1 of 2

**ECOLOGICAL STUDIES RELATED TO THE CONSTRUCTION OF
THE DEFENSE WASTE PROCESSING FACILITY
ON THE SAVANNAH RIVER SITE**

FY-1991 AND FY-1992 Annual Report

**Division of Wildlife Ecology and Toxicology
Savannah River Ecology Laboratory**

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FOREWORD

The Defense Waste Processing Facility (DWPF) was built on the Savannah River Site (SRS) during the mid-1980's. The Savannah River Ecology Laboratory (SREL) has completed 14 years of ecological studies related to the construction of the DWPF complex. Prior to construction, the 600-acre site (S-Area) contained a Carolina bay and the headwaters of a stream. Research conducted by the SREL has focused primarily on four questions related to these wetlands: 1) Prior to construction, what fauna and flora were present at the DWPF site and at similar, yet undisturbed, alternative sites? 2) By comparing the Carolina bay at the DWPF site (Sun Bay) with an undisturbed control Carolina bay (Rainbow Bay), what effect is construction having on the organisms that inhabited the DWPF site? 3) By comparing control streams with streams on the periphery of the DWPF site, what effect is construction having on the peripheral streams? 4) How effective have efforts been to lessen the impacts of construction, both with respect to erosion control measures and the construction of "refuge ponds" as alternative breeding sites for amphibians that formerly bred at Sun Bay?

Through the long-term census-taking of biota at the DWPF site and Rainbow Bay, SREL has begun to evaluate the impact of construction on the biota and the effectiveness of mitigation efforts. Similarly, the effects of erosion from the DWPF site on the water quality of S-Area peripheral streams are being assessed. This research provides supporting data relevant to the National Environmental Policy Act (NEPA) of 1969, the Endangered Species Act of 1973, Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands), and United States Department of Energy (DOE) Guidelines for Compliance with Floodplain/Wetland Environmental Review Requirements (10 CFR 1022).

I. INTRODUCTION AND OVERVIEW

David E. Scott and Joseph H.K. Pechmann

The Savannah River Ecology Laboratory initiated ecological studies related to the construction of the DWPF on the SRS in FY-1979. Two areas have been used for biological surveys and long-term monitoring: the DWPF construction site (S-Area), and two control sites (Rainbow Bay and Tinker Creek). The Rainbow Bay study area and S-Area are located within 5 km of each other on the SRS (Fig I-1), and both once contained Carolina bays which were very similar ecologically (SREL 1980). One goal of the SREL's faunal studies is to compare the natural variation in amphibian populations at the Rainbow Bay control site to the variation observed at the human-altered site (Sun Bay, formerly on the DWPF construction site). Amphibian populations exhibit large year-to-year variation in population size and breeding success (Vitt 1981, Vitt et al. 1982), thus long-term studies are necessary to separate natural variation from variation due to human perturbations (Pechmann et al. 1993).

Pre-construction biological surveys included data on vegetation, birds, mammals, amphibians, reptiles, fish, and several invertebrate groups (SREL 1979, 1980). No species on the Federal Endangered or Threatened lists were found on either site, but several plants and animals of threatened or special-concern status in South Carolina were present (SREL 1980, Vitt 1981).

DWPF construction began in FY-1984. Continuing studies are directed towards assessing construction impacts on the biota, and towards modeling the effects of alteration of wetland hydroperiod on the biota. Primary emphasis is being placed on evaluating the effectiveness of mitigation measures undertaken by the DOE.

Figure I-1

Locations of the DWPF construction site (S-Area) and the Rainbow Bay Study Area (control site) on the Savannah River Site.

SREL began baseline water quality monitoring on S-Area peripheral streams in November 1982 (prior to construction) to quantify natural variation in water quality parameters. Sampling has continued to the present on the streams that drain the DWPF site (Upper Three Runs Creek, McQueen Branch, and Crouch Branch; Figure II-1) and on a nearby, unimpacted blackwater stream, Tinker Creek. Erosion resulting from DWPF construction potentially could affect the productivity and biotic diversity of McQueen Branch, Crouch Branch, and Upper Three Runs Creek. Results of a baseline survey of macroinvertebrates in these streams were reported in Pechmann et al. (1984). Chapter II of this report contains the FY-1991 and FY-1992 water quality results, and an assessment of the effectiveness of erosion control measures which have been implemented during the DWPF construction (U.S. DOE 1982).

In FY-1984, the DWPF construction eliminated Sun Bay in S-Area. Carolina bays are extremely productive, natural wetlands which serve as important breeding sites for many species of amphibians (Bennett et al. 1979, Gibbons and Semlitsch 1981, Sharitz and Gibbons 1982). Amphibians are the most prevalent group of vertebrates on both the Rainbow Bay control site and the DWPF site (SREL 1980). A major objective of the SREL studies has been to evaluate the effects of the loss of Sun Bay on the breeding success of amphibians in S-Area (Pechmann et al. 1985, Scott et al. 1986). In an experimental attempt to mitigate the loss of the natural breeding habitat in S-Area (i.e., Sun Bay), four refuge ponds were constructed. Only three of these are currently in operation, because of the loss of one due to unanticipated construction activities. A summary of refuge pond captures, as well as summary data from the Rainbow Bay control site are presented in Chapter III.

The long-term nature of the Rainbow Bay study (currently 14 years) has allowed the natural variation in numbers of immigrating breeding adults and of emigrating juveniles at the control site to be documented. These data have provided a baseline to examine the natural year-to-year fluctuations in amphibian

populations. Numerous factors are responsible for this annual variation in amphibian numbers. One factor (hydroperiod, or the number of days a site holds water during a year), is a critical determinant of amphibian breeding success and population persistence. Biotic factors such as competition in the larval environment and predation by various invertebrate species may also affect amphibian population dynamics. Chapter IV addresses the relationship between these factors (particularly larval density) and body size at metamorphosis and a suite of adult traits that exert strong effects on the population dynamics of the marbled salamander, Ambystoma opacum.

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II. WATER QUALITY MONITORING OF PERIPHERAL STREAMS

Anne C. Chazal and David E. Scott

INTRODUCTION

The Savannah River Ecology Laboratory initiated a water quality monitoring program in November 1982 to assess the potential impact of the DWPF construction activities on peripheral streams. Upper Three Runs (UTR) Creek, which receives S- and Z-area drainage, is the only major stream on the Savannah River Site that has not been impacted significantly by thermal discharge.

In FY- 1983 before construction began, baseline information was collected on the natural water quality characteristics of all streams that could be impacted: UTR Creek, Crouch Branch, McQueen Branch, and Tinker Creek, a major upstream tributary of UTR. Rough grading of the construction site began on 15 September 1983 (Pechmann et al. 1984). Data gathered after ground-breaking through September 1987 have been used to evaluate impacts during construction and the initial effectiveness of erosion control measures. Data collected from October 1987 to the present are used to assess post-construction stream recovery and the continued effectiveness of erosion control measures; all major earth-moving and site preparation activities had been completed by this date.

METHODS

Site Selection

The four streams mentioned above are part of the DWPF watershed (Fig. II-1). McQueen Branch is the principle drainage tributary from the construction area. Crouch Branch receives the outflow from DWPF sediment basin 1. These tributaries are the two primary streams leaving S- and H-area, and are the streams most likely to

Figure II-1. DWPF Water Quality monitoring sites.

be impacted by construction activity. Both Crouch Branch and McQueen Branch flow into UTR Creek and impacts on them could potentially affect water quality in UTR Creek. Tinker Creek also flows into UTR just above the confluence of McQueen Branch and UTR. Similar in size to UTR Creek, Tinker serves as an unimpacted control stream within the watershed.

The SREL monitoring program previously focused on 10 sample sites in the UTR watershed; however, only nine sites are sampled currently (Fig. II-1). Two sites (3 and 4) are located on McQueen Branch. Site 3 is located approximately 2 km downstream of the construction area, and site 4 is located on the south side of road F. A third site on this Creek was sampled between November 1984 and September 1986 (Scott et al. 1988). Site 7 is located on Crouch Branch at Road 4 approximately 122 m downstream from the outflow of sedimentation basin 1. Site 7 was sampled twice in FY-1982 and deactivated until FY-1986 after which it was sampled regularly. Sites 1 and 2 are located on UTR Creek below the confluence with McQueen Branch, and two more sites (sites 6 and 8) are located on UTR Creek above this confluence. Two sites (sites 5 and 9) are monitored on Tinker Creek upstream from the construction area.

Sampling

From the second to the seventh year of sampling (November 1983 - September 1989), water quality monitoring was conducted monthly. During FY- 1983 (November 1982 - September 1983), sampling was conducted more frequently than in later years and with an emphasis on sampling during and after rainfall for the purpose of establishing existing water quality characteristics. Due to budgetary cuts, monitoring ceased between October 1989 and February 1990; however, monthly sampling resumed in March 1990. Thus, the first year (FY- 1983) includes data for 11

months and during FY- 1990 streams were sampled for seven months. Water quality measures from the remaining years are based on 12 months.

SREL personnel measured the following water quality variables: total suspended solids (TSS), percent ash, turbidity, and specific conductance. Total suspended solids is a measure of the dry weight of nonfilterable residue in each sample. Percent ash is a measure of the inorganic component of the TSS. The ratio of inorganic to organic matter may change relative to the specific stream inputs, e.g. erosion clays vs. leaf litter. Turbidity is based on measurements of refracted light and indicates the relative amount of undissolved particles in a stream sample. Specific conductance measures the ability of a sample to carry an electrical current and depends mostly on the level of dissolved salts (ions) present in the water. Stream profiles and flow measures were added to the routine sampling in October 1985 at three sites: 3 and 4 (McQueen Branch), and 9 (Tinker Creek).

Until February 1985, specific conductance was measured with a field conductivity bridge. Samples since February 1985 were analyzed in the laboratory using a Sybron PM-10CB conductivity bridge or an Orion Research Conductivity Meter Model 101 (25 C). Turbidity was determined in the laboratory using a nephelometer which measured in Nephelometric Turbidity Units (NTU; reduced sampling during the first year). Samples were analyzed for TSS and ash weight using EPA approved methods (US EPA, 1983). A rain gauge was placed adjacent to the DWPF construction site and monitored daily. Stream profiles and flow measures were added to the routine sampling in October 1985 at three sites: 4 (McQueen Branch), 3 (McQueen Branch), and 9 (Tinker Creek). Stream velocities (centimeters per second) were measured using a Marsh-McBirney Portable Flow Meter. These measures were used to calculate TSS load.

In FY- 1986 four plots were established on McQueen Branch to inventory the particle size composition and to observe composition changes over time. Based on

the analysis of 2 years of such data a recommendation to terminate that portion of the DWPF monitoring project was made (Scott et al. 1988) and adopted.

Data Analysis

For the statistical analysis of the water quality data, sampling sites were grouped into six watershed locations: the two McQueen Branch sites (3 and 4; McQueen), the two Tinker Creek sites (5 and 9; Tinker), the two UTR Creek sites above McQueen Branch (6 and 8; UTR- above), the UTR Creek site below McQueen Branch (2; UTR- below), and the Crouch Branch site (7; Crouch). General patterns observed in the data suggested further grouping of data based on rainfall one day prior to sampling. Data were grouped into three classes based on rainfall during the previous day: rainfall ≤ 0.1 cm (No Rain), $0.1 \text{ cm} < \text{rainfall} \leq 1.0$ cm (Low Rain), and rainfall > 1.0 cm (High Rain, see Scott et al. 1988). Data also were categorized based on the stages of the construction project: Before (FY- 1983), During (FY-1984 to FY-1987), and After (FY-1988 to FY-1992) Construction (see Introduction).

Analysis of variance (ANOVA) was used to assess the impact of DWPF construction on S- and Z-area stream water quality. In order to decrease variance and increase normality in the data, log transformations were performed on TSS, turbidity, specific conductivity, TSS load (kg per day per km²), and rainfall. The transformations were made by adding 1.0 to each observation and then taking the natural log of the sum. The transformed variables and percent ash measurements were used in ANOVA models to test for effects of DWPF construction activities in each rainfall class (No, Low, and High Rain).

Within the ANOVA models, a number of hypotheses were tested for each rainfall class. For each water quality variable (e.g., log TSS), statistical tests determined whether or not there was a significant location effect (i.e., Did the locations differ in their level of a given variable averaged across all construction periods?), a significant construction period effect (i.e., Did the construction periods

differ in their level of a given variable averaged across all locations?), and a significant location-by-construction interaction (i.e., Did the variable levels at some locations respond differently over the construction periods than at other locations?). This last test, the test of a location-by-construction interaction, is the primary test of whether construction activity has affected water quality in the DWPF peripheral streams.

This interaction test is depicted graphically in Figure II-2. In the example, a comparison of stream 1 vs. stream 2 reveals that stream 2 has higher levels of the measured variable, but both streams respond the same over the three construction periods, i.e., there is no location-by-construction interaction effect because the lines are parallel. However, when stream 1 is compared to stream 3, stream response is not the same during the construction periods; stream 3 increases more in the After Construction period than stream 1, i.e., there is an interaction effect because the lines are not parallel.

Using the ANOVA models, specific comparisons were made between control locations (UTR- above and Tinker) and impacted locations (McQueen, Crouch, UTR- middle, and UTR- below). These tests (statistical contrasts) were limited to particular comparisons of interest: UTR- above vs. UTR- middle, UTR- above vs. UTR- below, Tinker vs. McQueen, and Tinker vs. Crouch. Comparisons were made over three time intervals (Before vs. After, Before vs. During, and During vs. After Construction). Data were analyzed using SAS version 6.07 statistical package (SAS Institute Inc. 1985a, b).

Due to small sample sizes all Crouch Branch samples and all turbidity samples taken in the Before Construction period were omitted from the statistical analysis.

In the following results and discussion section graphical representations of the data accompany and illustrate statistical outcomes and trends. In addition,

Figure II-2. Log variable by construction period (ANOVA interaction test example schematic representation).

Appendix A lists numeric summaries of the water quality data by fiscal year and rainfall class, Appendix B lists P values of ANOVA main effects, Appendix C summarizes construction period means, and Appendix D contains plots at construction period means.

RESULTS AND DISCUSSION

Introduction

Log TSS values for each location were plotted against log rainfall levels one day prior to sampling for each construction period (Fig. II-3). These graphs illustrate several points. First, levels of TSS increase as rainfall increases, for all locations across all time periods. Second, TSS levels are generally higher During (DC) and After (AC) Construction than Before (BC) DWPF Construction, even in the No Rain class. These observations hold for streams that receive drainage directly from S- and Z-areas (Crouch Branch and McQueen Branch) as well as control locations (UTR- above and Tinker Creek). In addition, the smaller streams were higher than the larger streams in TSS irrespective of the construction period.

The main effect of location was significant across rain class levels for TSS, specific conductance and turbidity with the exception of TSS during Low Rain conditions ($p \leq 0.07$) (Appendix B). In general then, locations differed in their level of a given variable averaged over all construction periods.

The construction periods differed in their level of a given variable averaged over all locations. For the No Rain class, interpretation of the significant location and construction main effects is confounded by the significant location-by-construction interaction. Construction period exhibited significant effects in the No Rain class for all variables. In general, in the No Rain class levels of the water quality variables in the S-Area peripheral streams were elevated in the During Construction period, and have since declined. In the Low Rain class only specific conductance

Figure II-3. Log TSS by log rainfall for each location.

levels were effected by construction period. No significant effect of construction period was observed in the High Rain class, perhaps due to the extreme variation in levels of all variables under high rainfall conditions. Given these relationships, the location-by-construction period interaction term was used to test the effect of DWPF construction on stream water quality (as described in methods). Results of the ANOVA contrasts are listed and discussed by stream, beginning with the primary impact streams, McQueen Branch and Crouch Branch, and concluding with UTR Creek. Means for each construction period in each rainfall class are reported in Appendix C and graphically represented in Appendix D.

McQueen Branch

Water quality variables (i.e. TSS, turbidity, specific conductance, and percent ash) in McQueen Branch were compared to levels in the control stream, Tinker Creek, (Fig. II-4). TSS and turbidity levels rise more sharply as rainfall increases and percent ash levels are higher overall in McQueen Branch than in Tinker Creek. This difference is apparently a function of stream order; as a smaller stream, McQueen Branch is "flashier." The degree to which the flashiness of McQueen Branch was influenced by DWPF construction activity was assessed using the specific statistical contrast tests.

TSS: No Rain - TSS levels rose moderately in Tinker Creek over the three construction periods. Levels in McQueen Branch were higher than the control BC, and increased significantly more DC ($p \leq 0.005$). In the After Construction period, TSS levels in McQueen Branch fell below those of the control and returned to levels lower than McQueen Branch BC (BC $\bar{x}$ = 5.38; AC $\bar{x}$ = 4.63).

Low Rain - TSS levels were higher in McQueen Branch than the control for all construction periods. TSS levels increased between BC and DC and fell off slightly AC

Figure II-4. Log TSS, log turbidity, log specific conductance, and percent ash by log rainfall, for Tinker and McQueen.

in McQueen Branch and Tinker Creek. There were no significant differences in the responses of the two streams over time.

High Rain - TSS levels rose very slightly in Tinker Creek over the construction periods, and significantly more sharply ($P \leq 0.03$) in McQueen Branch DC but levels decreased AC. Overall, there was no significant difference in McQueen Branch as compared to Tinker Creek between BC and AC.

TURBIDITY: No Rain - Turbidity levels were higher BC and AC in McQueen Branch than Tinker Creek. Both creeks showed increases DC; however McQueen Branch decreased significantly more AC than Tinker Creek ($p \leq 0.005$).

Low and High Rain - Tinker Creek shows virtually no increase in turbidity over time, while McQueen Branch levels are higher DC than AC. This change in turbidity is statistically non-significant when compared to Tinker.

SPECIFIC CONDUCTANCE: No Rain - McQueen Branch specific conductance was higher than Tinker Creek for all construction periods and fell significantly less than Tinker Creek from BC to DC ($p \leq 0.005$). Comparing responses from BC to AC, McQueen Branch and Tinker Creek responded significantly different ($p \leq 0.05$) with McQueen Branch showing a net increase in specific conductance and the control showing a net decrease..

Low Rain - Specific conductance was higher during all construction periods in McQueen Branch than in Tinker Creek. Levels decreased DC and rose slightly AC in Tinker, while levels increased moderately in McQueen Branch DC and AC. The specific conductance response differed significantly from BC to AC in McQueen Branch when compared to Tinker ($p \leq 0.03$).

High Rain - McQueen's Branch specific conductance was higher than Tinker Creek for all construction periods. Tinker Creek behaved in a similar manner as for

the Low Rain class. McQueen Branch rose slightly DC and fell slightly AC. There was no significant difference in the responses between the two streams.

PERCENT ASH: No Rain - Percent ash levels increased moderately in Tinker Creek over the three construction periods. Levels in McQueen Branch were higher BC and rose significantly more than Tinker Creek DC ($p \leq 0.001$). Levels AC remained higher in McQueen Branch than in Tinker Creek.

Low Rain - Percent ash levels increased DC and decreased slightly AC in both McQueen Branch and Tinker Creek. Levels in McQueen Branch were higher than Tinker Creek over all time periods. There were no significant differences in responses between McQueen Branch and Tinker Creek over construction periods.

High Rain - Levels of percent ash in Tinker Creek decreased DC and increased slightly AC. Levels in McQueen Branch were higher than Tinker Creek BC and increased significantly DC ($p \leq 0.01$). Both streams had increased percent ash AC when compared to BC levels, and the increase in McQueen Branch was significantly greater than the increase at Tinker Creek ($p \leq 0.04$).

TSS LOAD: The log TSS load (kg per day per km²) is graphed against log rainfall for Tinker site 9 and each site on McQueen Branch (sites 3 and 4; Fig. II-5). No data is available for the BC period.

No Rain - TSS load for Tinker Creek rose moderately AC compared to levels DC. Load levels in McQueen Branch were higher DC and then decreased significantly AC when compared to Tinker Creek ($p \leq 0.007$).

Low and High Rain - TSS load in McQueen Branch decreased from the DC to the AC period under Low Rain conditions but increased slightly in Tinker Creek. Under High Rain conditions both creeks showed increases AC over the DC period. No changes in either group were significant.

Figure II-5. Log Tss load by log rainfall, for McQueen Branch (sites 4 and 3) and Tinker Creek (site 9).

The results listed above provide evidence that McQueen Branch clearly has been affected by DWPF construction-site runoff over the ten year sampling period, especially between the BC and DC period. These effects are evident in the TSS, specific conductivity and percent ash variables. TSS levels under No Rain conditions were lower AC than BC levels (Appendix D). Although levels of other variables remained elevated AC in McQueen Branch in most cases, generally there was a slight decrease from DC levels. Given 12 comparisons (4 variables by 3 rainfall classes), 5 showed a significant location-by-construction interaction indicating that McQueen Branch responded differently between BC and AC periods than Tinker Creek. Six comparisons were significant between the BC and DC periods. Three comparisons were significant between the DC and AC periods and all of these occurred under No Rain conditions. The differences may be attributed to increases in the control stream versus little to no increase (and a decrease in one instance) in McQueen Branch. Some recovery of the tributary seems evident in the AC period.

CROUCH BRANCH

Crouch Branch is the second primary impact site below the DWPF construction area. Like McQueen Branch, it is a small tributary that readily fills under High Rain conditions. Few data are available for this site BC; however, DC and AC data are used to test the location-by-construction period interaction between Crouch Branch and Tinker Creek for each water quality variable (Fig. II-6).

TSS: No Rain - Tinker Creek showed a slight increase in TSS from DC to AC. Crouch Branch TSS levels were considerably higher DC and AC although Crouch Branch showed a decrease AC. The difference in TSS level response between DC and AC for the two streams was significant ($p \leq 0.0001$). AC levels remained higher in Crouch Branch than in Tinker Creek.

Figure II-6. Log TSS, long turbidity, log specific conductivity, and percent ash by log rainfall, for Tinker and Crouch.

