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# SEDIMENTATION AND WATER QUALITY IN LAKE JEANETTE, GREENSBORO, NC

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## ABSTRACT

A study of the condition of Lake Jeanette was conducted from the fall of 1998 through the spring of 2000. This work included monitoring of sediment and flow in the major tributaries, analysis of seven sediment cores from the lake, a summer ambient monitoring program, and calibration of a spreadsheet-based water quality model. This study should be regarded as a baseline evaluation, serving as a basis for further investigation. The results indicate that, during the study period, sediment loading to the lake was low and surface water quality was good. According to the North Carolina trophic state index, Lake Jeanette is mesotrophic, with relatively low nutrient and chlorophyll a concentrations. The mesotrophic designation may be strongly influenced by the low secchi transparency of the lake, which results from the brown stained waters, an indication of humic substances probably of terrestrial origin. This study was conducted during an unusually dry period, during which there were few large storm events. These dry conditions probably resulted in lower than normal loading of sediments and nutrients to the lake.

Sediment core analyses indicate that sediment accumulation has been relatively low and consistent over time in the main body of the lake, but has accelerated in the northern arm near Richland Creek. Accretion rates are estimated at approximately a centimeter per year in the northern arm, though this is an average over the last 36 years. Projected areal losses in this region of the lake over the next 50 years range from approximately 15-20%, depending on assumptions regarding land use and sediment delivery.

Model estimates indicate that, while sedimentation could be accelerated by further watershed development, degradation of surface water quality, at least with regards to lake trophic status, should be minimal. We recommend the establishment of a routine ambient monitoring program, both in the lake and the tributaries, to document any changes in water quality.

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## SUMMARY AND CONCLUSIONS

- Water quality in Lake Jeanette is very good. Our results indicated only trace levels of pesticides and metals. Nutrient and chlorophyll concentrations were also generally low during this study; however, our sampling occurred during a very dry period when loading from the watershed was also low. The North Carolina trophic state index places Lake Jeanette in the mesotrophic category, though this may be, in part, due to low secchi depth readings resulting from the brown colored water in the lake. This color likely results from slowly decaying organic matter in and around the lake.

- The Eutromod model has been calibrated to estimate trophic conditions and sediment loading to Lake Jeanette, and should be an effective tool in future watershed planning. The model is useful to evaluate the possible effects of alternative land use changes on water quality in the lake. As calibrated, Eutromod predicts that future development in the watershed could result in substantial sediment loading increases but is likely to cause only modest changes in lake water quality. Use of this model should be viewed as an ongoing process with refinements to the model inputs as more information becomes available. In particular, soil nutrient levels were estimated from similar soil types in nearby areas and should be better quantified for this particular watershed. Additionally, the sediment delivery ratio is relatively uncertain. Studies during high flow events to better estimate the proportion of runoff-borne sediment that reaches the lake would help reduce the uncertainty in this model input.

- Sediment cores from the northern arm of the lake near Richland Creek suggest sediment deposition has increased, though precise dates when this increase began cannot be determined. As evidenced by the low sediment delivery during our study, sedimentation can vary over short time periods and is strongly associated with weather conditions.

- Based on our sampling it appears that problems of increased sedimentation are localized, largely confined to the arms of the lake near the main inlets. Sediment accumulation rates in the main body of the lake are relatively low and shown no clear recent changes. Sediment loading at baseflow conditions is minimal. Most loading likely occurs during storm events.

## RECOMENDATIONS

Our projections of future water quality conditions indicate that degradation, at least with regards to nutrients, is likely to be minimal. However, to document changes that do occur with time it is suggested that a regular ambient monitoring program be established in the lake. These data will be useful to further calibrate and verify the Eutromod model. Such a system will also help ensure that, if unexpected changes do occur, corrective action can be taken to alleviate any problems.

Long-term monitoring in the lake should be accompanied by monitoring in the major inlets. Our study indicated minimal sediment inputs during baseflow, but our sampling occurred during a very dry period. Installation of a permanent instream flow-monitoring device should be considered for greater flow measurement accuracy.

Eutromod or a similar model should be adopted as a part of the planning process for the watershed. Some of the values used in the model, such as the trapping factor, and soil nutrient levels are based literature values and judgement, and could be refined with site specific measurements. Future land use changes could also be incorporated into the model.

A program to involve the residents of the Lake Jeanette community in monitoring and maintenance of water quality should be considered. The lake is the attribute that brought most residents to that area, and they are likely to be very interested in preserving the aesthetic and recreational uses of the lake and supportive of measures that help maintain these features.

## INTRODUCTION

Lake Jeanette is a small reservoir (surface area approximately 110 hectares, 272 acres) in Guilford County, NC, just north of downtown Greensboro. The reservoir was built in 1942 by Cone Mills as a water source for local operations. Into the 1980s land use in this small watershed (1,960 hectares, 7.6 square miles) was a mix of agricultural and forested land and a small proportion of residential and commercial development. However, the watershed is currently under active development with large tracts of land under conversion to high and medium density residential housing. This rapid development has raised concerns that conditions in the reservoir may be deteriorating as a result of these intense watershed activities. In particular, residents of the area have questioned whether land use disturbance associated with construction activities may be causing accelerated sedimentation and eutrophication in the lake.

This study was undertaken to estimate sediment and nutrient loading into the lake and assess ambient lake conditions. We measured sediment loads in the major tributaries, estimated sedimentation rates from bottom cores collected in the lake, and monitored conditions related to lake trophic status through the summer of 1999. We also used the Eutromod watershed model (Reckhow et al. 1992) to integrate watershed land use and lake-water quality. We emphasize that this should be considered a base-line study, suggesting directions for further evaluation. The results of this work will provide guidance to evaluate the way that current watershed activities are influencing conditions in the lake and to provide a tool for regional planners to assess the way in which proposed development may affect future lake conditions.

# METHODS

## Assessment of Current Conditions

### *Water Quality Measurements*

Flow and total suspended sediment measurements were taken at two sites near the mouth of Richland Creek and one site near the mouth of South Creek (Figure 1). We measured stream velocity using a Swoffer Model 3000 current meter and multiplied by the cross sectional area to calculate flow. Water samples were collected at each site and filtered through a pre-weighed glass fiber filter. The filters were dried at 104°C to determine the mass of the suspended solids (Standard Methods 2540 D). Daily precipitation data, collected at the Greensboro airport, for use in the development of flow:precipitation relationships were provided by the State Climate Office of North Carolina at NC State University.

We collected sediment cores at four initial sites in Lake Jeanette in March 1999 and three additional sites in March 2000 (Figure 2) using a modified Livingston piston coring device. The cores were returned to the laboratory, extruded in 2 cm. intervals and refrigerated in ziplock bags. We immediately removed 0.5 $cm^3$ of each layer for bulk density measurement. Each sample was weighed and dried at 70°C for 24 hours. Bulk density was calculated as the dry weight divided by the initial wet volume. This dried sediment was then weighed and placed in a muffle furnace for 24 hours at 450°C, and we determined loss on ignition as the percent difference in weight.

The remainder of each sediment layer was dried and ground to uniform size for $^{137}Cs$ dating. Each ground layer was placed in a petri dish to achieve uniform volumes. The samples were counted on an EG&G Ortec planer gamma spectrometer for 24 hours. The $^{137}Cs$ (661.7 keV) photopeak was measured for each layer and the maximum value was assigned a date of 1963 (Schelske *et al* 1994).

Core horizons above the peak cesium layer were considered to have been deposited from the period 1964 through 1998 (35 years) for cores 1-4, and 1964-1999 (36 years) for cores 5-7. Sediments at and below the peak cesium layer were considered to have been deposited from 1942 through 1963, a period of either 21 or 22 years, depending on when the reservoir began to fill in. We calculated average accretion rates (cm/yr) by dividing core depths by the respective time periods from 1942 – 1963, and 1964 – 1998(9). Corresponding deposition rates ($g/cm^2/yr$) for both time periods were calculated from sediment bulk density measurements. The position of original land surface before sedimentation began was inferred from notes taken during sectioning of the cores and the point in each core profile where the bulk density exhibited a sudden rapid increase.

We measured water quality characteristics at six surface and two depth sites in Lake Jeanette on five sample dates (Figure 1). *In situ* measurements with depth of dissolved oxygen, turbidity, temperature, conductivity, and pH were collected with a Hydrolab MiniSonde water quality multiprobe. Epilimnion samples were collected approximately 0.5 meters below the water surface, and hypolimnion samples were collected using a Van Dorn sampler approximately 0.5 meters above the lake bottom. We filtered samples for dissolved nutrient fractions immediately using a 0.45 μm membrane filter. All samples were preserved and stored on ice for delivery to the laboratory.

Figure 1

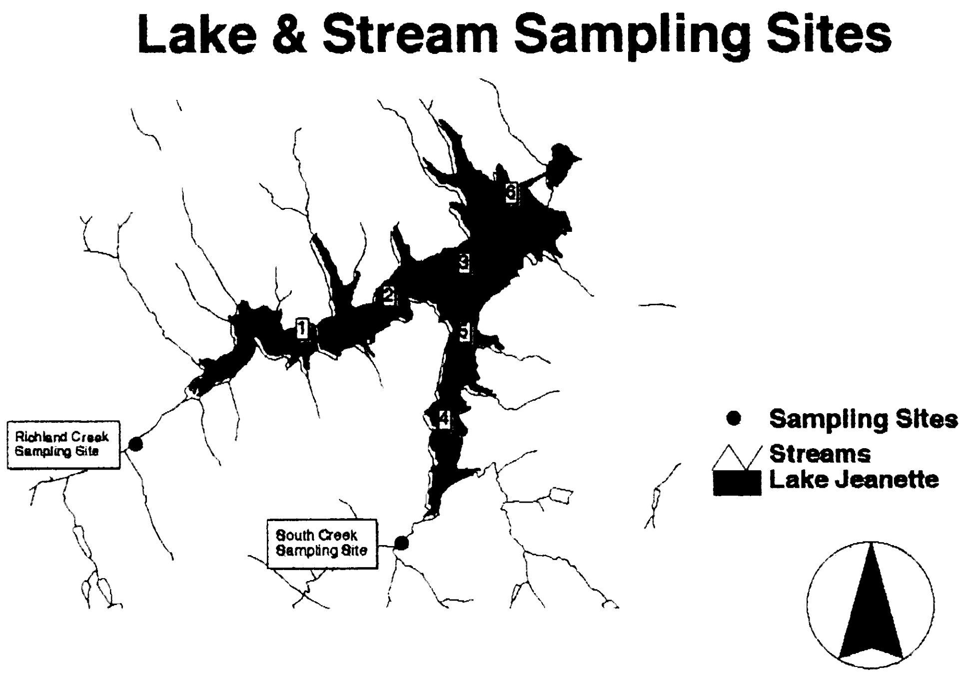
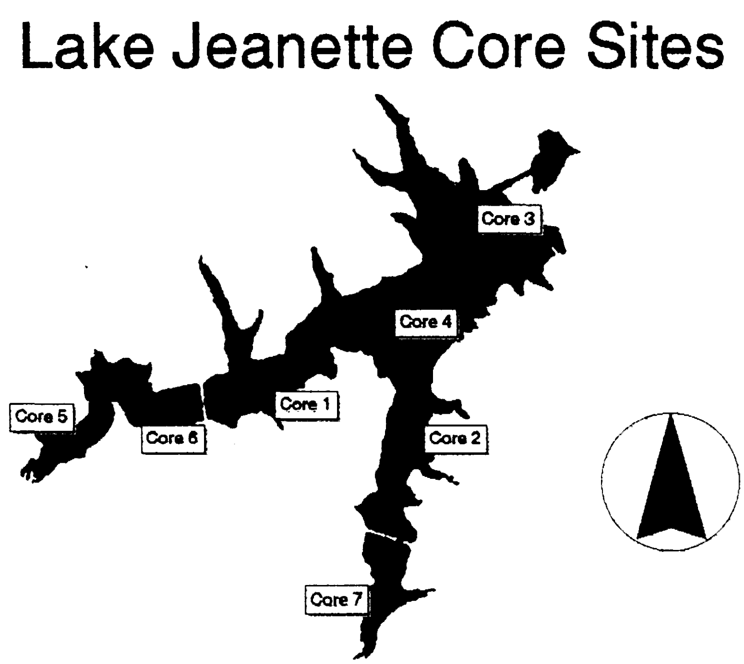



Figure 2



Pheophyton corrected chlorophyll a was measured spectrophotometrically (Standard Methods 10200 H), and total suspended solids were measured gravimetrically (Standard Methods 2540 D). Unfiltered total phosphorus was prepared using persulfate digestion and both total phosphorus and filtered orthophosphate were analyzed using the ascorbic acid method (Standard Methods 4500-P E). Nitrate + nitrite was measured using automated cadmium reduction (Standard Methods 4500-$NO_3$- F), ammonia was analyzed using the automated phenate method (Standard Methods 4500-$NH_3$ G), and total nitrogen was analyzed using the persulfate method (Standard Methods 4500-N C). Metals samples were analyzed using Inductively Coupled Plasma Mass Spectrometry (Standard Methods 3125 B). Enzyme-linked immunosorbent assays (ELISAs) and gas chromatography/mass spectrometry (GC/MS) were used for pesticide analysis (Walker et al. 2000). ELISA was used as a screening tool for results $<1 \mu g/L$ because the MCL for the pesticides examined are $>1 \mu g/L$.

### *GIS Development*

All reference files were received from Greensboro Storm Water Services as Arcview shape files of a section of the state plane grid at 1:2400 scale. These files were converted to ARC/INFO format, initially as route and region coverages, and then processed to become line and polygon coverages. These conversion steps preserved feature attributes associated with the original shape files. All resulting files were defined to their original state plane coordinate system. A Lake Jeanette watershed coverage was buffered and then used to clip the coverages to limit the extent to a relevant area. The coverages were then grouped by thematic context and used in later analyses.

A soil type code attribute was added to the soil polygon coverage. The polygon coverage was converted to a grid using this code. The value attribute table was then used to identify the percentage of a particular soil type relative to the entire watershed.

