Total Length *(mm)*		
		Minimum	Maximum	Average
bluegill	6	80	120	105
flier	1	35	35	35
hybrid lepomid	1	155	155	155
warmouth	1	70	70	70
gizzard shad	25	56	332	117
threadfin shad	288	35	119	64
blue catfish	70	56	290	113
channel catfish	68	48	237	106
flat bullhead	3	97	174	124
snail bullhead	2	88	155	122
white catfish	15	60	260	150
white perch	54	30	250	150
yellow perch	35	44	118	97

Note:

(1) Table includes only fish that were weighed and measured individually and not fish counted as part of batch counts.

TABLE 5-4. LENGTH-FREQUENCY DISTRIBUTIONS OF COMMONLY IMPINGED FISH SPECIES AT SUMMER STATION, JULY 2005 – JUNE 2006

Size Class	*Percent of fish in size class*							
	bluegill	threadfin shad	gizzard shad	yellow perch	white perch	white catfish	channel catfish	blue catfish
≤39	--	0.3	--	--	1.9	--	--	--
49	--	2.1	--	2.9	--	--	1.5	--
59	--	39.2	4.0	--	--	--	13.2	4.3
69	--	40.3	36.0	--	--	20.0	13.2	15.7
79	--	8.7	12.0	--	--	--	13.2	20.0
89	16.7	3.5	--	5.7	5.6	6.7	5.9	4.3
99	--	3.1	8.0	54.3	9.3	6.7	5.9	4.3
109	33.3	1.7	--	28.6	3.7	--	7.4	8.6
119	33.3	1.0	12.0	8.6	13.0	6.7	10.3	10.0
129	16.7	--	4.0	--	7.4	--	2.9	1.4
139	--	--	--	--	14.8	6.7	2.9	5.7
149	--	--	4.0	--	3.7	--	2.9	7.1
159	--	--	4.0	--	5.6	--	2.9	2.9
169	--	--	4.0	--	3.7	--	4.4	4.3
179	--	--	--	--	1.9	6.7	1.5	1.4
189	--	--	--	--	1.9	6.7	2.9	1.4
199	--	--	--	--	5.6	20.0	2.9	1.4
209	--	--	--	--	1.9	6.7	2.9	--
219	--	--	--	--	1.9	--	--	--
229	--	--	--	--	3.7	6.7	1.5	1.4
239	--	--	--	--	7.4	--	1.5	1.4
249	--	--	--	--	5.6	--	--	--
≥250	--	--	12.0	--	1.9	6.7	--	4.3
Number of fish	*6*	*288*	*25*	*35*	*54*	*15*	*68*	*70*

Notes:

Only commonly impinged fish are shown (i.e., more than 5 individuals).

Size class indicates the largest size in the category (i.e., 59 represents all fish 50 through 59 mm long)

TABLE 5-5. DIEL DISTRIBUTION OF ORGANISMS IMPINGED AT SUMMER STATION, JULY 2005 - JUNE 2006

	Day		Night	
Sample Date	**Number**	**Percent**	**Number**	**Percent**
12-Jul-05	16	67%	8	33%
26-Jul-05	6	40%	9	60%
09-Aug-05	2	25%	6	75%
24-Aug-05	2	18%	9	82%
06-Sep-05	5	45%	6	55%
20-Sep-05	6	46%	7	54%
04-Oct-05	0	0%	2	100%
18-Oct-05	4	40%	6	60%
01-Nov-05	2	17%	10	83%
15-Nov-05	3	27%	8	73%
29-Nov-05	11	50%	11	50%
13-Dec-05	5	22%	18	78%
27-Dec-05	24	30%	55	70%
10-Jan-06	12	57%	9	43%
24-Jan-06	52	64%	29	36%
07-Feb-06	52	58%	37	42%
21-Feb-06	9	43%	12	57%
07-Mar-06	17	57%	13	43%
21-Mar-06	5	38%	8	62%
04-Apr-06	0	0%	4	100%
18-Apr-06	1	13%	7	88%
02-May-06	1	8%	11	92%
16-May-06	7	30%	16	70%
30-May-06	4	25%	12	75%
13-Jun-06	0	0%	8	100%
27-Jun-06	4	57%	3	43%
Total	**250**	44%	**324**	56%

Note:

The difference between the day-night impingment rate was statistically significant (α=0.1)

TABLE 6-1. EXTRAPOLATED ANNUAL NUMBER OF ORGANISMS IMPINGED AT SUMMER STATION BASED ON MONTE CARLO SIMULATION, JULY 2005 – JUNE 2006

Species	Extrapolated Numbers		Actual Number of Organisms Impinged	Relative Abundance of Impinged Organisms
	Annual Estimate	"Upper Confidence Limit"		
gizzard shad	348	366	25	4.4%
threadfin shad	4,012	4,212	288	50.2%
snail bullhead	28	29	2	0.3%
white catfish	209	219	15	2.6%
flat bullhead	42	44	3	0.5%
blue catfish	975	1,024	70	12.2%
channel catfish	947	995	68	11.8%
white perch	752	790	54	9.4%
flier	14	15	1	0.2%
warmouth	14	15	1	0.2%
bluegill	84	88	6	1.0%
hybrid sunfish	14	15	1	0.2%
yellow perch	488	512	35	6.1%
grass shrimp	14	15	1	0.2%
crayfish	56	59	4	0.7%
TOTAL	**7,996**	**8,395**	**574**	**100%**

TABLE 6-2. EXTRAPOLATED ANNUAL BIOMASS OF ORGANISMS IMPINGED AT SUMMER STATION BASED ON MONTE CARLO SIMULATION, JULY 2005 – JUNE 2006

Species	Extrapolated Numbers		Actual Biomass of Organisms Impinged *(kg)*	Relative Abundance of Impinged Organisms
	Annual Estimate *(kg)*	**"Upper Confidence Limit"** *(kg)*		
gizzard shad	13.8	14.7	1.022	12.9%
threadfin shad	7.4	7.9	0.549	6.9%
snail bullhead	0.67	0.72	0.050	0.6%
white catfish	7.9	8.5	0.589	7.4%
flat bullhead	1.1	1.2	0.084	1.1%
blue catfish	17.1	18.3	1.272	16.1%
channel catfish	13.3	14.2	0.985	12.5%
white perch	39.0	41.7	2.893	36.6%
flier	0.013	0.014	0.001	0.0%
warmouth	0.067	0.072	0.005	0.1%
bluegill	1.6	1.7	0.116	1.5%
hybrid sunfish	0.700	0.750	0.052	0.7%
yellow perch	3.7	3.9	0.271	3.4%
grass shrimp	0.013	0.014	0.001	0.0%
crayfish	0.229	0.245	0.017	0.2%
TOTAL	**106.5**	**114.0**	**7.9**	**100%**

TABLE 6-3. CALCULATION BASELINE FOR ANNUAL NUMBER OF ORGANISMS IMPINGED AT SUMMER STATION BASED ON MONTE CARLO SIMULATION, JULY 2005 – JUNE 2006

Species	Extrapolated Numbers		Actual Number of Organisms Impinged	Relative Abundance of Impinged Organisms
	Annual Estimate	"Upper Confidence Limit"		
gizzard shad	380	399	25	4.4%
threadfin shad	4,377	4,593	288	50.2%
snail bullhead	30	32	2	0.3%
white catfish	228	239	15	2.6%
flat bullhead	46	48	3	0.5%
blue catfish	1,064	1,116	70	12.2%
channel catfish	1,033	1,084	68	11.8%
white perch	821	861	54	9.4%
flier	15	16	1	0.2%
warmouth	15	16	1	0.2%
bluegill	91	96	6	1.0%
hybrid sunfish	15	16	1	0.2%
yellow perch	532	558	35	6.1%
grass shrimp	15	16	1	0.2%
crayfish	61	64	4	0.7%
TOTAL	**8,723**	**9,154**	**574**	**100%**

TABLE 6-4. CALCULATION BASELINE FOR ANNUAL BIOMASS (KG) OF ORGANISMS IMPINGED AT SUMMER STATION BASED ON MONTE CARLO SIMULATION, JULY 2005 – JUNE 2006

Species	Extrapolated Numbers		Actual Biomass of Organisms Impinged *(kg)*	Relative Abundance of Impinged Organisms
	Annual Estimate *(kg)*	"Upper Confidence Limit" *(kg)*		
gizzard shad	14.9	15.9	1.022	12.9%
threadfin shad	8.0	8.6	0.549	6.9%
snail bullhead	0.73	0.78	0.050	0.6%
white catfish	8.6	9.2	0.589	7.4%
flat bullhead	1.2	1.3	0.084	1.1%
blue catfish	18.5	19.9	1.272	16.1%
channel catfish	14.4	15.4	0.985	12.5%
white perch	42.1	45.1	2.893	36.6%
flier	0.015	0.016	0.001	0.0%
warmouth	0.073	0.078	0.005	0.1%
bluegill	1.7	1.8	0.116	1.5%
hybrid sunfish	0.758	0.812	0.052	0.7%
yellow perch	3.9	4.2	0.271	3.4%
grass shrimp	0.015	0.016	0.001	0.0%
crayfish	0.248	0.265	0.017	0.2%
TOTAL	**115.2**	**123.4**	**7.9**	**100%**

TABLE 6-5. RELATIVE ABUNDANCE AND BIOMASS OF IMPINGED ORGANISMS FROM THE 2005-2006 AND 1983-1984 IMCS AT SUMMER STATION

Common Name	2005-2006 IMCS			1983-1984 IMCS [1]		
	Number of Organisms	Percent Abundance	Percent Biomass	Number of Organisms	Percent Abundance	Percent Biomass
longnose gar		--		10	0.2	0.2
gizzard shad	25	4.4	12.9	4245	82.6	51.8
threadfin shad	288	50.2	6.9	41	0.8	0.7
snail bullhead	2	0.3	0.6		--	
white catfish	15	2.6	7.4	123	2.4	17.6
yellow bullhead		--		1	0.02	0.08
flat bullhead	3	0.5	1.1	10	0.2	0.5
blue catfish	70	12.2	16.1		--	
channel catfish	68	11.8	12.5	66	1.3	4.7
white perch	54	9.4	36.6		--	
white bass		--		15	0.3	5.2
flier	1	0.2	0.0	1	0.02	0.08
pumpkinseed		--		56	1.1	1.1
warmouth	1	0.2	0.1	30	0.6	2.8
bluegill	6	1.0	1.5	77	1.5	2.1
redear sunfish		--		2	0.04	0.02
hybrid sunfish	1	0.2	0.7		--	
largemouth bass		--		1	0.02	0.01
white crappie		--		15	0.3	3.3
black crappie		--		66	1.3	2.5
yellow perch	35	6.1	3.4	381	7.6	8.0
grass shrimp	1	0.2	0.0		--	
crayfish	4	0.7	0.2		--	
Totals	**574**			**5140**		

Note:

(1) Dames and Moore, 1985.

TABLE 6-6. COMPARISON OF IMPINGEMENT RATES AMONG EXAMPLE POWER PLANTS

Facility	Location	Cooling Pump Flow Capacity *(gpm)*	Estimated Annual Impingement *(number of organisms)*	Sample Time Period	Impingement Rate *(organisms per million gallons)*
Browns Ferry	Wheeler Reservoir,TN	2,100,000	4,870,000	1974-1977	4.41
New Johnsonville	Kentucky Reservoir, TN	1,111,000	2,450,000	1974-1982	4.20
Cumberland	Barkely Reservoir, TN	1,896,000	1,700,000	1974-1976	1.71
Oconee Nuclear	Lake Keowee, SC	1,527,778	241,697	1974	0.30
Browns Ferry	Wheeler Reservoir, TN	2,100,000	162,350	1980	0.15
North Anna	Anna Reservoir, VA	2,500,000	45,610	1979 - 1983	0.05
Summer Station	Monticello Reservoir, SC	533,100	9,154	2005	0.03

Sources:

NRC, 1999; NRC, 2004; TVA, 1977; TVA 1984.