Low and High Rain - The TSS response profile was similar for both rain classes with TSS levels increasing in Crouch Branch AC compared to DC levels while Tinker Creek TSS levels rose only slightly. There was no significant location-by-construction period interaction for either rain class.

TURBIDITY: No Rain - Both Tinker Creek and Crouch Branch turbidity levels decreased between the DC and AC periods with Crouch Branch decreasing significantly more sharply ($p \leq 0.0003$) than Tinker Creek. Turbidity levels in Crouch Branch remained higher than the control stream during construction periods.

Low Rain - Turbidity levels in Crouch Branch and Tinker Creek decreased AC from the DC period; however, the changes were not statistically significant.

High Rain - Tinker Creek turbidity levels remained constant, while Crouch Branch levels increased from the DC to AC period. These trends were not significantly different however.

SPECIFIC CONDUCTANCE: No, Low, and High Rain - Tinker Creek showed a slight increase in specific conductance from the DC to the AC period. For the No and Low Rain classes, Crouch Branch also showed an increase. Under High Rain conditions Crouch Branch showed a slight decrease in specific conductance AC from the DC level. No changes were statistically significant.

PERCENT ASH: No Rain - Percent ash levels increased in Tinker Creek from the DC to the AC period. Crouch Branch decreased significantly AC from DC levels compared to Tinker ($p \leq 0.003$).

Low Rain - Tinker Creek showed relatively little change from DC to the AC period, while Crouch Branch decreased AC. No change was significant.

High Rain - Crouch Branch percent ash levels were considerably higher DC and AC than Tinker Creek. Levels in both creeks increased slightly AC from DC levels. Changes were non-significant.

Because few data are available for Crouch Branch in the Before Construction period, and because Crouch Branch is the smallest stream in the DWPF watershed, conclusions about overall changes in the stream are difficult to draw. However, the data do provide considerable evidence that Crouch Branch has been affected adversely by DWPF construction. First, for the High Rain class, levels of TSS, turbidity and percent ash increased in Crouch Branch during the AC period. Secondly, DC and AC levels in Crouch Branch are higher than every other sampled location in the watershed for each parameter measured in every rain class. Thirdly, significant decreases in TSS, turbidity, and percent ash levels are evident in the No Rain class during the AC period. Without the erosion input that occurs with low and high rainfall, Crouch Branch appears to show better water quality levels. Because it lies below a sedimentation basin, Crouch Branch water quality is a good measure of the effectiveness of the basin's performance. As the basin fills with sediment it becomes less able to hold construction area runoff under rainy conditions, and consequently higher silt levels will occur in the stream below. The elevated levels of TSS and turbidity in Crouch Branch may reflect this condition.

UPPER THREE RUNS CREEK

A principle concern of this monitoring program is to assess the potential impacts of DWPF construction on water quality in UTR Creek. Two contrast pairs were made: UTR- above vs UTR- middle (effects below the McQueen Branch and Tinker Creek confluences) and UTR- above vs UTR- below (effects below the confluence of Crouch Branch; Figs. II-7 and II-8).

Figure II-7. Log TSS, log turbidity, log specific conductivity, and percent ash by log rainfall, for UTR- above and UTR- middle.

Figure 11-8. Log TSS, log turbidity, log specific conductivity, and percent ash by log rainfall, for UTR- above and UTR- below.

TSS: No and Low Rain - Trends in the three UTR Creek locations were similar. TSS levels rose DC and fell AC except for TSS levels in UTR-below which increased slightly in No Rain conditions. However, UTR- middle and UTR- below levels were higher than UTR- above levels for all periods. All AC levels were higher than BC levels. No changes were significant.

High Rain - UTR- above showed little change in TSS level over the three construction periods and had the lowest TSS levels of all three sites during all time periods. UTR- middle and -below showed a decrease DC in TSS levels, but both increased during the AC period to levels comparable to BC at each location. Changes were non-significant.

TURBIDITY: No and Low Rain - All locations on UTR Creek showed a non-significant decrease in turbidity AC from DC levels.

High Rain - Turbidity levels increased in UTR- above and -below from the DC to AC period, while levels in UTR- middle decreased. These responses were also non-significant.

SPECIFIC CONDUCTANCE: No and Low Rain - For all locations on UTR Creek, specific conductance decreased from the BC to DC period and increased slightly AC. Levels AC were below levels BC. No changes were statistically significant.

High Rain - UTR- above and -below decreased from BC to DC and increased AC. UTR- middle showed an increase DC followed by a decrease AC to BC levels. The only significant interaction involved the UTR-above and middle sites during the BC and DC periods.

PERCENT ASH

UTR-Above vs. UTR-Middle: No and Low Rain - Both locations (UTR- above and UTR-middle) showed increasing percent ash levels over the three periods except levels at UTR-middle decreased slightly between DC and AC. Percent ash at UTR-middle was higher BC and levels at UTR- above were higher AC. No changes were significant.

High Rain - Percent ash levels at both UTR- above and -middle decreased DC and rose during the AC period to levels higher than the BC levels. The changes non-significant.

UTR-Above vs. UTR-Below: No Rain - Percent ash levels in UTR- above and -below followed parallel patterns of increase during the three periods. Percent ash levels for UTR-above remained below that of UTR-below.

Low Rain - Percent ash levels in UTR- below increased DC and decreased AC while UTR-above increased over all construction periods. Both locations ended with percent ash levels above BC levels.

High Rain - Percent ash levels in UTR- above decreased DC and rose only slightly AC. Levels in UTR- below increased significantly DC ($p = 0.03$) and increased further AC. When compared to UTR- above, both of these changes were significantly different (BC to DC $p = 0.003$, DC to AC $p = 0.004$).

The data collected over the ten years of this study show an increase in TSS, turbidity, and percent ash levels in UTR Creek, however, this increase can not be attributed to inputs from McQueen Branch and Crouch Branch alone. Comparisons of UTR Creek above the construction site to two locations below did not provide evidence that the S- and Z-area construction raised TSS or other parameter levels in UTR Creek. One possible explanation for the observed decrease in water quality in UTR Creek is the effects of additive inputs. Possible contributors to increased TSS levels besides DWPF construction might be: increases in off-plant construction

activities upstream on UTR Creek, increases due to clogged road drainage, flash flooding, or other unnoted disturbances along the creek drainage. A combination of such activities in conjunction with the S- and Z-area input, may have contributed to this alteration in water quality over time. For non-point pollutants, such as erosion, multiple effects are difficult to identify and accurately assess; however, based on this study, water quality in UTR Creek has not been significantly affected by the construction site input from McQueen Branch or Crouch Branch.

SUMMARY

FY- 1992 concludes ten years of water quality monitoring in the DWPF watershed. Based on the data collected in that period several conclusions can be drawn

- 1 TSS levels at all locations have risen during the sample period and have generally remained at higher levels than before construction began

- 2 The small tributaries below the construction site, Crouch Branch and McQueen Branch, have been significantly affected by erosion inputs since construction began. In both cases effects are most clearly evident under low and high rainfall conditions.

- 3 In general, during the AC period, water quality parameters have decreased under No Rain conditions but remain elevated under High Rain conditions. This may indicate some recovery under "Base-Line" conditions, however under heavy rain conditions, erosion may be a problem

- 4 Statistical evidence over the ten year period does not reveal that the DWPF construction-site runoff has impacted UTR Creek significantly

CONCLUSION

In a 1986 article Kenneth L. Dickson, former president of the Society of Environmental Toxicology and chemistry, suggested that rather than toxic chemicals, non-point pollutants such as siltation are causing the greatest harm to the aquatic environment (Dickson 1986). He states that one source of silt contamination arises from "poor erosion control practices at construction sites." Based on data from the DWPF watershed samples between 1982 and 1992, it appears that although extensive impact to UTR Creek has been minimized, elevated TSS and other parameter levels continue to persist in tributaries below construction-site sedimentation basins. Further attention to erosion control measures, such as dredging clogged sediment basins, is recommended to improve conditions for these aquatic tributaries.

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III. Reptile and Amphibian Captures at Rainbow Bay, a Nearby Wetland, and the DWPF Refuge Ponds

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INTRODUCTION

Previous DWPF reports have documented the high biodiversity of the Rainbow Bay site (SREL 1980), the extreme fluctuations of amphibian population sizes in Carolina bay wetlands (Vitt 1981,1982; Pechmann et al. 1993), the influence of hydroperiod on amphibian success (Scott et al. 1986), and the results of the experimental attempt to mitigate the impact of DWPF construction on the amphibian community at Sun Bay by building artificial refuge ponds (Pechmann et al. 1984, Pechmann et al. 1985, Scott et al. 1988, Pechmann et al. 1993). Studies that are designed to examine topics such as these require long-term census data. Data on amphibian adult population sizes and juvenile recruitment are now available for 14 years at Rainbow Bay, and 10 years at the DWPF refuge ponds. In this chapter we summarize the capture data for reptiles and amphibians for FY-1991 and FY-1992. Although a full analysis of the entire long-term data set is not the subject of this report, data from FY-1991 and FY-1992 will be integral to future analyses of natural population fluctuations and the effectiveness of the refuge pond experimental mitigation effort.

STUDY SITES AND METHODS

RAINBOW BAY

Rainbow Bay is a Carolina bay (Sharitz and Gibbons 1982, Schalles et al. 1989) located on the U.S. Department of Energy's 780-km² Savannah River Site in the upper coastal plain sandhills region in South Carolina. The pond is a natural depression of unresolved origin called a "Carolina bay" (Sharitz and Gibbons 1982); it is

approximately 1 ha with a maximum water depth of 1.04 m and usually fills during the winter and dries each spring or summer. Vegetation in the pond is dominated by Scirpus cyperinus, Polygonum sp., Panicum verrucosum, Liquidamber styraciflua, and Cephalanthus occidentalis. Rainbow Bay is surrounded by xeric habitats with deep, well-drained sandy soils planted with Pinus elliotii and Pinus taeda. Myrica cerifera and Rubus sp. are common in the understory around the edge of the bay. Rainbow Bay and the adjacent terrestrial habitats have been protected from most human impacts during the 14-year study, but were altered in the past.

Amphibians migrating to and from Rainbow Bay are captured using a terrestrial drift fence with pitfall traps that completely encircles the pond (Gibbons and Semlitsch 1981, Fig. III-1). The fence was constructed of 50-cm-high aluminum flashing buried 10-15 cm in the ground. Forty-liter pitfall traps were buried on each side of the fence at 10-m intervals. Traps were checked daily from 21 September 1978 - 30 September 1992. Upon capture, all amphibians are identified, marked by clipping toes, and released on the opposite side of the fence from where captured. Data from 1 October 1990 to 30 September 1992 are reported here.

Five species of salamanders and 11 species of frogs and toads are known to have bred at Rainbow Bay (Pechmann et al. 1989). Our drift fence census data are most complete for four species: Ambystoma opacum (marbled salamander), A. talpoideum (mole salamander), A. tigrinum tigrinum (eastern tiger salamander), and Pseudacris ornata (ornate chorus frog). The four are primarily terrestrial and fossorial except for the aquatic larval stage. Reproductive A. opacum migrate to breeding ponds from September to November, whereas breeding migrations of the other three species occur primarily from November to March. Adults spend a few days to weeks at the pond before returning to terrestrial habitats. Juveniles metamorphose and emigrate from the pond during the following spring and

summer. Age at first reproduction varies considerably, but some individuals of all four species reproduce at one year of age.

These species usually return to their natural pond to breed i.e., they are philopatric (unpublished data). Four other breeding sites (Bullfrog Pond, Linda's Pond, Pickerel Pond, and the NPR wetland) occur within 1 km of Rainbow Bay, and low rates of dispersal connect the amphibian populations of these sites to form metapopulations (Hanski and Gilpin 1991). Immigration and emigration are usually minor components of the population dynamics of these philopatric species, but may be important in long-term persistence (Sjogren 1991). Because "connectance" among sites may be important to these species, Rainbow Bay and the surrounding woodlands (containing Bullfrog Pond and Pickerel Pond) were added to the DOE Research Set-Aside program in FY-1992. In order to obtain more data on amphibian movement among sites, we installed a partial 90-m fence at the wetland on the proposed NPR site (300 m from Rainbow Bay) and began censusing amphibians on 4 October 1990. Capture data from this site (hereafter called Spadefoot Pond) are summarized separately and presented in Table III-1. Daily monitoring of Spadefoot Pond will continue, funded in the future from Biodiversity programs, because more data on amphibian movements among sites are needed to understand how metapopulations are related to the long-term persistence of amphibians species. These data are necessary to allow informed management decisions on the use and nature of terrestrial habitats that surround and connect isolated wetlands.

Fig III-1. Design of terrestrial drift fences with pitfall traps.

Refuge Pond Design

Four refuge ponds (A, B, C, and D) were completed on 20 June 1983 on the periphery of the DWPF construction site (Fig. III-2). Ponds were built as close to Sun Bay as permitted by DWPF construction activities (including Z-Area). When possible, sites were chosen where water tended to collect naturally, as evidenced by the presence of hydric plants such as mosses.

Each pond is circular, approximately 16 m in diameter, and has a maximum depth of approximately 1 m. Ponds were originally lined with hard-packed clay so they would collect and hold rainwater. Carolina bays are underlaid by an impervious clay lens (Bryant and McCracken 1964; Shalles 1979), and typically received no water input other than rain (Sharitz and Gibbons 1982).

Refuge pond water retention was poor during FY-1984 in spite of high rainfall (Pechmann et al. 1984). To rectify this problem, fish-grade plastic (CPE) pond liners were installed on 19 November 1984. An overflow pipe was also installed in each pond. Since the plastic liners initially provided an inert substrate, leaf litter was added to the ponds during February and March 1985. These leaves supplied cover, nutrients, and organic matter for biota.

At request of DOE, Refuge Pond C (Fig. III-2) was dismantled on 7 June 1985 to accommodate expansion of the planned Z-Area. Daily sampling at refuge ponds A, B, and D was discontinued on 9 December 1991. Drift fences were left in place to allow future sampling, but sections were removed and buckets were closed to allow natural movements of animals to and from the ponds. The existing 10-yr data set will allow assessment of the impact of DWPF construction on the Sun Bay amphibian community and the effectiveness of the experimental refuge pond mitigation effort. These concerns will be addressed in the FY-1993 DWPF report.

Fig III-2. Locations of DWPF refuge ponds.

Table III-1. Summary of captures of amphibians and reptiles at Rainbow Bay and Spadefoot Pond during FY-1991 and FY-1992. Only incoming adults and outgoing juveniles were tabulated.

AMPHIBIAN SPECIES	RAINBOW BAY (FY-1991)			SPADEFOOT POND (FY-1991)		
	<u>M</u>	<u>F</u>	<u>J</u>	<u>M</u>	<u>F</u>	<u>J</u>
<u>Ambystoma talpoideum</u>	134	202	5956	2	6	576
<u>Ambystoma opacum</u>	263	342	1407	30	43	50
<u>Ambystoma tigrinum</u>	3	7	243	0	0	0
<u>Notophthalmus viridescens</u>	72	112	1502	1	0	0
<u>Plethodon glutinosus</u>	7	4	--	11	11	--
<u>Eurycea cirrigera</u>	1	0	--	0	0	--
<u>Eurycea quadridigitata</u>	5	2	0	0	0	0
<u>Scaphiopus holbrookii</u>	17	8	(57) #	9	3	49
<u>Bufo terrestris</u>	374	192	91	7	3	5
<u>Acris gryllus</u>	6	10	4	0	0	0
<u>Hyla cinerea</u>	*	1	1	0	0	0
<u>Hyla gratiosa</u>	1	1	31	0	0	0
<u>Hyla femoralis</u>	*	*	3	0	0	0
<u>Hyla squirrelia</u>	1	1	4(4) #	0	0	0
<u>Hyla chrysoscelis</u>	*	*	83	0	0	0
<u>Pseudacris crucifer</u>	14	24	685	0	0	0
<u>Pseudacris nigrita</u>	1	1	0	0	0	0
<u>Pseudacris ornata</u>	11	10	40	0	0	0
<u>Gastrophryne carolinensis</u>	198	174	143 (1788)	#57	80	34
<u>Rana catesbeiana</u>	*	*	3	0	0	0
<u>Rana clamitans</u>	1	6	76	0	1	0
<u>Rana utricularia</u>	6	6	3240	*	*	4
REPTILE SPECIES	(All captures)			(All captures)		
<u>Chelydra serpentina</u>	2			0		
<u>Sternotherus odoratus</u>	2			0		
<u>Kinosternum subrubrum</u>	11			1		
<u>Trachemys scripta</u>	3			0		
<u>Deirochelys reticularia</u>	1			0		
<u>Anolis carolinensis</u>	93			11		
<u>Sceloporus undulatus</u>	3			2		
<u>Scincella laterale</u>	18			9		
<u>Eumeces fasciatus</u>	1			2		
<u>Eumeces laticeps</u>	0			3		
<u>Eumeces inexpectatus</u>	1			1		
<u>Nerodia fasciata</u>	4			1		
<u>Storeria dekayi</u>	1			0		
<u>Storeria occipitomaculata</u>	13			5		

Table III-1. (Con't)

<u>Thamnophis sirtalis</u>	1	0
<u>Virginia valeriae</u>	3	3
<u>Diadophis punctatus</u>	20	2
<u>Lampropeltis triangulum</u>	1	0
<u>Cemophora coccinea</u>	1	1
<u>Tantilla coronata</u>	27	4
<u>Agkistrodon contortrix</u>	1	0

AMPHIBIAN SPECIES	RAINBOW BAY (FY-1992)			SPADEFoot POND (FY-1992)		
	<u>M</u>	<u>F</u>	<u>J</u>	<u>M</u>	<u>F</u>	<u>J</u>
<u>Ambystoma talpoideum</u>	631	275	78	4	7	0
<u>Ambystoma opacum</u>	110	27	6	81	36	22
<u>Ambystoma tigrinum</u>	24	1	0	0	0	0
<u>Notophthalmus viridescens</u>	101	115	(5) #	0	0	0
<u>Plethodon glutinosus</u>	16	16	--	13	15	--
<u>Eurycea cirrigera</u>	5	4	--	0	0	--
<u>Eurycea quadridigitata</u>	15	33	0	0	2	0
<u>Scaphiopus holbrookii</u>	7	3	0	1	1	0
<u>Bufo terrestris</u>	449	78	0	4	4	0
<u>Acris gryllus</u>	1	1	4	0	0	0
<u>Hyla cinerea</u>	0	1	0	0	0	0
<u>Hyla chrysoscelis</u>	2	0	0	0	0	0
<u>Pseudacris crucifer</u>	486	599	3573	*	1	1
<u>Pseudacris nigrita</u>	0	1	0	0	0	0
<u>Pseudacris ornata</u>	21	20	198	0	0	0
<u>Gastrophryne carolinensis</u>	105	158	0	2	3	0
<u>Rana catesbeiana</u>	0	2	0	0	0	0
<u>Rana clamitans</u>	4	3	4	0	0	0
<u>Rana utricularia</u>	73	46	56	0	0	0

REPTILE SPECIES	(All captures)	(All captures)
<u>Chelydra serpentina</u>	1	0
<u>Sternotherus odoratus</u>	2	0
<u>Kinosternum subrubrum</u>	7	0
<u>Terrapene carolina</u>	3	1
<u>Anolis carolinensis</u>	135	11
<u>Sceloperus undulatus</u>	2	1
<u>Cnemidophorus sexlineatus</u>	3	0
<u>Scincella laterale</u>	29	5
<u>Eumeces fasciatus</u>	3	0

Table III-1. (Con't)

<u>Eumeces laticeps</u>	5	3
<u>Nerodia fasciata</u>	16	1
<u>Storeria dekayi</u>	0	1
<u>Storeria occipitomaculata</u>	3	2
<u>Thamnophis sirtalis</u>	3	0
<u>Thamnophis sauritis</u>	1	0
<u>Virginia valeriae</u>	7	1
<u>Heterodon platyrhinos</u>	1	0
<u>Diadophis punctatus</u>	19	5
<u>Coluber constrictor</u>	4	0
<u>Elaphe obsoleta</u>	1	0
<u>Lampropeltis getulus</u>	2	0
<u>Lampropeltis triangulum</u>	1	0
<u>Cnemidophorus coccineus</u>	1	1
<u>Tantilla coronata</u>	14	3
<u>Agkistrodon contortrix</u>	4	0

*Indicates that, although no adults were captured, one or more must have been present and evaded capture because juveniles were produced.

#Indicates that the number of juveniles listed in parentheses was the offspring of parents from the previous year but were not captured until the fiscal year listed

-Indicates that the species does not breed in ponds/bays and would not be expected to produce juveniles

Table III-2 Summary of captures of amphibians and reptiles from three refuge ponds during FY-1991 and FY-1992. Incoming adults and outgoing juveniles were tabulated for amphibians, all captures were tabulated for reptiles.

AMPHIBIAN SPECIES	FY-1991		FY-1992#	
	Total Captures		Total Captures	
	Adults	Juveniles	Adults	Juveniles
<u>Ambystoma talpoideum</u>	168	249	9	128
<u>Notophthalmus viridescens</u>	40	93	6	169
<u>Plethodon glutinosus</u>	17	--	0	--
<u>Pseudotriton ruber</u>	2	--	0	--
<u>Scaphiopus holbrooki</u>	2	2	1	0
<u>Bufo terrestris</u>	108	147	3	0
<u>Acris gryllus</u>	14	211	1*	18
<u>Hyla arenicolor</u>	*	103	*	14
<u>Hyla chrysoscelis</u>	1*	3	2	0
<u>Pseudacris crucifer</u>	5	55	0	0
<u>Gastrophryne carolinensis</u>	110	1	1*	1
<u>Rana catesbeiana</u>	*	6	0	0
<u>Rana clamitans</u>	2*	79	*	9
<u>Rana utricularia</u>	9	185	3	0
REPTILE SPECIES	(All captures)		(All captures)	
<u>Kinosternum subrubrum</u>	1		0	
<u>Anolis carolinensis</u>	14		3	
<u>Sceloporus undulatus</u>	17		1	
<u>Cnemidophorus sexlineatus</u>	18		0	
<u>Eumeces laticeps</u>	1		0	
<u>Nerodia erythrogaster</u>	1		0	
<u>Nerodia fasciata</u>	5		0	
<u>Storeria dekayi</u>	1		0	
<u>Virginia valerieae</u>	3		3	
<u>Heterodon platyrhinos</u>	5		1	
<u>Heterodon simus</u>	0		1	
<u>Diadophis punctatus</u>	1		0	
<u>Coluber constrictor</u>	2		1	
<u>Lampropeltis triangulum</u>	1		0	
<u>Cemophora coccinea</u>	1		0	
<u>Tantilla coronata</u>	25		0	

#Daily monitoring of the refuge ponds was stopped on December 9, 1991. Because capture data for FY-1992 cover only 2 months, they are not comparable to the 12-mo data summary from FY-1991.