A land use code attribute was added to the land use coverage. The polygon coverage was converted to a grid using this code. The value attribute table was used to identify the number of cells of each particular land use. This number of cells was multiplied by the size of the cell (10x10 feet) and this area was converted to hectares for use in Eutromod.

The digital elevation model (DEM) was used to determine the LS for Eutromod. A series of transects were drawn onto the DEM parallel to flow paths (using the stream coverage as guidance). The lake coverage was buffered by 400, 600, 800, and 1000 feet. These buffered coverages were overlayed onto the DEM and the transects. The elevation was recorded where the transect crossed the lake buffered coverages. The elevation at the lake edge was subtracted from these elevations to identify the elevation rise. This rise amount was divided by the distance from the lake to determine the percent slope. These percent slopes were averaged for all the transects a particular distance from the lake. A Universal Soil Loss Equation (USLE) table was consulted for the identified length (distance from lake) and slope (average percent slope of the transects). The most reasonable value was determined to be $1.0 \pm .10$.

### *Depth Mapping Field Survey*

Depth measurements at Lake Jeanette were obtained in the following method. Using USGS Lake Brandt topographic map, the lake was divided into 11 sections, labeled A though K. Before mapping each section, a lake level reference measurement was taken at the Guilford Wildlife Club gazebo dock. Transects crossing the lake section were identified, primarily from distinctive physical topography (i.e. points, coves, docks, etc) and these were drawn onto the section reference map and numerically identified. The boat was driven along these transects at a constant speed and depth measurements were taken and recorded at regular intervals. This process was completed for all lake sections.

The field measurements were entered into a spreadsheet under their section letter and transect identification number. The reference measurements recorded prior to each section depth measurement were used to normalize all depths to a common lake reference level of 18 inches. This eliminated depth section inconsistencies resulting from changing lake levels over the data collection period. These data were converted to a tab-delimited file for entry into the UNIX-based Arc/Info GIS.

ArcEdit was used to draw the data collection transects onto the lake coverage. The lake edge was deleted, creating a coverage of only the transects. Vertices were added at regular intervals to each transect to represent the depth measurements taken along the transect in the field. This line coverage was converted to a point coverage. This resulted in a coverage of only the measurement points. The depth measurements from the tab-delimited file were associated with their respective measurement points.

The lake shoreline coverage was converted to a line coverage. Vertices were added to this line at regular intervals. This line coverage was converted to a point coverage and all the points were assigned a value of zero (no depth). These points were then added onto the transect points to form a coverage of both shore and depth measured points.

The point coverage was used to create a TIN. This tin was interpolated by Arc/Info to create a 10 foot by 10 foot grid of lake depth. The depth grid was then used in ArcView to generate the contour line coverage.

The lake depth grid value attribute table was displayed. This file exhibits the number of square cells in the grid that have a particular value. The values of the depth grid were the depth. The value attribute table showed the number of 10x10 cells in the grid that were a particular depth. This number of cells was multiplied by 100 (10x10) and the depth to determine the volume for that particular depth. This was performed for each depth then summed to get the volume entire lake volume.

### *Watershed and Water Quality Modeling*

We estimated the effects of land use on water quality and sediment delivery in the Lake Jeanette watershed using Eutromod, a spreadsheet-based model that has been calibrated to lakes and reservoirs in the southeastern United States. (Reckhow et al. 1992). Two nutrient components are calculated in Eutromod. The first is the dissolved component calculated as:

$$LD_k = C_k Q_k A_k$$

where $LD_k$ is the annual mass load from land use k, $C_k$ is the nutrient concentration from land use k, $Q_k$ is the runoff from land use k, and $A_k$ is the area of land use k. The second component is the sediment-attached fraction, calculated as:

$$LS_k = Cs_k X_k SD_k$$

where $LS_k$ is the annual mass load from land use k, $Cs_k$ is the nutrient concentration in the eroded soil, $X_k$ is the annual soil loss mass, and $SD_k$ is a dimensionless delivery ratio. The annual soil loss, $X_k$, is estimated from the Universal Soil Loss Equation (USDA 1995):

$$X = 1.29\ RE\ \ K\ \ LS\ \ C\ \ P$$

where X is the annual mass of soil loss, 1.29 is a units conversion factor, RE is a measure of the rainfall intensity in a geographic region, K is the soil erodibility, LS is a topographic factor, C is a factor incorporating the effect of different crop covers, and P is a land-use practice factor.

The watershed inputs we used in the Eutromod model are summarized in Tables 1 and 2. Land use categories and areas were obtained from the GIS data base. Based on our observations, we estimated that approximately one fourth of the area categorized as open land (forest) in the data base had been converted to medium density residential housing, so we made this change in the model input. We used runoff coefficients characteristic of these land uses, obtained from several sources (Reckhow et al. 1992, Novotny and Olem 1994). Factors for the Universal Soil Loss Equation were obtained from the Revised Universal Soil Loss Equation Manual (USDA, NRCS 1995), and Novotny and Olem (1994). Values for nutrient concentrations are based on information regarding soil types in this area (USDA 1977, Richter and Markewitz 2000). Additionally, Eutromod incorporates a "trapping factor" to account for the fact that the Universal Soil Loss Equation was developed to estimate loss from the edge of a particular land area, and may overestimate the sediment that is actually delivered to the lake. We used this trapping factor as one of our principal calibration parameters and set it equal to 0.70 for all land uses (30% sediment delivery) based on judgement and systematic manipulation to match observed lake trophic conditions.

**Table 1 - Watershed-Level Inputs**

| Surface Water Runoff & Soil Loss Input | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Land Use Category | Land Use Type | Runoff Coef. | USLE: Xi=1.29*R*K*LS*C*P (R in SI, K in English) | | | | | Area (ha) |
| | | | R | K | LS | C | P | |
| Ag1 | **Cropland** | **0.35** | **382.00** | **0.25** | **1.00** | **0.3000** | **1.00** | **2** |
| Residential | **High Density** | **0.60** | **382.00** | **0.25** | **1.00** | **0.1000** | **1.00** | **103** |
| Residential | **Medium Density** | **0.30** | **382.00** | **0.25** | **1.00** | **0.1000** | **1.00** | **188** |
| Residéntial | **Low Density** | **0.20** | **382.00** | **0.25** | **1.00** | **0.0500** | **1.00** | **740** |
| Forest | **Forest** | **0.15** | **382.00** | **0.25** | **1.00** | **0.0005** | **1.00** | **586** |
| Other1 | **Commercial, Industrial** | **0.60** | **382.00** | **0.25** | **1.00** | **0.1000** | **1.00** | **52** |
| Other2 | **Unclassified** | **0.20** | **382.00** | **0.25** | **1.00** | **0.05000** | **1.00** | **178** |
| Other3 | **Water** | **1.00** | **382.00** | **0.00** | **0.00** | **0.0000** | **0.00** | **110** |
| | | | | | | Total Area (ha) | | **1959** |

**Table 2 – Nutrient Characteristics**

| Nutrients | Phosphorus | | | Nitrogen | | |
|---|---|---|---|---|---|---|
| Land Use Category | Dissolved (mg/l) | Sediment Attached (mg/kg) | Total (mg/l) | Dissolved (mg/l) | Sediment Attached (mg/kg) | Total (mg/l) |
| Cropland | 0.200 | 20.0 | | 2.50 | 500.00 | |
| High Density | 0.070 | 10.0 | | 1.00 | 200.00 | |
| Medium Density | 0.050 | 10.0 | | 1.00 | 200.00 | |
| Low Density | 0.030 | 10.0 | | 1.00 | 200.00 | |
| Forest | 0.009 | 10.0 | | 0.20 | 200.00 | |
| Commercial, Industrial | 0.070 | 10.0 | | 1.00 | 200.00 | |
| Unclassified | 0.050 | 10.0 | | 1.00 | 200.00 | |
| Water | 0.000 | 0.0 | | 0.00 | 0.00 | |
| Precipitation | | | 0.01 | | | 0.10 |

| | | | |
|---|---|---|---|
| P-enrichment ratio | 1.00 | N-enrichment ratio | 1.00 |

Eutromod uses these lake specific inputs to estimate the trophic characteristics of a lake, based on regional models derived from a cross-section of lakes. Lake nutrient concentrations are estimated based on the following equations, developed in Reckhow (1988):

$$C = \frac{M}{Q + kV} = \frac{C_{in}}{1 + k\tau_w}$$

where C is the average lake nutrient concentration, M is the annual nutrient mass input, Q is the annual volumetric water input, V is the lake volume, $C_{in}$ is the average influent nutrient concentration, $\tau_w$ is the hydraulic residence time, and k is a first-order loss rate. Eutromod also predicts chlorophyll a concentration and secchi disk transparency based on regional regression models, and the probabilities of blue-green algal dominance and hypolimnetic anoxia based on maximum likelihood logistic regression models (Reckhow et al. 1992).

## Projection of Future Conditions

### *Water Quality*

We used the Eutromod model to evaluate the possible effects of land use change under two future scenarios: one with moderate development in the watershed and one with a more extreme degree of land conversion. In the moderate development scenario we assumed that half of the currently forested land would be converted to medium density housing, resulting in 293 hectares of forest and 481 hectares of medium density housing. For the extreme development scenario we assumed all of the forested land would be converted to medium density housing, resulting in no forested land and 774 hectares of medium density housing. The resultant changes in water quality are then estimated from the calibrated Eutromod model.

### *Sedimentation*

To estimate potential future sedimentation patterns we used the empirical area reduction method (Borland and Miller 1960, Lara 1962). The procedure requires projection of the annual volume of sediment trapped in the reservoir, and classification of the reservoir into one of four sediment deposition types. The four sedimentation types are based on reservoir shape, mode of operation, and properties of the sediment particles, with reservoir shape being the most important factor (Strand and Pemberton 1987). These four deposition categories are: lake (Type I), flood plain-foothill (Type II), hill (Type III), or gorge (Type IV). These categories define whether a reservoir is expected to fill in predominantly in the shallower regions (Type I) or the deeper regions (Type IV) with II and III representing intermediate categories. The categorization for a particular reservoir is chosen primarily from the shape of the reservoir as determined by the reciprocal of the slope of the relationship between the log (base 10) of reservoir depth (feet) and the log of the reservoir capacity (acre feet). For Lake Jeanette we estimated this value from a simple linear regression of the log of capacity on the log of depth. In this case the resultant estimate was 2.63 (± 0.038 standard error units), placing Lake Jeanette in the Type II deposition category.

# RESULTS AND DISCUSSION

## Current Conditions

### *Estimation of Potential Sediment Loading and Accumulation*

To estimate an upper bound on sedimentation in Lake Jeanette we considered the precipitation record from the Greensboro Airport with some generous assumptions regarding runoff and sediment concentration. National Weather Service data from Greensboro 1949-1998 indicate an average annual rainfall of 1.08 meters. Over the 56 year period 1942-1998 this is a total of 60.48 meters. GIS data indicate a total watershed area of 1,960 hectares and a lake surface area of 110 hectares, or a watershed land area of 1,850 hectares. To estimate the total potential runoff we multiply:

$$1{,}850 \text{ hectares} \times 10{,}000 \text{ m}^2/\text{hectare} \times 60.48 \text{ meters} \times 1{,}000 \text{ liters/m}^3 = 1.12 \times 10^{12} \text{ liters.}$$

To estimate an extreme upper bound, if we assume 100% runoff with a suspended solids concentration of 500 mg/L, then:

$$500 \text{ mg/L} \times 1.12 \times 10^{12} \text{ liters} = 5.6 \times 10^{14} \text{ mg or } 5.6 \times 10^{11} \text{ g of potential sediment.}$$

At a bulk density of 0.6 $g/cm^3$ or $6 \times 10^5$ $g/m^3$ sediment volume is estimated as:

$$\frac{5.6 \times 10^{11} \text{ g}}{6 \times 10^5 \text{ g/m}^3} = 9.33 \times 10^5 \text{ m}^3 \text{ of potential sediment.}$$

Then the total sediment accumulation from external loading would be:

$$\frac{9.33 \times 10^5 \text{ m}^3}{1.10 \times 10^6 \text{ m}^2} = 0.85 \text{ meters or } \frac{85 \text{ cm}}{56 \text{ years}} \text{ or } 1.5 \text{ cm/year lakewide,}$$

or on a mass basis approximately 0.93 $g/cm^2$/year.

The assumptions in this analysis include: 100% runoff, 100% trapping in the reservoir, suspended solids concentration of 500 mg/L, sediment bulk density of 0.6 $g/m^3$, and no other sediment sources such as internal production or leaf litter.

These results indicate that even under extreme conditions, lake wide sedimentation is not a likely problem. However, locally higher rates of sedimentation could occur, particularly in shallow areas near the mouths of the main tributaries.

### *Sediment Estimates from the Eutromod Model*

In addition to predictions of lake water quality, Eutromod provides estimates of sediment inputs from watershed land uses. The largest estimated sediment load comes from low density residential areas (Table 3), because this constitutes the single largest land use (Table 1). This is followed by medium and high density residential housing. Cropland is a relatively small contributor, because it currently constitutes a small proportion of the watershed land use (Table 1).

**Table 3 - Land Use/Soil Loss**

| Land Use Type | Runoff Volume $10^6$ $m^3$/yr | Soil Loss Mg/ha-yr | Soil Loss Mg/yr | Sediment Load Mg/yr |
|---|---|---|---|---|
| Cropland | 0.0 | 37.0 | 92 | 28 |
| High Density | 0.7 | 12.3 | 1269 | 381 |
| Medium Density | 1.1 | 12.3 | 4127 | 695 |
| Low Density | 1.6 | 6.2 | 4558 | 1367 |
| Forest | 0.7 | 0.1 | 27 | 11 |
| Commercial, Industrial | 0.3 | 12.3 | 640 | 192 |
| Unclassified | 0.4 | 6.2 | 1096 | 329 |
| Water | 1.2 | 0.0 | 0 | 0 |
| Basin Total ---> | 5.9 $10^6$ $m^3$ | 6.03 Mg/ha-yr | 11810 Mg/yr | 3003 Mg/yr |

The total estimated sediment load, 3.003 x $10^9$g/year is equal to a sediment accumulation rate of 0.27 g/cm$^2$/year.