3

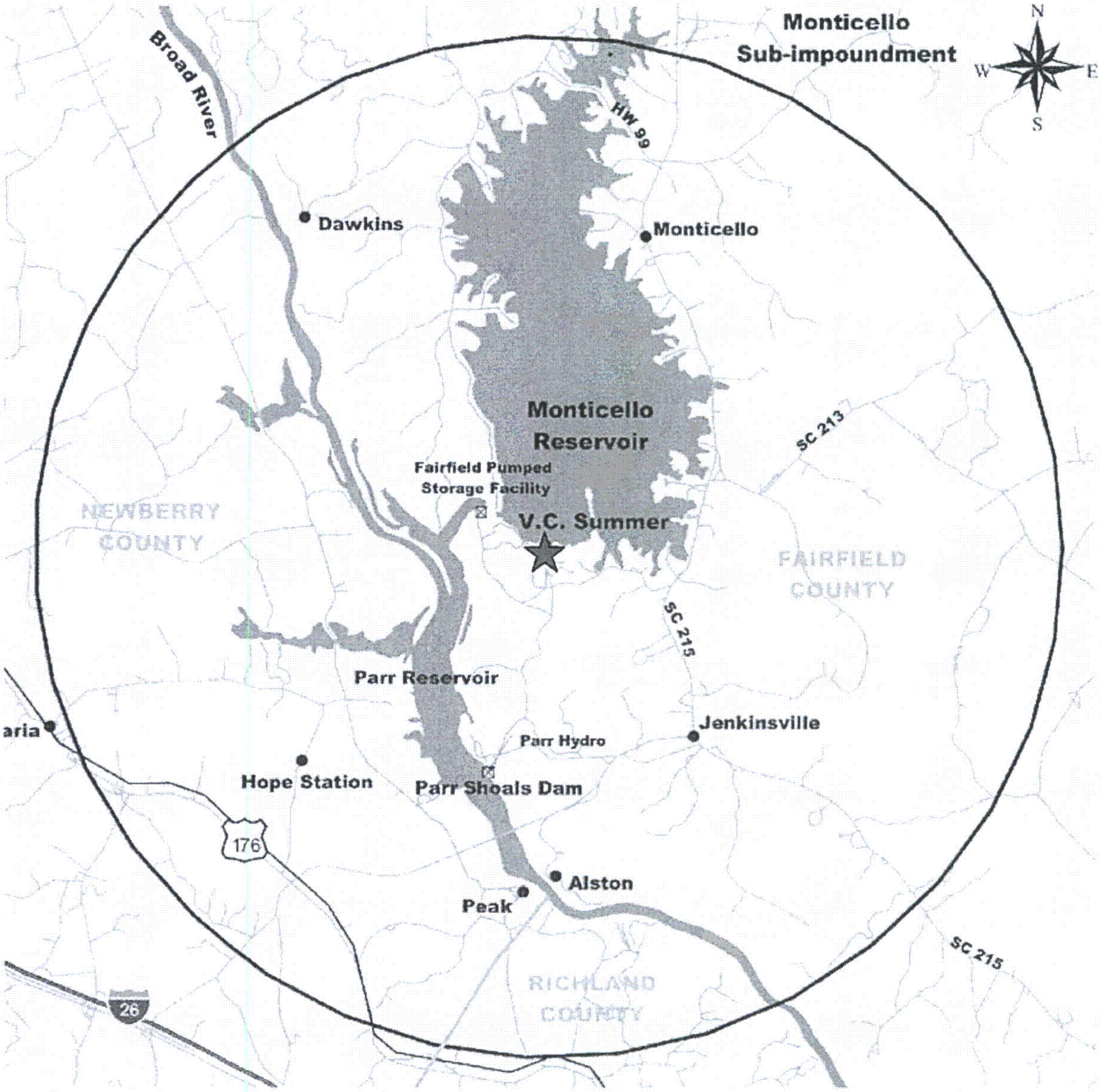
TABLE 6-7. MONETARY VALUATION FOR ORGANISMS IMPINGED AT SUMMER STATION, JULY 2005 – JUNE 2006

Species	Calculation Baseline Number of Organisms	Annual Value
gizzard shad	172	$43.88
threadfin shad	1,981	$505.46
snail bullhead	35	$8.92
white catfish	338	$86.29
flat bullhead	163	$41.68
blue catfish	1,085	$277.01
channel catfish	957	$244.10
white perch	2,564	$654.34
flier	15	$3.95
warmouth	17	$4.39
bluegill	156	$39.93
hybrid sunfish	76	$19.45
yellow perch	1,592	$406.29
grass shrimp	0.1	$0.02
crayfish	1	$0.31
TOTAL	**9,154**	**$2,336.01**

Note:
Annual values were calculated using hatchery replacement costs (Southwick, 2003) and commercial landing and values (NMFS, 2006).

FIGURES

SITE VICINITY MAP FOR SUMMER STATION



LEGEND

- 10-km (6-mi) radius of V.C. Summer
- Interstates
- Major Roads
- Minor Roads
- County Boundaries
- Lakes and Rivers

1 0 1 2 3 Kilometers

1 0 1 2 3 Miles

Source: NRC, 2004.

GEOSYNTEC CONSULTANTS
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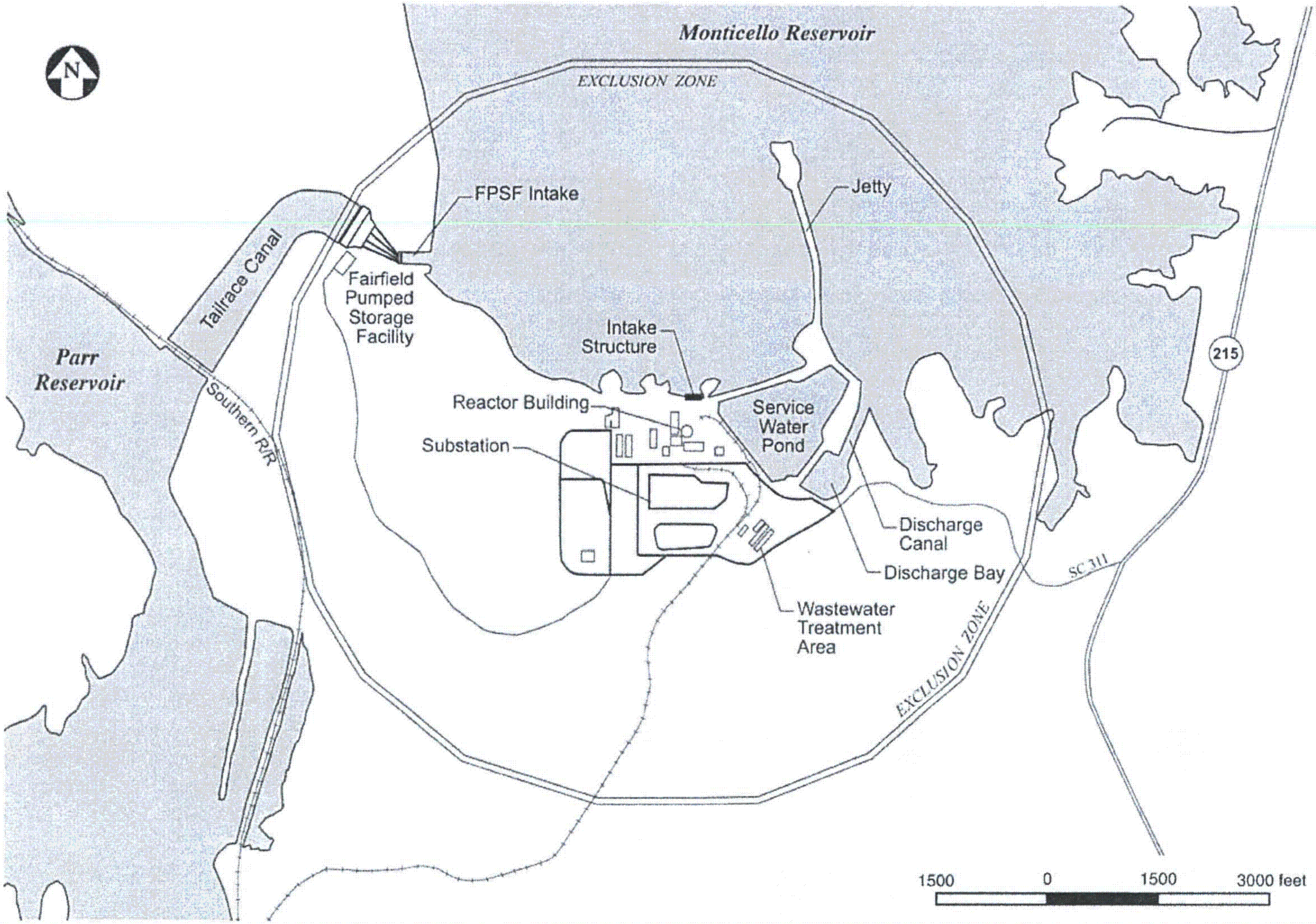
FIGURE NO.:	2-1
PROJECT NO.:	GK3601
DOCUMENT NO.:	GA060413
FILE:	Figure2-1.ppt