*Indicates that, although no adults were captured, one or more must have been present and evaded capture because juveniles were produced.

--Indicates that the species does not breed in ponds/bays and would not be expected to produce juveniles.

RESULTS AND DISCUSSION

Rainbow Bay refilled on August 23, 1990, and held water until September 21, 1990. This late summer filling enabled several species to breed and produce juveniles, and accounts for many of the captures of juveniles recorded in FY-1991 (Table III-1). Pond filling and drying for FY-1991 occurred October 11, 1990 and November 5, 1992 (respectively), and December 29, 1991 and May 18, 1992 in FY-1992. The length of time that a bay holds water (hydroperiod), as well as the timing of pond filling and drying, exert large effects on the community of pond-breeding amphibians (Pechmann et al. 1989).

The number of amphibian and reptile species using and breeding successfully in the DWPF refuge ponds (Table III-2) was similar to numbers observed in FY-1989 and FY-1990. In general, since construction of the ponds in FY-1983, an increased number of species have colonized and become established in the ponds in recent years. Although the hydrologic cycle of the ponds is not similar to the former cycle at Sun Bay, the ponds do appear to have potential for mitigating loss of amphibian breeding habitat. Again, because the area of the three remaining refuge ponds is ~600 m² and the area of Sun Bay was ~10,000 m² this should be viewed as an experimental "pilot project" and not mitigation per se.

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IV. The effect of larval density on adult demographic traits in Ambystoma opacum.

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INTRODUCTION

Fourteen years of study of the amphibian community at the Rainbow Bay site have documented the extreme year-to-year variation in amphibian numbers and breeding success (Pechmann et al. 1993). Numerous factors, both biotic and abiotic, influence the population dynamics of amphibians at Rainbow Bay (Scott et al. 1986). One objective of the amphibian portion of the DWPF study is to develop a predictive model of the population dynamics for several of the species found at Rainbow Bay, the old Sun Bay site, and numerous wetlands in the southeast. To succeed in such a modeling effort, it is necessary to couple a long-term record of the natural population dynamics with results from experimental manipulations that will increase our understanding of the mechanisms underlying the dynamics of natural amphibian populations. A realistic model of amphibian population dynamics must include the density-dependent and density-independent factors that affect the larval and adult stages (Wilbur 1980).

The population dynamics of species with complex life cycles (Istock 1967) may be influenced by factors in the larval stage, the adult stage, or both (Wilbur 1980). Numerous laboratory and field studies have documented the effects of the larval environment, especially larval density, on larval traits such as body size, length of the larval period, and survival (see Wilbur 1980, Scott 1990). Potential larval effects on adult traits are less well documented. Larval density, with its associated effects on body size and timing of metamorphosis, may affect post-metamorphic survival and age at first reproduction, and consequently the population growth rate (Harris 1987). Thus, the "quality" of juveniles that metamorphose from the larval stage may

influence the population dynamics through effects on adult traits related to fitness (Wilbur 1980, Morin 1983, Semlitsch 1987).

The influence of larval environment on adult traits has been demonstrated convincingly for insects. Experimental studies have shown that larval density and food availability affect adult body size, fecundity, survival, and age at first reproduction [e. g., fruit flies (Chiang and Hodson 1950, Barker and Padger 1970, Pratt and McChesney 1985, Pratt 1986); pitcher plant mosquitoes (Mouer and Istock 1980, Bradshaw 1986, Bradshaw and Holzopful 1988); Aedes mosquitoes (Hawley 1985); damsel flies (Banks and Thompson 1987, Anholt 1991); house flies (Black and Krafusur 1986), and crickets (Simmons 1987)].

Among vertebrate taxa, only amphibians exhibit complex life cycles (Wilbur 1980), and evidence of links between the larval environment and adult traits related to fitness is limited. Several correlative studies have linked larval and adult traits, and suggest that larval density may regulate populations. In one anuran species, the wood frog (Rana sylvatica), individuals that metamorphosed at large body size maintained the size advantage through first reproduction, and produced more eggs than individuals that metamorphosed at smaller sizes (Berven and Gill 1983). Adults from a pond of high tadpole density were smaller and averaged lower clutch sizes than frogs originally from a pond of low tadpole density (Berven 1988). Frogs that were small at metamorphosis exhibited reduced adult survival and later age at first reproduction than those that were large (Berven 1990). In the chorus frog, Pseudacris triseriata, both an early date and large size at metamorphosis were associated with a larger body size and earlier age at first reproduction (Smith 1987). Similar relationships have been demonstrated for salamanders. In a field study of terrestrial morphs of the mole salamander, Ambystoma talpoideum, both date and size at metamorphosis were correlated with adult body size, but not survival

(Semlitsch et al. 1988). However, larger adult body size was associated with delayed metamorphosis in Desmognathus monticola (Bruce and Hairston, 1990)

Few experimental studies have been conducted to determine the influence of larval conditions on adult traits in amphibians. In an experiment in artificial ponds, Semlitsch (1987) found that initial larval density, food levels, and pond-drying regime influenced the growth and body size of larval A. talpoideum, and in turn affected adult body size and fecundity of paedomorphic adults. Harris (1987) observed similar results in artificial-pond experiments with red-spotted newts, Notophthalmus viridescens; low larval density was associated with rapid growth rates and early reproductive maturity of paedomorphs.

Collectively, these studies suggest that factors in the larval environment may exert a particularly strong influence on population dynamics because they affect both larval and adult traits. The work reported here is the first experimental field study that has manipulated factors in the larval environment to test effects on free-ranging adults. An experimental approach is necessary to partition total variance in adult traits into components and thereby separate variation due to larval density from variation caused by differences among ponds, years, or genotypes

I examined the effect of larval density on adult traits in the marbled salamander, Ambystoma opacum. At high initial hatchling densities, larvae grew more slowly and exhibited reduced larval survival, longer larval periods, and smaller body size at metamorphosis than larvae from low density treatments (Scott 1990). Do these effects extend beyond metamorphosis and also influence adult traits? I tested for differences among individuals reared at high and low densities in the following traits: energy stores (i.e., non-polar lipids) at metamorphosis, laboratory survival of juveniles in the absence of predation, body size of first-time breeding adults, female clutch size, and survival to and age at first reproduction.

METHODS

Natural history of *Ambystoma opacum*

Ambystoma opacum is a widespread salamander species that ranges from Massachusetts to north Florida and west to Texas (Conant and Collins 1991). In autumn adults migrate to ponds that are dry or have lowered water levels (Noble and Brady 1933, Jackson et al. 1989). Marbled salamanders, like other species of pond-breeding salamanders, are thought to be relatively philopatric (Pechmann et al. 1991); most adults return to breed in their natal pond (unpublished data, DES). The species is unusual within its genus in that it exhibits terrestrial breeding, nest construction, and nest brooding by females (Nussbaum 1985). Eggs do not hatch until nests are flooded and eggs experience reduced oxygen pressure (Petranka et al. 1982). In our study populations, the larval period is 4-6 mos, followed by metamorphosis and a terrestrial growth stage of 1 to 5 yrs until reproductive maturity is achieved.

Study sites

Most data presented below resulted from two years of experimental manipulations of larval density of *A. opacum* at Ginger's Bay (GB), a 0.8 ha temporary pond located on the Savannah River Site in Aiken County, South Carolina. Details of these manipulations have been described previously (Scott 1990) and are summarized below.

Ginger's Bay is a Carolina bay (see Sharitz and Gibbons 1982) which typically fills with rainwater by early December and dries in mid-summer, although dates of filling and drying vary considerably. Vegetation within the wetland consists primarily of knotweed (*Polygonum* sp.), a sedge (*Scirpus cyperinus*), and buttonbush (*Cephalanthus occidentalis*). The dominant tree species in the surrounding woodlands include sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and loblolly pine (*Pinus taeda*). Some data from Bullfrog Pond (BP) and Rainbow Bay

(RB) also are presented below. Descriptions of these two sites may be found in Scott (1990; BP) and Pechmann et al. (1991; RB).

Field methods

In winter of FY 1986 and FY 1987 (hereafter referred to as 1986 and 1987) I manipulated larval densities of A. opacum in large-scale (41-m²) replicate field enclosures (n = 6) at GB (Scott 1990). In 1987 I also manipulated larval density in 23-m² pens (n = 5) at BP. Low (4-8 individuals/m²) and high (22-41 individuals/m²) density levels were chosen to simulate observed mean field densities for A. opacum (Scott 1990). Newly metamorphosed animals (n = 3400 at GB, n = 403 at BP) were captured as they attempted to leave the enclosures. Body mass (± 0.01 g) and snout-vent length to the posterior edge of the cloaca (SVL; ± 0.5 mm) were measured for most individuals. I randomly collected animals (range from 6-35) from all pens at both GB and BP for non-polar lipid analyses. In 1987 at GB an additional 48 newly metamorphosed animals were selected randomly from high- and low-density treatments (8 from each of three replicate pens) for use in a laboratory inanition study. In 1989 and 1990 at GB I stocked pens with low densities of larval A. opacum at different predator (larval odonate) levels. These results will be reported elsewhere except as stated below. All animals at GB not collected for the laboratory studies were toe-clipped to identify their larval treatment group and released into the woods surrounding GB.

Adult A. opacum that returned to GB to breed in subsequent years were recaptured in 20-L pitfall traps at a drift fence (Gibbons and Semlitsch 1982) that encircled the site. In October, 1990 heavy rainfall from tropical storms Klaus and Marco flooded the bay beyond the drift fence, and it is likely that not all immigrating adults were captured. In other years the drift-fence technique effectively captures all A. opacum that enter the wetland to breed. Upon recapture of an individual, the treatment group toe-clip marks were reclipped, along with one

additional toe to indicate the year of recapture. The larval treatment group mark, date, sex, and SVL were recorded, and animals were released into the bay. Post-breeding survivors were allowed to exit the site and return to the woodlands. In October 1990, six or seven females from each treatment group in 1986 and 1987 were collected and dissected to determine clutch size by direct egg count. Adult drift-fence censuses continued through December 1990, when individuals from the 1986 and 1987 cohorts were 5- and 4-yrs old, respectively.

In an analysis of the relationship between mean body size at metamorphosis and the proportion of animals that return to breed at ages 1 and 2 (presented below), I included data from the 1989 and 1990 manipulations of predator levels. In addition to the GB pen populations, I also collected data on the natural (unmanipulated) population from GB proper in all years. Juveniles that emigrated from the site were measured and marked to indicate the year of metamorphosis, and returning adults from these cohorts were captured, tallied and measured. Similar data were collected for a population of *A. opacum* at RB (Pechmann et al. 1991), and summary data from four RB cohorts were included in the analyses.

Laboratory methods

Total non-polar lipid levels were determined by a 6-hr extraction of dried samples using petroleum ether in a Soxhlet apparatus. Animals were sacrificed, oven-dried at 65°C for one week to a constant mass, ground with a mortar and pestle, placed in pre-weighed cellulose thimbles, and weighed before and after extraction. Lipid amounts were calculated as the mass lost during extraction. Lipid proportions are expressed as total lipids (g)/ total dry mass (g).

The 48 salamanders collected for the laboratory-survival study were housed in individual compartments (4 cm X 4 cm) in plastic bins on a substrate of moistened vermiculite. Within each treatment group, the 24 animals from three pens were mixed. Six juveniles that experienced low larval density and six from high density

were assigned haphazardly to compartments in each of four bins. All bins were placed in a single environmental chamber at 17°C on a 12 hr light: 12 hr dark cycle. The substrate was rewetted every three days to maintain moist conditions. Animals were not fed, and were checked daily to census survivors.

Statistical analyses

Lipids and laboratory survival. Lipid data from GB and BP, and from each year at GB, were analyzed separately. Analysis of variance (ANOVA) was used to test the effects of larval density on total lipid levels and the proportion of lipids in the carcass dry mass. Proportion data were arcsine-squareroot transformed to better meet the assumptions of analysis of variance. Because individuals within a pen cannot be treated as statistically independent observations (Hurlbert 1984), the effect of larval density level (DENSITY) was tested over the pen-by-treatment interaction, i.e., the PEN (DENSITY) term. This is tantamount to using pen means for the analysis (Wilbur 1987). After testing for "bin" effects, similar one-way ANOVA model was used to test the effect of larval density on the number of days animals survived in the laboratory.

Adult body size. Recently metamorphosed juveniles from the density manipulations at GB were given a treatment mark, but not a "pen" mark. Consequently, the ANOVA model described above with PEN (DENSITY) as an error term cannot be used in an analysis of the effect of larval density on the SVL of adults breeding for the first time. Wilbur (1987) stated that tests are based on population means, rather than individual values, because individuals may be competing with each other which results in a negative covariance in the response variables among members of a population. I used the individual as the unit of observation, ignoring by necessity any PEN(DENSITY) effects that carried over to the adults. I used the residual error term in 3-way ANOVA models to test the effects of larval density, sex, age, and their interactions on adult body size (SVL) at first reproduction. I restricted the analyses to

individuals breeding for the first time to avoid problems of repeated measurements on an individual, because animals were not individually marked. Type III SS ANOVA models were used for all tests.

Proportion surviving and age at first reproduction. An animal was counted as a survivor if it returned to GB to breed at least once. Total recaptures of first-breeding animals were tallied to obtain the total number surviving from each treatment group over the course of the experiment. The effects of larval density, cohort year, and sex on survival to first reproduction (FATE) were assessed using a log-linear model in a 4-way contingency table analysis. A reduced model, without the 4-way interaction, was used to obtain a maximum-likelihood estimate of model parameters and a likelihood-ratio test for independence between survival and the other variables. A similar analysis was conducted to test for density, cohort, and sex effects on the age at first reproduction (REPRO) of survivors. In these two analyses, it is the first and second order interactions that involve the "effect" of the factor variables (i.e., DENSITY, YEAR, SEX) on the response variable (FATE or REPRO) that are of particular interest (Everitt 1977; pg. 103).

I used regression analysis to examine the relationship between mean body size at metamorphosis of a cohort and the proportion of the cohort that returned to breed at age 1 or 2 years. Separate analyses were conducted for males and females for each age. For these analyses I assumed a 1:1 sex ratio in the newly metamorphosed juveniles. Proportion data were arcsine-squareroot transformed for the analyses, but the original data are presented in the figures. All analyses were conducted using either the General Linear Models or the Catmod procedures of the Statistical Analysis System (SAS Institute 1985).

RESULTS

Effect on lipid levels in juveniles

Larval density tended to affect the proportion of lipids in the carcass dry mass of juveniles (Table IV-1). Means for the low-density treatment groups were higher than for high-density, though only significantly higher in one of the three tests (BP: $F_{1,2} = 13.9$, $P = 0.06$; GB 1986: $F_{1,1} = 3.2$, $P = 0.17$; GB 1987: $F_{1,4} = 27.2$, $P < 0.01$). In conjunction with the treatment-induced differences in body size, the higher lipid proportions in low-density groups contributed to significantly higher total lipid levels in juveniles from the low density treatments (Table IV-1--BP: $F_{1,2} = 17.6$, $P = 0.05$; GB 1986: $F_{1,3} = 11.9$, $P = 0.04$; GB 1987: $F_{1,4} = 196.2$, $P < 0.001$).

Effect on juvenile survival (laboratory)

Juveniles from the two treatments differed in the number of days that individuals survived under unfed conditions. Survival for the low-density-treatment animals was approximately two weeks longer (Table IV-1-- $F_{1,4} = 74.8$, $P < 0.001$).

Effects on adult traits

Adult body size (SVL). The effect of larval density on body size extended beyond the larval environment to the adults. First-breeding adults that were reared at low larval densities were larger than those from high densities (Figure IV-1). For both the 1986 and 1987 cohorts, significant 2- and 3-way interactions precluded a direct examination of the main effects of density, age, and sex (Table IV-2). Separate 2-way ANOVA models were run for each age group.

For the 1986 cohort, no animals returned to breed at age 1. At ages 2 through 5 years, there was a significant effect of larval density on adult SVL at all ages ($P < 0.02$ for ages 2, 3, 4, and 5). Low density promoted larger body size at metamorphosis, which in turn translated to larger SVL at first reproduction. There was no significant main effect of sex at any age; male and female first-breeders did

Table IV-1. Measures of body size and amounts of non-polar lipids in whole carcass, and laboratory survival at 17°C of juvenile Ambystoma opacum from high- and low-density treatments at Bullfrog Pond (BP) and Ginger's Bay (GB). Values represent $\bar{X} \pm 1SE$. N = number of replicate enclosures.

Site (Year)	Density level*	N	SVL(mm)	Body dry mass (g)	Total lipids (g)	Proportion lipids (%)	Laboratory** survival (days)
BP (1987)	LOW (24)	2	40.7 ± 0.1^b	0.32 ± 0.01^b	0.033 ± 0.006^a	$10.2 \pm 1.3^{a=0.06}$	..
	HIGH (30)	2	32.2 ± 1.0	0.14 ± 0.02	0.005 ± 0.003	2.6 ± 1.3	..
GB (1986)	LOW (64)	2	37.8 ± 0.4^b	0.26 ± 0.01^b	0.017 ± 0.001^a	6.6 ± 0.1^{NS}	..
	HIGH (31)	3	31.6 ± 1.2	0.15 ± 0.03	0.008 ± 0.002	5.5 ± 0.5	..
GB (1987)	LOW (18)	3	41.6 ± 0.2^c	0.32 ± 0.01^c	0.025 ± 0.001^c	7.5 ± 0.3^b	37.3 ± 1.5^c
	HIGH (18)	3	34.6 ± 0.5	0.14 ± 0.01	0.003 ± 0.001	1.9 ± 0.7	24.4 ± 1.3

*Number in parentheses indicates total number of individuals sampled from all enclosures.

**24 individuals from each treatment group (8 per pen) were used in the laboratory survival experiment.

^{a,b,c}Treatment differences at the $P \leq 0.05$, 0.01, and 0.001 levels are represented by a, b and c, respectively. No significant difference between treatments is indicated by NS.

Figure IV-1. Snout-vent length (mm) of newly metamorphosed animals and of adults returning to breed for the first time for animals from the density manipulations at Ginger's Bay. Data points represent the mean, and vertical bars are 1SE. Males and females from each year's manipulation are plotted separately. Connecting lines are drawn assuming a linear growth rate between time periods. Dotted lines depict high-density treatments, and solid lines depict low-density treatments.

Table IV-2. Analysis of variance of the effect of larval density, sex and age on adult body size (SVL) at first reproduction in Ambystoma opacum from high- and low-density treatment groups at Ginger's Bay.

Cohort	Source	df	SS	F	P
1986	DENSITY	1	285.2	39.7	0.0001
	SEX	1	0.8	0.1	NS
	AGE	3	305.3	14.2	0.0001
	SEX*AGE	3	37.0	1.7	NS
	DENSITY*AGE	3	11.2	0.5	NS
	DENSITY*SEX	1	1.3	0.2	NS
	D*S*A	3	60.5	2.8	0.04
	Error	157	1127.7		
1987	DENSITY	1	371.4	52.1	0.0001
	SEX	1	0.7	0.1	NS
	AGE	3	1258.4	58.9	0.0001
	SEX*AGE	3	90.0	4.3	0.007
	DENSITY*AGE	3	55.0	2.6	0.06
	DENSITY*SEX	1	4.2	0.6	NS
	D*S*A	2	64.8	4.6	0.01
	Error	124	883.2		

not differ in body size. In 3-yr-old individuals there was a significant DENSITY*SEX interaction ($F_{1,63} = 5.1$, $P = 0.02$); females from high density were larger than males in that group, but in the low-density treatment females were smaller.

For the 1987 cohort, the effect of larval density persisted at all ages ($F_{1,11} = 4.7$, $P = 0.05$ at Age 1, $P < 0.01$ at Ages 2, 3, and 4), smaller animals at metamorphosis returned as smaller adults. In 2-yr-old individuals from this cohort a significant DENSITY*SEX interaction existed ($F_{1,60} = 9.5$, $P < 0.01$), 2-yr-old females did not differ in SVL, but 2-yr-old males from low density were larger than males from high density. Body size generally did not differ between males and females, except in 4-yr-old animals, when males were larger than females ($F_{1,11} = 8.3$, $P < 0.01$).

Age at first reproduction. Very few animals from the density manipulations metamorphosed in the spring and returned to GB to breed the following autumn as 1-yr-old animals (Table IV-3). Survivors were grouped into those that bred at age 2 yrs (or less), and those that were ≥ 3 yrs old at first-breeding. Because these groups are mutually exclusive and completely partition the data, only one contingency-table analysis was necessary to examine the effects of density, sex, and cohort year on the proportion of surviving animals that matured at ≤ 2 yrs or ≥ 3 yrs (Table IV-4).

Larval density exerted a strong influence on age at first reproduction (DENSITY*REPRO). Averaged across sexes and years, approximately 52% of the survivors from low-density treatments matured in ≤ 2 yrs, compared to 32% from high-density.

Males differed from females in age at first reproduction (SEX*REPRO), averaged across density levels and years. A higher proportion of males (55%) than females (35%) matured at ≤ 2 yrs old. A significant YEAR*SEX*REPRO interaction indicated that fewer of the surviving females from the 1986 cohort (22%) matured in ≤ 2 yrs, versus 49% from the 1987 cohort.