***Measurement of Sediment Delivery***

Both Richland Creek and South Creek exhibited clear relationships between suspended solids concentration and flow (Figure 3a). Standard statistical testing indicated the data from these two streams could be combined, resulting in a joint relationship of:

$$\ln(\text{TSS}) = 4.41 + 0.80 \ln(\text{Flow}) + \varepsilon \quad (1)$$

intercept standard error = 0.30 slope standard error = 0.079
$R^2 = 0.67$ mean squared error = 0.50

where TSS = total suspended solids (mg/L)
Flow = stream flow ($m^3$/second)
and $\varepsilon$ is the error term with mean zero, and variance estimated by the mean squared error. This term represents the random variation in the ln of TSS at each value of the ln of flow.

The relationship in equation 1 is potentially useful to estimate sediment loads and the associated uncertainty from stream flow data.

However, flow monitoring in both Richland and South Creek yielded poorly defined relationships between precipitation and stream flow (Figure 3b). The absence of good relationships probably occurred for several reasons. The most likely reason is that instantaneous flow monitoring was inadequate to capture the temporal relationship between precipitation and stream flow in such a small watershed. The hydrographic response to rainfall in a small watershed is usually brief and would be better reflected with continuous flow-monitoring. Additionally, because the watershed is so small, precipitation recorded at the Greensboro airport may not always accurately reflect precipitation in the Lake Jeanette watershed. Another

**Figure 3a Relationship between suspended solids concentration and stream flow in Richland and South Creeks**

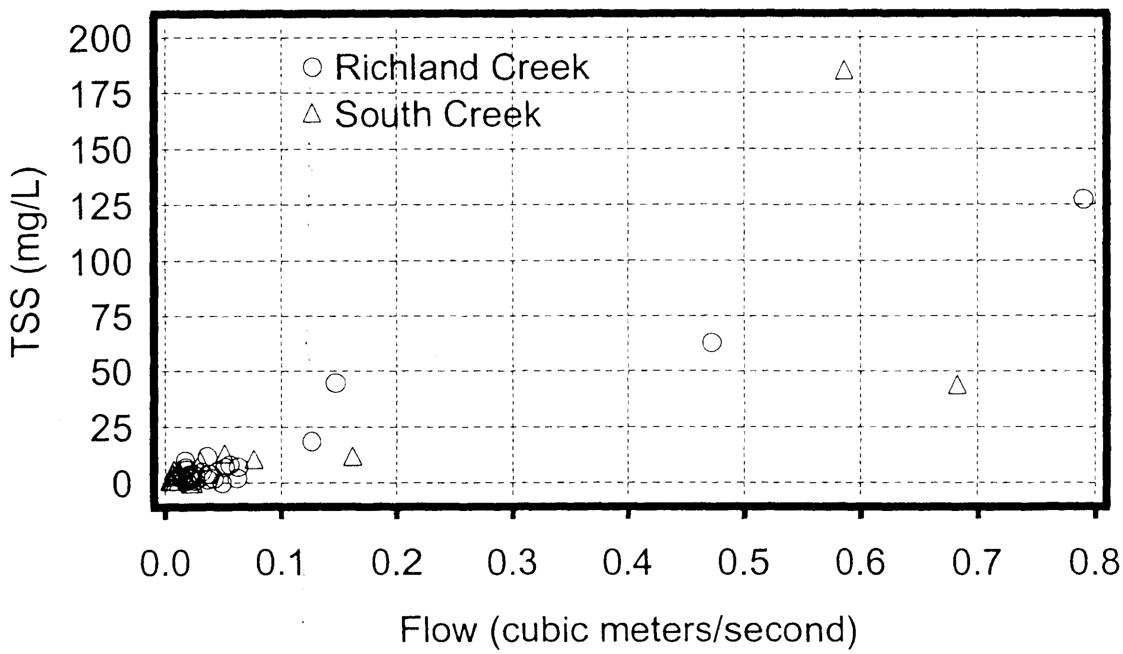
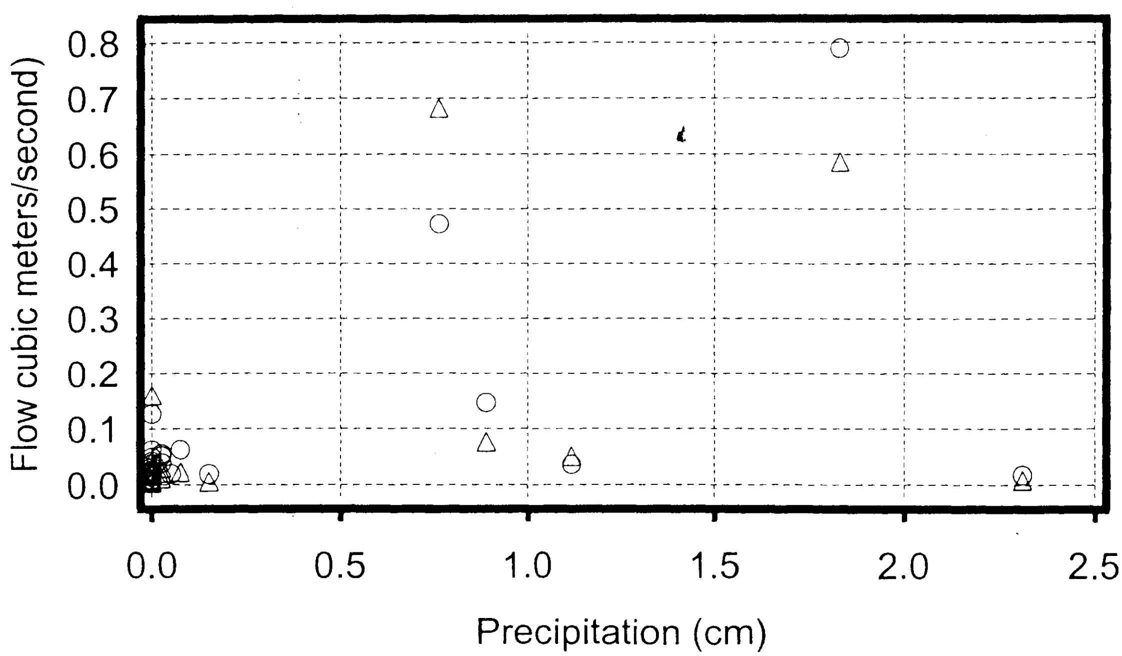



**Figure 3b Relationship between precipitation and stream flow in Richland and South Creeks**



contributing factor is that we sampled these streams during an unusually dry period, when there were few high flow events. Extreme events are important in defining these kinds of empirical relationships. Because these precipitation:stream flow relationships were not well-defined we did not attempt to extrapolate this information to obtain estimates of historic sediment loading in this watershed using these data.

By comparing these observations to the estimate of potential sediment loading we can conclude that sediment loading under base-flow conditions is inconsequential. However, equation 1 predicts that the suspended solids concentration would equal 500 mg/L, the value used in the potential sediment loading estimate, at a stream flow of approximately 1.3 $m^3$/second. Our data suggest that flows this high probably occur when precipitation exceeds 2.5 cm/day. Analysis of the historic precipitation record indicates that approximately 40% of the rainfall in the Greensboro area occurs during precipitation events of 2.5 cm/day or greater. If approximately 40% of the rainfall in the watershed is sufficient to result in conditions similar to those assumed in the potential loading estimate then the lake wide sedimentation rate would be approximately 0.40 x 1.5 cm/year or 0.6 cm/year.

***Sediment Core Analysis***

The first four sediment cores exhibited fairly consistent results, with the original land surface apparent in cores 1, 2, and 3. The bottom fell out of core 4 during collection, so sedimentation since 1942 could not be estimated from this sample. Bulk densities were similar in cores 1, 2, and 4 (Figure 4) as were percent loss on ignition values (Figure 5), consistent with a fairly mineral based sediment. Core 3 exhibited a consistently lower bulk density (Figure 4), and percent loss on ignition (Figure 5), indicating a more organic sediment than the other three cores. Peak cesium activity was also fairly consistent across these cores (Figure 6), yielding similar estimates of sedimentation at all sites (Table 4).

**Table 4 - Core Data – First Core Set**

| SEDIMENT ACCUMULATION | CORE 1 | CORE 2 | CORE 3 | CORE 4 |
|---|---|---|---|---|
| Total Accretion (cm) 1942 – 1998 | 26 | 22 – 26 | 32 - 34 | ≥ 24 |
| Average Accretion (cm/yr) 1964 – 1998 | 0.51 | 0.51 | 0.63 | 0.51 |
| Average Accretion (cm/yr) 1942 – 1963 | 0.36 - 0.38 | 0.18 - 0.38 | 0.45 – 0.57 | ≥ 0.29 |
| Average Deposition ($g/cm^2/yr$) 1964 – 1998 | 0.22 | 0.24 | 0.16 | 0.21 |
| Average Deposition ($g/cm^2/yr$) 1942 – 1963 | 0.22 - 0.23 | 0.12 – 0.33 | 0.22 – 0.28 | ≥ 0.17 |

Accretion rates in cores 1 - 4 are similar with accretion from the latter period (1964-1998) exceeding that of the earlier period (1942-1963). Ranges expressed in deposition and accretion rates for the period 1942-1963 reflect uncertainty in the position of the original land surface and the number of intervening years (21 or 22 years, depending on when the reservoir began to fill in). Interestingly, core 3, the core furthest from the main inlets, displayed the highest sediment accretion rate, largely because of the lower bulk density of this core. Differences in bulk density are also largely responsible for the higher recent accretion rates in each core. On a mass basis sediment deposition is essentially the same for the periods 1942-1963 and 1964-1998 in core 1. The exact position of the original land surface was somewhat uncertain in core 2, resulting in a range of possible deposition rates from 0.12 to 0.33 $g/cm^2/yr$ in the earlier period, compared to 0.24 $g/cm^2/yr$ more recently. Measurements from 3 indicate mass deposition to be lower from 1964-1998 than from 1942-1963.

The highly organic nature of core 3 relative to cores 1, 2, and 4 suggests material deposited in this area originates from a different source than the sediment in the other areas. Sediment in this region of the lake may result from internal primary production or may be derived from allochthonous (derived from sources external to the lake) organic material entering the northeastern portion of the lake.

Cores 5-7 were collected closer to the main inlets than cores 1-4 (Figure 2) and exhibit different deposition patterns than do the first four cores. Core 7 was taken near the mouth of South Creek and exhibits a higher bulk densities and lower losses on ignition (Figures 4 and 5) than any of the other cores. Additionally, there was no discernible cesium pattern in core 7 (Figure 6). The region where core 7 was collected is probably an active scour zone where lighter