SUMMER STATION SITE LAYOUT



GeoSyntec Consultants

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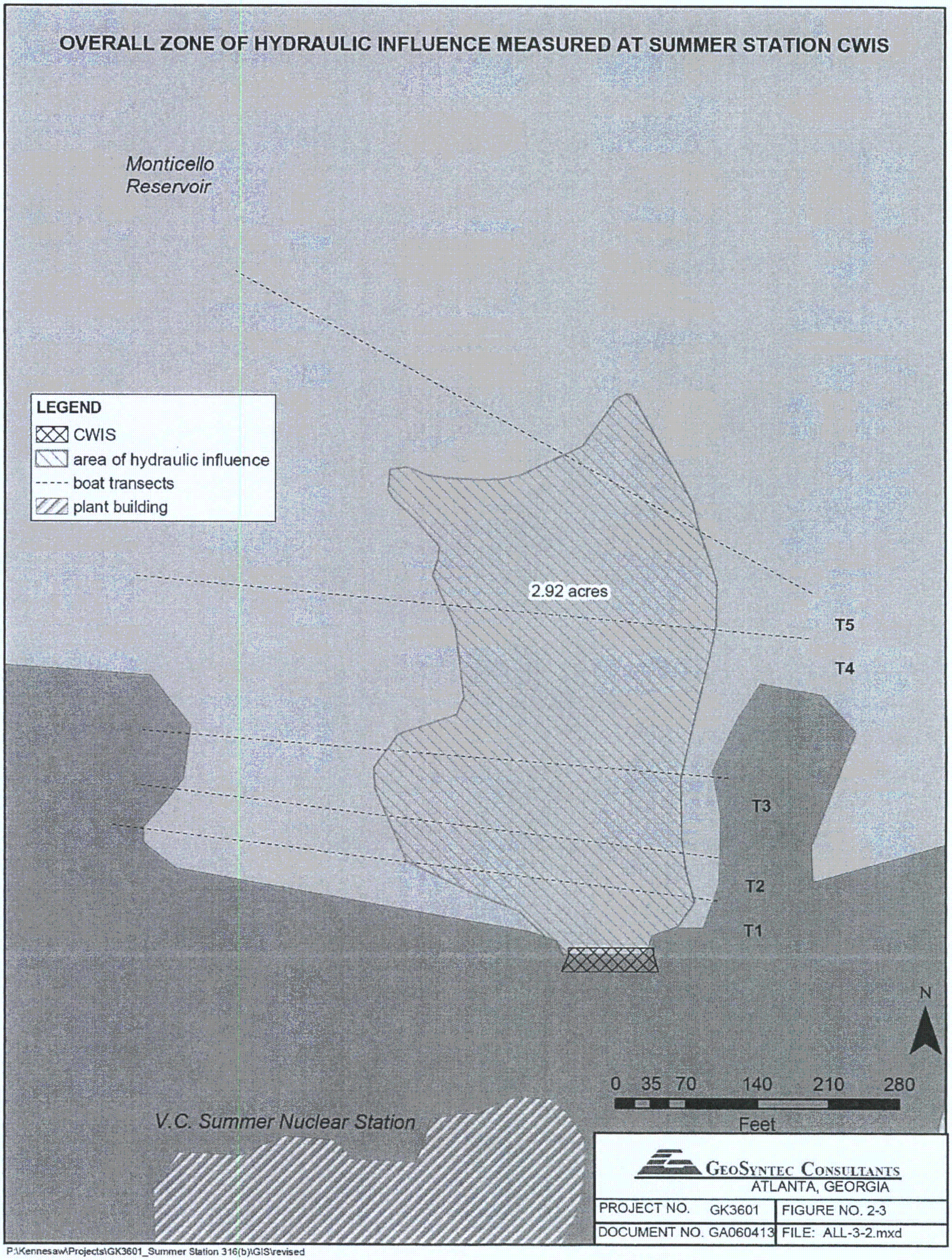
FIGURE NO.:	2-2
PROJECT NO.:	GK3601
DOCUMENT NO.:	GA060413
FILE:	Figure2-2.ppt

SOURCE: NRC, 2004.



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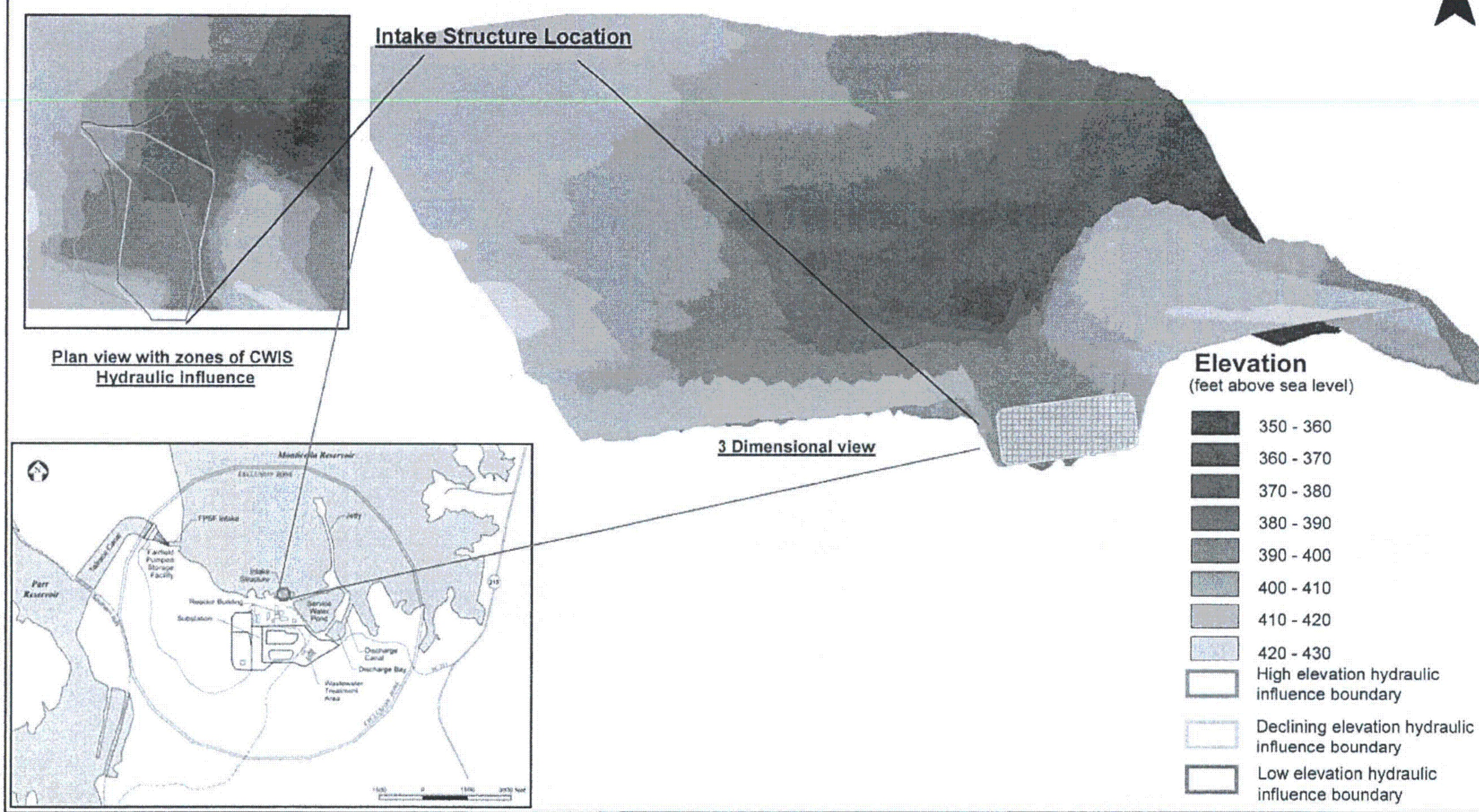
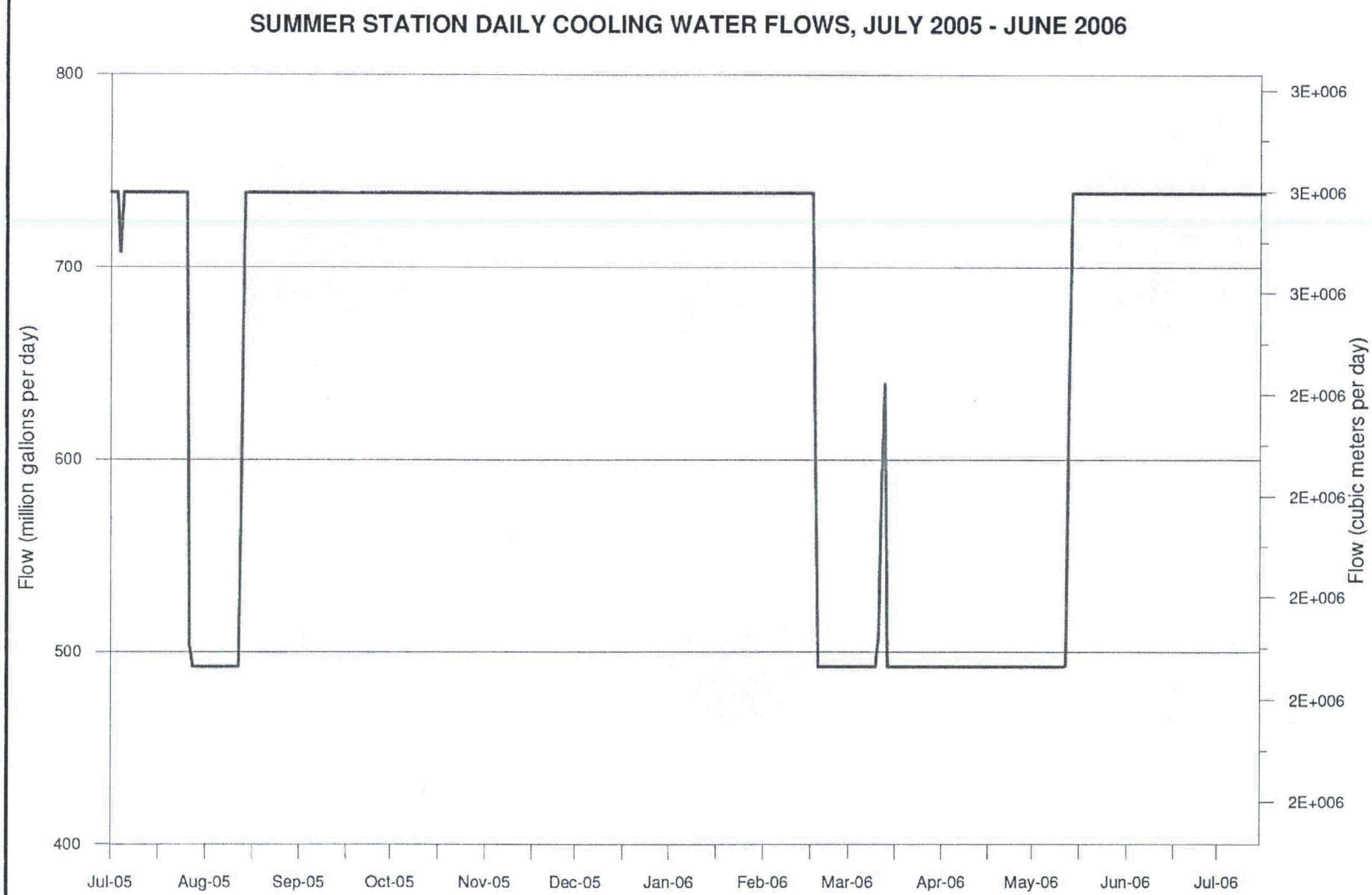
MONTICELLO RESERVOIR BATHYMETRY NEAR SUMMER STATION CWIS