Table IV-3. Survival and age at first reproduction of two cohorts of adult Ambystoma opacum from high- and low-density treatments at Ginger's Bay.

Cohort	Larval* density	Sex	Number first-time breeders returning at:					Total survival
			Age 1	Age 2	Age 3	Age 4	Age 5	
1986	LOW (124)	F	0	14	22	6	6	48
	LOW (124)	M	0	41	24	5	11	81
1986	HIGH (84)	F	0	1	13	3	3	20
	HIGH (84)	M	0	15	9	1	2	27
1987	LOW (434)	F	3	19	7	9	..	38
	LOW (434)	M	9	32	9	8	..	58
1987	HIGH (680)	F	0	7	9	5	..	21
	HIGH (680)	M	0	6	5	9	..	20

*Number in parentheses indicates the total number of recently metamorphosed animals from each treatment that were marked by toe-clipping and released to the woodlands surrounding Ginger's Bay, assuming a 1:1 sex ratio of juveniles.

Table IV-4. Maximum-likelihood analysis (log-linear model) for effects of larval density (DENSITY), sex (SEX), and cohort year (YEAR) on the proportion of survivors reproducing for the first time (REPRO) at ≤ 2 yrs old versus ≥ 3 yrs old for Ambystoma opacum from the 1986 and 1987 cohorts at Ginger's Bay. Only first and second order interactions between main (design) effects and the response variable REPRO are presented (see Statistical Methods).

<u>Source of variation</u>	<u>df</u>	<u>Chi-square</u>	<u>P</u>
DENSITY*REPRO	1	10.19	<0.01
YEAR*REPRO	1	4.65	<0.05
SEX*REPRO	1	10.78	<0.001
DENSITY*YEAR*REPRO	1	3.04	0.08
DENSITY*SEX*REPRO	1	0.76	NS
YEAR*SEX*REPRO	1	3.88	<0.05

Cohorts from the two years also differed in age at first reproduction (YEAR*REPRO), averaged across density levels and sexes. Approximately 55% of the survivors from the 1987 density manipulation returned to GB at ≤ 2 yrs old, while 40% from 1986 matured by age 2 yrs.

Analyses of data gathered for other studies involving A. opacum provide additional evidence to elucidate further the link between larval conditions and age at first reproduction. The amphibian census data from RB provided four cohorts of A. opacum from a natural population that varied in mean body size at metamorphosis among cohorts. Similar data are available for five natural (unmanipulated) cohorts from GB, and four "pen" populations from experimental manipulations of predator density at GB. Differences in the mean body size at metamorphosis in these populations were generated by variation in several factors in the larval environment: density levels, predation intensity, food resource levels, hydroperiod, and other physical/chemical parameters. For males, there is a significant relationship ($E_{1,15} = 16.2$, $P < 0.01$) between SVL at metamorphosis and the proportion of metamorphs able to reach maturity in 1 yr (Fig. IV-2A). For females there is no relationship between SVL at metamorphosis and the proportion returning at age 1, but a weak relationship ($E_{1,13} = 3.6$, $P = 0.08$) exists at age 2 (Fig. IV-2B).

Adult survival. Survivorship was based on the number of animals in a cohort that survived to breed at least once. Larval density differentially affected survival (Table IV-3; Table IV-5, DENSITY*FATE). Averaged across years and sexes, survival of individuals from low-density groups was 20.2%, compared to 5.7% for individuals from high density.

On the average, males exhibited higher survival (14.1%) to first reproduction than females (9.6%; Table IV-5, SEX*FATE). This difference tended to be greater between males and females from low-density treatments than from high-density (Table 5, DENSITY*SEX*FATE).

Figure IV-2. Relationship between snout-vent length at metamorphosis and the proportion of the cohort that returned to breed at one year of age for males (2A) and two years old for females (2B) assuming a 1:1 sex ratio in newly metamorphosed juveniles. Each point represents a cohort from a different experimental field treatment or a natural population.

Table IV-5. Maximum-likelihood analysis (log-linear model) for effects of larval density (DENSITY), sex (SEX), and cohort year (YEAR) on adult survival (FATE) for Ambystoma opacum from the 1986 and 1987 cohorts at Ginger's Bay. Only first and second order interactions between main (design) effects and the response variable FATE are presented (see Statistical Methods).

<u>Source of variation</u>	<u>df</u>	<u>Chi-square</u>	<u>P</u>
DENSITY*FATE	1	65.52	<0.0001
YEAR*FATE	1	252.73	<0.0001
SEX*FATE	1	9.61	<0.01
DENSITY*YEAR*FATE	1	1.55	NS
DENSITY*SEX*FATE	1	3.38	0.06
YEAR*SEX*FATE	1	3.35	0.06

Survivorship also differed based on the year in which metamorphosis occurred (Table IV-5, YEAR*FATE). The 1987 cohort suffered significantly higher mortality; 6.1% survived compared to 42.3% from the 1986 cohort. The difference in survival between males and females tended to be greater in 1986 than in 1987 (Table IV-5, YEAR*SEX*FATE).

Clutch size. Females from the 1986 and 1987 experiments were collected in October 1990 at ages 5 yrs and 4 yrs, respectively. Larval density effects were evident in the 5-yr old females (Table IV-6; $F_{1,10} = 4.8$, $P = 0.05$) but were not significant for the 4-yr-old group ($F_{1,11} = 0.37$, $P > 0.50$).

DISCUSSION

In this study I experimentally generated a broad range of phenotypic variation in body size of A. opacum and examined the relationship between this variation and adult traits. In some amphibian species the timing (date) of metamorphosis also is correlated with traits such as adult body size and survival (Smith 1987, Semlitsch et al. 1988, Berven 1990). In my experimental manipulations of larval density of A. opacum, size and date at metamorphosis typically are coupled; large larvae metamorphose earlier than small larvae (Scott 1990). However, even in experiments in which treatment-induced differences in timing of metamorphosis did occur, the low-density groups metamorphosed only 5-9 days before the high-density groups (Scott 1990). For amphibian larvae in a drying pond, this difference in date of metamorphosis may be extremely critical because delayed metamorphosis may result in catastrophic mortality (Wilbur 1980, Newman 1988). A relatively short delay in metamorphosis (5-9 days) is probably not important to adult A. opacum, however. Given the contracted period of metamorphosis, it seems unlikely that differences in timing of metamorphosis alone would exert strong effects on adult traits. In the discussion that follows I concentrate on the link between body size at metamorphosis and traits related to adult fitness.

Table IV-6. Body size and clutch size of females (collected in 1990) from high- and - low density larval treatments in 1986 and 1987 at Ginger's Bay. Values represent $\bar{X} \pm 1SE$. N = number of females in the sample.

Cohort	Density	Age (yrs)	N	SVL (mm)	Clutch size
1986	LOW	5	5	61.3 ± 2.0	122.0 ± 20.1
	HIGH	5	7	56.5 ± 0.6	80.6 ± 7.4
1987	LOW	4	6	60.1 ± 0.9	99.0 ± 9.0
	HIGH	4	7	56.3 ± 1.0	91.2 ± 9.0

Lipid stores and survival. The survival differences observed in the laboratory study between animals from high- and low-density larval treatments probably are biologically meaningful. At Ginger's Bay, larval A. opacum typically metamorphose and leave the pond from mid-April through late May. Dry conditions may force individuals to remain inactive underground or under cover objects. Under these conditions, animals rely on energy reserves accumulated during their larval period, which allow them to subsist for some time without feeding. Based on coefficients determined by Feder (1976) for the relationship of standard metabolic rate (SMR) to body size in temperate-zone lunged salamanders at 15°C, I estimated the SMR of low-density animals (X wet mass = 1.66g) at approximately 57 ml O_2 /hr, or 6.5 cal/day. The energy available from lipid metabolism in the low density group is approximately 233.7 cal ($X = 0.246$ g lipids $\times$ 9500 cal/g), and individuals might survive ~36 days based solely on utilization of non-polar lipid reserves. Similar calculations for the high- density group (X mass = 1.01g, X lipids = 0.0029g) predict survival for ~6.3 days (at an SMR of 38 ml O_2 /hr). Actual survival time was longer, especially for the high-density group, which may indicate that other tissues also were metabolized.

Survival to reproduction under field conditions also was influenced by larval density. Large size appeared to enhance survival, perhaps by directly reducing mortality in the first year (Berven 1990) and by decreasing age at maturity. The laboratory-survival study suggests that the higher survival exhibited by adults reared at low larval densities is at least partially related to their greater post-metamorphic stored lipid levels and larger body size. In anurans, larger size at metamorphosis may increase time to exhaustion during forced locomotion and increase aerobic capacity (Pough and Kamel 1984). Additionally, if predation on juvenile and adult A. opacum is also an important component of mortality, then predation risk may be size-related and therefore influenced by larval density. In Bufo woodhosei fowleri, locomotor capacities and stamina are related to body size and larval density, and

large body size may enable individuals to evade and escape predators (John-Alder and Morin 1990).

Although both the low- and high-density groups in 1987 exhibited larger body size at metamorphosis than in 1986 (Scott 1990), survival in the 1987 cohort was significantly lower. The cause of the pronounced survival difference between years (cohorts) is unclear, but did not result from any obvious climatic differences. Most animals metamorphosed in mid-May in both 1986 and 1987; the amount and timing of rainfall prior to, during, and for 3 months after metamorphosis was similar in both years. Differences between males and females in adult survival likely were due to earlier age at maturity in males (Gibbons 1990, Lovich and Gibbons 1990).

I have assumed in these survival analyses that an individual's propensity to disperse from its natal pond is unrelated to larval density. However, dispersal ability may be size related and therefore density related (John-Adler and Morin 1990). Dispersal from crowded larval conditions may be important in population regulation in species with complex life cycles (Crowley et al. 1987). If small individuals from high larval densities are more likely to disperse (e.g., as with juvenile mantids, Hurd and Eisenberg 1984), then my estimates of survival differences between treatments are overestimated. However, in a damselfly species (Enallagma boreale), the individuals most likely to disperse to new ponds were the heaviest while the smallest ones return to the natal pond to breed (Anholt 1990). If a similar pattern exists in A. opacum, then estimates of survival differences between density treatments are conservative.

Phenotypic variation in age and size at maturity. The phenotype is a product of genetic and environmental influences. I experimentally generated a broad range of phenotypic variation in body size at metamorphosis and examined the relationship between this variation and adult traits. An experimentally broadened range of phenotypes is useful in understanding the relationship between phenotype and fitness, and how natural selection acts on potential variation (Anholt 1991). I

assume that fitness is linked to age at maturity through both generation time and juvenile mortality, and to size through size-dependent mortality and the size-fecundity relationship (Stearns and Koella 1986).

Manipulation of larval density created strong treatment differences in larval (Scott 1990) and adult traits. Because hatchlings were drawn from a genetically mixed pool of animals, the between-treatment differences are attributed to known environmental differences. In a comparison between high- and low-density treatments, an apparent negative relationship exists between size and age at maturity; larger individuals from low-density treatment groups matured at an earlier age than slowly growing individuals from high-density groups. The variation I observed between treatments in size at metamorphosis, and subsequently in adult traits, was environmentally induced, but individual growth rate in amphibians may also have an underlying genetic component (Travis 1980, 1981; Travis et al. 1987). The within-treatment variation in size and age at maturity that I observed may have resulted from genetic variation in growth rates. Within a treatment group the relationship between size and age at maturity was positive; older first-breeders were larger than young first-breeders. The underlying process behind both patterns (between- vs. within-treatment) appears to be the same. Slowly growing animals mature at a later age than rapidly growing animals. From a population perspective, this variation in age at maturity may serve to enhance population persistence.

Phenotypic plasticity in size and age at maturity is often viewed in the context of reaction norms (*sensu* Stearns and Koella 1986). A norm of reaction "represents the range of potential phenotypes that a single genotype could develop if exposed to a specified range of environmental conditions." Stearns and Koella (1986) pose the questions: If an organism encounters a generalized stress that slows its growth, how should it alter its age and size at maturity to keep fitness as high as possible under the given constraints? Can these changes be interpreted as life-history adaptations that maximize fitness?

In this study I imposed high density as a generalized stress on larval A. opacum, and observed alterations in age and size at maturity that are consistent with the Stearns and Koella (1986) reaction-norm model. The different growth trajectories initiated in the larval environment produce a reaction norm similar to that observed in Drosophila (see Fig. 12, Stearns and Koella 1986). Larval salamanders appear to exhibit a flexible pattern of development which allows them to adjust size and age at metamorphosis (Wilbur and Collins 1973). Size at maturity is also flexible. There is likely a minimum size below which an individual may not attain maturity, but not a fixed size at maturity. Flexibility in age and size at maturity is indicative of potentially adaptive plasticity in life-history traits (Reznick 1990). However, the demonstration of this pattern of phenotypic plasticity does not necessarily reflect the process of adaptation (Reznick 1990). Estimates of the contribution of age and size at maturity to individual fitness are necessary to demonstrate that flexibility is adaptive (Reznick 1990).

Adult traits and population regulation. These experimental data corroborate correlational data from previous field studies; larval density affects body size at metamorphosis and thereby a suite of adult traits presumably related to fitness. Size and age at first reproduction are critical life-history traits that influence individual reproductive success and the rate of population increase (Cole 1954, Semlitsch 1987). A decrease in age at first reproduction generally results in an increase in population growth rate. The observation that salamanders change size and age at maturity predictably as environmental conditions change has important consequences for population dynamics (Stearns and Koella 1986).

In this study, low larval density was associated with higher survival to first reproduction, larger body size at first reproduction, and earlier maturity. Also, females from low larval densities tended to have larger clutches. Data from females collected in a separate study on lipid utilization (unpublished data) revealed a significant positive relationship between female SVL and clutch size (Fig. IV-3; $F_{1,23} = 85.3$, $P < 0.0001$, $R^2 = 0.79$). Collectively, these traits could increase population growth rate (Harris 1987), and result in higher larval densities. High density might then promote small body size at metamorphosis, low larval and juvenile survival, small adult body size, and later age at first reproduction, i.e., slowed population growth.

The experimental densities I used in the larval manipulations were realistic and encompassed the range of naturally occurring mean densities (Scott 1990). This study therefore provides further evidence that density-dependent processes in the larval stage are an important component in the regulation of natural populations of Ambystoma. The effects of larval density on larval traits in Ambystoma are well-documented (Wilbur 1972, Stenhouse 1985, Petranka and Sih 1986, Petranka 1989, Scott 1990, Smith 1990, Van Buskirk and Smith 1991). In light of data presented here, it is obvious that larval density also affects adult traits strongly related to fitness. Future studies of potential density-dependent regulation in the adult (terrestrial) stage, coupled with this study, will provide a more complete understanding of population regulation in Ambystoma (Van Buskirk and Smith 1991).

Figure IV-3. Relationship between snout-vent length and clutch size in female Ambystoma opacum collected at Ginger's Bay in 1986.

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APPENDIX A

DWPF Water Quality Data

FY-1983 to FY-1992

(summarized by rainfall class and location)

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL	FY-1983	UTR CK ABOVE	-----		
TSS	3.42	0.24	7.20	1.53	33
LTSS	1.44	0.05	2.10	0.93	33
TURB	6.00	2.00	8.00	4.00	2
LTURB	1.90	0.29	2.20	1.61	2
PTSASH	44.18	1.53	56.56	12.60	33
SCOND	26.44	1.04	35.29	15.25	26
LSCOND	3.29	0.04	3.59	2.79	26
----- NO RAINFALL	FY-1983	TINKER CK	-----		
TSS	3.82	0.36	11.14	1.81	31
LTSS	1.51	0.06	2.50	1.03	31
TURB	1.00		1.00	1.00	1
LTURB	0.69		0.69	0.69	1
PTSASH	42.54	1.52	52.30	19.40	30
SCOND	49.55	2.04	68.64	32.81	25
LSCOND	3.90	0.04	4.24	3.52	25
----- NO RAINFALL	FY-1983	MCQUEEN BR	-----		
TSS	5.38	0.31	8.56	3.37	22
LTSS	1.83	0.05	2.26	1.47	22
TURB	5.00	0.00	5.00	5.00	2
LTURB	1.79	0.00	1.79	1.79	2
PTSASH	58.64	1.75	69.86	34.11	22
SCOND	58.89	3.90	81.59	32.38	15
LSCOND	4.06	0.07	4.41	3.51	15
----- NO RAINFALL	FY-1983	UTR CK MID.	-----		
TSS	4.04	0.42	8.58	2.02	17
LTSS	1.57	0.07	2.26	1.11	17
TURB	5.00	-	5.00	5.00	1
LTURB	1.79	-	1.79	1.79	1
PTSASH	47.39	1.13	52.67	36.60	15
SCOND	36.50	1.99	46.17	23.11	13
LSCOND	3.61	0.06	3.85	3.18	13
----- NO RAINFALL	FY-1983	CROUCH BR	-----		
TSS	--	--	--	--	--
LTSS	--	--	--	--	--
TURB	--	--	--	--	--
LTURB	--	--	--	--	--
PTSASH	--	--	--	--	--
SCOND	--	--	--	--	--
LSCOND	--	--	--	--	--

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL FY-1983 UTR BR BELOW -----					
TSS	4.10	0.49	9.02	0.89	17
LTSS	1.56	0.09	2.30	0.64	17
TURB	5.00		5.00	5.00	1
LTURB	1.79		1.79	1.79	1
PTSASH	45.73	2.33	55.47	15.09	16
SCOND	36.60	2.05	47.33	23.96	14
LSCOND	3.61	0.06	3.88	3.22	14
----- NO RAINFALL FY-1984 UTR CK ABOVE -----					
TSS	3.14	0.31	6.35	1.79	20
LTSS	1.37	0.07	1.99	1.02	20
TURB	2.87	0.41	7.00	1.00	18
LTURB	1.27	0.09	2.08	0.69	18
PTSASH	39.31	1.49	49.48	24.25	18
SCOND	13.14	2.19	30.48	1.26	20
LSCOND	2.39	0.17	3.45	0.81	20
----- NO RAINFALL FY-1984 TINKER CK -----					
TSS	3.50	0.43	6.65	1.32	18
LTSS	1.43	0.09	2.04	0.84	18
TURB	4.62	1.54	27.00	1.00	16
LTURB	1.48	0.15	3.33	0.69	16
PTSASH	39.32	2.11	54.40	24.20	16
SCOND	13.96	2.10	31.34	1.54	18
LSCOND	2.48	0.18	3.48	0.93	18
----- NO RAINFALL FY-1984 MCQUEEN BR -----					
TSS	27.69	11.26	233.82	2.74	20
LTSS	2.75	0.22	5.46	1.32	20
TURB	41.67	21.35	390.00	1.00	18
LTURB	2.66	0.34	5.97	0.69	18
PTSASH	72.51	1.70	85.02	58.12	18
SCOND	36.30	14.28	305.50	6.02	20
LSCOND	3.20	0.16	5.73	1.95	20
----- NO RAINFALL FY-1984 UTR CK MID. -----					
TSS	4.77	0.84	9.52	2.01	10
LTSS	1.67	0.14	2.35	1.10	10
TURB	3.78	0.87	9.00	0.00	9
LTURB	1.40	0.23	2.30	0.00	9
PTSASH	45.02	2.15	53.11	38.71	9
SCOND	14.74	3.49	40.18	1.50	10
LSCOND	2.52	0.24	3.72	0.91	10

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL FY-1984 CROUCH BR -----					
TSS	--	--	--	--	--
LTSS	--	--	--	--	--
TURB	--	--	--	--	--
LTURB	--	--	--	--	--
PTSASH	--	--	--	--	--
SCOND	--	--	--	--	--
LSCOND	--	--	--	--	--
----- NO RAINFALL FY-1984 UTR BR BELOW -----					
TSS	4.95	0.75	8.82	2.86	10
LTSS	1.72	0.12	2.28	1.35	10
TURB	4.01	0.53	7.00	1.00	9
LTURB	1.56	0.12	2.08	0.69	9
PTSASH	42.90	2.77	58.28	34.38	9
SCOND	14.85	2.22	29.32	1.49	10
LSCOND	2.62	0.21	3.41	0.91	10
----- NO RAINFALL FY-1985 UTR CK ABOVE -----					
TSS	6.83	1.57	24.90	1.30	16
LTSS	1.83	0.17	3.25	0.83	16
TURB	3.49	0.63	11.50	1.50	16
LTURB	1.40	0.11	2.53	0.92	16
PTSASH	42.55	3.45	57.00	12.87	16
SCOND	19.71	1.64	39.37	11.85	15
LSCOND	3.00	0.07	3.70	2.55	15
----- NO RAINFALL FY-1985 TINKER CK -----					
TSS	6.84	1.40	27.60	1.40	19
LTSS	1.86	0.14	3.35	0.88	19
TURB	3.72	0.54	10.80	1.20	19
LTURB	1.45	0.10	2.47	0.79	19
PTSASH	48.20	1.71	59.00	32.77	19
SCOND	25.97	2.41	34.97	5.93	14
LSCOND	3.21	0.13	3.58	1.94	14
----- NO RAINFALL FY-1985 MCQUEEN BR -----					
TSS	8.13	0.83	12.18	4.70	11
LTSS	2.17	0.09	2.58	1.74	11
TURB	12.43	2.77	32.00	5.20	11
LTURB	2.44	0.16	3.50	1.82	11
PTSASH	69.84	1.62	79.30	60.73	11
SCOND	58.18	8.88	121.23	22.73	10
LSCOND	3.99	0.14	4.81	3.17	10