**Figure 4  Core Bulk Densities**

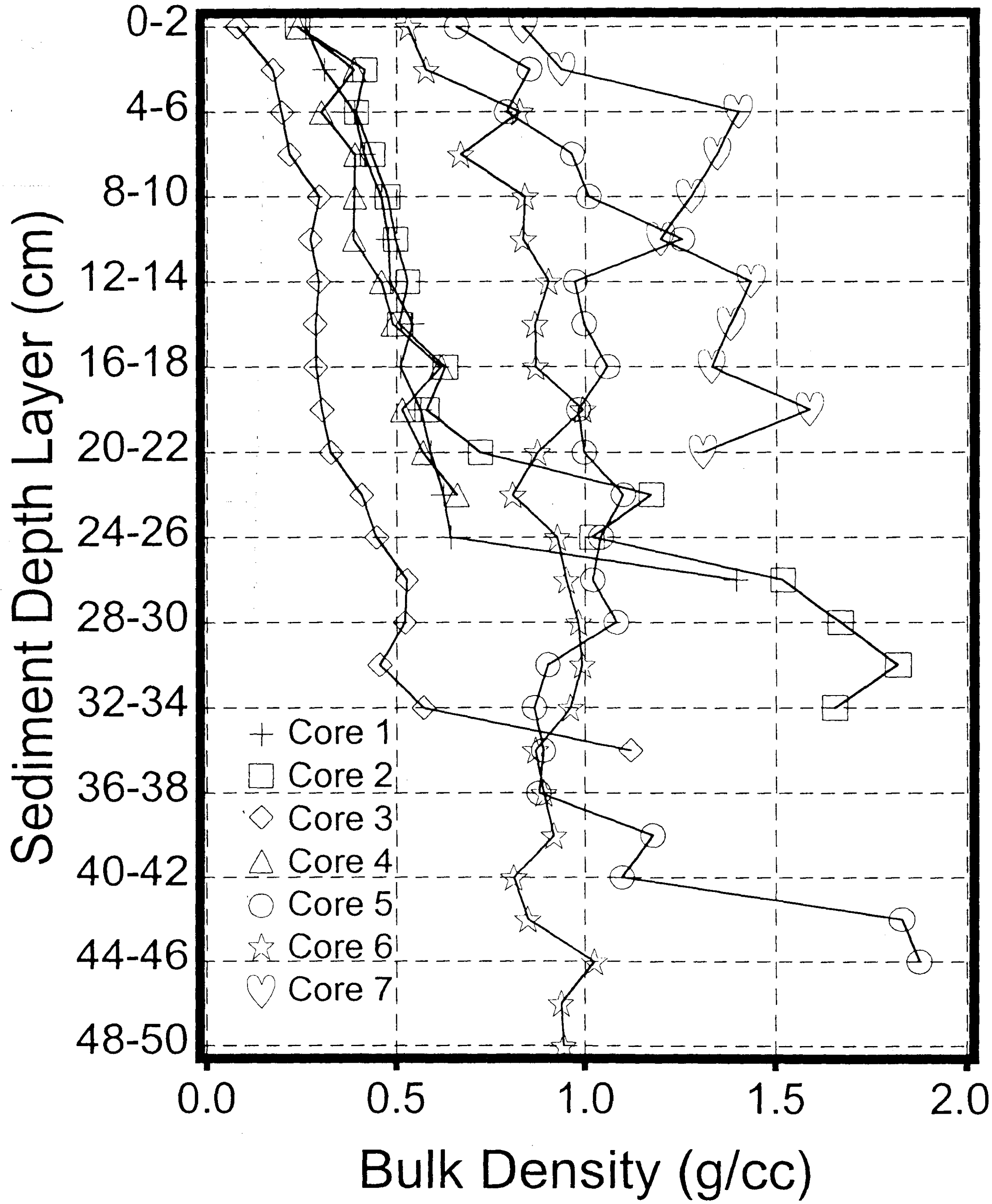


**Figure 5 Core Loss on Ignition**

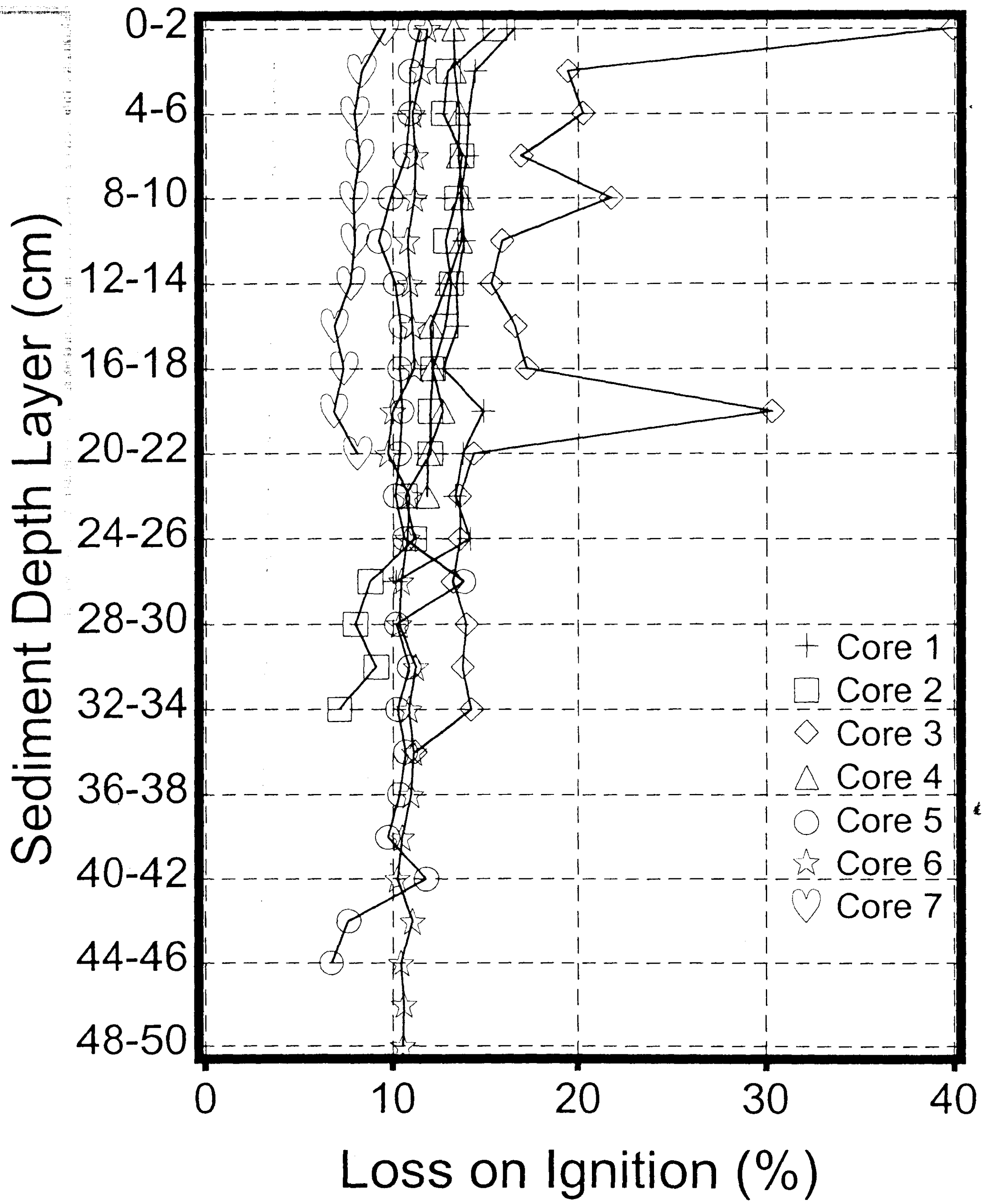
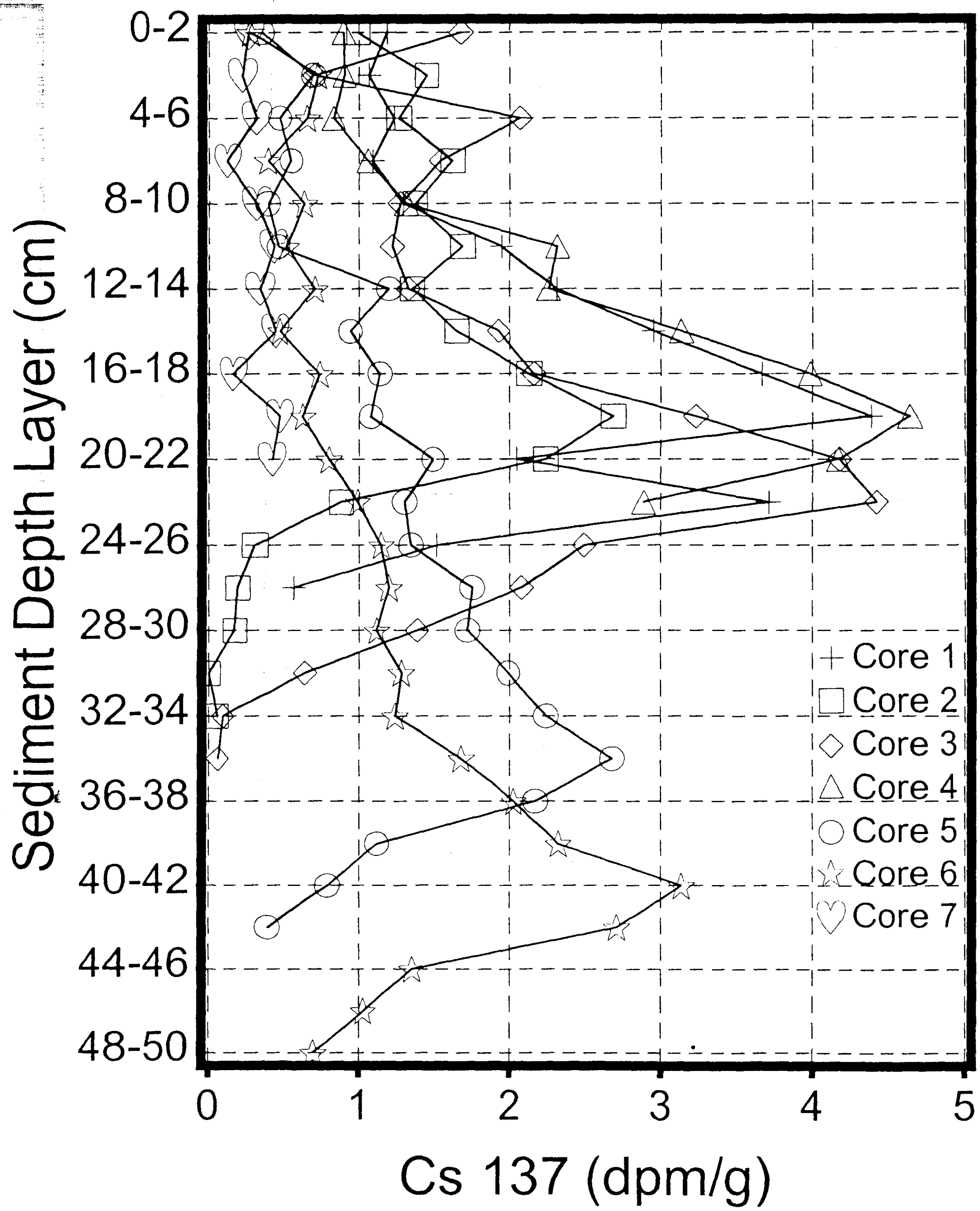


**Figure 6 Core Cesium Results**



sediment is resuspended and carried downstream during high flow events. Net accumulation in this region is dominated by denser more mineral-based sediment.

Cores 5 and 6 were collected in the northern arm of the lake, which is fed by Richland Creek. These two cores exhibit slightly higher deposition, but similar accretion rates to cores 1-4 in the period from 1942-1963 (Tables 4 and 5). However, in the period from 1964-1999 cores 5 and 6 both exhibit deposition and accretion rates that are much higher than in the period from 1942-1963, and much higher than in cores 1-4. While the cesium measurements do not provide sufficient temporal resolution to indicate exactly when the sediment deposition rate in this area began to increase, the fact that cesium peak is very broad suggests that the period of increased deposition began before the recent development of the Lake Jeanette watershed.

**Table 5 - Core Data – Second Core Set**

| SEDIMENT ACCUMULATION | CORE 5 | CORE 6 | CORE 7 |
|---|---|---|---|
| Total Accretion (cm) 1942 – 1999 | 42 | 48 – 50 | ~ 22 |
| Average Accretion (cm/yr) 1964 – 1999 | 0.94 | 1.17 | - |
| Average Accretion (cm/yr) 1942 – 1963 | 0.36 – 0.38 | 0.27 - 0.38 | - |
| Average Deposition ($g/cm^2/yr$) 1964 – 1999 | 0.97 | 0.99 | - |
| Average Deposition ($g/cm^2/yr$) 1942 – 1963 | 0.29 – 0.30 | 0.26 – 0.36 | - |

Overall, the deposition measurements are very consistent the Eutromod based estimate of 0.27 $g/cm^2$/year for an overall lake average. The measurements from the main body of the lake are slightly below this estimate, while measurements nearer the tributaries are higher than the Eutromod estimate. Based on these measurements there is no evidence that sediment accumulation in the main body of the lake has undergone any sustained recent increases. However, increased sedimentation in at least some portions the northern tributary arm is indicated.

### *Depth Mapping and Storage Capacity*

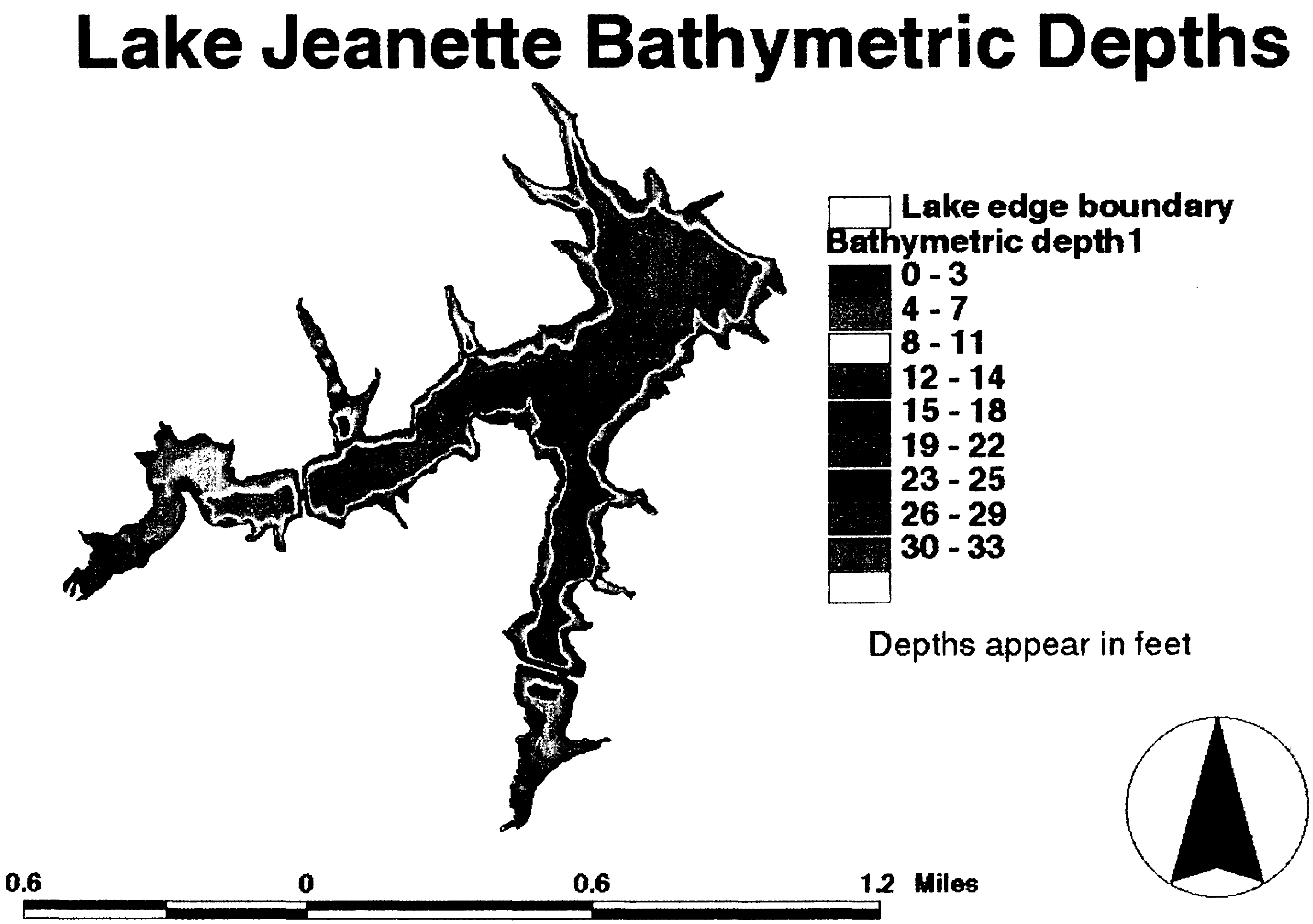
Depth transects are shown in Figure 7 and interpolated contours for the lake from the summer depth survey are depicted in Figure 8. The lake edges are steeply sloped with the main body of the lake generally greater than seven meters deep. Not surprisingly, the lake is relatively shallow near the mouths of the two inlet creeks, possibly resulting from local sediment deposition, but it is also likely that these areas were not originally very deep.