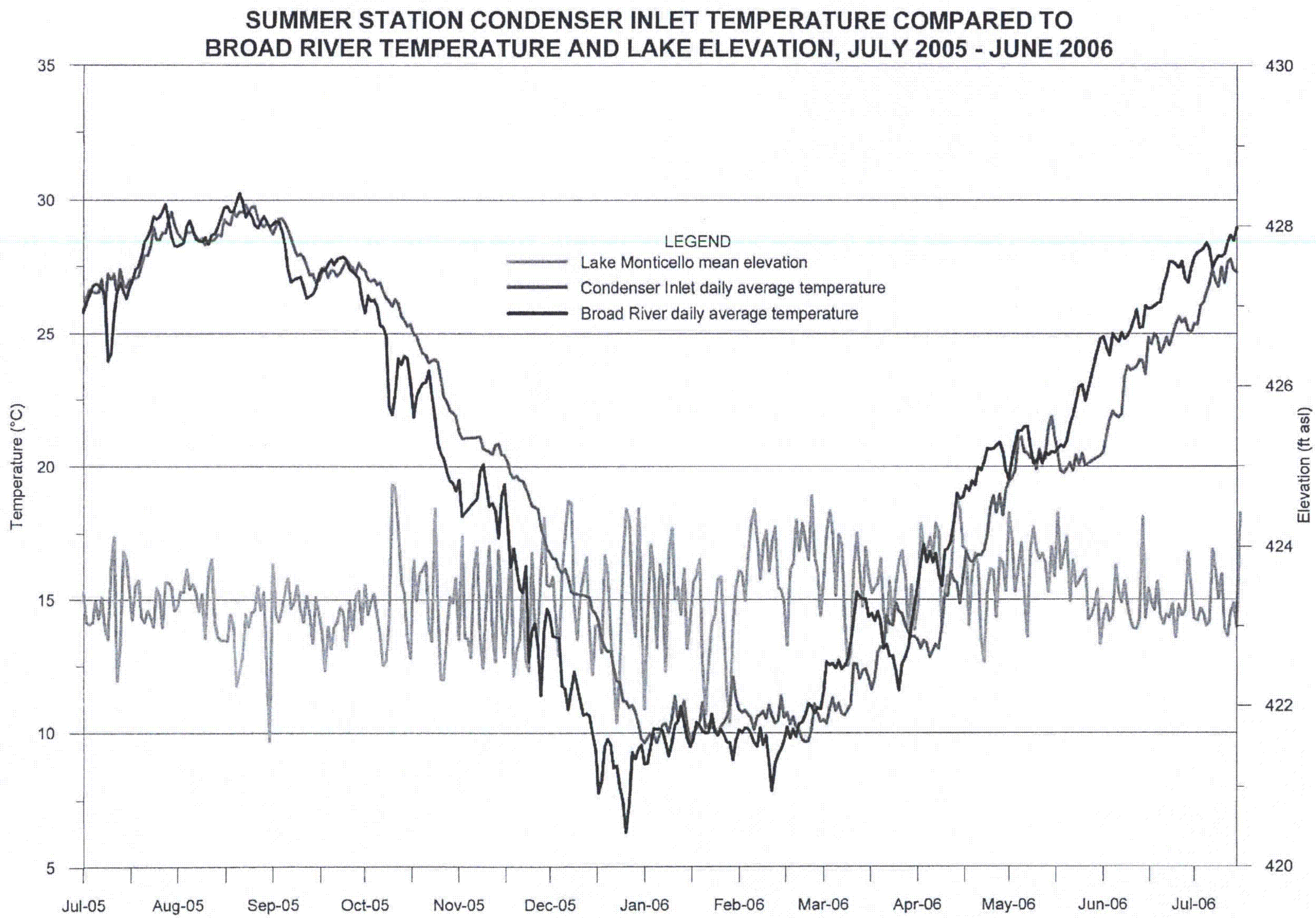


GEOSYNTEC CONSULTANTS ATLANTA, GEORGIA	FIGURE NO.:	2-4	SOURCE: GeoSyntec, 2005
	PROJECT NO.:	GK3601	
	DOCUMENT NO.:	GA060413	
	FILE:	Figure2-4.ppt	



GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.: 4-1	NOTES:
PROJECT NO.: GK3601	
DOCUMENT NO.: GA060413	
FILE: summer flow day totals.xls	

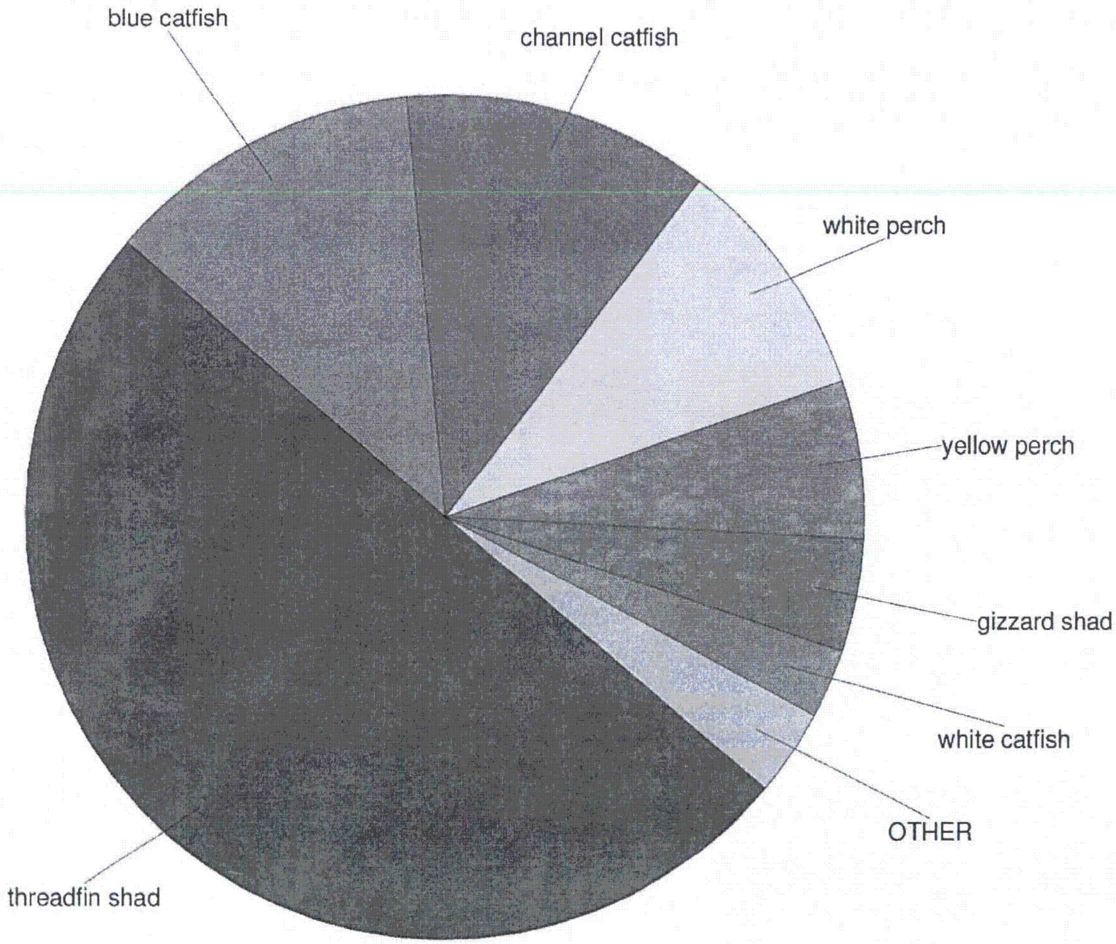


GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.: 4-2
PROJECT NO.: GK3601
DOCUMENT NO.: GA060413
FILE: summer temp.xls

NOTES:

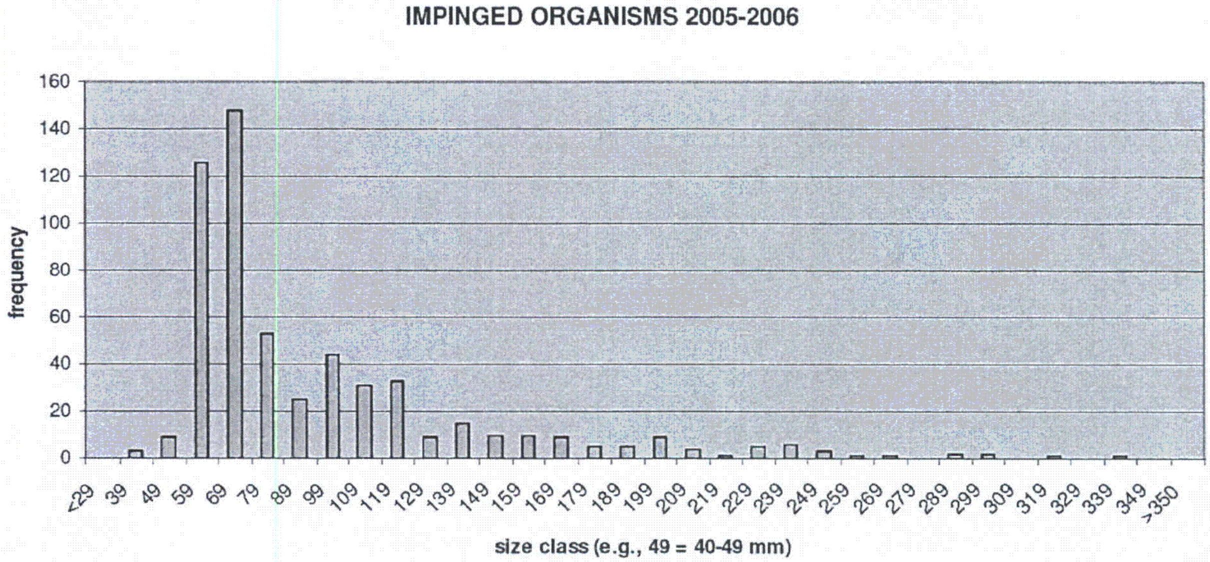
RELATIVE ABUNDANCE OF ORGANISMS IMPINGED AT SUMMER STATION, JULY 2005 - JUNE 2006

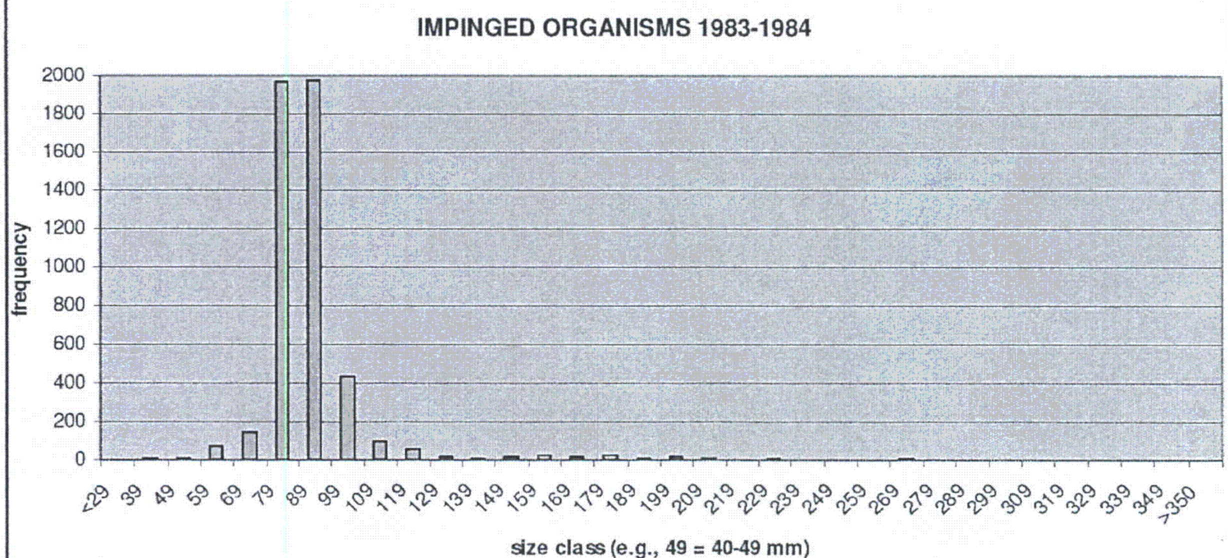


GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.: 5-1	NOTES:
PROJECT NO.: GK3601	Species with 10 or more individuals are shown.
DOCUMENT NO.: GA060413	See Table 5-1 for complete list of impinged species.
FILE: summary for Fig 5-.xls	