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL	FY-1985	UTR CK MID.	-----		
TSS	6.49	0.99	13.00	2.60	10
LTSS	1.94	0.13	2.64	1.28	10
TURB	3.92	0.53	6.90	2.10	10
LTURB	1.55	0.10	2.07	1.13	10
PTSASH	48.33	3.14	57.00	25.09	10
SCOND	19.45	0.84	21.93	13.76	9
LSCOND	3.01	0.05	3.13	2.69	9
----- NO RAINFALL	FY-1985	CROUCH BR	-----		
TSS	35.00	17.71	70.00	12.80	3
LTSS	3.34	0.48	4.26	2.62	3
TURB	79.77	45.59	170.00	23.30	3
LTURB	4.06	0.57	5.14	3.19	3
PTSASH	85.43	1.50	88.40	83.60	3
SCOND	75.26	8.21	92.26	63.83	3
LSCOND	4.36	0.11	4.54	4.17	3
----- NO RAINFALL	FY-1985	UTR BR BELOW	-----		
TSS	5.79	0.78	9.50	3.10	10
LTSS	1.86	0.11	2.35	1.41	10
TURB	4.21	0.60	7.80	2.60	10
LTURB	1.60	0.11	2.17	1.28	10
PTSASH	50.19	1.36	58.00	43.80	10
SCOND	20.79	0.99	24.87	14.90	9
LSCOND	3.07	0.05	3.25	2.77	9
----- NO RAINFALL	FY-1986	UTR CK ABOVE	-----		
TSS	8.93	2.39	43.90	2.90	18
LTSS	2.01	0.16	3.80	1.36	18
TURB	4.03	0.96	19.00	1.30	18
LTURB	1.45	0.12	2.99	0.83	18
PTSASH	54.76	1.21	66.70	44.80	18
SCOND	16.99	0.39	20.30	14.40	18
LSCOND	2.89	0.02	3.06	2.73	18
----- NO RAINFALL	FY-1986	TINKER CK	-----		
TSS	6.37	1.38	25.60	2.20	17
LTSS	1.82	0.14	3.28	1.16	17
TURB	3.22	0.49	9.70	0.90	17
LTURB	1.36	0.10	2.37	0.64	17
PTSASH	50.28	1.90	56.70	30.80	17
SCOND	33.21	1.01	41.70	26.70	17
LSCOND	3.53	0.03	3.75	3.32	17

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL		FY-1986	MCQUEEN BR	-----	
TSS	16.02	3.57	35.50	5.10	9
LTSS	2.67	0.20	3.60	1.81	9
TURB	19.89	6.20	56.00	6.40	9
LTURB	2.71	0.28	4.04	2.00	9
PTSASH	78.86	2.37	89.00	65.70	9
SCOND	85.50	9.91	133.20	54.00	9
LSCOND	4.41	0.11	4.90	4.01	9
----- NO RAINFALL		FY-1986	UTR CK MID.	-----	
TSS	8.33	2.09	19.20	3.10	8
LTSS	2.07	0.21	3.01	1.41	8
TURB	4.72	1.17	13.00	1.40	9
LTURB	1.61	0.18	2.64	0.88	9
PTSASH	55.48	2.68	68.40	44.40	8
SCOND	23.82	1.00	30.00	20.80	9
LSCOND	3.21	0.04	3.43	3.08	9
----- NO RAINFALL		FY-1986	CROUCH BR	-----	
TSS	105.13	27.51	217.10	16.10	9
LTSS	4.28	0.34	5.38	2.84	9
TURB	177.28	46.07	365.00	19.00	9
LTURB	4.79	0.35	5.90	2.99	9
PTSASH	86.40	1.67	90.00	76.40	9
SCOND	97.33	4.85	125.20	76.70	9
LSCOND	4.58	0.05	4.84	4.35	9
----- NO RAINFALL		FY-1986	UTR BR BELOW	-----	
TSS	7.04	1.33	14.30	3.30	9
LTSS	1.99	0.15	2.73	1.46	9
TURB	4.60	1.09	12.00	2.20	9
LTURB	1.61	0.16	2.56	1.16	9
PTSASH	54.24	2.59	72.10	45.30	9
SCOND	24.68	1.24	33.20	21.70	9
LSCOND	3.24	0.04	3.53	3.12	9
----- NO RAINFALL		FY-1987	UTR CK ABOVE	-----	
TSS	5.00	0.61	7.80	3.20	8
LTSS	1.76	0.10	2.17	1.44	8
TURB	2.70	0.77	7.30	0.90	8
LTURB	1.19	0.18	2.12	0.64	8
PTSASH	52.68	1.67	61.50	45.50	8
SCOND	16.85	0.93	21.70	14.60	8
LSCOND	2.87	0.05	3.12	2.75	8

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL	FY-1987	TINKER CR	-----		
TSS	4.36	0.45	6.10	2.80	8
LTSS	1.65	0.08	1.96	1.34	8
TURB	2.21	0.29	3.40	1.00	8
LTURB	1.14	0.10	1.48	0.69	8
PTSASH	51.21	1.90	58.30	42.90	8
SCOND	28.86	1.55	35.50	24.30	8
LSCOND	3.39	0.05	3.59	3.23	8
----- NO RAINFALL	FY-1987	MCQUEEN BR	-----		
TSS	11.13	2.36	22.00	4.30	8
LTSS	2.37	0.19	3.14	1.67	8
TURB	14.13	4.86	40.50	3.20	8
LTURB	2.41	0.28	3.73	1.44	8
PTSASH	80.60	1.96	85.00	70.00	8
SCOND	68.90	6.73	101.50	45.90	8
LSCOND	4.21	0.10	4.63	3.85	8
----- NO RAINFALL	FY-1987	UTR CK MID.	-----		
TSS	5.20	0.74	6.80	3.70	4
LTSS	1.80	0.12	2.05	1.55	4
TURB	2.98	0.89	5.40	1.30	4
LTURB	1.31	0.22	1.86	0.83	4
PTSASH	57.38	1.42	60.00	54.10	4
SCOND	22.60	1.07	24.70	20.10	4
LSCOND	3.16	0.05	3.25	3.05	4
----- NO RAINFALL	FY-1987	CROUCH BR	-----		
TSS	91.50	50.12	180.20	6.70	3
LTSS	3.91	0.96	5.20	2.04	3
TURB	179.50	95.58	350.00	8.50	3
LTURB	4.44	1.11	5.86	2.25	3
PTSASH	86.17	4.29	90.80	77.60	3
SCOND	96.57	3.44	102.40	90.50	3
LSCOND	4.58	0.04	4.64	4.52	3
----- NO RAINFALL	FY-1987	UTR BR BELOW	-----		
TSS	7.75	2.72	15.90	4.70	4
LTSS	2.05	0.26	2.83	1.74	4
TURB	3.60	1.10	6.10	1.60	4
LTURB	1.43	0.25	1.96	0.96	4
PTSASH	55.57	4.07	63.50	50.00	3
SCOND	23.05	0.74	25.10	21.60	4
LSCOND	3.18	0.03	3.26	3.12	4

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL FY-1988 UTR CK ABOVE -----					
TSS	4.27	0.86	7.90	2.10	6
LTSS	1.60	0.16	2.19	1.13	6
TURB	1.37	0.23	2.20	0.70	6
LTURB	0.84	0.10	1.16	0.53	6
PTSASH	53.30	1.40	57.40	47.60	6
SCOND	14.70	0.33	16.10	14.00	6
LSCOND	2.75	0.02	2.84	2.71	6
----- NO RAINFALL FY-1988 TINKER CK -----					
TSS	7.82	2.30	17.50	2.50	6
LTSS	2.01	0.25	2.92	1.25	6
TURB	2.63	0.59	4.50	0.80	6
LTURB	1.21	0.18	1.70	0.59	6
PTSASH	57.08	2.99	71.70	52.00	6
SCOND	31.82	1.53	36.10	27.70	6
LSCOND	3.49	0.05	3.61	3.36	6
----- NO RAINFALL FY-1988 MCQUEEN BR -----					
TSS	5.80	1.36	10.30	2.10	6
LTSS	1.82	0.20	2.42	1.13	6
TURB	6.90	3.02	21.10	1.70	6
LTURB	1.77	0.32	3.09	0.99	6
PTSASH	75.37	3.14	85.40	66.70	6
SCOND	137.72	46.21	349.00	58.10	6
LSCOND	4.71	0.28	5.86	4.08	6
----- NO RAINFALL FY-1988 UTR CK MID. -----					
TSS	5.73	1.27	7.60	3.30	3
LTSS	1.87	0.21	2.15	1.46	3
TURB	2.00	0.51	2.70	1.00	3
LTURB	1.07	0.19	1.31	0.69	3
PTSASH	48.07	7.38	55.60	33.30	3
SCOND	20.80	1.07	22.90	19.40	3
LSCOND	3.08	0.05	3.17	3.01	3
----- NO RAINFALL FY-1988 CROUCH BR -----					
TSS	13.60	4.17	18.40	5.30	3
LTSS	2.57	0.36	2.97	1.84	3
TURB	21.37	8.64	36.00	6.10	3
LTURB	2.90	0.49	3.61	1.96	3
PTSASH	78.10	2.42	81.90	73.60	3
SCOND	106.30	12.23	120.00	81.90	3
LSCOND	4.66	0.12	4.80	4.42	3

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL FY-1988 UTR BR BELOW -----					
TSS	5.43	0.87	6.50	3.70	3
LTSS	1.84	0.15	2.01	1.55	3
TURB	1.90	0.47	2.60	1.00	3
LTURB	1.04	0.18	1.28	0.69	3
PTSASH	53.80	2.66	57.40	48.60	3
SCOND	21.47	1.08	23.50	19.80	3
LSCOND	3.11	0.05	3.20	3.03	3
----- NO RAINFALL FY-1989 UTR CK ABOVE -----					
TSS	3.60	0.43	4.50	2.10	6
LTSS	1.50	0.10	1.70	1.13	6
TURB	0.73	0.26	2.00	0.32	6
LTURB	0.50	0.13	1.10	0.28	6
PTSASH	49.87	1.71	57.50	46.50	6
SCOND	14.92	0.33	16.40	14.20	6
LSCOND	2.77	0.02	2.86	2.72	6
----- NO RAINFALL FY-1989 TINKER CK -----					
TSS	5.67	1.63	12.50	1.90	6
LTSS	1.76	0.23	2.60	1.06	6
TURB	1.63	0.55	3.30	0.38	6
LTURB	0.85	0.21	1.46	0.32	6
PTSASH	52.52	2.48	60.00	43.2	6
SCOND	30.68	1.44	34.80	27.10	6
LSCOND	3.45	0.05	3.58	3.34	6
----- NO RAINFALL FY-1989 MCQUEEN BR -----					
TSS	5.25	1.13	9.10	2.60	6
LTSS	1.75	0.18	2.31	1.28	6
TURB	6.90	2.41	18.00	2.00	6
LTURB	1.87	0.27	2.94	1.10	6
PTSASH	76.90	2.04	83.50	73.00	6
SCOND	92.83	24.14	180.00	41.20	6
LSCOND	4.39	0.24	5.20	3.74	6
----- NO RAINFALL FY-1989 UTR CK MID. -----					
TSS	4.23	0.94	6.00	2.80	3
LTSS	1.62	0.18	1.95	1.34	3
TURB	1.07	0.57	2.20	0.40	3
LTURB	0.66	0.26	1.16	0.34	3
PTSASH	53.03	0.67	53.80	51.70	3
SCOND	22.17	1.62	25.40	20.50	3
LSCOND	3.14	0.07	3.27	3.07	3

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL FY-1989 CROUCH BR -----					
TSS	32.93	14.33	55.40	6.30	3
LTSS	3.22	0.63	4.03	1.99	3
TURB	66.63	30.87	110.00	6.90	3
LTURB	3.73	0.84	4.71	2.07	3
PTSASH	86.13	1.88	88.80	82.50	3
SCOND	99.60	4.33	107.00	92.00	3
LSCOND	4.61	0.04	4.68	4.53	3
----- NO RAINFALL FY-1989 UTR BR BELOW -----					
TSS	5.33	1.39	7.40	2.70	3
LTSS	1.79	0.25	2.13	1.31	3
TURB	1.48	0.92	3.30	0.43	3
LTURB	0.78	0.34	1.46	0.36	3
PTSASH	58.80	3.05	64.90	55.60	3
SCOND	23.17	1.72	26.60	21.30	3
LSCOND	3.18	0.07	3.32	3.10	3
----- NO RAINFALL FY-1990 UTR CK ABOVE -----					
TSS	4.85	0.49	6.40	3.30	6
LTSS	1.75	0.09	2.00	1.46	6
TURB	1.03	0.19	1.60	0.52	6
LTURB	0.69	0.09	0.96	0.42	6
PTSASH	55.92	1.24	60.90	52.40	6
SCOND	15.30	0.35	16.40	14.40	6
LSCOND	2.79	0.02	2.86	2.73	6
----- NO RAINFALL FY-1990 TINKER CK -----					
TSS	9.93	0.93	12.20	6.40	6
LTSS	2.37	0.09	2.58	2.00	6
TURB	2.32	0.32	2.80	0.72	6
LTURB	1.17	0.13	1.34	0.54	6
PTSASH	52.18	2.74	56.70	39.30	6
SCOND	32.28	1.72	39.30	27.70	6
LSCOND	3.50	0.05	3.70	3.36	6
----- NO RAINFALL FY-1990 MCQUEEN BR -----					
TSS	3.92	0.48	5.90	2.50	6
LTSS	1.57	0.09	1.93	1.25	6
TURB	3.02	0.31	4.20	2.00	6
LTURB	1.38	0.08	1.65	1.10	6
PTSASH	75.58	1.75	81.80	70.50	6
SCOND	54.82	4.54	75.10	45.40	6
LSCOND	4.01	0.08	4.33	3.84	6

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- NO RAINFALL FY-1990 UTR CK MID. -----					
TSS	6.87	0.44	7.40	6.00	3
LTSS	2.06	0.06	2.12	1.95	3
TURB	1.68	0.42	2.20	0.84	3
LTURB	0.96	0.17	1.16	0.61	3
PTSASH	55.13	1.51	58.10	53.20	3
SCOND	20.73	0.63	21.60	19.50	3
LSCOND	3.08	0.03	3.12	3.02	3
----- NO RAINFALL FY-1990 CROUCH BR -----					
TSS	27.00	15.82	58.50	8.70	3
LTSS	3.02	0.55	4.09	2.27	3
TURB	29.97	14.76	55.00	3.90	3
LTURB	3.02	0.74	4.02	1.59	3
PTSASH	74.13	5.48	80.30	63.20	3
SCOND	130.63	42.14	212.00	70.90	3
LSCOND	4.78	0.32	5.36	4.26	3
----- NO RAINFALL FY-1990 UTR BR BELOW -----					
TSS	8.47	1.82	12.10	6.60	3
LTSS	2.21	0.18	2.57	2.03	3
TURB	1.26	0.47	2.20	0.71	3
LTURB	0.78	0.20	1.16	0.54	3
PTSASH	57.23	0.67	58.50	56.20	3
SCOND	21.77	0.54	22.40	20.70	3
LSCOND	3.12	0.02	3.15	3.08	3
----- NO RAINFALL FY-1991 UTR CK ABOVE -----					
TSS	2.91	0.10	3.16	2.71	4
LTSS	1.36	0.03	1.43	1.31	4
TURB	0.52	0.01	0.55	0.48	4
LTURB	0.42	0.01	0.44	0.39	4
PTSASH	49.55	2.56	54.60	43.70	4
SCOND	15.18	0.23	15.70	14.70	4
LSCOND	2.78	0.01	2.82	2.75	4
----- NO RAINFALL FY-1991 TINKER CK -----					
TSS	2.79	0.35	3.47	1.91	4
LTSS	1.32	0.10	1.50	1.07	4
TURB	0.54	0.06	0.67	0.40	4
LTURB	0.43	0.04	0.51	0.34	4
PTSASH	51.33	2.48	58.10	46.60	4
SCOND	29.25	1.30	32.80	26.70	4
LSCOND	3.41	0.04	3.52	3.32	4

STD ERROR MAXIMUM MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- NO RAINFALL FY-1991 MCQUEEN BR -----					
TSS	3.29	0.24	3.89	2.76	4
LTSS	1.45	0.06	1.59	1.32	4
TURB	1.24	0.12	1.50	0.93	4
LTURB	0.80	0.06	0.92	0.66	4
PTSASH	71.65	1.90	76.10	68.20	4
SCOND	39.65	0.82	41.90	38.40	4
LSCOND	3.70	0.02	3.76	3.67	4
----- NO RAINFALL FY-1991 UTR CK MID. -----					
TSS	3.29	0.11	3.40	3.18	2
LTSS	1.46	0.03	1.48	1.43	2
TURB	0.56	0.07	0.62	0.49	2
LTURB	0.44	0.04	0.48	0.40	2
PTSASH	47.65	3.25	50.90	44.40	2
SCOND	20.95	0.85	21.80	20.10	2
LSCOND	3.09	0.04	3.13	3.05	2
----- NO RAINFALL FY-1991 CROUCH BR -----					
TSS	11.83	1.81	13.63	10.02	2
LTSS	2.54	0.14	2.68	2.40	2
TURB	5.63	2.58	8.20	3.05	2
LTURB	1.81	0.41	2.22	1.40	2
PTSASH	75.50	7.00	82.50	68.50	2
SCOND	76.95	4.85	81.80	72.10	2
LSCOND	4.35	0.06	4.42	4.29	2
----- NO RAINFALL FY-1991 UTR BR BELOW -----					
TSS	4.10	0.16	4.25	3.94	2
LTSS	1.63	0.03	1.66	1.60	2
TURB	0.66	0.07	0.72	0.59	2
LTURB	0.50	0.04	0.54	0.46	2
PTSASH	55.50	0.90	56.40	54.60	2
SCOND	21.15	0.65	21.80	20.50	2
LSCOND	3.10	0.03	3.13	3.07	2
----- NO RAINFALL FY-1992 UTR CK ABOVE -----					
TSS	3.71	0.46	4.17	3.25	2
LTSS	1.54	0.10	1.64	1.45	2
TURB	0.44	0.04	0.47	0.40	2
LTURB	0.36	0.02	0.39	0.34	2
PTSASH	41.85	1.55	43.40	40.30	2
SCOND	15.15	0.15	15.30	15.00	2
LSCOND	2.78	0.01	2.79	2.77	2

STD ERROR MAXIMUM MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- NO RAINFALL FY-1992 TINKER CK -----					
TSS	4.55	0.43	4.97	4.12	2
LTSS	1.71	0.08	1.79	1.63	2
TURB	0.53	0.02	0.54	0.51	2
LTURB	0.42	0.01	0.43	0.41	2
PTSASH	47.60	0.50	48.10	47.10	2
SCOND	25.40	2.20	27.60	23.20	2
LSCOND	3.27	0.08	3.35	3.19	2
----- NO RAINFALL FY-1992 MCQUEEN BR -----					
TSS	4.12	0.67	4.79	3.45	2
LTSS	1.62	0.13	1.76	1.49	2
TURB	1.28	0.42	1.70	0.86	2
LTURB	0.81	0.19	0.99	0.62	2
PTSASH	55.95	0.85	56.80	55.10	2
SCOND	53.30	7.50	60.80	45.80	2
LSCOND	3.98	0.14	4.12	3.85	2
----- NO RAINFALL FY-1992 UTR CK MID. -----					
TSS	4.00	--	4.00	4.00	1
LTSS	1.61	--	1.61	1.61	1
TURB	0.46	--	0.46	0.46	1
LTURB	0.38	--	0.38	0.38	1
PTSASH	39.00	--	39.00	39.00	1
SCOND	20.40	--	20.40	20.40	1
LSCOND	3.06	--	3.06	3.06	1
----- NO RAINFALL FY-1992 CROUCH BR -----					
TSS	20.27	--	20.27	20.27	1
LTSS	3.06	--	3.06	3.06	1
TURB	39.00	--	39.00	39.00	1
LTURB	3.69	--	3.69	3.69	1
PTSASH	78.60	--	78.60	78.60	1
SCOND	78.20	--	78.20	78.20	1
LSCOND	4.37	--	4.37	4.37	1
----- NO RAINFALL FY-1992 UTR BR BELOW -----					
TSS	4.51	--	4.51	4.51	1
LTSS	1.71	--	1.71	1.71	1
TURB	0.51	--	0.51	0.51	1
LTURB	0.41	--	0.41	0.41	1
PTSASH	48.60	--	48.60	48.60	1
SCOND	20.80	--	20.80	20.80	1
LSCOND	3.08	--	3.08	3.08	1

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- LOW RAINFALL FY-1983 UTR CK ABOVE -----					
TSS	4.85	0.41	6.97	2.86	10
LTSS	1.74	0.07	2.08	1.35	10
TURB	--	--	--	--	0
LTURB	--	--	--	--	0
PTSASH	47.73	5.67	72.64	15.38	8
SCOND	23.84	3.06	34.49	14.19	8
LSCOND	3.16	0.13	3.57	2.72	8
----- LOW RAINFALL FY-1983 TINKER CK -----					
TSS	5.20	0.63	7.41	2.45	8
LTSS	1.78	0.11	2.13	1.24	8
TURB	--	--	--	--	0
LTURB	--	--	--	--	0
PTSASH	42.14	3.16	54.67	30.42	7
SCOND	38.99	4.98	57.31	19.61	7
LSCOND	3.64	0.14	4.07	3.03	7
----- LOW RAINFALL FY-1983 MCQUEEN BR -----					
TSS	6.93	0.75	8.97	3.75	7
LTSS	2.04	0.10	2.30	1.56	7
TURB	--	--	--	--	0
LTURB	--	--	--	--	0
PTSASH	61.00	3.19	69.10	54.12	5
SCOND	50.07	5.96	70.36	36.47	5
LSCOND	3.91	0.11	4.27	3.62	5
----- LOW RAINFALL FY-1983 UTR CK MID. -----					
TSS	6.16	0.76	8.02	3.95	5
LTSS	1.94	0.11	2.20	1.60	5
TURB	--	--	--	--	0
LTURB	--	--	--	--	0
PTSASH	43.81	3.16	49.73	34.88	4
SCOND	33.02	3.60	42.26	26.48	4
LSCOND	3.51	0.10	3.77	3.31	4
----- LOW RAINFALL FY-1983 CROUCH BR -----					
TSS	--	--	--	--	--
LTSS	--	--	--	--	--
TURB	--	--	--	--	--
LTURB	--	--	--	--	--
PTSASH	--	--	--	--	--
SCOND	--	--	--	--	--
LSCOND	--	--	--	--	--