The area-capacity curve developed from this survey (Figure 9, Table 6) indicates a current storage capacity of approximately 4.5 million cubic meters (3,783 acre feet).

Figure 7

# Depth Mapping Transects

Figure 8


Lake Jeanette Bathymetric Depths
Lake edge boundary
Bathymetric depth1
0 - 3
4 - 7
8 - 11
12 - 14
15 - 18
19 - 22
23 - 25
26 - 29
30 - 33
Depths appear in feet
0.6
0
0.6
1.2 Miles

## Figure 9 Depth vs Capacity Curve

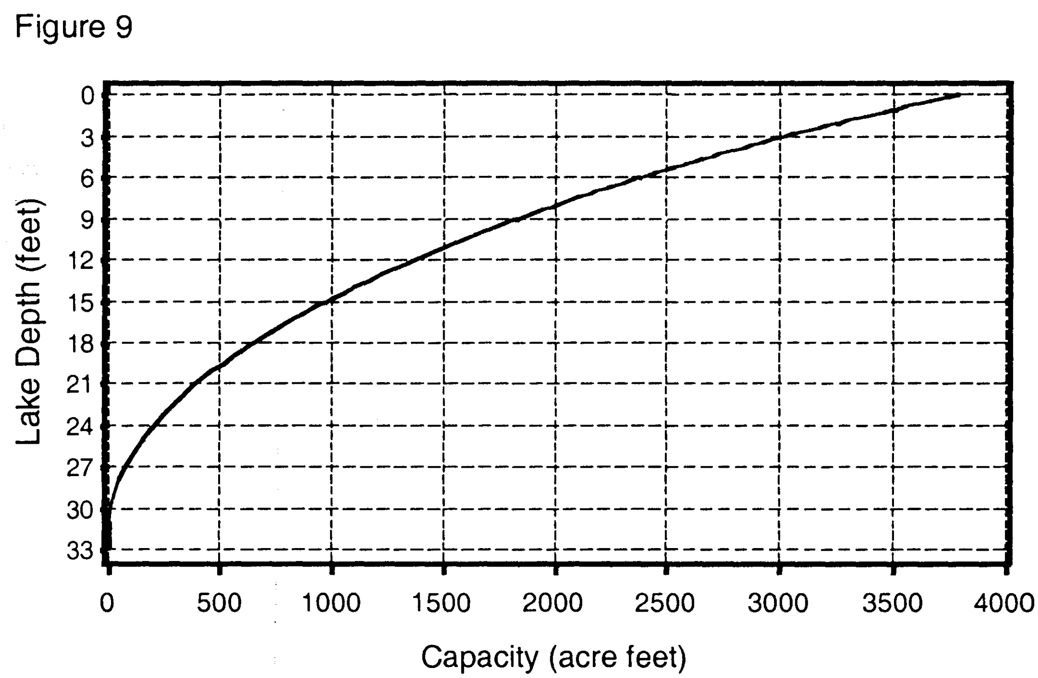



**Table 6 – Depth Capacity**

| Depth (feet) | Capacity (acre-feet) | Depth (feet) | Capacity (acre-feet) |
|---|---|---|---|
| 0 | 3783.71 | 17 | 749.17 |
| 1 | 3514.73 | 18 | 648.40 |
| 2 | 3262.89 | 19 | 556.02 |
| 3 | 3024.48 | 20 | 470.93 |
| 4 | 2798.59 | 21 | 393.57 |
| 5 | 2584.46 | 22 | 323.95 |
| 6 | 2381.19 | 23 | 261.29 |
| 7 | 2188.48 | 24 | 205.70 |
| 8 | 2005.86 | 25 | 157.26 |
| 9 | 1833.19 | 26 | 115.27 |
| 10 | 1669.97 | 27 | 79.43 |
| 11 | 1515.14 | 28 | 50.30 |
| 12 | 1367.90 | 29 | 27.95 |
| 13 | 1228.18 | 30 | 12.75 |
| 14 | 1097.08 | 31 | 4.37 |
| 15 | 974.06 | 32 | 0.98 |
| 16 | 857.98 | 33 | 0.00 |

***Water Quality Monitoring***

Results from the summer water quality survey are presented in Appendix A. Concentrations of dissolved nutrients, filtered orthophosphate, nitrate + nitrite, and ammonia, were generally very low, often below the method detection limit (Table A1). The mean total phosphorus concentration was 13.2 ± 3.3 μg/L, and the mean total nitrogen was 452.8 ± 42.6 μg/L (inverse variance weighted by date ± one standard error). Chlorophyll a was also low, with a mean of 7.86 ± 1.25 μg/L, and the mean secchi depth was 1.1 ± 0.1 meters. The North Carolina Trophic State Index (NC Department of Natural Resources and Community Development 1982) puts Lake Jeanette in the mesotrophic category. However, this ranking may not truly represent the status of primary productivity in the lake. We found the lake to consistently be dark brown stained, a condition likely to result from the presence of slowly decaying humic substances of terrestrial origin, rather than from algal production in the lake water. This condition of dystrophy (Wetzel 1975) decreases the secchi transparency and may also elevate total nutrient concentrations, though these nutrients may be organically bound and not effectively be available for algal uptake.

Temperature depth profiles indicate that Lake Jeanette was strongly stratified by our first sampling in mid-June (Figure A1). Stratification continued through the summer, though was beginning to break down by the end of September. Conductivity depth profiles indicate a well mixed epilimnion, with conductivity increasing in the hypolimnion (Figure A2). Surface dissolved oxygen concentrations were generally high, but oxygen levels dropped off rapidly through the thermocline and the hypolimnion was hypoxic throughout the summer (Figure A3). Surface DO was near or slightly above saturation throughout the summer (Figure A4). Surface pH was generally above 8, with hypolimnetic pH in the 7-8 range (Figure A5). Turbidity did not change much with depth (Figure A6), but values generally around 20-30 NTUs indicate a lack of clarity, though suspended solids and chlorophyll concentrations were low (Table A1).

Metals concentrations in the lake water were generally very low, often registering below laboratory deionized water blanks (Table A2). The only elements that appeared much above trace levels were manganese, magnesium, and calcium, typical products of mineral weathering. Interestingly, manganese and barium were both somewhat elevated in the hypolimnetic samples suggesting a possible dissolution of these metals in the lake water most closely associated with the underlying soil and rocks.

Results from the pesticide analyses indicated only trace levels of simazine and 2,4-D on one occasion (Table A3).

### *Trophic State Modeling*

Eutromod predictions for trophic state characteristics are compared to observed values from the 1999 summer survey in Table 7. Predicted median nutrient values are comparable to the observed values, while secchi depth is slightly overestimated and chlorophyll a is slightly underestimated.

**Table 7 – Eutromod Predictions – Current Conditions**

| | PREDICTED -1 STD ERR | PREDICTED MEDIAN | PREDICTED +1 STD ERR | OBSERVED MEDIAN |
|---|---|---|---|---|
| | | | | |
| Total P (mg/L) | 0.012 | 0.018 | 0.027 | 0.015 |
| Total N (mg/L) | 0.389 | 0.504 | 0.654 | 0.446 |
| Chlorophyll a (μg/L) | | 4.67 | | 8.15 |
| Secchi Depth (m) | 1.3 | 1.7 | 2.3 | 1.0 |

We believe the general agreement between these predictions and observations indicates that Eutromod is a useful tool for assessment in this watershed. However, we caution that these Eutromod predictions, as well as the other Eutromod inputs and outputs, should not be considered definitive, rather they should be used to provide guidance for possible lake responses to changes in watershed inputs. This modeling exercise should be regarded as the beginning of a process to better understand the functioning of this small watershed. Many model inputs are based on experience and judgement. As more information regarding the watershed is gathered, model inputs should be updated to better reflect the current state of knowledge. The Eutromod inputs and outputs presented in this report are a summary of the information contained in the full spreadsheet. The full Eutromod model in a Microsoft Excel format is available from WRRI upon request.

## Future Conditions

### *Sedimentation*

Eutromod provides an estimate of the current annual sediment load in the Lake Jeanette watershed, based on the Universal Soil Loss Equation (Wischmeier and Smith 1965, USDA 1995). The estimated load from this analysis is approximately 3 x $10^6$ kg/yr (Table 3). Using an estimated sediment trapping efficiency of 0.95 (Figure A-9 in Strand and Pemberton 1987) this becomes a deposition of 2.85 x $10^6$ kg/yr. From the sediment core data, the mean bulk density of deposited sediment is 0.436 g/cm$^3$ (436 kg/m$^3$). Therefore, the annual sediment volume added to the lake is approximately 6.54 x $10^3$ m$^3$ (5.3 acre feet).

With Lake Jeanette in the Type II sediment deposition category, we calculated relative sediment areas ($A_p$) at one-foot depth increments from the reservoir bottom, using the formula:

$$A_p = 2.3240\ p^{0.5}\ (1-p)^{0.4}$$

where p is the relative reservoir depth (Borland and Miller 1960). At each one-foot depth increment we calculated the total sediment volume that would accumulate in the reservoir, and divided that volume by 5.3 acre feet/year to predict future volume (Figure 10a) and areal losses (Figure 10b) under current estimated sediment loading conditions. Under current sediment loading, projected losses in storage capacity are approximately 4%, 8%, 15%, and 21%, by the years 2025, 2055, 2104, and 2146, respectively. Projected areal losses through this time differ with depth. In the northern arm of the lake, in the 4-7 foot depth range, projected losses through 2146 are approximately 9-13%. In the 8-11 foot depth range the estimated losses are approximately 14-19%.

In addition to projecting sedimentation under current estimated sediment loading conditions, the Eutromod model allows prediction under alternative future land-use scenarios. Under the moderate development scenario (conversion of half of the forested land to medium density housing) the estimated sediment load increases from 3 x $10^6$ kg/year to 4.08 x $10^6$ kg/year. With a trapping efficiency of 0.95 and a bulk density of 0.436 g/cm$^3$ the projected sediment volume increases from 6.54 x $10^3$ to 8.89 x $10^3$ m$^3$/year (7.2 acre feet).

Under the extreme development scenario (the conversion of all forested land to medium density housing) the projected sediment load increases to 5.16 x $10^6$ kg/year, or 11.25 x $10^3$ m$^3$/year (9.1 acre feet). Increasing the estimated annual sediment loading effectively speeds up the projected losses in storage capacity and area depicted in figure 10. Under the moderate scenario the depicted losses in capacity and area that correspond to the years 2025, 2055, 2104, and 2146, are pushed forward to 2018, 2040, 2076, and 2107, respectively. Under the extreme development scenario the estimated years by which these same losses will occur are 2014, 2032, 2060, and 2085.

**Figure 10a. Estimated Storage Capacity in Years (bottom to top) 1999, 2025, 2055, 2104, 2146**

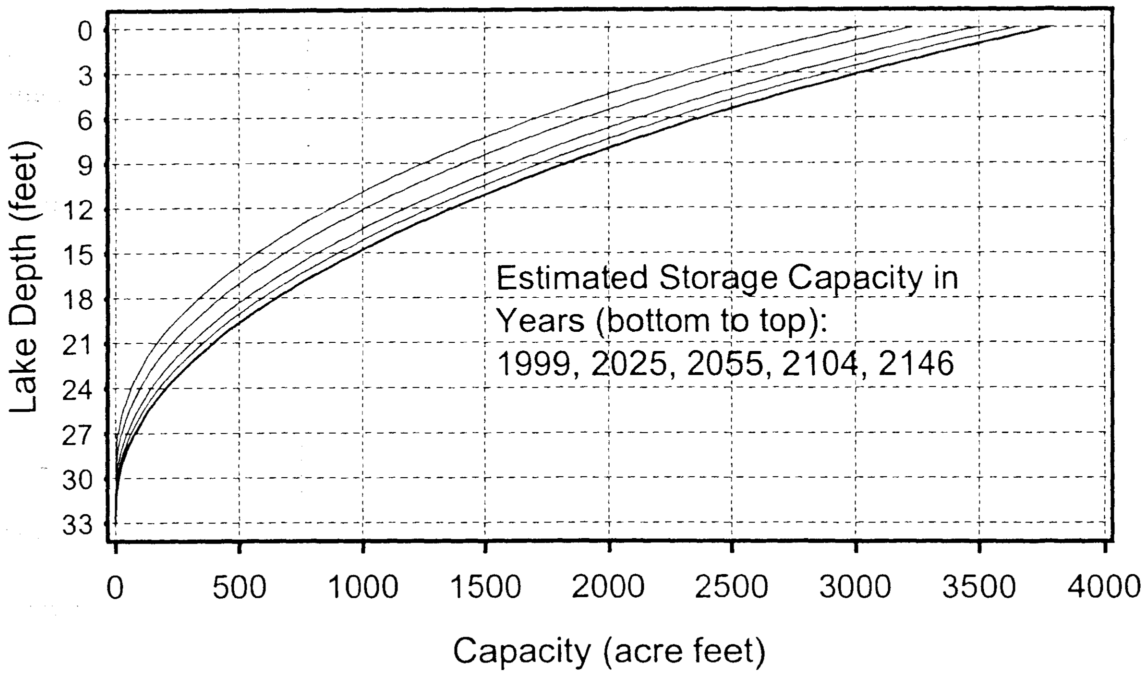
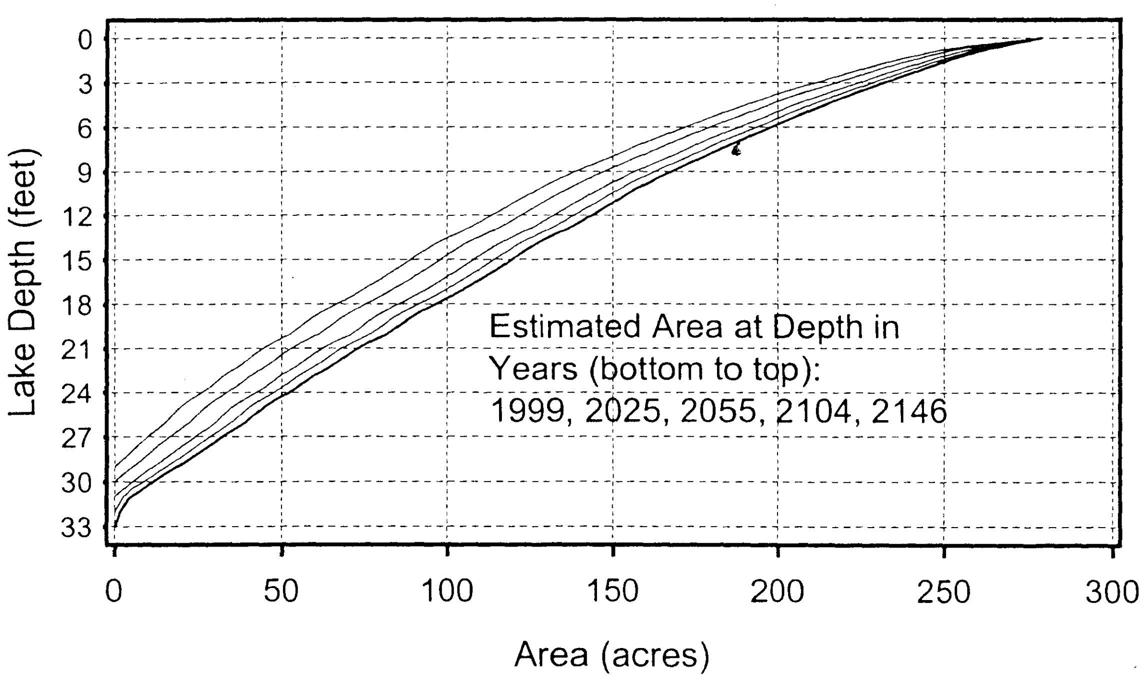