LENGTH-FREQUENCY DISTRIBUTIONS OF ORGANISMS IMPINGED AT SUMMER STATION CWIS, 2005-2006 AND 1983-1984

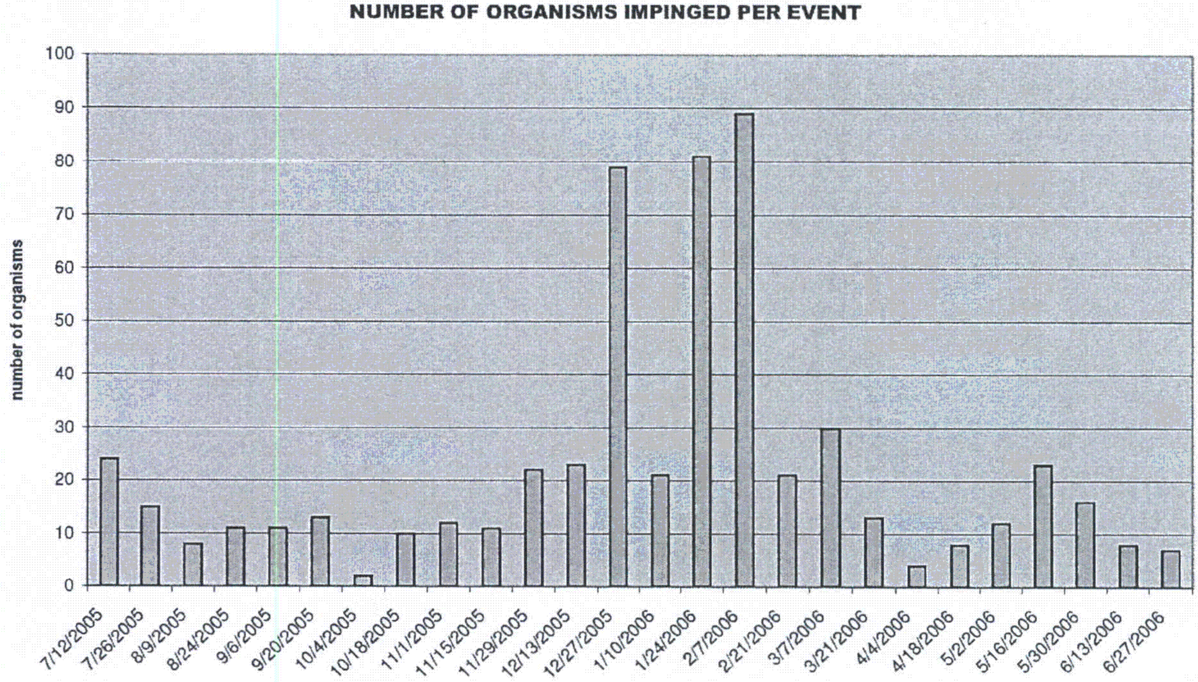


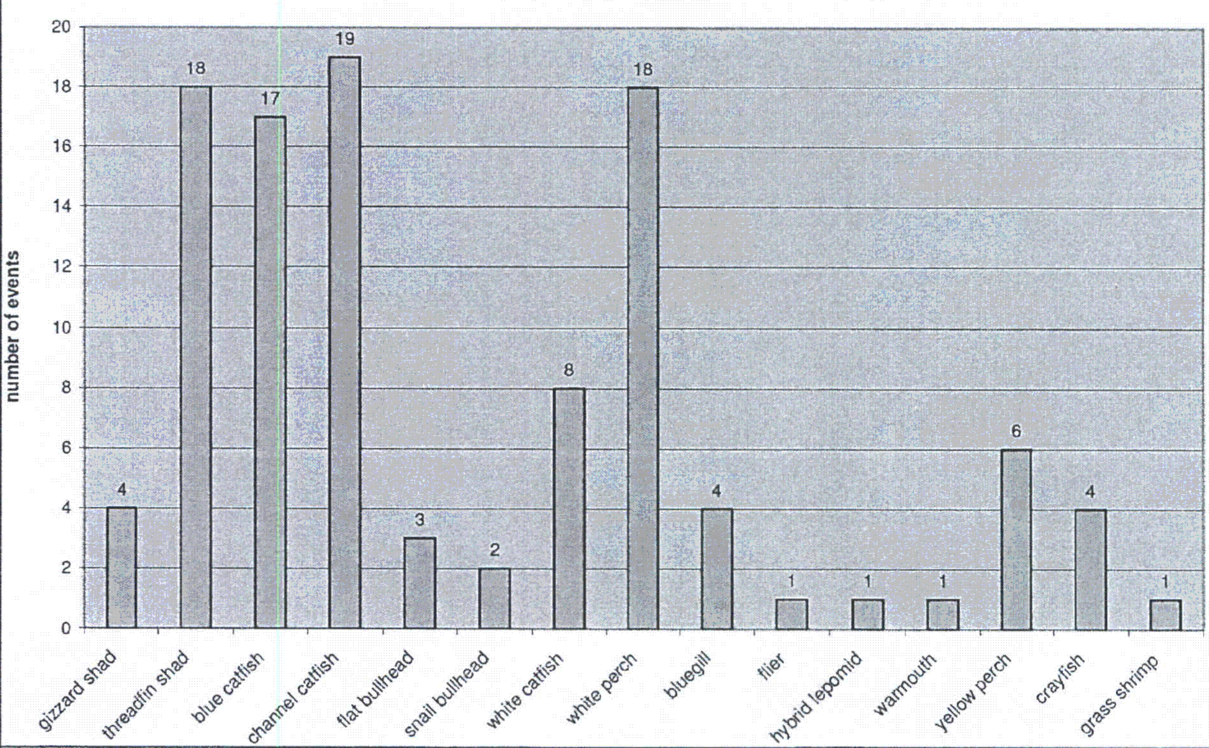


GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.: 5-2	
PROJECT NO.: GK3601	
DOCUMENT NO.: GA060413	
FILE: length_freq.xls	

NUMBER OF ORGANISMS IMPINGED PER EVENT AND FREQUENCY OF TAXA OCCURRENCE AT SUMMER STATION, JULY 2005 – JUNE 2006



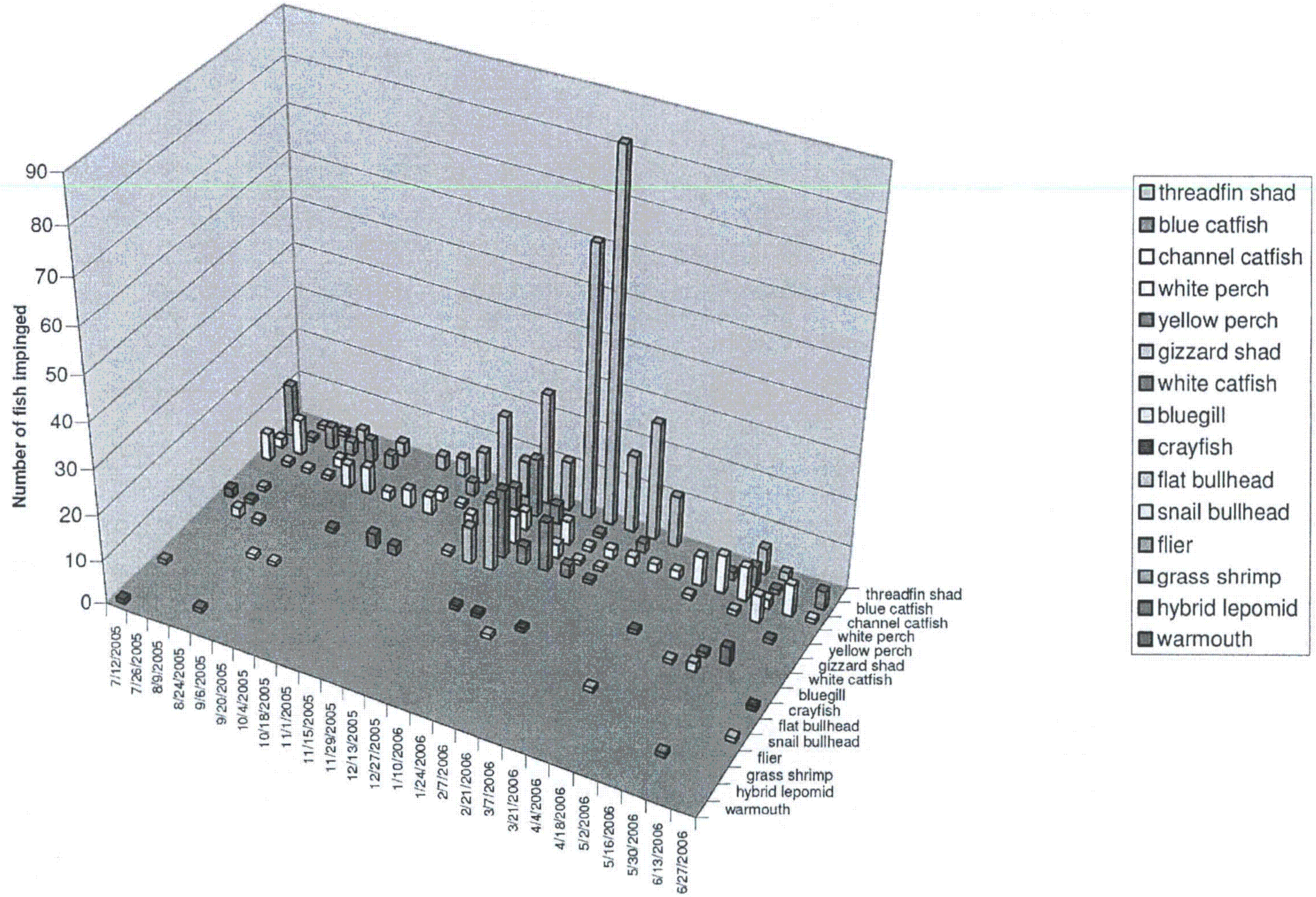


GEOSYNTEC CONSULTANTS

ATLANTA, GEORGIA

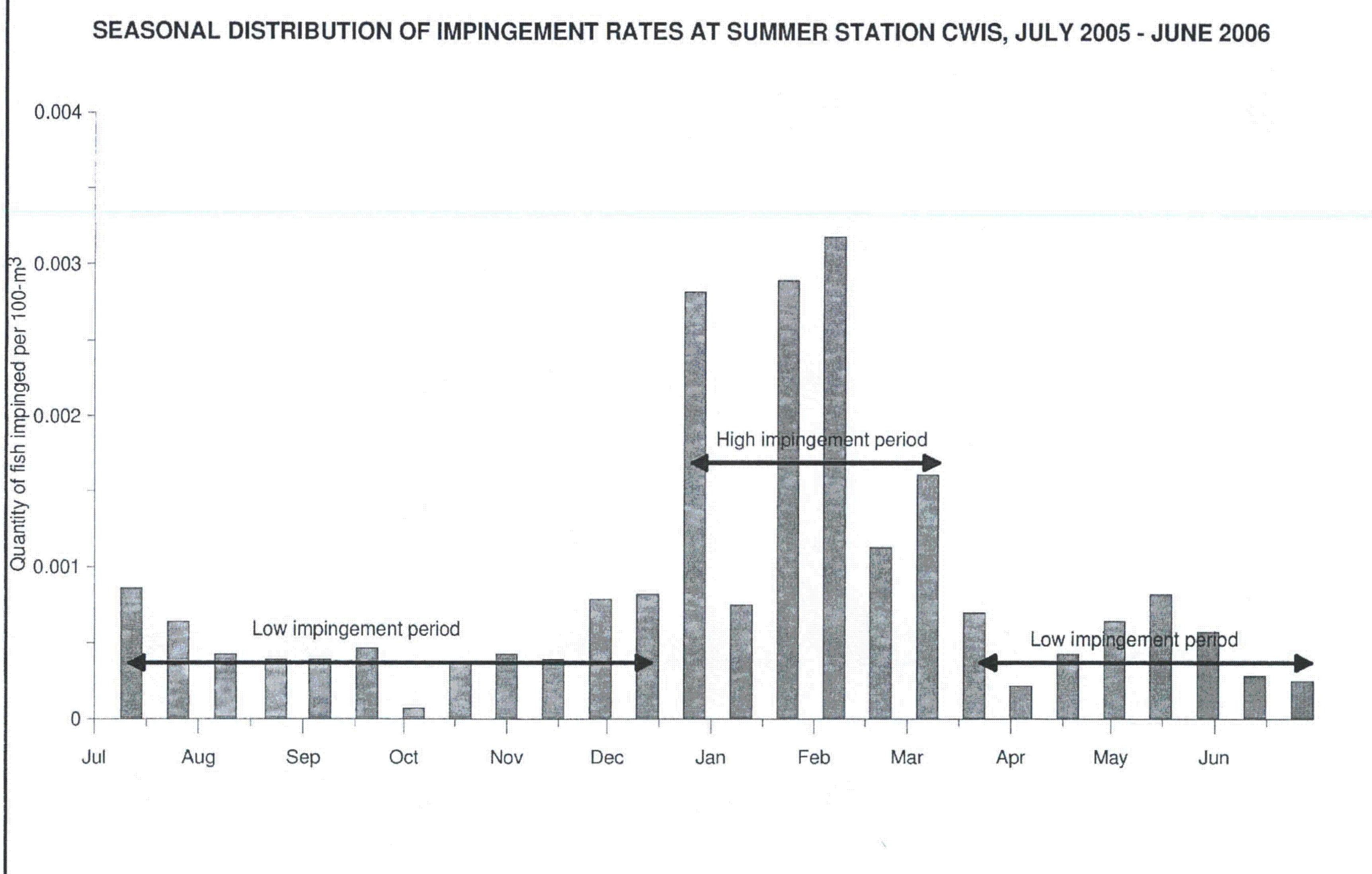
FIGURE NO.: 5-3	
PROJECT NO.: GK3601	
DOCUMENT NO.: GA060413	
FILE: summary for Fig5.xls	