STD ERROR MAXIMUM MINIMUM

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VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- LOW RAINFALL FY-1983 UTR BR BELOW -----					
TSS	6.15	0.73	8.02	4.18	5
LTSS	1.94	0.11	2.20	1.65	5
TURB	--	--	--	--	0
LTURB	--	--	--	--	0
PTSASH	44.41	1.73	49.35	41.34	4
SCOND	32.64	4.63	44.71	25.31	4
LSCOND	3.49	0.13	3.82	3.27	4
----- LOW RAINFALL FY-1984 UTR CK ABOVE -----					
TSS	6.30	0.37	6.66	5.93	2
LTSS	1.99	0.05	2.04	1.94	2
TURB	3.45	0.85	4.30	2.60	2
LTURB	1.47	0.19	1.67	1.28	2
PTSASH	43.92	0.07	43.99	43.84	2
SCOND	12.88	0.25	13.13	12.62	2
LSCOND	2.63	0.02	2.65	2.61	2
----- LOW RAINFALL FY-1984 TINKER CK -----					
TSS	9.47	0.73	10.19	8.74	2
LTSS	2.35	0.07	2.42	2.28	2
TURB	5.10	0.50	5.60	4.60	2
LTURB	1.80	0.08	1.89	1.72	2
PTSASH	47.48	2.86	50.34	44.62	2
SCOND	17.59	4.96	22.54	12.62	2
LSCOND	2.89	0.27	3.16	2.61	2
----- LOW RAINFALL FY-1984 MCQUEEN BR -----					
TSS	16.91	0.27	17.18	16.64	2
LTSS	2.89	0.02	2.90	2.87	2
TURB	19.00	1.00	20.00	18.00	2
LTURB	2.99	0.05	3.04	2.94	2
PTSASH	69.40	0.89	70.28	68.51	2
SCOND	22.68	4.43	27.12	18.25	2
LSCOND	3.15	0.19	3.34	2.96	2
----- LOW RAINFALL FY-1984 UTR CK MID. -----					
TSS	10.51	--	10.51	10.51	1
LTSS	2.44	--	2.44	2.44	1
TURB	5.20	--	5.20	5.20	1
LTURB	1.82	--	1.82	1.82	1
PTSASH	52.33	--	52.33	52.33	1
SCOND	6.51	--	6.51	6.51	1
LSCOND	2.02	--	2.02	2.02	1
		STD ERROR	MAXIMUM	MINIMUM	

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- LOW RAINFALL FY-1984 CROUCH BR -----					
TSS	--	--	--	--	--
LTSS	--	--	--	--	--
TURB	--	--	--	--	--
LTURB	--	--	--	--	--
PTSASH	--	--	--	--	--
SCOND	--	--	--	--	--
LSCOND	--	--	--	--	--
----- LOW RAINFALL FY-1984 UTR BR BELOW -----					
TSS	9.64	--	9.64	9.64	1
LTSS	2.36	--	2.36	2.36	1
TURB	5.80	--	5.80	5.80	1
LTURB	1.92	--	1.92	1.92	1
PTSASH	52.28	--	52.28	52.28	1
SCOND	5.40	--	5.40	5.40	1
LSCOND	1.86	--	1.86	1.86	1
----- LOW RAINFALL FY-1985 UTR CK ABOVE -----					
TSS	4.73	0.92	5.70	2.90	3
LTSS	1.72	0.18	1.90	1.36	3
TURB	3.80	0.42	4.40	2.99	3
LTURB	1.56	0.09	1.69	1.38	3
PTSASH	65.47	8.29	75.90	49.10	3
SCOND	17.86	0.49	19.15	17.10	4
LSCOND	2.94	0.03	3.00	2.90	4
----- LOW RAINFALL FY-1985 TINKER CK -----					
TSS	6.90	1.51	10.10	2.90	4
LTSS	2.00	0.23	2.41	1.36	4
TURB	4.43	0.32	5.30	3.90	4
LTURB	1.69	0.06	1.84	1.59	4
PTSASH	61.40	9.23	86.20	44.60	4
SCOND	32.93	2.08	36.84	27.82	4
LSCOND	3.52	0.06	3.63	3.36	4
----- LOW RAINFALL FY-1985 MCQUEEN BR -----					
TSS	34.75	18.75	53.50	16.00	2
LTSS	3.42	0.58	4.00	2.83	2
TURB	33.60	11.60	45.20	22.00	2
LTURB	3.48	0.35	3.83	3.14	2
PTSASH	75.65	3.75	79.40	71.90	2
SCOND	68.55	25.14	93.69	43.41	2
LSCOND	4.17	0.38	4.55	3.79	2
		STD ERROR	MAXIMUM	MINIMUM	

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- LOW RAINFALL		FY-1985	UTR CK MID.	-----	
TSS	7.05	2.15	9.20	4.90	2
LTSS	2.05	0.27	2.32	1.77	2
TURB	4.70	0.70	5.40	4.00	2
LTURB	1.73	0.12	1.86	1.61	2
PTSASH	64.35	13.25	77.60	51.10	2
SCOND	20.46	0.73	21.19	19.73	2
LSCOND	3.07	0.03	3.10	3.03	2
----- LOW RAINFALL		FY-1985	CROUCH BR	-----	
TSS	65.30	--	65.30	65.30	1
LTSS	4.19	--	4.19	4.19	1
TURB	158.00	--	158.00	158.00	1
LTURB	5.07	--	5.07	5.07	1
PTSASH	86.70	--	86.70	86.70	1
SCOND	78.71	--	78.71	78.71	1
LSCOND	4.38	--	4.38	4.38	1
----- LOW RAINFALL		FY-1985	UTR BR BELOW	-----	
TSS	6.55	2.25	8.80	4.30	2
LTSS	1.96	0.31	2.28	1.67	2
TURB	5.75	1.25	7.00	4.50	2
LTURB	1.89	0.19	2.08	1.70	2
PTSASH	62.75	11.65	74.40	51.10	2
SCOND	24.74	1.05	25.79	23.61	2
LSCOND	3.25	0.04	3.29	3.21	2
----- LOW RAINFALL		FY-1986	UTR CK ABOVE	-----	
TSS	10.10	0.30	10.40	9.80	2
LTSS	2.41	0.03	2.43	2.38	2
TURB	5.90	0.90	6.80	5.00	2
LTURB	1.92	0.13	2.05	1.79	2
PTSASH	57.00	2.20	59.20	54.80	2
SCOND	15.75	0.15	15.90	15.60	2
LSCOND	2.82	0.01	2.83	2.81	2
----- LOW RAINFALL		FY-1986	TINKER CK	-----	
TSS	12.50	3.10	15.60	9.40	2
LTSS	2.58	0.23	2.81	2.34	2
TURB	4.75	0.15	4.90	4.60	2
LTURB	1.75	0.03	1.77	1.72	2
PTSASH	50.80	1.80	52.60	49.00	2
SCOND	30.40	1.60	32.00	28.80	2
LSCOND	3.45	0.05	3.50	3.39	2

STD ERROR

MAXIMUM

MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- LOW RAINFALL FY-1986 MCQUEEN BR -----					
TSS	46.40	--	46.40	46.40	1
LTSS	3.86	--	3.86	3.86	1
TURB	79.00	--	79.00	79.00	1
LTURB	4.38	--	4.38	4.38	1
PTSASH	88.40	--	38.40	88.40	1
SCOND	66.60	--	66.60	66.60	1
LSCOND	4.21	--	4.21	4.21	1
----- LOW RAINFALL FY-1986 UTR CK MID. -----					
TSS	13.90	--	13.90	13.90	1
LTSS	2.70	--	2.70	2.70	1
TURB	5.10	--	5.10	5.10	1
LTURB	1.81	--	1.81	1.81	1
PTSASH	54.70	--	54.70	54.70	1
SCOND	22.10	--	22.10	22.10	1
LSCOND	3.14	--	3.14	3.14	1
----- LOW RAINFALL FY-1986 CROUCH BR -----					
TSS	62.50	--	62.50	62.50	1
LTSS	4.15	--	4.15	4.15	1
TURB	110.00	--	110.00	110.00	1
LTURB	4.71	--	4.71	4.71	1
PTSASH	86.20	--	86.20	86.20	1
SCOND	104.60	--	104.60	104.60	1
LSCOND	4.66	--	4.66	4.66	1
----- LOW RAINFALL FY-1986 UTR BR BELOW -----					
TSS	14.80	--	14.80	14.80	1
LTSS	2.76	--	2.76	2.76	1
TURB	5.70	--	5.70	5.70	1
LTURB	1.90	--	1.90	1.90	1
PTSASH	54.10	--	54.10	54.10	1
SCOND	22.50	--	22.50	22.50	1
LSCOND	3.16	--	3.16	3.16	1
----- LOW RAINFALL FY-1987 UTR CK ABOVE -----					
TSS	5.95	0.75	8.80	3.10	8
LTSS	1.89	0.12	2.28	1.41	8
TURB	2.36	0.25	3.40	1.20	8
LTURB	1.19	0.08	1.48	0.79	8
PTSASH	53.51	1.63	59.60	45.20	8
SCOND	15.49	0.39	17.20	13.90	8
LSCOND	2.80	0.02	2.90	2.70	8

STD ERROR

MAXIMUM

MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- LOW RAINFALL		FY-1987	TINKER CK	-----	
TSS	8.13	1.52	15.00	2.10	8
LTSS	2.09	0.20	2.77	1.13	8
TURB	2.74	0.28	3.90	1.50	8
LTURB	1.30	0.08	1.59	0.92	8
PTSASH	50.23	0.96	54.70	46.90	8
SCOND	28.38	1.29	35.70	24.40	8
LSCOND	3.37	0.04	3.60	3.23	8
----- LOW RAINFALL		FY-1987	MCQUEEN BR	-----	
TSS	28.67	12.24	95.10	6.80	7
LTSS	2.95	0.37	4.57	2.05	7
TURB	45.81	22.71	165.00	4.40	7
LTURB	3.06	0.52	5.11	1.69	7
PTSASH	84.46	3.15	97.20	75.30	7
SCOND	64.83	7.92	93.10	39.80	7
LSCOND	4.14	0.13	4.54	3.71	7
----- LOW RAINFALL		FY-1987	UTR CK MID.	-----	
TSS	8.13	1.77	12.00	3.90	4
LTSS	2.15	0.21	2.56	1.59	4
TURB	3.33	0.66	5.10	2.10	4
LTURB	1.43	0.15	1.81	1.13	4
PTSASH	55.65	1.33	57.40	51.70	4
SCOND	22.35	1.08	25.20	20.30	4
LSCOND	3.15	0.05	3.27	3.06	4
----- LOW RAINFALL		FY-1987	CROUCH BR	-----	
TSS	43.23	15.74	80.70	12.10	4
LTSS	3.55	0.42	4.40	2.57	4
TURB	81.00	31.75	165.00	21.00	4
LTURB	4.14	0.44	5.11	3.09	4
PTSASH	87.33	2.24	92.90	82.60	4
SCOND	89.20	9.94	108.60	61.80	4
LSCOND	4.48	0.12	4.70	4.14	4
----- LOW RAINFALL		FY-1987	UTR BR BELOW	-----	
TSS	8.45	1.64	11.50	3.90	4
LTSS	2.19	0.21	2.53	1.59	4
TURB	3.55	0.81	5.90	2.30	4
LTURB	1.47	0.16	1.93	1.19	4
PTSASH	58.65	0.57	59.50	57.00	4
SCOND	22.30	1.05	25.40	20.90	4
LSCOND	3.15	0.04	3.27	3.09	4

STD ERROR

MAXIMUM

MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- LOW RAINFALL FY-1988 UTR CK ABOVE -----					
TSS	4.51	0.40	6.70	3.30	8
LTSS	1.69	0.07	2.04	1.46	8
TURB	2.00	0.30	3.90	1.20	8
LTURB	1.07	0.09	1.59	0.79	8
PTSASH	55.64	1.57	64.20	51.20	8
SCOND	15.94	0.60	19.40	14.40	8
LSCOND	2.83	0.03	3.02	2.73	8
----- LOW RAINFALL FY-1988 TINKER CK -----					
TSS	5.49	0.78	8.40	2.00	8
LTSS	1.81	0.14	2.24	1.10	8
TURB	2.10	0.19	2.90	1.40	8
LTURB	1.12	0.06	1.36	0.88	8
PTSASH	52.25	0.85	55.50	48.10	8
SCOND	30.48	1.34	37.40	26.20	8
LSCOND	3.44	0.04	3.65	3.30	8
----- LOW RAINFALL FY-1988 MCQUEEN BR -----					
TSS	87.18	41.82	331.20	4.80	8
LTSS	3.63	0.51	5.81	1.76	8
TURB	128.86	61.45	495.00	3.20	8
LTURB	3.89	0.59	6.21	1.44	8
PTSASH	85.91	1.48	91.10	79.20	8
SCOND	192.93	58.20	510.00	50.30	8
LSCOND	4.95	0.30	6.24	3.94	8
----- LOW RAINFALL FY-1988 UTR CK MID. -----					
TSS	5.38	0.51	6.70	4.30	4
LTSS	1.84	0.08	2.04	1.67	4
TURB	2.58	0.50	4.00	1.70	4
LTURB	1.25	0.13	1.61	0.99	4
PTSASH	57.05	2.44	64.20	53.50	4
SCOND	22.13	0.53	23.70	21.50	4
LSCOND	3.14	0.02	3.21	3.11	4
----- LOW RAINFALL FY-1988 CROUCH BR -----					
TSS	96.50	35.53	167.50	8.40	4
LTSS	4.15	0.66	5.13	2.24	4
TURB	175.65	66.18	300.00	8.60	4
LTURB	4.60	0.80	5.71	2.26	4
PTSASH	88.45	1.73	90.70	83.30	4
SCOND	117.60	5.41	127.00	102.00	4
LSCOND	4.77	0.05	4.85	4.63	4

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- LOW RAINFALL FY-1988 UTR BR BELOW -----					
TSS	5.55	0.54	6.70	4.10	4
LTSS	1.87	0.09	2.04	1.63	4
TURB	2.58	0.45	3.70	1.80	4
LTURB	1.25	0.12	1.55	1.03	4
PTSASH	59.10	1.56	62.70	56.10	4
SCOND	22.93	0.43	24.20	22.30	4
LSCOND	3.17	0.02	3.23	3.15	4
----- LOW RAINFALL FY-1989 UTR CK ABOVE -----					
TSS	3.60	0.38	5.90	2.30	8
LTSS	1.50	0.08	1.93	1.19	8
TURB	0.59	0.12	1.40	0.36	8
LTURB	0.45	0.06	0.88	0.31	8
PTSASH	52.21	0.92	56.90	48.50	8
SCOND	16.15	0.29	17.20	15.10	8
LSCOND	2.84	0.02	2.90	2.78	8
----- LOW RAINFALL FY-1989 TINKER CK -----					
TSS	8.23	3.51	32.50	3.20	8
LTSS	1.94	0.24	3.51	1.44	8
TURB	5.41	4.38	36.00	0.43	8
LTURB	1.01	0.39	3.61	0.36	8
PTSASH	52.94	2.03	61.50	46.30	8
SCOND	33.33	1.15	37.50	28.90	8
LSCOND	3.53	0.03	3.65	3.40	8
----- LOW RAINFALL FY-1989 MCQUEEN BR -----					
TSS	23.78	7.01	64.10	4.00	8
LTSS	2.91	0.31	4.18	1.61	8
TURB	40.80	12.11	110.00	4.00	8
LTURB	3.35	0.37	4.71	1.61	8
PTSASH	85.01	1.42	88.50	76.10	8
SCOND	60.84	2.36	75.70	53.50	8
LSCOND	4.12	0.04	4.34	4.00	8
----- LOW RAINFALL FY-1989 UTR CK MID. -----					
TSS	4.55	0.81	6.90	3.20	4
LTSS	1.68	0.14	2.07	1.44	4
TURB	1.12	0.56	2.80	0.41	4
LTURB	0.66	0.23	1.34	0.34	4
PTSASH	52.88	2.52	59.60	47.60	4
SCOND	23.48	0.45	24.60	22.70	4
LSCOND	3.20	0.02	3.24	3.17	4

STD ERROR MAXIMUM MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- LOW RAINFALL FY-1989 CROUCH BR -----					
TSS	79.73	39.19	183.20	16.60	4
LTSS	3.95	0.57	5.22	2.87	4
TURB	148.75	70.35	330.00	31.00	4
LTURB	4.58	0.56	5.80	3.47	4
PTSASH	86.48	2.53	90.80	80.80	4
SCOND	116.75	7.51	135.00	103.00	4
LSCOND	4.76	0.06	4.91	4.64	4
----- LOW RAINFALL FY-1989 UTR BR BELOW -----					
TSS	4.93	0.68	6.60	3.30	4
LTSS	1.76	0.12	2.03	1.46	4
TURB	1.39	0.77	3.70	0.51	4
LTURB	0.74	0.27	1.55	0.41	4
PTSASH	57.03	1.66	61.90	54.60	4
SCOND	24.18	0.45	25.00	23.30	4
LSCOND	3.23	0.02	3.26	3.19	4
----- LOW RAINFALL FY-1990 UTR CK ABOVE -----					
TSS	6.48	0.92	9.20	3.50	6
LTSS	1.97	0.13	2.32	1.50	6
TURB	1.20	0.30	2.20	0.41	6
LTURB	0.74	0.14	1.16	0.34	6
PTSASH	54.88	0.91	57.00	51.30	6
SCOND	15.48	0.19	16.10	14.80	6
LSCOND	2.80	0.01	2.84	2.76	6
----- LOW RAINFALL FY-1990 TINKER CK -----					
TSS	12.55	3.07	25.20	4.00	6
LTSS	2.47	0.24	3.26	1.61	6
TURB	2.54	0.63	4.30	0.73	6
LTURB	1.17	0.24	1.67	0.55	6
PTSASH	52.88	1.35	56.50	48.10	6
SCOND	34.47	1.58	39.90	29.50	6
LSCOND	3.56	0.04	3.71	3.42	6
----- LOW RAINFALL FY-1990 MCQUEEN BR -----					
TSS	5.97	1.54	13.10	2.80	6
LTSS	1.84	0.19	2.64	1.34	6
TURB	3.64	1.02	7.70	0.91	6
LTURB	1.41	0.22	2.16	0.65	6
PTSASH	74.80	2.65	83.70	67.50	6
SCOND	58.18	3.25	67.30	46.50	6
LSCOND	4.07	0.06	4.22	3.86	6
		STD ERROR	MAXIMUM	MINIMUM	

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- LOW RAINFALL	FY-1990	UTR CK MID.	-----		
TSS	7.73	1.54	9.70	4.70	3
LTSS	2.13	0.20	2.37	1.74	3
TURB	1.31	0.65	2.60	0.47	3
LTURB	0.76	0.27	1.28	0.39	3
PTSASH	52.03	3.27	55.30	45.50	3
SCOND	20.53	0.26	21.00	20.10	3
LSCOND	3.07	0.01	3.09	3.05	3
----- LOW RAINFALL	FY-1990	CROUCH BR	-----		
TSS	15.57	2.11	18.80	11.60	3
LTSS	2.79	0.13	2.99	2.53	3
TURB	21.57	6.54	30.00	8.70	3
LTURB	3.00	0.37	3.43	2.27	3
PTSASH	69.30	2.95	75.00	65.10	3
SCOND	74.70	14.00	102.00	55.70	3
LSCOND	4.29	0.18	4.63	4.04	3
----- LOW RAINFALL	FY-1990	UTR BR BELOW	-----		
TSS	7.67	1.85	9.90	4.00	3
LTSS	2.10	0.25	2.39	1.61	3
TURB	1.68	0.57	2.40	0.55	3
LTURB	0.93	0.25	1.22	0.44	3
PTSASH	55.33	1.19	57.30	53.20	3
SCOND	21.87	0.50	22.60	20.90	3
LSCOND	3.13	0.02	3.16	3.09	3
----- LOW RAINFALL	FY-1991	UTR CK ABOVE	-----		
TSS	7.78	1.39	19.03	2.91	14
LTSS	2.04	0.14	3.00	1.36	14
TURB	1.63	0.41	5.60	0.35	14
LTURB	0.85	0.12	1.89	0.30	14
PTSASH	53.08	1.37	62.70	45.50	14
SCOND	16.19	0.77	25.80	14.90	14
LSCOND	2.83	0.04	3.29	2.77	14
----- LOW RAINFALL	FY-1991	TINKER CK	-----		
TSS	7.79	1.31	17.75	2.04	14
LTSS	2.02	0.15	2.93	1.11	14
TURB	1.23	0.25	3.50	0.27	14
LTURB	0.73	0.10	1.50	0.24	14
PTSASH	48.16	1.85	55.60	33.60	14
SCOND	27.41	0.98	32.80	21.70	14
LSCOND	3.34	0.03	3.52	3.12	14