**Figure 10b Estimated Area at Depth in Years (bottom to top) 1999, 2025, 2055, 2104, 2146**



*Water Quality*

Eutromod predicts only modest changes in water quality under the two development scenarios outlined in the previous section (Table 8). Even under the extreme development scenario the estimated annual nitrogen and phosphorus loads to the lake would increase approximately 50%, resulting in very slight changes in water quality. A systematic manipulation of nutrient inputs to the lake using Eutromod indicates that if the nitrogen and phosphorus inputs were both doubled, the chlorophyll a concentration would still only reach approximately 12-13 μg/L. Thus, while land-use changes could substantially influence sediment loading, they are unlikely to produce large changes in lake trophic status.

**Table 8 – Eutromod Predictions – Future Scenarios**

| | PREDICTED MEDIAN CONCENTRATION | | |
|---|---|---|---|
| | CURRENT | MODERATE | EXTREME |
| Total P (mg/L) | 0.018 | 0.019 | 0.021 |
| Total N (mg/L) | 0.504 | 0.550 | 0.613 |
| Chlorophyll a (μg/L) | 4.67 | 5.27 | 6.14 |
| Secchi depth (m) | 1.7 | 1.6 | 1.6 |

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Wischmeier, W.H. and D.D. Smith. 1965. Predicting rainfall-erosion losses from cropland east of Rocky Mountains. USDA Agricultural Handbook No. 282, Washington, DC.

### Publications arising from this work

Cason, R.D. 2000. Characterization of sedimentation and water quality in Lake Jeanette through physical measures and modeling. (Masters Thesis, Nicholas School of the Environment, Duke University, 2000).

Wintergreen, J.T. 2000. Considering water quality and residential development in the Lake Jeanette Watershed: A hedonic analysis. (Masters thesis, Nicholas School of the Environment, Duke University, 2000).

## Appendix A
## Results from the Summer 1999 Water Quality Survey

**Table A1 – Ambient Monitoring Data**

| JUNE 14 | SITE 1 | SITE 2 | SITE 3 | SITE 4 | SITE 5 | SITE 6 |
|---|---|---|---|---|---|---|
| Filtered Orthophosphate (μg/L) | 3.6 | < MDL | < MDL | 4.9 | 2.3 | 2 |
| Unfiltered Total Phosphorus (μg/L) | 24.2 | 22.1 | 23.7 | 32.2 | 24.8 | 29.5 |
| Nitrate + Nitrite (μg/L) | 8.6 | 4.7 | 4.9 | 6.6 | 5.9 | 4.7 |
| Ammonia (μg/L) | 18.8 | 11.3 | < MDL | 12.2 | 12.5 | 12.8 |
| Total N (μg/L) | - | - | - | - | - | - |
| Chlorophyll a (μg/L) | - | - | - | - | - | - |
| Total Suspended Solids (mg/L) | 7 | 5 | 3 | 8 | 6 | 5 |
| Secchi Depth (meters) | 0.6 | 0.8 | 1 | 0.6 | 0.7 | 0.9 |
| Lake Depth (meters) | 3.7 | 6.1 | 7.9 | 2.8 | 5.3 | 8.8 |

| JULY 7 | SITE 1 | SITE 2 | SITE 3 | SITE 4 | SITE 5 | SITE 6 |
|---|---|---|---|---|---|---|
| Filtered Orthophosphate (μg/L) | < MDL | < MDL,<br>< MDL | < MDL | < MDL | < MDL | 2.2,<br>< MDL |
| Unfiltered Total Phosphorus (μg/L) | 6.8 | 4.3,<br>13.5 | 14.1 | 9.2 | 5.0 | 6.2,<br>15.3 |
| Nitrate + Nitrite (μg/L) | 5.7 | < MDL,<br>5.0 | 6.2 | 4.9 | 5.7 | 4.2,<br>7.1 |
| Ammonia (μg/L) | < MDL | < MDL,<br>581.5 | < MDL | 11.9 | < MDL | < MDL,<br>403.2 |
| Total N (μg/L) | 513.8 | 411.7,<br>1,032.7 | 437.9 | 545.3 | 409.4 | 594.2,<br>1,104.6 |
| Chlorophyll a (mg/L) | - | - | - | - | - | - |
| Total Suspended Solids (mg/L) | 2 | 6,<br>9 | 0 | 3 | 4 | 2,<br>5 |
| Secchi Depth (meters) | 1.2 | 1.3 | 1.3 | 1.0 | 1.2 | 1.4 |
| Lake Depth (meters) | 3.4 | 6.1 | 7.6 | 2.9 | 6.1 | 8.5 |

| JULY 28 | SITE 1 | SITE 2 | SITE 3 | SITE 4 | SITE 5 | SITE 6 |
|---|---|---|---|---|---|---|
| Filtered Orthophosphate (μg/L) | < MDL | < MDL | 5.6 | < MDL | 3.5 | 2.5,<br>2.2 |
| Unfiltered Total Phosphorus (μg/L) | 22.7 | 14.6 | 30.8 | 18.2 | 16.7 | 19.7,<br>19.7 |
| Nitrate + Nitrite (μg/L) | 4.8 | 4.1 | 4.9 | 7.4 | 5.5 | 4.2,<br>5.9 |
| Ammonia (μg/L) | 12.0 | 10.4 | 17.6 | 14.0 | 16.4 | 10.6,<br>15.4 |
| Total N (μg/L) | 454.0 | 363.8 | 373.8 | 407.5 | 296.1 | 357.2,<br>433.3 |
| Chlorophyll a (μg/L) | 1.6 | 8.0 | 0 | 11.5 | 1.6 | 8.3 |
| Total Suspended Solids (mg/L) | 6 | 4 | 5,<br>7 | 5 | 3 | 4,<br>7 |
| Secchi Depth (meters) | 1.1 | 1.3 | 1.3 | 1.1 | 1.3 | 1.5 |
| Lake Depth (meters) | 3.6 | 6.4 | 7.9 | 2.9 | 6.4 | 8.8 |

| AUGUST 26 | SITE 1 | SITE 2 | SITE 3 | SITE 4 | SITE 5 | SITE 6 |
|---|---|---|---|---|---|---|
| Filtered Orthophosphate (μg/L) | < MDL | < MDL | < MDL,<br>< MDL | < MDL | < MDL | < MDL,<br>2.6 |
| Unfiltered Total Phosphorus (μg/L) | 24.9 | 17.2 | 12.7,<br>20.3 | 21.7 | 15.4 | 12.2,<br>20.8 |
| Nitrate + Nitrite (μg/L) | 7.5 | 6.8 | 9.7,<br>7.9 | 8.3 | 5.5 | 8.8,<br>9.6 |
| Ammonia (μg/L) | 9.5 | <MDL | 18.9,<br>35.0 | 12.4 | 10.0 | <MDL,<br>483.7 |
| Total N (μg/L) | 506.7 | 471.5 | 562.3,<br>480.5 | 515.3 | 613.5 | 637.4,<br>1,054.1 |
| Chlorophyll a (μg/L) | 13.8 | 6.6 | 9.8 | 16.2 | 9.8 | 3.4 |
| Total Suspended Solids (mg/L) | 8 | 7 | 6,<br>9 | 8 | 6 | 5,<br>9 |
| Secchi Depth (meters) | 0.7 | 1.0 | 1.0 | 0.8 | 1.0 | 1.0 |
| Lake Depth (meters) | 3.5 | 6.0 | 7.9 | 3.3 | 6.4 | 8.5 |

| SEPTEMBER 26 | SITE 1 | SITE 2 | SITE 3 | SITE 4 | SITE 5 | SITE 6 |
|---|---|---|---|---|---|---|
| Filtered Orthophosphate (μg/L) | 3.4 | 3.4 | 2.4,<br>3.1 | 3.1 | 3.1 | 3.1,<br>3.1 |
| Unfiltered Total Phosphorus (μg/L) | 10.9 | 7.5 | 6.5,<br>18.8 | 11.9 | 10.4 | 10.4,<br>18.8 |
| Nitrate + Nitrite (μg/L) | 8.7 | 9.2 | 9.0,<br>8.8 | 7.1 | 7.0 | 7.7,<br>10.9 |
| Ammonia (μg/L) | 26 | 9.8 | <MDL,<br>* | 19.2 | 96 | <MDL,<br>120.7 |
| Total N (μg/L) | 457.8 | 434.3 | 362.9,<br>686.4 | 642.9 | 374.2 | 365.3,<br>570.1 |
| Chlorophyll a (μg/L) | 9.6 | 3.6 | 12.1 | 4.8 | 11.7 | 7.4 |
| Total Suspended Solids (mg/L) | 4 | 2 | 3,<br>7 | 3 | 2 | 1,<br>4 |
| Secchi Depth (meters) | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | 1.2 |
| Lake Depth (meters) | 3.6 | 6.1 | 7.9 | 3.2 | 5.2 | 8.5 |

**Method Detection Limits** (MDL)
Filtered Orthophosphate – 2 μg/L
Nitrate + Nitrite – 4 μg/L
Ammonia – 8 μg/L
Samples from the hypolimnion are the bottom number in any row.
*Above quantification.

## Table A2 – Metals Analysis

| | Be 9 | Mg 26 | Al 27 | P 31 | Ca 48 | V 51 | Cr 52 | Mn 55 | Fe 57 | Ni 60 | Cu | As 75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ppb | ppb | ppb | ppb | ppm | ppb | ppb | ppb | ppb | ppb | ppb | ppb |
| 1e | 0.416 | 2252.9 | 9.750 | 7.895 | 7.095 | -1.232 | 0.564 | 3.072 | 19.989 | 0.198 | 1.397 | 0.768 |
| 2e | 0.416 | 2525.4 | 12.948 | 9.239 | 8.157 | -1.230 | 0.614 | 6.281 | 16.127 | 0.233 | 1.576 | 0.819 |
| 3h | 0.409 | 2720.3 | 14.211 | 12.324 | 11.996 | -1.188 | 0.597 | >160 | 24.733 | 0.303 | 1.539 | 0.794 |
| 3e | 0.418 | 2656.5 | 12.805 | 12.049 | 9.066 | -0.837 | 0.713 | 11.077 | 15.185 | 0.265 | 1.657 | 0.834 |
| 4e | 0.405 | 2431.0 | 32.759 | 9.427 | 8.843 | -1.004 | 0.667 | 3.628 | 17.466 | 0.329 | 1.925 | 0.842 |
| 5e | 0.422 | 2458.0 | 10.862 | 8.675 | 9.135 | -1.014 | 0.615 | 3.068 | 12.229 | 0.234 | 1.553 | 0.833 |
| 6h | 0.417 | 2484.5 | 9.588 | 10.799 | 11.490 | -1.058 | 0.606 | >160 | 16.094 | 0.390 | 2.066 | 0.799 |
| 6e | 0.395 | 2255.1 | 8.837 | 7.645 | 9.495 | -0.942 | 0.577 | 3.603 | 10.444 | 0.205 | 1.943 | 0.773 |
| FB | 0.450 | 2.839 | 3.333 | 2.589 | 0.788 | -1.401 | 0.714 | 1.248 | 7.316 | 0.126 | 0.806 | 0.090 |
| Lab DI | 0.427 | -10.73 | -0.779 | 0.214 | 0.159 | -0.138 | 0.482 | 0.816 | 0.207 | 0.028 | 0.466 | 0.036 |