NUMBER OF ORGANISMS IMPINGED BY TAXA PER SAMPLING EVENT AT SUMMER STATION, JULY 2005 – JUNE 2006



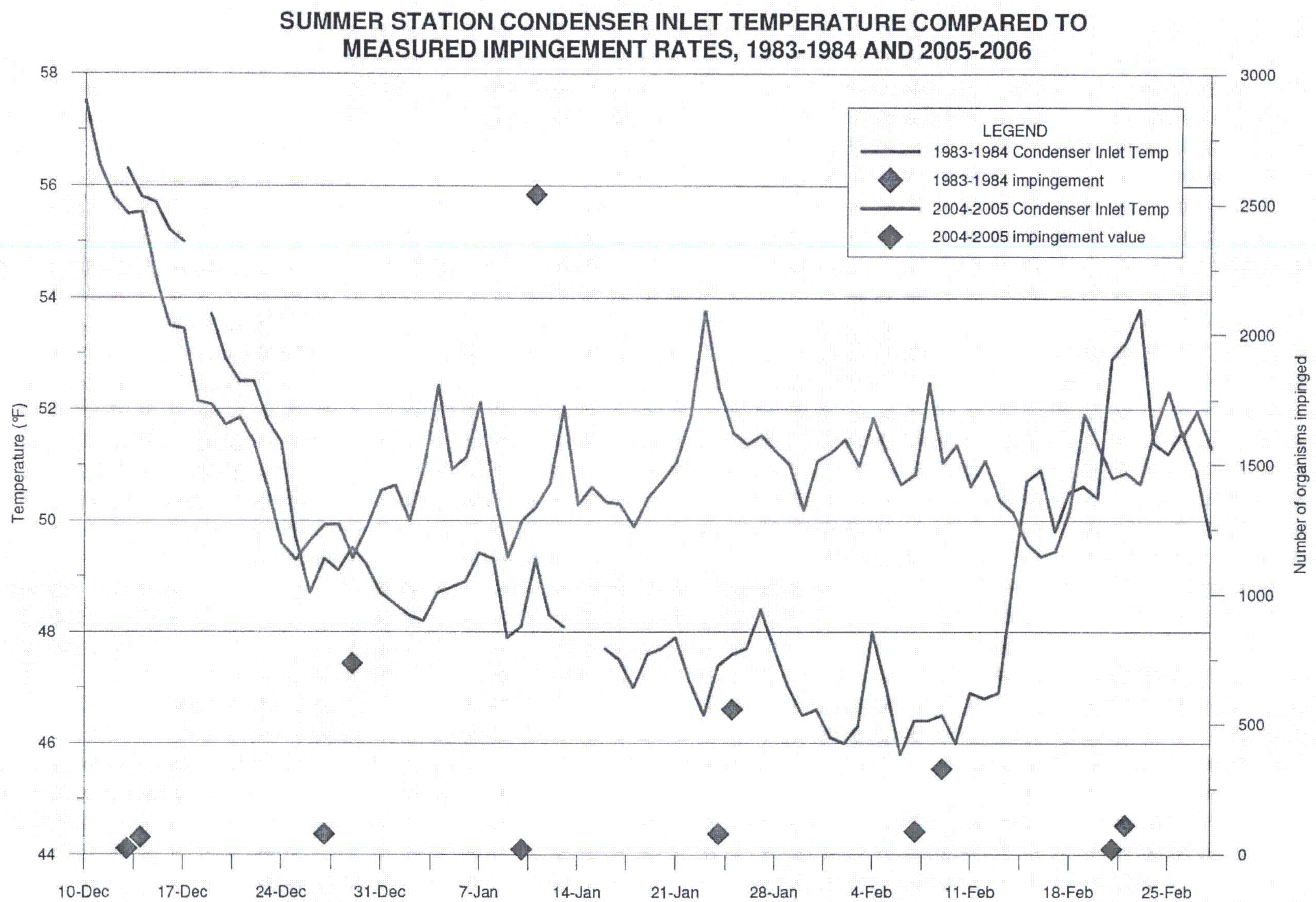
GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.: 5-4	NOTE:
PROJECT NO. GK3601:	
DOCUMENT NO.: GA060413	
FILE: summary for Fig5.xls	



GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.: 6-1
PROJECT NO.: GK3601
DOCUMENT NO.: GA060413
FILE: daily imp rate.xls



GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.: 6-2
PROJECT NO.: GK3601
DOCUMENT NO.: GA060413
FILE: summer temp.xls

APPENDIX A

Impingement Data Summary Tables

TABLE A-1. SPECIES SUMMARY BY SAMPLE DATE OF ORGANISMS IMPINGED AT SUMMER STATION, JULY 2005 – JUNE 2006

SpeciesName	7/12/2005	7/26/2005	8/9/2005	8/24/2005	9/6/2005	9/20/2005	10/4/2005	10/18/2005	11/1/2005	11/15/2005	11/29/2005	12/13/2005	12/27/2005	1/10/2006	1/24/2006	2/7/2006	2/21/2006	3/7/2006	3/21/2006	4/4/2006	4/18/2006	5/2/2006	5/16/2006	5/30/2006	6/13/2006	6/27/2006	Number	% of Total
blue catfish	12	1	5	3	5	3				3	1	5	13	4		1		2				2	5	1		4	**70**	*12.2%*
bluegill		2	1																			1	2				**6**	*1.0%*
channel catfish	2	8		2					2	1			4	1	5	1	2	2	2	2	7	9	8	2	7	1	**68**	*11.8%*
crayfish													1	1		1										1	**4**	*0.7%*
flat bullhead				1	1										1												**3**	*0.5%*
flier	1																										**1**	*0.2%*
gizzard shad		1									1	8	15														**25**	*4.4%*
grass shrimp																								1			**1**	*0.2%*
hybrid lepomid				1																							**1**	*0.2%*
snail bullhead																				1						1	**2**	*0.3%*
threadfin shad		1	1	3		3		3	4	7	17	8	25	11	61	82	17	26	11				6	2			**288**	*50.2%*
warmouth	1																										**1**	*0.2%*
white catfish	2	1				1		3	2											1			1	4			**15**	*2.6%*
white perch	6	1	1	1	5	6	2	4	4		3	2	6		3	1	1				1		1	6			**54**	*9.4%*
yellow perch													15	4	11	3	1								1		**35**	*6.1%*
TOTALS	**24**	**15**	**8**	**11**	**11**	**13**	**2**	**10**	**12**	**11**	**22**	**23**	**79**	**21**	**81**	**89**	**21**	**30**	**13**	**4**	**8**	**12**	**23**	**16**	**8**	**7**	**574**	***100%***

TABLE A-2. SPECIES SUMMARY BY SAMPLE DATE OF BIOMASS OF ORGANISMS IMPINGED AT SUMMER STATION, JULY 2005 -- JUNE 2006

SpeciesName	7/12/2005	7/26/2005	8/9/2005	8/24/2005	9/6/2005	9/20/2005	10/4/2005	10/18/2005	11/1/2005	11/15/2005	11/29/2005	12/13/2005	12/27/2005	1/10/2006	1/24/2006	2/7/2006	2/21/2006	3/7/2006	3/21/2006	4/4/2006	4/18/2006	5/2/2006	5/16/2006	5/30/2006	6/13/2006	6/27/2006	Number	% of Total
blue catfish	557	19	90	24	66	36				158	13	19	47	8		2		7				13	25	3		185	**1,272**	*16.1%*
bluegill		46	21																			21	28				**116**	*1.5%*
channel catfish	58	145		103					51	7			9	1	12	1	3	8	23	11	28	20	127	82	226	70	**985**	*12.5%*
crayfish																										17	**17**	*0.2%*
flat bullhead				51	14										19												**84**	*1.1%*
flier	1																										**1**	*0.0%*
gizzard shad		197									245	24	556														**1,022**	*12.9%*
grass shrimp																								1			**1**	*0.0%*
hybrid lepomid				52																							**52**	*0.7%*
snail bullhead																				6						44	**50**	*0.6%*
threadfin shad		1	5	11		14		15	15	12	31	20	56	18	91	103	30	47	23				37	20			**549**	*6.9%*
warmouth	5																										**5**	*0.1%*
white catfish	193	100				121		43	0											60			2	70			**589**	*7.4%*
white perch	137	50	26	29	580	660	118	280	205		58	31	112		147	29	13				213		31	174			**2,893**	*36.6%*
yellow perch													115	38	80	21	16								1		**271**	*3.4%*
TOTALS	**951**	**558**	**142**	**270**	**660**	**831**	**118**	**338**	**271**	**177**	**347**	**94**	**895**	**65**	**349**	**156**	**62**	**62**	**46**	**77**	**241**	**54**	**250**	**350**	**227**	**316**	**7,907**	***100%***

Note:

All values reported in grams.