STD ERROR MAXIMUM MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- LOW RAINFALL FY-1991 MCQUEEN BR -----					
TSS	16.80	4.10	51.24	4.86	14
LTSS	2.62	0.19	3.96	1.77	14
TURB	6.86	3.28	49.0	1.60	14
LTURB	1.64	0.20	3.91	0.96	14
PTSASH	71.97	2.13	91.70	61.00	14
SCOND	42.28	2.12	61.60	30.20	14
LSCOND	3.75	0.05	4.14	3.44	14
----- LOW RAINFALL FY-1991 UTR CK MID. -----					
TSS	6.91	0.98	11.32	3.04	7
LTSS	2.01	0.13	2.51	1.40	7
TURB	1.22	0.20	2.00	0.51	7
LTURB	0.77	0.10	1.10	0.41	7
PTSASH	51.56	1.56	57.30	45.90	7
SCOND	20.34	0.22	21.20	19.70	7
LSCOND	3.06	0.01	3.10	3.03	7
----- LOW RAINFALL FY-1991 CROUCH BR -----					
TSS	29.35	16.62	128.60	8.60	7
LTSS	2.91	0.34	4.86	2.26	7
TURB	37.11	21.50	160.0	2.30	7
LTURB	2.74	0.54	5.08	1.19	7
PTSASH	79.69	2.89	90.60	70.60	7
SCOND	78.70	5.23	99.90	64.20	7
LSCOND	4.37	0.06	4.61	4.18	7
----- LOW RAINFALL FY-1991 UTR BR BELOW -----					
TSS	7.71	0.82	10.39	4.26	7
LTSS	2.13	0.10	2.43	1.66	7
TURB	1.19	0.14	1.50	0.66	7
LTURB	0.77	0.07	0.92	0.51	7
PTSASH	54.13	1.48	59.30	46.70	7
SCOND	20.99	0.27	22.00	19.80	7
LSCOND	3.09	0.01	3.14	3.03	7
----- LOW RAINFALL FY-1992 UTR CK ABOVE -----					
TSS	5.42	0.37	7.72	3.62	14
LTSS	1.84	0.06	2.17	1.53	14
TURB	1.13	0.37	5.40	0.40	14
LTURB	0.64	0.12	1.86	0.34	14
PTSASH	52.50	1.22	58.20	42.40	14
SCOND	17.79	0.95	29.90	15.80	14
LSCOND	2.92	0.04	3.43	2.82	14

STD ERROR MAXIMUM MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- LOW RAINFALL	FY-1992		TINKER CK	-----	
TSS	6.63	0.72	10.40	2.73	14
LTSS	1.97	0.10	2.43	1.32	14
TURB	1.42	0.35	4.50	0.37	14
LTURB	0.78	0.12	1.70	0.31	14
PTSASH	52.02	1.50	66.70	42.60	14
SCOND	26.20	0.91	30.40	18.60	14
LSCOND	3.30	0.04	3.45	2.98	14
----- LOW RAINFALL	FY-1992		MCQUEEN BR	-----	
TSS	18.20	5.47	60.00	4.18	14
LTSS	2.54	0.24	4.11	1.64	14
TURB	23.27	9.78	102.0	1.50	14
LTURB	2.16	0.38	4.63	0.92	14
PTSASH	75.88	1.94	87.20	66.30	14
SCOND	45.40	2.22	68.50	37.70	14
LSCOND	3.82	0.04	4.24	3.66	14
----- LOW RAINFALL	FY-1992		UTR CK MID.	-----	
TSS	7.82	2.01	18.60	3.85	7
LTSS	2.06	0.19	2.98	1.58	7
TURB	2.50	1.56	11.80	0.45	7
LTURB	0.90	0.29	2.55	0.37	7
PTSASH	55.64	1.91	64.70	49.80	7
SCOND	21.86	0.48	23.70	20.20	7
LSCOND	3.13	0.02	3.21	3.05	7
----- LOW RAINFALL	FY-1992		CROUCH BR	-----	
TSS	34.26	11.09	87.21	5.63	7
LTSS	3.23	0.35	4.48	1.89	7
TURB	52.04	19.92	140.00	3.30	7
LTURB	3.28	0.55	4.95	1.46	7
PTSASH	79.71	4.03	88.60	58.80	7
SCOND	82.71	3.43	93.40	73.00	7
LSCOND	4.42	0.04	4.55	4.30	7
----- LOW RAINFALL	FY-1992		UTR BR BELOW	-----	
TSS	8.18	1.90	18.6	4.13	7
LTSS	2.12	0.17	2.98	1.64	7
TURB	2.70	1.65	12.50	0.49	7
LTURB	0.97	0.29	2.60	0.40	7
PTSASH	56.34	2.24	63.40	46.60	7
SCOND	22.60	0.59	24.60	20.20	7
LSCOND	3.16	0.03	3.24	3.05	7

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFALL		FY-1983	UTR CK ABOVE	-----	
TSS	9.36	1.62	22.20	5.26	10
LTSS	2.25	0.13	3.14	1.83	10
TURB	--	--	--	--	0
LTURB	--	--	--	--	0
PTSASH	53.04	0.74	57.07	49.62	10
SCOND	29.15	1.62	37.09	25.41	7
LSCOND	3.40	0.05	3.64	3.27	7
----- HIGH RAINFALL		FY-1983	TINKER CK	-----	
TSS	11.15	2.10	21.79	4.76	9
LTSS	2.39	0.16	3.13	1.75	9
TURB	--	--	--	--	0
LTURB	--	--	--	--	0
PTSASH	52.00	4.96	90.54	41.53	9
SCOND	44.37	1.05	48.26	39.63	7
LSCOND	3.81	0.02	3.90	3.70	7
----- HIGH RAINFALL		FY-1983	MCQUEEN BR	-----	
TSS	59.04	16.31	114.97	8.89	6
LTSS	3.81	0.38	4.75	2.29	6
TURB	--	--	--	--	0
LTURB	--	--	--	--	0
PTSASH	76.81	3.06	82.34	62.59	6
SCOND	51.28	6.23	63.57	43.36	3
LSCOND	3.94	0.11	4.17	3.79	3
----- HIGH RAINFALL		FY-1983	UTR CK MID.	-----	
TSS	28.59	12.81	73.74	8.00	5
LTSS	3.01	0.43	4.31	2.20	5
TURB	--	--	--	--	0
LTURB	--	--	--	--	0
PTSASH	63.25	4.27	75.96	5.97	5
SCOND	34.80	3.19	39.69	25.84	4
LSCOND	3.56	0.10	3.71	3.29	4
----- HIGH RAINFALL		FY-1983	CROUCH BR	-----	
TSS	--	--	--	--	--
LTSS	--	--	--	--	--
TURB	--	--	--	--	--
LTURB	--	--	--	--	--
PTSASH	--	--	--	--	--
SCOND	--	--	--	--	--
LSCOND	--	--	--	--	--

STD ERROR MAXIMUM MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- HIGH RAINFALL FY-1983 UTR BR BELOW -----					
TSS	39.01	18.60	105.70	8.12	5
LTSS	3.24	0.48	4.67	2.21	5
TURB	--	--	--	--	0
LTURB	--	--	--	--	0
PTSASH	60.64	9.35	78.03	29.90	5
SCOND	34.19	2.50	38.17	27.01	4
LSCOND	3.55	0.08	3.67	3.33	4
----- HIGH RAINFALL FY-1984 UTR CK ABOVE -----					
TSS	8.03	0.32	8.34	7.71	2
LTSS	2.20	0.03	2.23	2.16	2
TURB	7.55	2.15	9.70	5.40	2
LTURB	2.11	0.26	2.37	1.86	2
PTSASH	57.75	0.29	58.03	57.46	2
SCOND	19.47	2.18	21.65	17.28	2
LSCOND	3.01	0.11	3.12	2.91	2
----- HIGH RAINFALL FY-1984 TINKER CK -----					
TSS	11.34	8.42	19.76	2.92	2
LTSS	2.20	0.83	3.03	1.37	2
TURB	3.60	0.10	3.70	3.50	2
LTURB	1.53	0.02	1.55	1.50	2
PTSASH	48.79	12.49	61.29	36.30	2
SCOND	21.38	0.09	21.47	21.30	2
LSCOND	3.11	<0.01	3.11	3.10	2
----- HIGH RAINFALL FY-1984 MCQUEEN BR -----					
TSS	37.35	2.01	39.36	35.34	2
LTSS	3.65	0.05	3.70	3.59	2
TURB	54.00	8.00	62.00	46.00	2
LTURB	4.00	0.15	4.14	3.85	2
PTSASH	78.00	0.92	78.91	77.08	2
SCOND	23.52	1.69	25.21	21.83	2
LSCOND	3.20	0.07	3.27	3.13	2
----- HIGH RAINFALL FY-1984 UTR CK MID. -----					
TSS	12.89	--	12.89	12.89	1
LTSS	2.63	--	2.63	2.63	1
TURB	6.40	--	6.40	6.40	1
LTURB	2.00	--	2.00	2.00	1
PTSASH	28.16	--	28.16	28.16	1
SCOND	303.71	--	303.71	303.71	1
LSCOND	5.72	--	5.72	5.72	1

STD ERROR MAXIMUM MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- HIGH RAINFALL FY-1984 CROUCH BR -----					
TSS	--	--	--	--	--
LTSS	--	--	--	--	--
TURB	--	--	--	--	--
LTURB	--	--	--	--	--
PTSASH	--	--	--	--	--
SCOND	--	--	--	--	--
LSCOND	--	--	--	--	--
----- HIGH RAINFALL FY-1984 UTR BR BELOW -----					
TSS	9.82	--	9.82	9.82	1
LTSS	2.38	--	2.38	2.38	1
TURB	6.90	--	6.90	6.90	1
LTURB	2.07	--	2.07	2.07	1
PTSASH	53.87	--	53.87	53.87	1
SCOND	21.60	--	21.60	21.60	1
LSCOND	3.12	--	3.12	3.12	1
----- HIGH RAINFALL FY-1986 UTR CK ABOVE -----					
TSS	14.30	6.96	35.10	6.10	4
LTSS	2.48	0.37	3.59	1.96	4
TURB	4.60	1.49	9.00	2.60	4
LTURB	1.63	0.23	2.30	1.28	4
PTSASH	52.75	1.43	55.00	48.60	4
SCOND	18.80	2.44	25.50	14.90	4
LSCOND	2.96	0.12	3.28	2.77	4
----- HIGH RAINFALL FY-1986 TINKER CK -----					
TSS	9.73	1.94	14.90	5.80	4
LTSS	2.32	0.18	2.77	1.92	4
TURB	4.68	0.82	6.50	3.00	4
LTURB	1.70	0.15	2.01	1.39	4
PTSASH	51.13	1.21	53.40	47.70	4
SCOND	44.03	9.82	71.50	27.40	4
LSCOND	3.74	0.21	4.28	3.35	4
----- HIGH RAINFALL FY-1986 MCQUEEN BR -----					
TSS	32.45	6.55	39.00	25.90	2
LTSS	3.49	0.20	3.69	3.29	2
TURB	53.00	14.00	67.00	39.00	2
LTURB	3.95	0.27	4.22	3.69	2
PTSASH	85.45	3.25	88.70	82.20	2
SCOND	75.10	14.40	89.50	60.70	2
LSCOND	4.31	0.19	4.51	4.12	2

STD ERROR MAXIMUM MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- HIGH RAINFALL		FY-1986	UTR CK MID.	-----	
TSS	17.70	7.90	25.60	9.80	2
LTSS	2.83	0.45	3.28	2.38	2
TURB	11.40	6.60	18.00	4.80	2
LTURB	2.35	0.59	2.94	1.76	2
PTSASH	55.95	1.85	57.80	54.10	2
SCOND	31.70	10.30	42.00	21.40	2
LSCOND	3.44	0.33	3.76	3.11	2
----- HIGH RAINFALL		FY-1986	CROUCH BR	-----	
TSS	59.35	34.45	93.80	24.90	2
LTSS	3.90	0.65	4.55	3.25	2
TURB	130.00	80.00	210.00	50.00	2
LTURB	4.64	0.71	5.35	3.93	2
PTSASH	88.75	0.45	89.20	88.30	2
SCOND	103.70	7.80	111.50	95.90	2
LSCOND	4.65	0.07	4.72	4.57	2
----- HIGH RAINFALL		FY-1986	UTR BR BELOW	-----	
TSS	16.70	5.70	22.40	11.00	2
LTSS	2.82	0.33	3.15	2.48	2
TURB	11.55	7.45	19.00	4.10	2
LTURB	2.31	0.68	2.99	1.63	2
PTSASH	57.60	3.10	60.70	54.50	2
SCOND	30.35	5.95	36.30	24.40	2
LSCOND	3.43	0.19	3.62	3.23	2
----- HIGH RAINFALL		FY-1987	UTR CK ABOVE	-----	
TSS	7.88	1.33	15.90	4.00	8
LTSS	2.11	0.14	2.83	1.61	8
TURB	3.41	0.52	6.50	1.70	8
LTURB	1.44	0.11	2.01	0.99	8
PTSASH	51.28	0.66	54.80	48.40	8
SCOND	16.15	0.54	18.30	13.80	8
LSCOND	2.84	0.03	2.96	2.69	8
----- HIGH RAINFALL		FY-1987	TINKER CK	-----	
TSS	13.71	3.88	34.20	4.20	7
LTSS	2.51	0.23	3.56	1.65	7
TURB	7.49	2.78	24.00	3.20	7
LTURB	1.94	0.22	3.22	1.44	7
PTSASH	51.99	1.25	58.20	49.10	7
SCOND	29.86	1.54	35.60	24.50	7
LSCOND	3.42	0.05	3.60	3.24	7

STD ERROR

MAXIMUM

MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- HIGH RAINFALL FY-1987 MCQUEEN BR -----					
TSS	256.04	75.18	655.00	54.00	8
LTSS	5.20	0.33	6.49	4.01	8
TURB	327.44	75.05	650.00	88.50	8
LTURB	5.56	0.28	6.48	4.49	8
PTSASH	89.70	0.96	93.20	85.40	8
SCOND	75.55	10.09	118.30	41.70	8
LSCOND	4.28	0.13	4.78	3.75	8
----- HIGH RAINFALL FY-1987 UTR CK MID. -----					
TSS	14.65	5.16	29.10	5.20	4
LTSS	2.59	0.33	3.40	1.82	4
TURB	12.83	5.81	29.00	2.50	4
LTURB	2.34	0.45	3.40	1.25	4
PTSASH	63.05	3.74	71.30	55.80	4
SCOND	22.50	1.26	25.90	20.10	4
LSCOND	3.15	0.05	3.29	3.05	4
----- HIGH RAINFALL FY-1987 CROUCH BR -----					
TSS	119.75	34.79	215.50	50.40	4
LTSS	4.67	0.30	5.38	3.94	4
TURB	216.75	60.07	390.00	97.00	4
LTURB	5.26	0.28	5.97	4.58	4
PTSASH	88.78	0.86	90.50	86.50	4
SCOND	110.55	9.58	127.20	84.30	4
LSCOND	4.70	0.09	4.85	4.45	4
----- HIGH RAINFALL FY-1987 UTR BR BELOW -----					
TSS	20.15	6.48	36.80	6.60	4
LTSS	2.89	0.34	3.63	2.03	4
TURB	20.78	7.56	40.00	3.10	4
LTURB	2.80	0.49	3.71	1.41	4
PTSASH	68.40	3.56	76.10	62.10	4
SCOND	23.73	1.26	26.30	20.60	4
LSCOND	3.20	0.05	3.31	3.07	4
----- HIGH RAINFALL FY-1988 UTR CK ABOVE -----					
TSS	13.34	1.97	22.40	3.10	10
LTSS	2.54	0.18	3.15	1.41	10
TURB	8.76	2.20	24.00	1.50	10
LTURB	2.04	0.24	3.22	0.92	10
PTSASH	58.07	1.08	65.20	53.80	10
SCOND	19.25	1.21	26.90	14.70	10
LSCOND	2.99	0.06	3.33	2.75	10

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFALL		FY-1988	TINKER CK	-----	
TSS	24.28	4.44	45.00	2.20	10
LTSS	2.99	0.27	3.83	1.16	10
TURB	14.34	4.05	45.00	1.60	10
LTURB	2.40	0.29	3.83	0.96	10
PTSASH	57.46	2.55	72.40	49.90	10
SCOND	36.80	3.54	55.30	22.30	10
LSCOND	3.59	0.10	4.03	3.15	10
----- HIGH RAINFALL		FY-1988	MCQUEEN BR	-----	
TSS	162.56	30.03	273.90	22.00	10
LTSS	4.86	0.26	5.62	3.14	10
TURB	237.30	39.69	395.00	35.00	10
LTURB	5.27	0.24	5.98	3.58	10
PTSASH	88.39	0.43	90.10	86.40	10
SCOND	101.16	28.62	328.00	46.70	10
LSCOND	4.40	0.20	5.80	3.86	10
----- HIGH RAINFALL		FY-1988	UTR CK MID.	-----	
TSS	34.22	9.90	66.90	9.10	5
LTSS	3.38	0.32	4.22	2.31	5
TURB	40.92	11.91	74.00	4.10	5
LTURB	3.43	0.47	4.32	1.63	5
PTSASH	73.66	2.63	78.90	63.70	5
SCOND	30.18	3.20	38.40	22.10	5
LSCOND	3.42	0.11	3.67	3.14	5
----- HIGH RAINFALL		FY-1988	CROUCH BR	-----	
TSS	250.94	47.84	398.30	135.40	5
LTSS	5.45	0.20	5.99	4.92	5
TURB	430.00	74.10	670.00	260.00	5
LTURB	6.01	0.17	6.51	5.56	5
PTSASH	90.26	0.67	92.60	88.90	5
SCOND	108.32	10.34	128.50	72.30	5
LSCOND	4.67	0.10	4.86	4.29	5
VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFALL		FY-1988	UTR BR BELOW	-----	
TSS	43.46	9.73	66.60	9.50	5
LTSS	3.63	0.33	4.21	2.35	5
TURB	50.88	12.37	78.50	5.40	5
LTURB	3.68	0.46	4.38	1.86	5
PTSASH	74.80	2.69	81.10	66.30	5
SCOND	32.50	3.30	40.20	23.60	5

LSCOND	3.49	0.10	3.72	3.20	5
----- HIGH RAINFALL FY-1989 UTR CK ABOVE -----					
TSS	5.69	0.55	7.80	3.10	10
LTSS	1.87	0.09	2.17	1.41	10
TURB	2.39	0.47	4.00	0.60	10
LTURB	1.12	0.16	1.61	0.47	10
PTSASH	51.95	1.51	59.20	41.00	10
SCOND	16.89	0.57	19.40	14.80	10
LSCOND	2.88	0.03	3.02	2.76	10
----- HIGH RAINFALL FY-1989 TINKER CK -----					
TSS	14.24	3.32	35.30	4.10	10
LTSS	2.54	0.20	3.59	1.63	10
TURB	4.52	0.71	9.60	2.20	10
LTURB	1.64	0.12	2.36	1.16	10
PTSASH	53.53	1.10	60.90	48.70	10
SCOND	30.99	1.40	38.30	26.30	10
LSCOND	3.46	0.04	3.67	3.31	10
----- HIGH RAINFALL FY-1989 MCQUEEN BR -----					
TSS	217.39	62.32	742.50	92.00	10
LTSS	5.16	0.20	6.61	4.53	10
TURB	254.00	49.38	680.00	140.00	10
LTURB	5.43	0.14	6.52	4.95	10
PTSASH	88.73	0.84	92.50	82.60	10
SCOND	54.99	5.90	95.90	41.40	10
LSCOND	3.98	0.09	4.57	3.75	10
----- HIGH RAINFALL FY-1989 UTR CK MID. -----					
TSS	26.00	13.14	76.00	6.10	5
LTSS	2.87	0.44	4.34	1.96	5
TURB	31.90	16.27	89.00	3.20	5
LTURB	2.84	0.62	4.50	1.44	5
PTSASH	70.64	5.40	82.90	57.40	5
SCOND	25.48	1.20	28.70	23.30	5
LSCOND	3.27	0.04	3.39	3.19	5

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFALL FY-1989 CROUCH BR -----					
TSS	246.32	59.55	466.50	119.70	5
LTSS	5.41	0.22	6.15	4.79	5
TURB	362.00	58.77	560.00	210.00	5
LTURB	5.84	0.16	6.33	5.35	5
PTSASH	91.22	0.65	92.90	89.60	5
SCOND	91.32	11.19	126.00	63.40	5
LSCOND	4.50	0.12	4.84	4.17	5
----- HIGH RAINFALL FY-1989 UTR BR BELOW -----					
TSS	39.16	17.33	93.60	5.50	5
LTSS	3.24	0.50	4.55	1.87	5
TURB	45.82	21.33	105.00	2.80	5
LTURB	3.19	0.64	4.66	1.34	5
PTSASH	75.04	5.12	85.00	56.40	5
SCOND	25.98	1.12	29.30	23.90	5
LSCOND	3.29	0.04	3.41	3.21	5
----- HIGH RAINFALL FY-1990 UTR CK ABOVE -----					
TSS	14.80	0.70	15.50	14.10	2
LTSS	2.76	0.04	2.80	2.71	2
TURB	3.55	0.15	3.70	3.40	2
LTURB	1.51	0.03	1.55	1.48	2
PTSASH	49.10	7.10	56.20	42.00	2
SCOND	21.60	3.50	25.10	18.10	2
LSCOND	3.11	0.16	3.26	2.95	2
----- HIGH RAINFALL FY-1990 TINKER CK -----					
TSS	36.25	24.35	60.60	11.90	2
LTSS	3.34	0.78	4.12	2.56	2
TURB	9.05	0.75	9.80	8.30	2
LTURB	2.30	0.07	2.38	2.23	2
PTSASH	59.80	8.00	67.80	51.80	2
SCOND	33.85	5.45	39.30	28.40	2
LSCOND	3.54	0.16	3.70	3.38	2
----- HIGH RAINFALL FY-1990 MCQUEEN BR -----					
TSS	571.10	250.70	821.80	320.40	2
LTSS	6.24	0.47	6.71	5.77	2
TURB	455.00	180.00	635.00	275.00	2
LTURB	6.04	0.42	6.46	5.62	2
PTSASH	89.15	0.25	89.40	88.90	2
SCOND	30.90	2.40	33.30	28.50	2
LSCOND	3.46	0.08	3.54	3.38	2