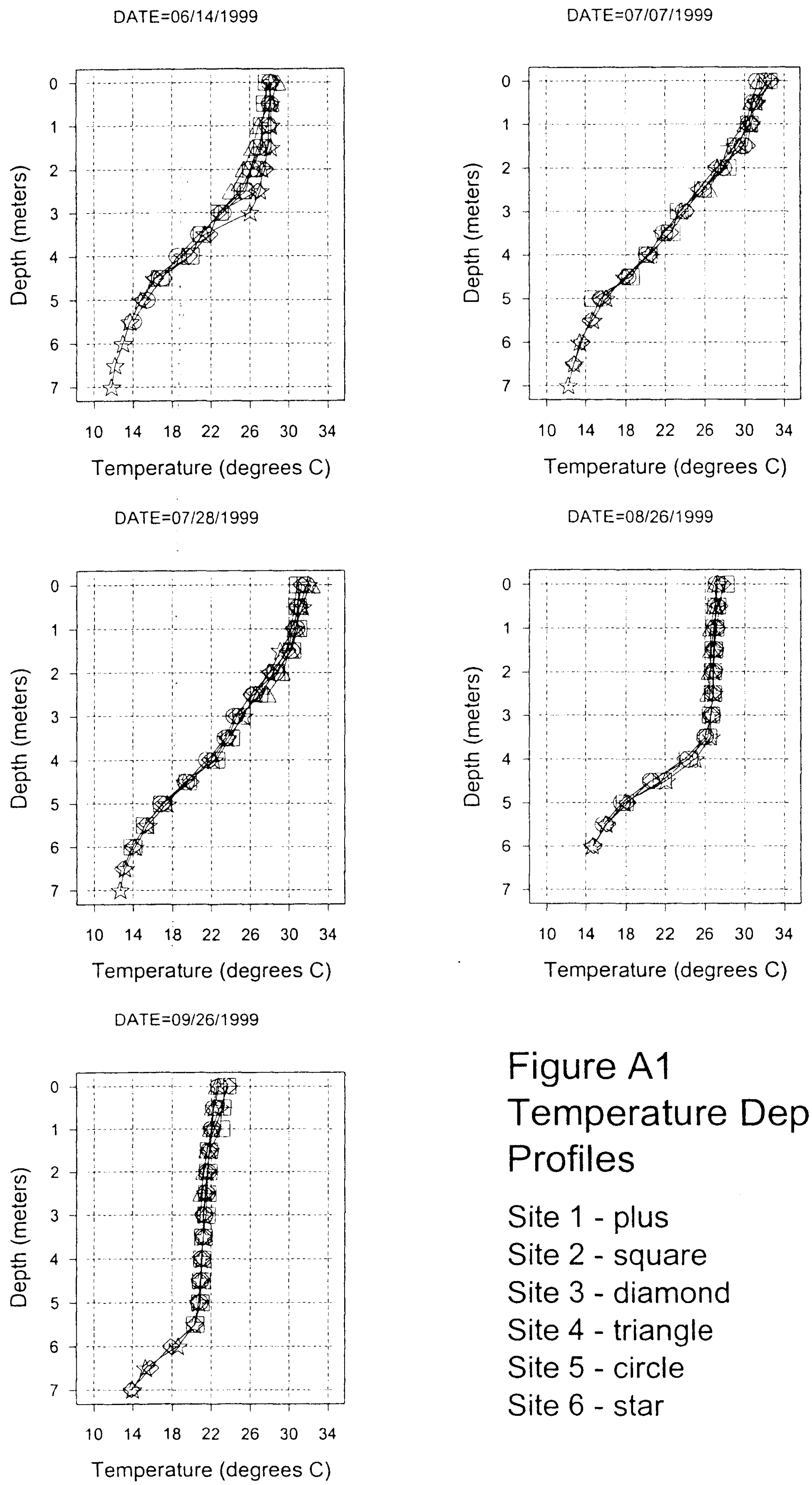
| | Se 78 | Rb 85 | Sr 86 | Mo | Ag | Cd | Sb | Cs 133 | Ba 137 | Ce 140 | Pb | Th 232 | U 238 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ppb | ppb | ppb | ppb | ppb | ppb | ppb | ppb | ppb | ppb | ppb | ppb | ppb |
| 1e | -0.38 | 4.809 | 66.917 | 2.329 | 0.061 | 0.137 | 0.382 | 0.074 | 11.861 | 0.544 | 0.059 | 0.878 | 0.795 |
| 2e | -0.04 | 5.203 | 72.828 | 2.360 | 0.057 | 0.138 | 0.288 | 0.073 | 12.100 | 0.517 | 0.049 | 0.572 | 0.785 |
| 3h | 0.127 | 5.422 | 101.18 | 2.378 | 0.057 | 0.151 | 0.250 | 0.076 | 43.104 | 0.556 | 0.065 | 0.534 | 0.785 |
| 3e | 0.597 | 5.224 | 72.187 | 2.221 | 0.056 | 0.168 | 0.251 | 0.086 | 10.974 | 0.837 | 0.208 | 0.576 | 1.086 |
| 4e | -0.22 | 5.049 | 72.343 | 2.295 | 0.055 | 0.182 | 0.402 | 0.074 | 12.564 | 0.532 | 0.081 | 0.448 | 0.797 |
| 5e | 0.122 | 5.144 | 72.619 | 2.207 | 0.055 | 0.144 | 0.241 | 0.072 | 11.706 | 0.508 | 0.044 | 0.416 | 0.784 |
| 6h | 0.549 | 5.057 | 86.868 | 2.963 | 0.061 | 0.177 | 0.350 | 0.073 | 18.594 | 0.530 | 0.083 | 0.437 | 0.780 |
| 6e | -0.42 | 4.775 | 69.338 | 2.431 | 0.058 | 0.142 | 0.232 | 0.069 | 11.315 | 0.503 | 0.056 | 0.389 | 0.775 |
| FB | 1.181 | -0.029 | -0.524 | 1.980 | 0.135 | 0.169 | 0.355 | 0.072 | -1.576 | 0.691 | 0.211 | 0.445 | 1.075 |
| Lab DI | 0.425 | -0.030 | -0.852 | 0.016 | 0.053 | 0.133 | -0.02 | 0.072 | -1.848 | 0.486 | 0.020 | 0.323 | 0.770 |

FB = field blank, Lab DI = laboratory blank, e = sample from epilimnion, h = sample from hypolimnion

**Table A3 – Pesticides Analysis**

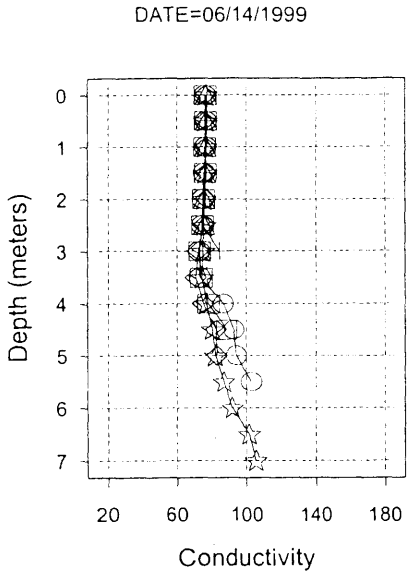
| Sample Location | Atrazine | Chlorpyrifos | Chlorothalonil | Simazine | 2,4-D |
|---|---|---|---|---|---|
| | | | | | |
| Date: 7/20/1999 | | | | | |
| Richland Creek | nd | nd | nd | nd | nd |
| South Creek | nd | nd | nd | nd | nd |
| Site 4, epilimnion | nd | nd | nd | nd | 0.89 |
| Site 3, epilimnion | nd | nd | nd | nd | nd |
| Site 3, hypolimnion | nd | nd | nd | 0.09 | nd |
| Site 1, epilimnion | nd | nd | nd | nd | nd |
| | | | | | |
| Date: 8/26/1999 | | | | | |
| Richland Creek | nd | nd | nd | nd | nd |
| South Creek | nd | nd | nd | nd | nd |
| Site 4, epilimnion | nd | nd | nd | nd | nd |
| Site 3, epilimnion | nd | nd | nd | nd | nd |
| Site 3, hypolimnion | nd | nd | nd | nd | nd |
| Site 1, epilimnion | nd | nd | nd | nd | nd |
| | | | | | |
| MCL (ug/L) | 3 | none | none | 4 | 70 |
| Detect Limit (ug/L) | 0.05 | 0.1 | 0.07 | 0.05 | 0.7 |

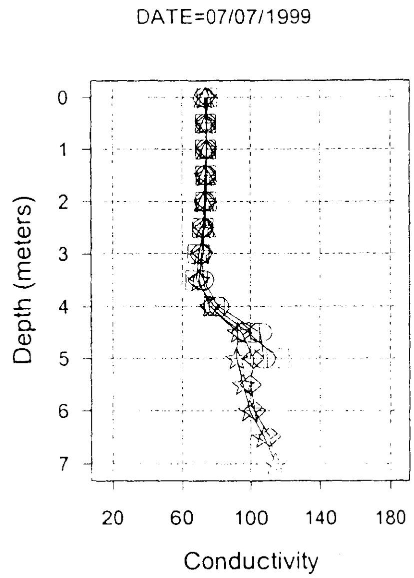
nd = not detected

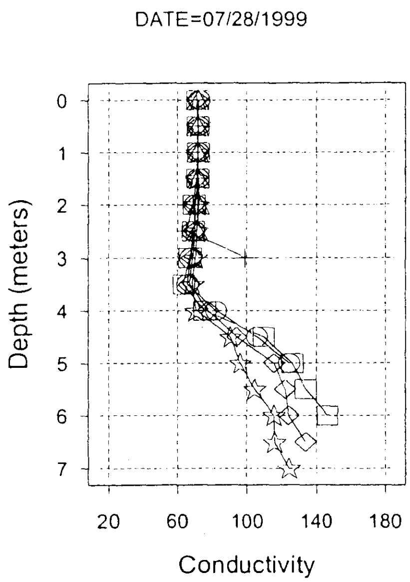


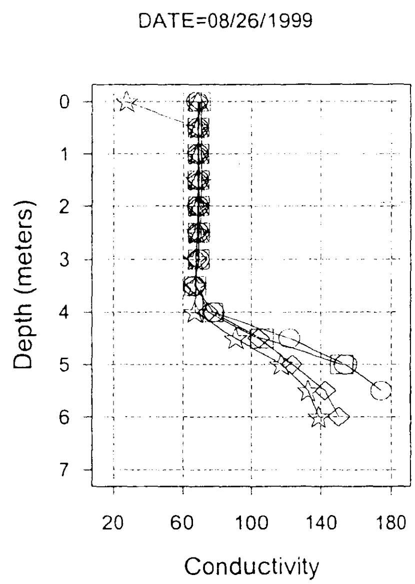

# Figure A1
# Temperature Depth Profiles

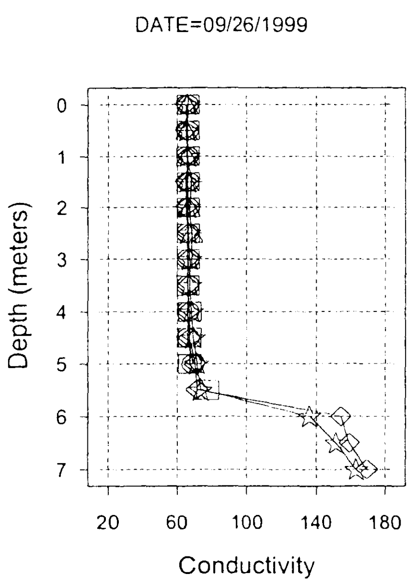
Site 1 - plus
Site 2 - square
Site 3 - diamond
Site 4 - triangle
Site 5 - circle
Site 6 - star