APPPENDIX B

Statistical Documentation Supporting the Summer Station Calculation Baseline Estimate of Impingement Mortality

FLUCL tool output for impingement rates 9/26/06

Summary Statistics for number	
Number of Samples	26
Number of Censored Data	0
Minimum	7.15E-05
Maximum	0.003183
Mean	0.000859
Median	0.000605
Standard Deviation	0.00084
Variance	7.05E-07
Coefficient of Variation	0.976857
Skewness	1.983052

95% UCL (Assuming Normal Data)	
Student's-t	0.001141

95% UCL (Adjusted for Skewness)	
Adjusted-CLT	0.001199
Modified-t	0.001151

95% Non-parametric UCL	
CLT	0.00113
Jackknife	NA
Standard Bootstrap	0.001118
Bootstrap-t	0.001336
Chebyshev (Mean, Std)	0.001577

Summary Statistics for ln(number)	
Minimum	-9.545506477
Maximum	-5.750017166
Mean	-7.406537863
Standard Deviation	0.839351121
Variance	0.704510304

Goodness-of-Fit Results	
Distribution Recommended	Lognormal
Distribution Used	Lognormal

Estimates Assuming Lognormal Distribution	
MLE Mean	0.000863702
MLE Standard Deviation	0.000873517
MLE Median	0.00060727
MLE Coefficient of Variation	1.011363366
MVUE Estimate of Mean	0.000848574
MVUE Estimate of Std. Dev.	0.00080559
MVUE Estimate of SE	0.000154357
MVUE Coefficient of Variation	0.949344874

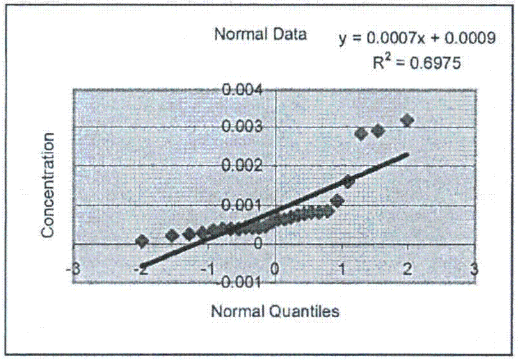
UCL Assuming Lognormal Distribution	
95% H-UCL	0.001278303
95% Chebyshev (MVUE) UCL	0.0015214
99% Chebyshev (MVUE) UCL	0.00238441

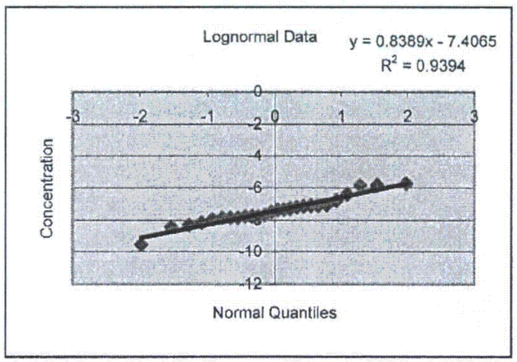
FDEP Recommended UCL to Use:

0.001278

FDEP UCL Calculator Version 1.0

Goodness-of-fit test results





Shapiro-Francia Results (Adjust for Censoring)

SF for Normal Distribution	0.6975
SF for LogNormal Distribution	0.9394
Shapiro-Francia critical value for $p<0.05$	NA

Test stat > critical value indicates a reasonable fit

Shapiro-Wilk's Test Results for All Data (BDL replaced with 1/2 DL)

SW test statistic for Normal Distribution	0.700
SW test statistic for LogNormal Distribution	0.947
Shapiro-Wilk's critical value for $p<0.05$	0.92

Test stat > critical value indicates a reasonable fit

Based on the results of the Shapiro-Wilk's test
Distribution is best described as: Lognormal

Lognormal

FLUCL tool output for BIOMASS impingement rates 9/26/06

Summary Statistics for biomass	
Number of Samples	26
Number of Censored Data	0
Minimum	0.002324
Maximum	0.034009
Mean	0.011491
Median	0.009298
Standard Deviation	0.0094
Variance	8.84E-05
Coefficient of Variation	0.818002
Skewness	1.288934

95% UCL (Assuming Normal Data)	
Student's-t	0.01464

95% UCL (Adjusted for Skewness)	
Adjusted-CLT	0.015022
Modified-t	0.014718

95% Non-parametric UCL	
CLT	0.014524
Jackknife	NA
Standard Bootstrap	0.01453
Bootstrap-t	0.016769
Chebyshev (Mean, Std)	0.019527

Summary Statistics for ln(biomass)	
Minimum	-6.064266205
Maximum	-3.381139755
Mean	-4.774646557
Standard Deviation	0.811955242
Variance	0.659271314

Goodness-of-Fit Results	
Distribution Recommended	Lognormal
Distribution Used	Lognormal

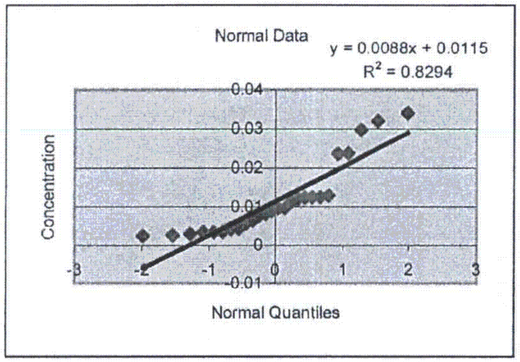
Estimates Assuming Lognormal Distribution	
MLE Mean	0.011736978
MLE Standard Deviation	0.0113393
MLE Median	0.008441067
MLE Coefficient of Variation	0.966117484
MVUE Estimate of Mean	0.011547278
MVUE Estimate of Std. Dev.	0.010522453
MVUE Estimate of SE	0.002021466
MVUE Coefficient of Variation	0.911249697

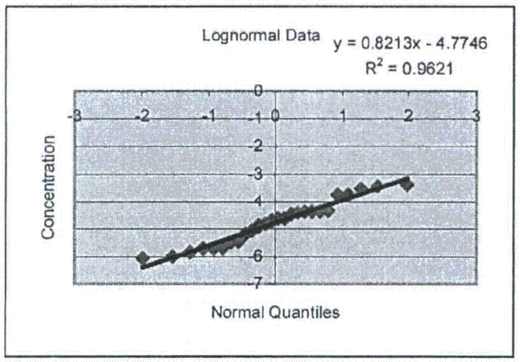
UCL Assuming Lognormal Distribution	
95% H-UCL	0.017062604
95% Chebyshev (MVUE) UCL	0.020358646
99% Chebyshev (MVUE) UCL	0.031660665

FDEP Recommended UCL to Use:
0.017063

FDEP UCL Calculator Version 1.0

Goodness-of-fit test results





Shapiro-Francia Results (Adjust for Censoring)

SF for Normal Distribution	0.8294
SF for LogNormal Distribution	0.9621
Shapiro-Francia critical value for $p<0.05$	NA

Test stat > critical value indicates a reasonable fit

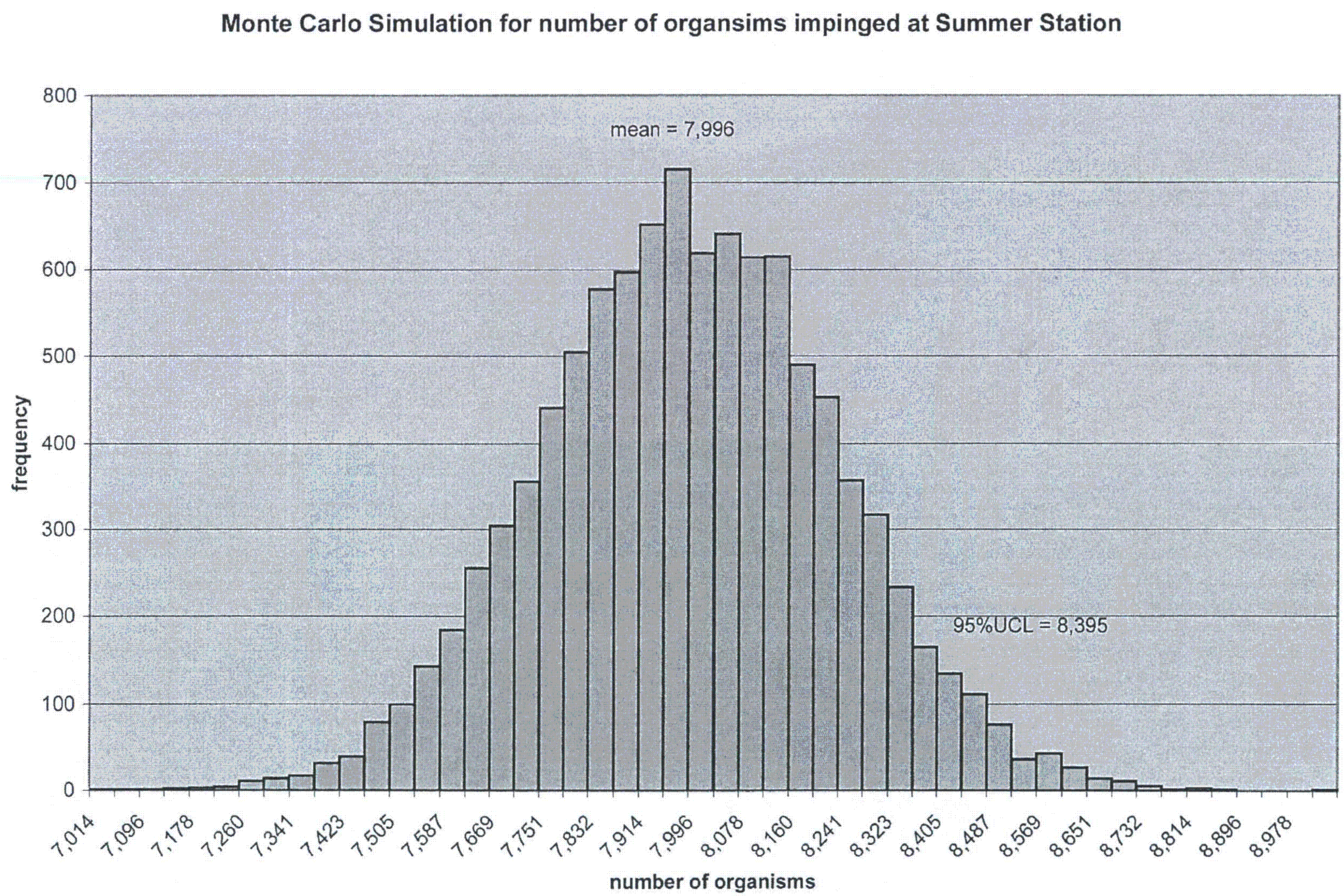
Shapiro-Wilk's Test Results for All Data (BDL replaced with 1/2 DL)