VARIABLE	MEAN	STD ERROR OF MEAN	MAXIMUM VALUE	MINIMUM VALUE	N
----- HIGH RAINFALL FY-1990 UTR CK MID. -----					
TSS	40.20	--	40.20	40.20	1
LTSS	3.72	--	3.72	3.72	1
TURB	60.00	--	60.00	60.00	1
LTURB	4.11	--	4.11	4.11	1
PTSASH	81.80	--	81.80	81.80	1
SCOND	76.10	--	76.10	76.10	1
LSCOND	4.35	--	4.35	4.35	1
----- HIGH RAINFALL FY-1990 CROUCH BR -----					
TSS	401.00	--	401.00	401.00	1
LTSS	6.00	--	6.00	6.00	1
TURB	490.00	--	490.00	490.00	1
LTURB	6.20	--	6.20	6.20	1
PTSASH	91.30	--	91.30	91.30	1
SCOND	32.90	--	32.90	32.90	1
LSCOND	3.52	--	3.52	3.52	1
----- HIGH RAINFALL FY-1990 UTR BR BELOW -----					
TSS	180.30	--	180.30	180.30	1
LTSS	5.20	--	5.20	5.20	1
TURB	240.00	--	240.00	240.00	1
LTURB	5.48	--	5.48	5.48	1
PTSASH	90.20	--	90.20	90.20	1
SCOND	38.90	--	38.90	38.90	1
LSCOND	3.69	--	3.69	3.69	1
----- HIGH RAINFALL FY-1991 UTR CK ABOVE -----					
TSS	7.02	1.06	10.34	4.14	6
LTSS	2.04	0.13	2.43	1.64	6
TURB	1.44	0.32	2.30	0.49	6
LTURB	0.84	0.14	1.19	0.40	6
PTSASH	58.52	1.03	61.80	54.60	6
SCOND	20.48	3.27	32.10	14.70	6
LSCOND	3.01	0.14	3.50	2.75	6
----- HIGH RAINFALL FY-1991 TINKER CK -----					
TSS	10.00	3.02	20.65	2.70	6
LTSS	2.20	0.28	3.08	1.31	6
TURB	1.69	0.41	3.00	0.60	6
LTURB	0.93	0.15	1.39	0.47	6
PTSASH	54.65	2.54	65.30	48.30	6
SCOND	30.88	2.65	41.80	25.20	6
LSCOND	3.45	0.08	3.76	3.27	6

STD ERROR MAXIMUM MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- HIGH RAINFALL FY-1991 MCQUEEN BR -----					
TSS	158.85	65.20	402.10	13.69	6
LTSS	4.42	0.58	6.00	2.69	6
TURB	122.03	48.15	290.00	5.20	6
LTURB	4.16	0.60	5.67	1.82	6
PTSASH	82.27	1.89	87.20	75.70	6
SCOND	35.13	4.65	50.50	21.90	6
LSCOND	3.54	0.13	3.94	3.13	6
----- HIGH RAINFALL FY-1991 UTR CK MID -----					
TSS	44.35	35.72	115.70	5.55	3
LTSS	3.06	0.87	4.76	1.88	3
TURB	51.09	49.46	150.00	0.68	3
LTURB	2.27	1.39	5.02	0.52	3
PTSASH	67.77	10.55	88.80	55.80	3
SCOND	25.63	4.73	35.10	20.70	3
LSCOND	3.25	0.17	3.59	3.08	3
----- HIGH RAINFALL FY-1991 CROUCH BR -----					
TSS	130.08	103.99	337.00	8.53	3
LTSS	3.97	1.03	5.82	2.25	3
TURB	152.67	115.35	380.00	5.00	3
LTURB	4.01	1.21	5.94	1.79	3
PTSASH	85.47	4.51	92.20	76.90	3
SCOND	60.30	21.33	95.20	21.60	3
LSCOND	3.95	0.43	4.57	3.12	3
----- HIGH RAINFALL FY-1991 UTR CK BELOW -----					
TSS	30.79	20.15	70.80	6.68	3
LTSS	3.03	0.66	4.27	2.04	3
TURB	25.94	24.04	74.00	0.92	3
LTURB	2.11	1.12	4.32	0.65	3
PTSASH	71.10	8.32	86.80	58.50	3
SCOND	26.50	5.45	37.40	21.00	3
LSCOND	3.28	0.18	3.65	3.09	3
----- HIGH RAINFALL FY-1992 UTR CK ABOVE -----					
TSS	7.06	1.08	13.20	4.75	8
LTSS	2.04	0.12	2.65	1.75	8
TURB	1.14	0.31	2.70	0.48	8
LTURB	0.70	0.13	1.31	0.39	8
PTSASH	55.51	1.16	59.20	49.00	8
SCOND	17.79	0.67	19.90	15.30	8
LSCOND	2.93	0.04	3.04	2.79	8

STD ERROR

MAXIMUM

MINIMUM

VARIABLE	MEAN	OF MEAN	VALUE	VALUE	N
----- HIGH RAINFALL	FY-1992	TNIKER CK	-----		
TSS	8.98	2.23	23.60	4.40	8
LTSS	2.18	0.18	3.02	1.69	8
TURB	1.23	0.25	2.10	0.40	8
LTURB	0.76	0.12	1.13	0.34	8
PTSASH	47.81	2.53	53.40	32.80	8
SCOND	27.05	1.08	31.50	23.90	8
LSCOND	3.33	0.04	3.48	3.21	8
----- HIGH RAINFALL	FY-1992	MCQUEEN BR	-----		
TSS	16.69	2.46	30.30	9.62	8
LTSS	2.81	0.13	3.44	2.36	8
TURB	18.09	6.42	53.00	4.00	8
LTURB	2.56	0.33	3.99	1.61	8
PTSASH	82.44	1.98	87.90	71.40	8
SCOND	45.18	2.29	58.30	36.30	8
LSCOND	3.82	0.05	4.08	3.62	8
----- HIGH RAINFALL	FY-1992	UTR CK MID	-----		
TSS	8.75	0.72	10.80	7.71	4
LTSS	2.27	0.07	2.47	2.16	4
TURB	1.63	0.49	2.70	0.67	4
LTURB	0.91	0.19	1.31	0.51	4
PTSASH	55.63	1.78	60.50	52.20	4
SCOND	23.55	0.61	25.30	22.60	4
LSCOND	3.20	0.02	3.27	3.16	4
----- HIGH RAINFALL	FY-1992	CROUCH BR	-----		
TSS	44.08	15.40	89.90	23.50	4
LTSS	3.67	0.29	4.51	3.20	4
TURB	67.75	20.80	130.00	43.00	4
LTURB	4.12	0.25	4.88	3.78	4
PTSASH	86.70	2.08	90.80	81.10	4
SCOND	84.83	9.22	110.00	67.70	4
LSCOND	4.44	0.10	4.71	4.23	4
----- HIGH RAINFALL	FY-1992	UTR CK BELOW	-----		
TSS	9.05	0.82	11.40	7.70	4
LTSS	2.30	0.08	2.52	2.16	4
TURB	1.99	0.59	3.60	0.74	4
LTURB	1.03	0.20	1.53	0.55	4
PTSASH	57.55	2.53	64.50	52.40	4
SCOND	22.88	0.80	24.80	21.10	4
LSCOND	3.17	0.03	3.25	3.10	4

APPENDIX B
P Values of ANOVA Main Effects

P VALUES OF ANOVA MAIN EFFECTS

NO RAIN

Main Effect	Log TSS	Log Specific Conductivity	Log Percent Ash	Log Turbidity
Location	0.0001	0.0001	0.0001	0.0001
Construction	0.0001	0.0001	0.0001	0.0001
Loc*Con	0.0001	0.0165	0.0001	0.0043
R ² =	0.4929	0.5752	0.6926	0.6492

LOW RAIN*

Main Effect	Log TSS	Log Specific Conductivity	Log Percent Ash	Log Turbidity
Log Rain	0.5018	0.0024	0.6662	0.0046
Location	0.0773	0.0001	0.0001	0.0010
Construction	0.8097	0.0391	0.3910	0.1205
Log Rain*Loc	0.0765	0.9985	0.8031	0.1686
Log Rain*Con	0.2358	0.0045	0.0328	0.6636
Loc*Con	0.7165	0.2405	0.4622	0.9587
R ² =	0.4475	0.7808	0.7692	0.6061

HIGH RAIN*

Main Effect	Log TSS	Log Specific Conductivity	Log Percent Ash	Log Turbidity
Log Rain	0.0001	0.6546	0.0001	0.0005
Location	0.0001	0.0001	0.0001	0.0001
Construction	0.2747	0.4752	0.2111	0.2997
Log Rain*Loc	0.0085	0.0001	0.0001	0.0004
Log Rain*Con	0.5238	0.8472	0.6695	0.5156
Loc*Con	0.4826	0.3786	0.0861	0.9225
R ² =	0.6765	0.7008	0.8487	0.7426

*"RAIN" is for amount of precipitation 24 hours prior to sampling.

APPENDIX C

DWPF Means By Construction Period

FY-1983 to FY-1992

(summarized by rainfall class and location)

MEANS BY CONSTRUCTION PERIOD

---- NO RAIN -- TSS -- BEFORE CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	3.42	0.24	33
TINKER CREEK	3.82	0.36	31
MCQUEEN BRANCH	5.38	0.31	22
UTR - MIDDLE	4.04	0.42	17
CROUCH BRANCH	--	--	--
UTR - BELOW	4.10	0.49	17

---- NO RAIN -- PERCENT ASH -- BEFORE CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	44.18	1.53	33
TINKER CREEK	42.54	1.52	31
MCQUEEN BRANCH	58.64	1.75	22
UTR - MIDDLE	47.39	1.13	17
CROUCH BRANCH	--	--	--
UTR - BELOW	45.73	2.33	17

---- NO RAIN -- SPECIFIC CONDUCTANCE -- BEFORE CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	26.44	1.04	33
TINKER CREEK	49.55	2.04	31
MCQUEEN BRANCH	58.89	3.90	22
UTR - MIDDLE	36.50	1.99	17
CROUCH BRANCH	--	--	--
UTR-BELOW	36.60	2.05	17

MEANS BY CONSTRUCTION PERIOD

---- NO RAIN -- TSS -- DURING CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	6.01	0.85	66
TINKER CREEK	5.42	0.61	66
MCQUEEN BRANCH	18.26	4.84	48
UTR - MIDDLE	6.25	0.68	33
CROUCH BRANCH	88.38	19.83	16
UTR - BELOW	6.12	0.58	33

---- NO RAIN - TURBIDITY -- DURING CONSTRUCTION --

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	3.36	0.37	66
TINKER CREEK	3.62	0.47	66

MCQUEEN BRANCH	25.62	8.58	48
UTR - MIDDLE	3.99	0.45	33
CROUCH BRANCH	158.22	34.27	16
UTR - BELOW	4.19	0.40	33

----- NO RAIN -- PERCENT ASH -- DURING CONSTRUCTION -----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	46.60	1.39	66
TINKER CREEK	46.82	1.13	66
MCQUEEN BRANCH	74.52	1.11	48
UTR - MIDDLE	50.38	1.59	33
CROUCH BRANCH	86.16	1.25	16
UTR - BELOW	49.77	1.47	33

----- NO RAIN -- SPECIFIC CONDUCTANCE -- DURING CONSTRUCTION -----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	16.38	0.89	66
TINKER CREEK	24.74	1.40	66
MCQUEEN BRANCH	55.93	7.17	48
UTR - MIDDLE	19.60	1.30	33
CROUCH BRANCH	93.37	3.80	16
UTR - BELOW	20.31	1.07	33

MEANS BY CONSTRUCTION PERIOD

---- NO RAIN -- TSS -- AFTER CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	3.97	0.29	24
TINKER CREEK	6.70	0.87	24
MCQUEEN BRANCH	4.63	0.47	24
UTR - MIDDLE	5.09	0.53	12
CROUCH BRANCH	22.04	5.29	12
UTR - BELOW	5.87	0.71	12

---- NO RAIN -- TURBIDITY -- AFTER CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	0.90	0.11	24
TINKER CREEK	1.78	0.26	24
MCQUEEN BRANCH	4.52	1.04	24
UTR - MIDDLE	1.32	0.25	12
CROUCH BRANCH	33.68	9.86	12
UTR - BELOW	1.31	0.30	12

---- NO RAIN -- PERCENT ASH -- AFTER CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	51.52	1.07	24
TINKER CREEK	52.97	1.30	24
MCQUEEN BRANCH	73.57	1.54	24
UTR - MIDDLE	50.25	2.16	12
CROUCH BRANCH	78.73	2.10	12
UTR - BELOW	55.76	1.23	12

---- NO RAIN -- SPECIFIC CONDUCTANCE -- AFTER CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	15.02	0.15	24
TINKER CREEK	30.69	0.78	24
MCQUEEN BRANCH	82.39	14.43	24
UTR - MIDDLE	21.12	0.48	12
CROUCH BRANCH	103.48	11.02	12
UTR - BELOW	21.86	0.52	12

MEANS BY CONSTRUCTION PERIOD

----- LOW RAIN -- TSS -- BEFORE CONSTRUCTION -----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	4.85	0.41	10
TINKER CREEK	5.20	0.63	8
MCQUEEN BRANCH	6.93	0.75	7
UTR - MIDDLE	6.16	0.76	5
CROUCH BRANCH	--	--	--
UTR - BELOW	6.15	0.73	5

----- LOW RAIN -- PERCENT ASH -- BEFORE CONSTRUCTION -----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	47.73	5.67	10
TINKER CREEK	42.14	3.16	8
MCQUEEN BRANCH	61.00	3.19	7
UTR - MIDDLE	43.81	3.16	5
CROUCH BRANCH	--	--	--
UTR - BELOW	44.41	1.73	5

----- LOW RAIN -- SPECIFIC CONDUCTANCE -- BEFORE CONSTRUCTION -----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	23.84	3.06	10
TINKER CREEK	39.00	4.98	8
MCQUEEN BRANCH	50.07	5.96	7
UTR - MIDDLE	33.02	3.60	5
CROUCH BRANCH	--	--	--
UTR - BELOW	32.64	4.63	5

MEANS BY CONSTRUCTION PERIOD

---- LOW RAIN -- TSS -- DURING CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	6.31	0.60	16
TINKER CREEK	8.53	0.96	16
MCQUEEN BRANCH	29.20	7.62	13
UTR - MIDDLE	8.88	1.22	8
CROUCH BRANCH	50.12	10.88	6
UTR - BELOW	8.92	1.27	8

---- LOW RAIN -- TURBIDITY -- DURING CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	3.27	0.37	16
TINKER CREEK	3.71	0.30	16
MCQUEEN BRANCH	42.08	13.65	13
UTR - MIDDLE	4.13	0.45	8
CROUCH BRANCH	98.67	23.80	6
UTR - BELOW	4.65	0.61	8

---- LOW RAIN -- PERCENT ASH -- DURING CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	55.09	2.36	16
TINKER CREEK	52.75	2.51	16
MCQUEEN BRANCH	80.81	2.63	13
UTR - MIDDLE	57.29	3.03	8
CROUCH BRANCH	87.03	1.43	6
UTR - BELOW	58.31	2.57	8

---- LOW RAIN -- SPECIFIC CONDUCTANCE -- DURING CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	15.79	0.44	16
TINKER CREEK	28.42	1.48	16
MCQUEEN BRANCH	58.57	7.31	13
UTR - MIDDLE	19.87	2.00	8
CROUCH BRANCH	90.02	7.14	6
UTR - BELOW	20.82	2.30	8

MEANS BY CONSTRUCTION PERIOD

---- LOW RAIN -- TSS -- AFTER CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	5.77	1.46	50
TINKER CREEK	7.74	0.81	50
MCQUEEN BRANCH	28.27	7.65	50
UTR - MIDDLE	6.64	0.67	25
CROUCH BRANCH	47.88	10.86	25
UTR - BELOW	7.05	0.65	25

---- LOW RAIN -- TURBIDITY -- AFTER CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	1.33	0.17	50
TINKER CREEK	2.25	0.71	50
MCQUEEN BRANCH	36.02	11.58	50
UTR - MIDDLE	1.79	0.46	25
CROUCH BRANCH	79.30	19.65	25
UTR - BELOW	1.93	0.48	25

---- LOW RAIN -- PERCENT ASH -- AFTER CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	53.40	0.61	50
TINKER CREEK	51.23	0.79	50
MCQUEEN BRANCH	77.72	1.19	50
UTR - MIDDLE	53.85	0.98	25
CROUCH BRANCH	80.94	1.81	25
UTR - BELOW	56.15	0.86	25

---- LOW RAIN -- SPECIFIC CONDUCTANCE -- AFTER CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	16.50	0.37	50
TINKER CREEK	29.36	0.66	50
MCQUEEN BRANCH	72.13	11.67	25
UTR - MIDDLE	21.58	0.28	25
CROUCH BRANCH	91.66	4.41	25
UTR - BELOW	22.36	0.30	25

MEANS BY CONSTRUCTION PERIOD

---- HIGH RAIN -- TSS -- BEFORE CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	9.36	1.62	10
TINKER CREEK	11.15	2.09	9
MCQUEEN BRANCH	59.04	16.31	6
UTR - MIDDLE	28.59	12.81	5
CROUCH BRANCH	--	--	--
UTR - BELOW	39.01	18.60	5

---- HIGH RAIN -- PERCENT ASH -- BEFORE CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	53.04	0.74	10
TINKER CREEK	52.00	4.96	9
MCQUEEN BRANCH	76.81	3.06	6
UTR - MIDDLE	63.25	4.27	5
CROUCH BRANCH	--	--	--
UTR - BELOW	60.64	9.35	5

---- HIGH RAIN -- SPECIFIC CONDUCTANCE -- BEFORE CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	29.15	1.62	10
TINKER CREEK	44.37	1.05	9
MCQUEEN BRANCH	51.28	6.23	6
UTR - MIDDLE	34.80	3.19	5
CROUCH BRANCH	--	--	--
UTR - BELOW	34.20	2.50	5

MEANS BY CONSTRUCTION PERIOD

---- HIGH RAIN -- TSS -- DURING CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	9.73	2.09	14
TINKER CREEK	12.12	2.35	13
MCQUEEN BRANCH	182.33	58.19	12
UTR - MIDDLE	15.27	3.32	7
CROUCH BRANCH	99.62	26.93	6
UTR - BELOW	17.69	3.96	7

---- HIGH RAIN -- TURBIDITY -- DURING CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	4.34	0.66	14
TINKER CREEK	6.02	1.53	13
MCQUEEN BRANCH	236.13	62.53	12
UTR - MIDDLE	11.50	3.53	7
CROUCH BRANCH	187.83	47.98	6
UTR - BELOW	16.16	4.90	7

---- HIGH RAIN -- PERCENT ASH -- DURING CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	52.62	0.80	14
TINKER CREEK	51.23	1.62	13
MCQUEEN BRANCH	87.04	1.51	12
UTR - MIDDLE	56.04	5.23	7
CROUCH BRANCH	88.77	0.56	6
UTR - BELOW	63.24	3.20	7

---- HIGH RAIN -- SPECIFIC CONDUCTANCE -- DURING CONSTRUCTION ----			
LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	17.38	0.83	14
TINKER CREEK	32.91	3.65	13
MCQUEEN BRANCH	66.80	8.97	12
UTR - MIDDLE	65.30	39.84	7
CROUCH BRANCH	108.27	6.54	6
UTR - BELOW	25.32	1.98	3

MEANS BY CONSTRUCTION PERIOD

---- HIGH RAIN -- TSS -- AFTER CONSTRUCTION ----

LOCATION	MEAN TSS	STD. ERR.	N
UTR - ABOVE	8.85	0.84	36
TINKER CREEK	16.38	2.30	36
MCQUEEN BRANCH	167.45	31.09	36
UTR - MIDDLE	28.30	7.17	18
CROUCH BRANCH	191.88	34.26	18
UTR - BELOW	40.11	10.57	18

---- HIGH RAIN -- TURBIDITY -- AFTER CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	3.79	0.81	36
TINKER CREEK	6.30	1.43	36
MCQUEEN BRANCH	186.11	27.68	36
UTR - MIDDLE	32.44	9.70	18
CROUCH BRANCH	287.72	47.21	18
UTR - BELOW	44.96	14.27	18

---- HIGH RAIN -- PERCENT ASH -- AFTER CONSTRUCTION ----

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	55.38	0.82	36
TINKER CREEK	53.89	1.22	36
MCQUEEN BRANCH	86.18	0.77	36
UTR - MIDDLE	68.28	2.81	18
CROUCH BRANCH	88.99	0.97	18
UTR - BELOW	71.27	2.81	18

---- HIGH RAIN -- SPECIFIC CONDUCTANCE -- AFTER CONSTRUCTION --

LOCATION	MEAN	STD. ERR.	N
UTR - ABOVE	18.61	0.70	36
TINKER CREEK	31.87	1.29	36
MCQUEEN BRANCH	60.99	9.00	36
UTR - MIDDLE	29.20	3.03	18
CROUCH BRANCH	86.18	7.19	18
UTR - BELOW	27.93	1.60	18

APPENDIX D
DWPF Means by Construction Period
FY 1983 to FY 1992
(graphical representations)

MEAN TSS (mg/L)

Tinker Creek vs. McQueen Branch

MEAN TURBIDITY (NTU) Tinker Creek vs. McQueen Branch

MEAN SPECIFIC CONDUCTANCE (uohms/cm) Tinker Creek vs. McQueen Branch

MEAN PERCENT ASH

Tinker Creek vs. McQueen Branch

MEAN TSS (mg/L)

Tinker Creek vs. Crouch Branch

MEAN TURBIDITY (NTU)

Tinker Creek vs. Crouch Branch

MEAN SPECIFIC CONDUCTANCE($\mu\text{ohms}/\text{cm}$) Tinker Creek vs. Crouch Branch

MEAN PERCENT ASH

Tinker Creek vs. Crouch Branch

MEAN TSS (mg/L)

UTR Above vs UTR Middle

MEAN TURBIDITY (NTU) UTR Above vs. UTR Middle

MEAN SPECIFIC CONDUCTANCE (uohms/cm) UTR Above vs. UTR Middle

MEAN PERCENT ASH

UTR Above vs. UTR Middle

MEAN TSS (mg/L)

UTR Above vs UTR Below

MEAN TURBIDITY (NTU) UTR Above vs. UTR Below

MEAN SPECIFIC CONDUCTANCE (uohms/cm) UTR Above vs. UTR Below

MEAN PERCENT ASH

UTR Above vs. UTR Below

**DATE
FILMED**

12 / 30 / 93

END