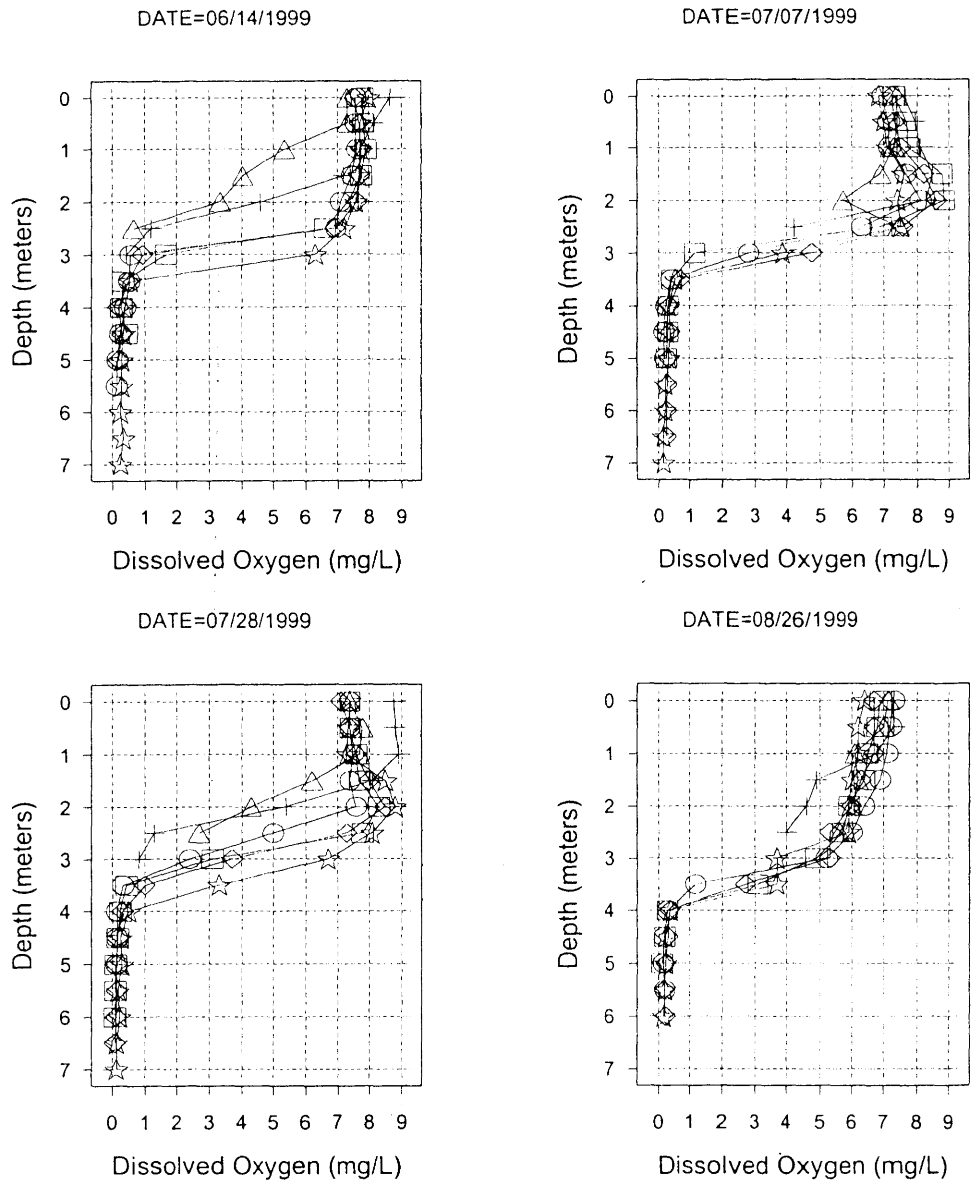



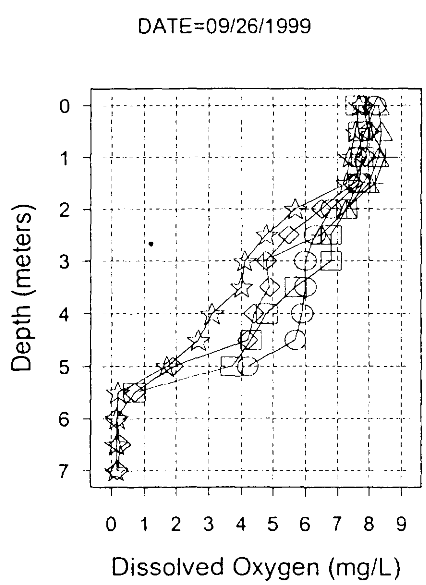




# Figure A2
# Conductivity Depth Profiles

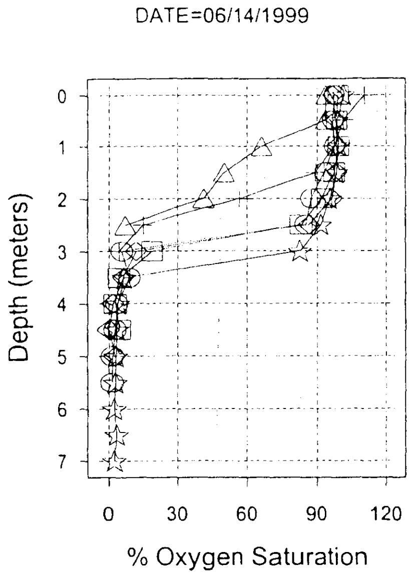
Site 1 - plus
Site 2 - square
Site 3 - diamond
Site 4 - triangle
Site 5 - circle
Site 6 - star

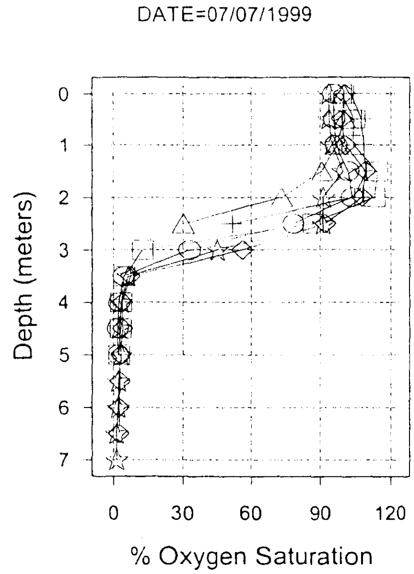


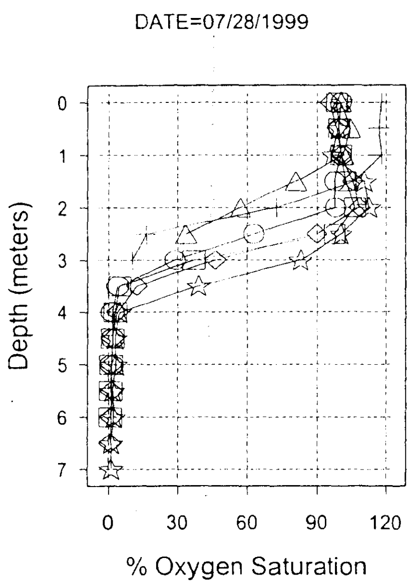



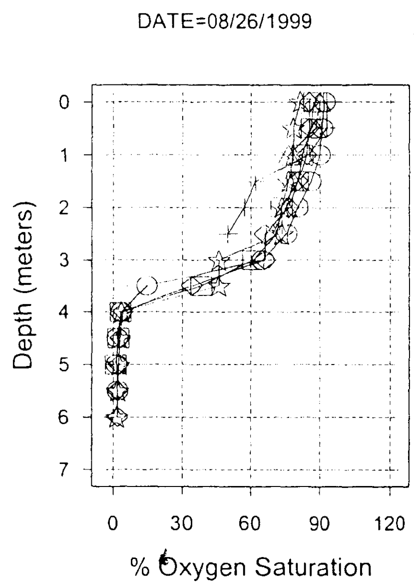

# Figure A3 Dissolved Oxygen Depth Profiles

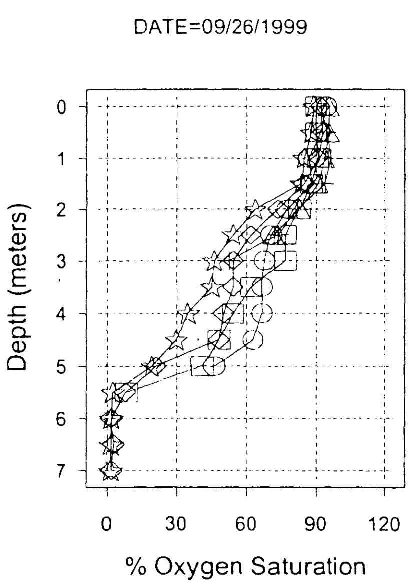
Site 1 - plus
Site 2 - square
Site 3 - diamond
Site 4 - triangle
Site 5 - circle
Site 6 - star



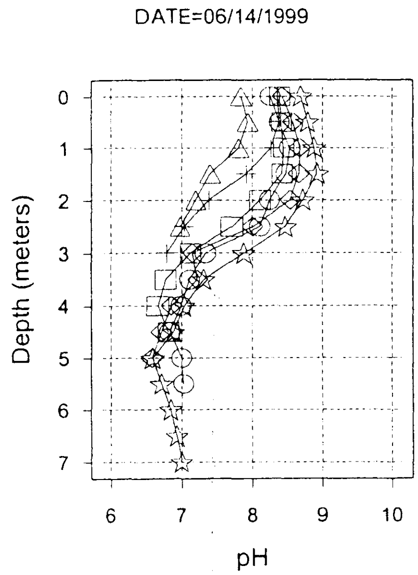



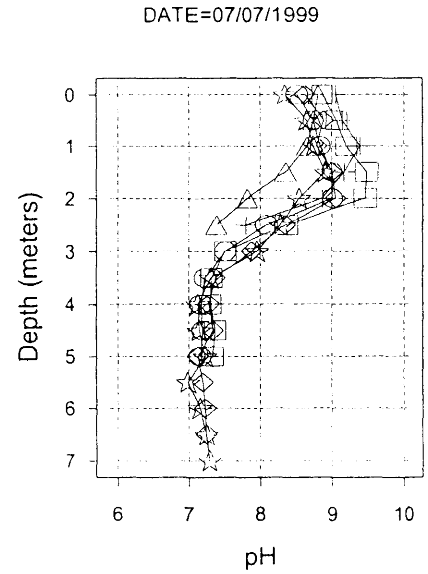



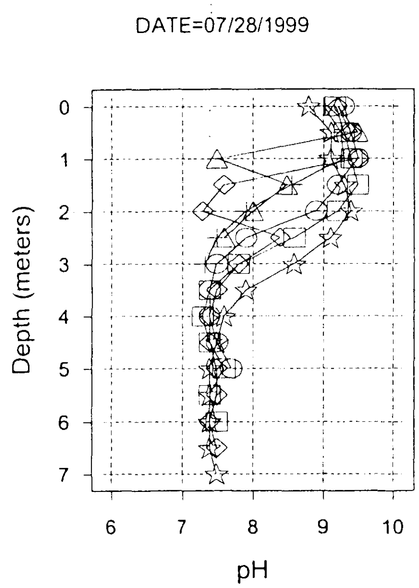



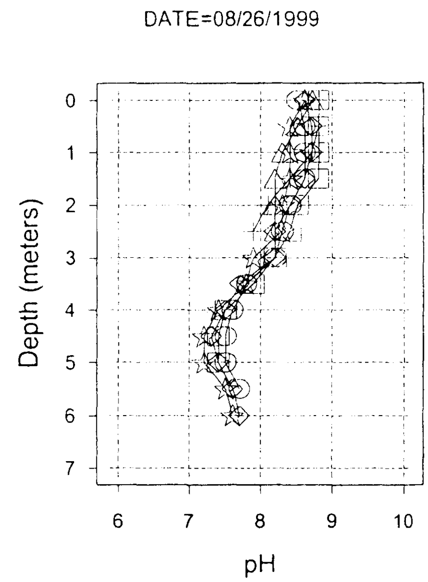

# Figure A4
# Oxygen Saturation Profiles

Site 1 - plus
Site 2 - square
Site 3 - diamond
Site 4 - triangle
Site 5 - circle
Site 6 - star



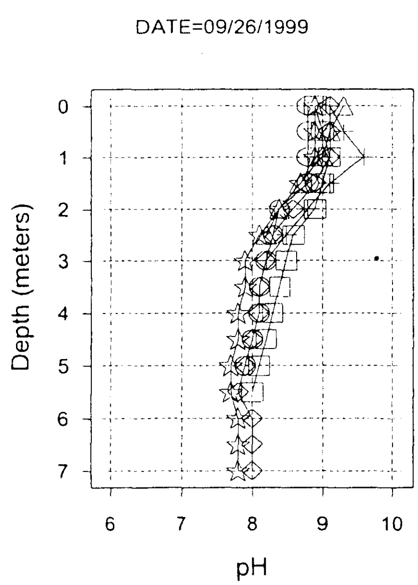
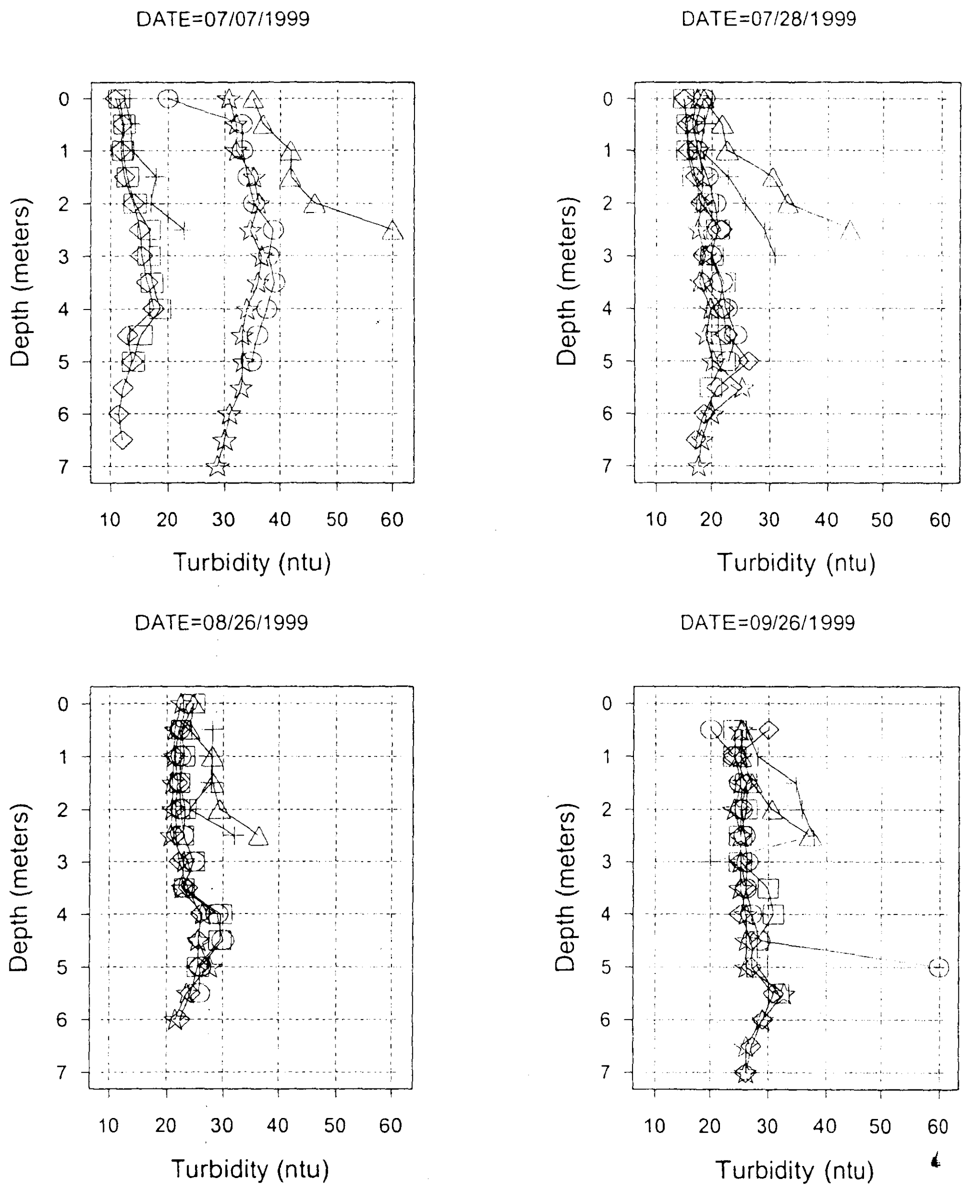




Figure A5
pH Depth
Profiles

Site 1 - plus
Site 2 - square
Site 3 - diamond
Site 4 - triangle
Site 5 - circle
Site 6 - star




# Figure A6
# Turbidity Depth Profiles

Site 1 - plus
Site 2 - square
Site 3 - diamond
Site 4 - triangle
Site 5 - circle
Site 6 - star