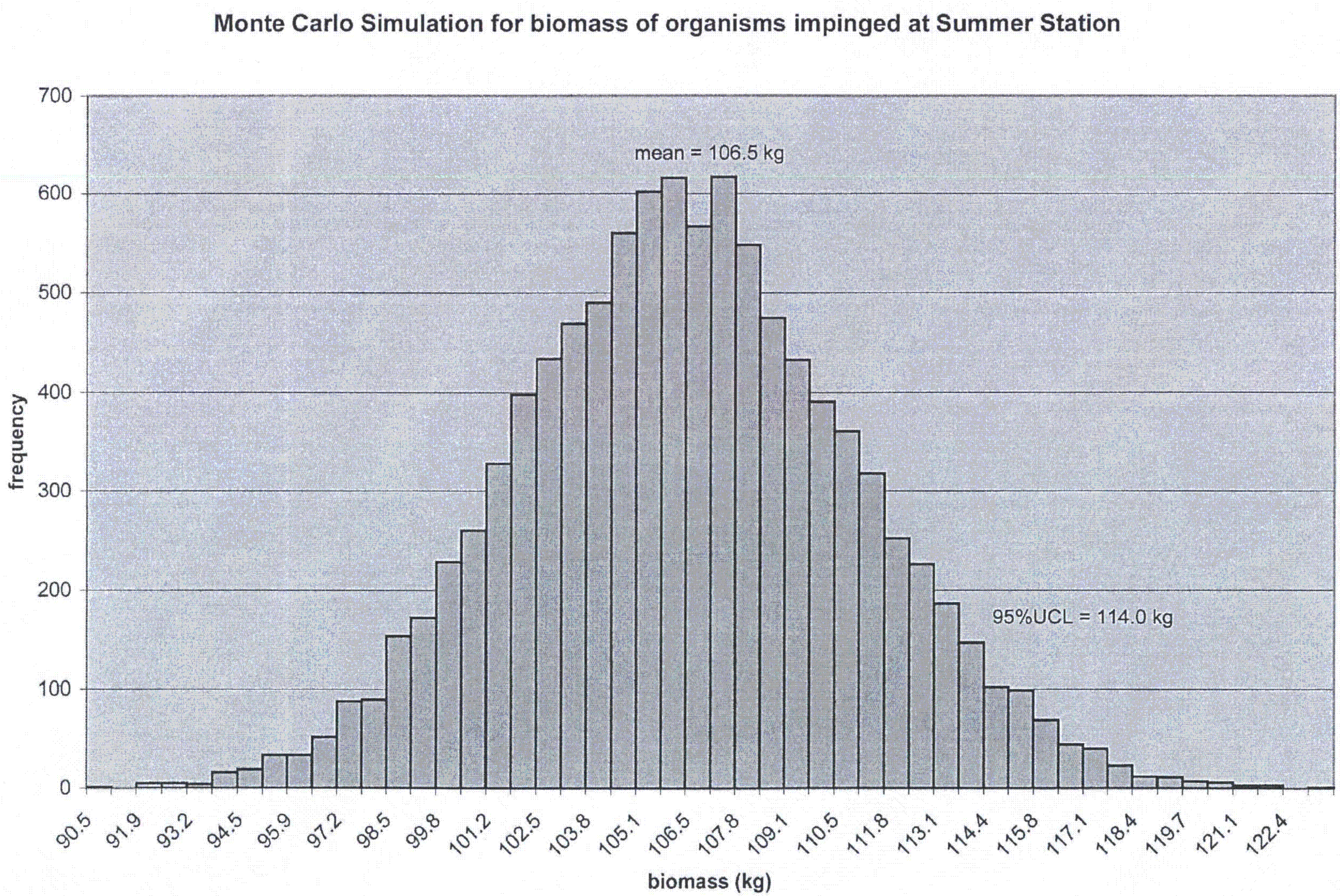
SW test statistic for Normal Distribution	0.820
SW test statistic for LogNormal Distribution	0.945
Shapiro-Wilk's critical value for $p<0.05$	0.92

Test stat > critical value indicates a reasonable fit

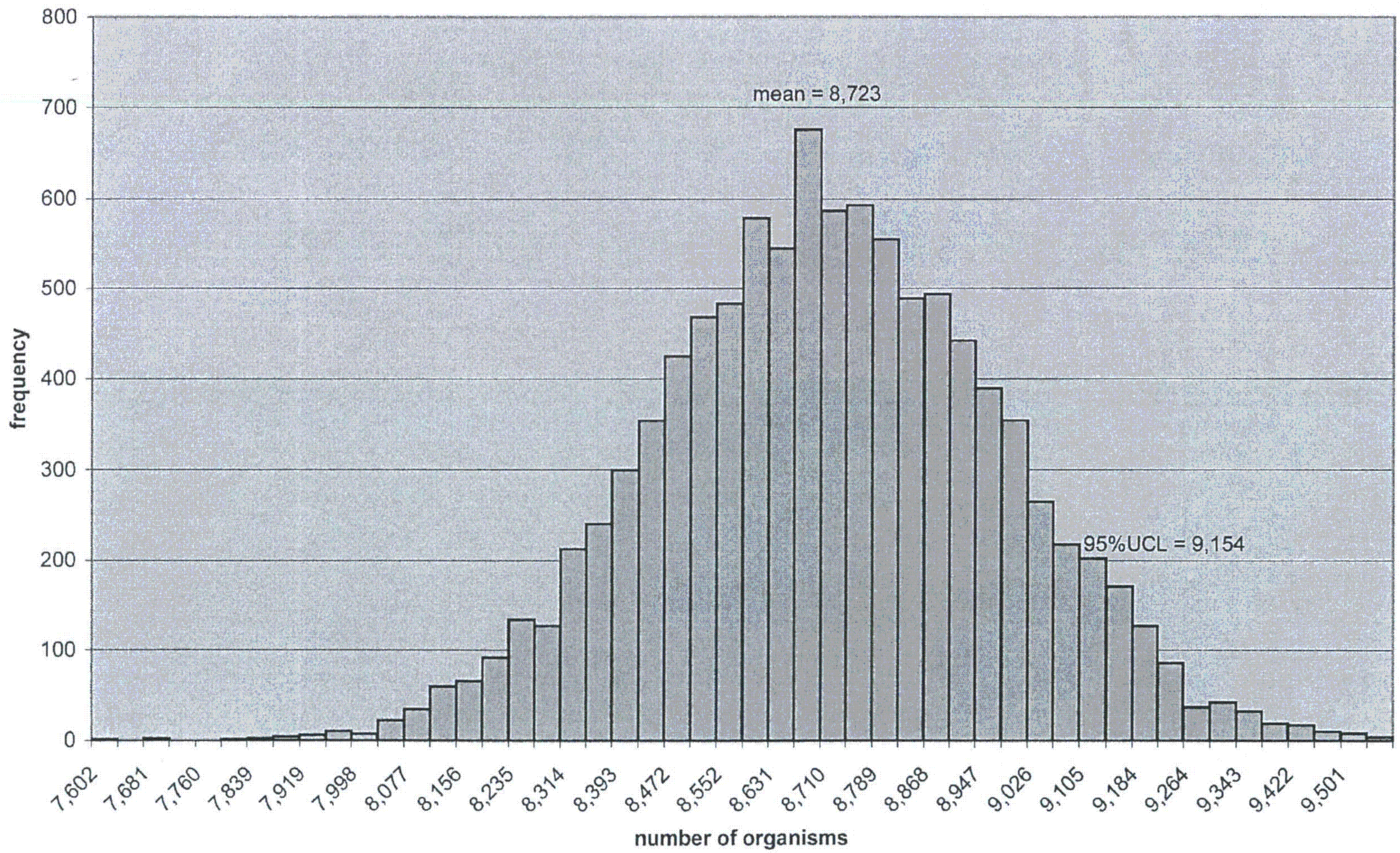
Based on the results of the Shapiro-Wilk's test
Distribution is best described as: Lognormal

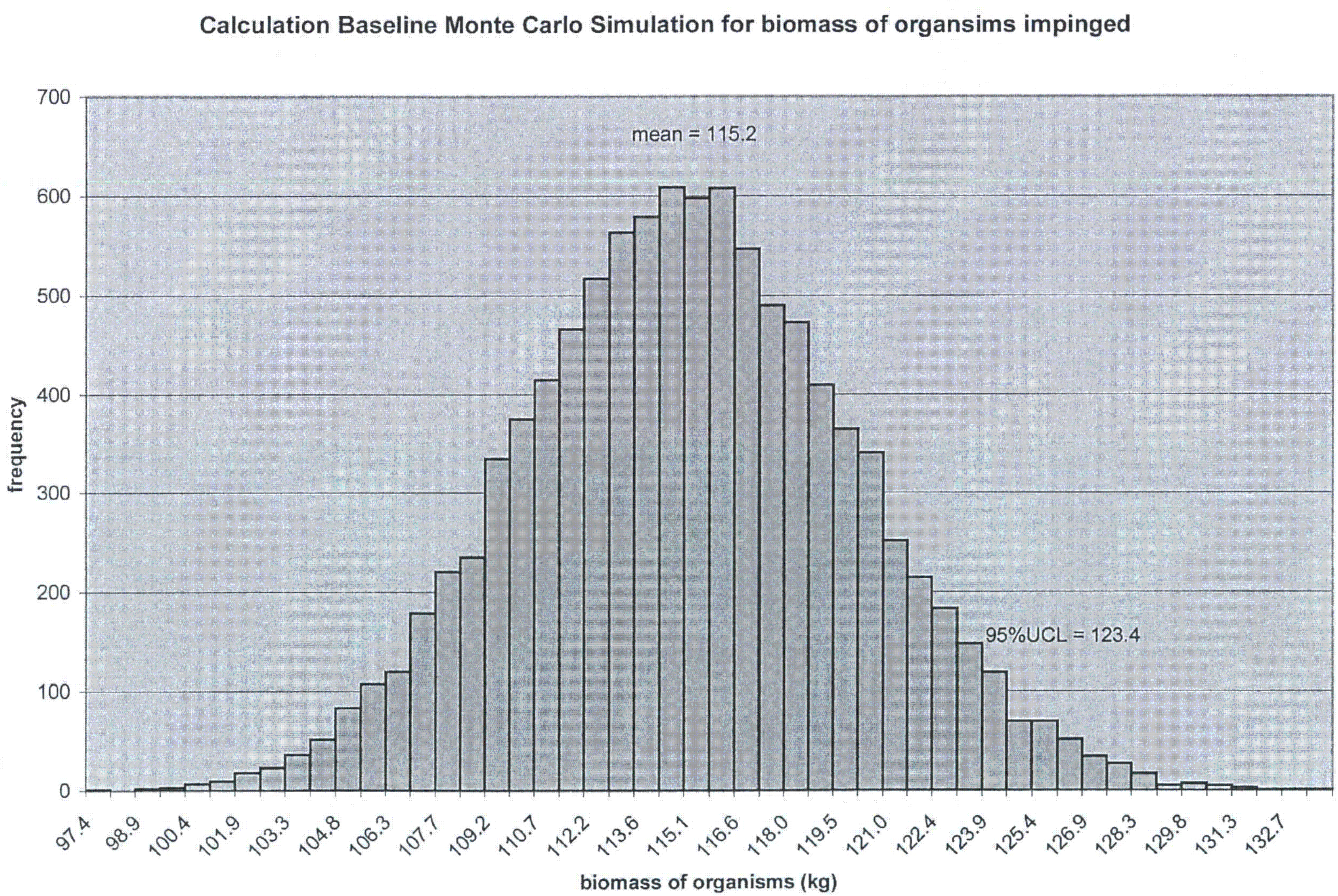
Lognormal


Monte Carlo Simulation for number of organsims impinged at Summer Station
mean = 7,996
95%UCL = 8,395
frequency
0
100
200
300
400
500
600
700
800
7,014
7,096
7,178
7,260
7,341
7,423
7,505
7,587
7,669
7,751
7,832
7,914
7,996
8,078
8,160
8,241
8,323
8,405
8,487
8,569
8,651
8,732
8,814
8,896
8,978
number of organisms


Monte Carlo Simulation for biomass of organisms impinged at Summer Station
mean = 106.5 kg
95%UCL = 114.0 kg
frequency
0
100
200
300
400
500
600
700
90.5
91.9
93.2
94.5
95.9
97.2
98.5
99.8
101.2
102.5
103.8
105.1
106.5
107.8
109.1
110.5
111.8
113.1
114.4
115.8
117.1
118.4
119.7
121.1
122.4
biomass (kg)

Calculation Baseline Monte Carlo Simulation for number of organsims impinged





Calculation Baseline Monte Carlo Simulation for biomass of organsims impinged
mean = 115.2
95%UCL = 123.4
frequency
0
100
200
300
400
500
600
700
97.4
98.9
100.4
101.9
103.3
104.8
106.3
107.7
109.2
110.7
112.2
113.6
115.1
116.6
118.0
119.5
121.0
122.4
123.9
125.4
126.9
128.3
129.8
131.3
132.7
biomass of organisms (kg)