University of Alabama at Birmingham

Department of Civil and Environmental Engineering

Summary of
Graduate Non - Thesis Research Project

The Use of Peepers to Measure Nutrient and Bacteria Stratification in Urban Lake Sediments

By

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I. Overview

A. Methodology

The bottom sediment of lakes is comprised of particles that have been transported by both natural processes and human activities. Natural processes affecting lake sediment may be both biological and chemical, which may result in the accumulation of nutrients and bacteria species throughout the bottom sediment. Natural water bodies such as lakes and creeks are also vulnerable to human activities. Human activities may result in the deposition of various bacteria species, nutrients, and contaminants into lake sediment. Anthropogenic contaminants may enter a lake through storm water run-off and the direct discharge of various compounds.

Contaminants located in bottom sediment are referred to as "in-place toxics" and may pose a threat to water quality, as well as biological and human life. Thus, there is a need to determine the concentrations of contaminants located within bottom sediment in order to monitor water quality. Studies have indicated that a distribution equilibrium of contaminants has been established among the bottom sediment of various water bodies. This equilibrium is "established among suspended and bottom sediments, sediment pore water, overlying water column and biota." The equilibrium component of interest in this study is sediment porewater (MacKnight and Murdoch, 1-2).

The depth profile of various parameters of interest in aquatic systems may be viewed using sediment porewater samples. There are two main methods used for retrieving porewater sediment samples: separation of porewater from sediments collected using grab samplers and coring devices, and by in situ sampling devices. The basic methods for separating porewater from sediment samples includes the following (Brandl and Hanselmann, 56)):

1) Supernatants after centrifugation of sliced sediment cores (Sholkovitz 1973, Emerson 1976)
2) Pressure filtrates of sliced sediment cores (squeeze water) (Stuab 1981, Presley et al. 1967)

3) Porewater expelled through sampling ports from pressurized intact sediment cores (Bender et al. 1987, Jahnke 1988)
4) Samples obtained by suction of porewater into a sampling device (Sayles et al. 1973)

The main method of recovering porewater is from in situ devices. Porewater collection from grab samplers and coring devices may alter concentrations of dissolved species within the porewater sample due to changes in collection temperatures and pressures from the in situ conditions. The collection of porewater samples outside the benthic environment may also allow for the oxidation of the sample during the sample retrieval. The use of in situ samplers avoid these problems because the samples are collected within the aquatic environment (MacKnight and Murdroch, 179). The technique of interest in this study is the use of the equilibrium diffusion technique (Hesslein 1976, Brandel and Hanselmann 1981).

The equilibrium diffusion technique developed by Hesslein in 1976, consists of the use of porewater equilibrators known as peepers to obtain a stratified porewater sample. Hesslein's peepers have been modified by various studies since their initial introduction, but the basic design of the peeper has remained the same. Heisslein's peeper consists of two-pieces of acrylic plastic, a 0.3 cm cover piece and a 1.3 cm thick body. The body portion of the peeper contains a series of horizontal compartments to be filled with de-ionized or distilled water. A piece of nylon mesh membrane is laid over the body of the instrument, and it is held together by a series of stainless steel or plastic screws. The peeper is placed into sediment and allowed to equilibrate for a chosen period of time (Hesslein, 912 - 914).

Hesslein's technique was based on the premise that once equilibrium is established among the deionized cell water of the peeper and the surrounding lake water, the concentration of deionized water within the peeper would be equal to the lake water at the corresponding depth. Heisslein's studies indicated that stratification of pollutants may be observed using

peepers and have lead to many other studies using various modifications to Heisslein's peeper design (MacKnight and Murdoch, 179).

B. Objective

The objective of this study is to test several modifications to the traditional peeper design. After reviewing Hesslein's work, Dr. Robert Pitt of the University of Alabama at Birmingham made the following modifications to Hesslein's porewater analysis:

1) The use of a larger aperture screen than previously tested. The monofilament mesh screen used in this study is 75 - microns.
2) Bacteria analysis is conducted using a small volume of sample.
3) A short equilibration time will be tested. An equilibration time of 2 hours will be used versus Hesslein's equilibration time of approximately one week.
4) A slight change in the size and material of the instrument to prevent breakage.

An illustration of the peeper used in this study is found in appendix A. A second objective of this study is to demonstrate the effectiveness of the modified peepers in measuring bacteria and nutrient stratification in contaminated urban lake sediments.

II. Materials and Locations

A. Materials

There was a variety of materials used in this study for both field and laboratory work. Materials used to conduct the field work include the following:

- 10 machined Delrin™ pore water samplers
- 75 micron monofilament nylon mesh
- stainless steel screws
- de-ionized water
- drill
- sautering iron
- syringes
- 60 ml plastic bottles
- yardstick
- coolers containing ice packs
- sharpie markers

The following materials used for the laboratory analysis were adapted from Standard Methods for the Examination of Water and Wastewater:

- deionized water
- Horiba pH meter and calibration solutions
- Horiba conductivity meter and calibration solution
- spectrophotometer
- chemical standards for all reagents
- 1 ml automatic pipette
- 2 ml glass pipette and bulb
- Chem wipes
- 50 ml plastic beakers
- Test tubes
- glass stirrer

Study Site # 3: Star Lake

Star Lake is located within a suburban residential area off of Patton Chapel Road in Hoover, Alabama. The lake was developed as a stormwater detention pond and is approximately 1/8 of a mile in width and 1/16 of a mile in length. Star lake is surrounded by a gravel path used for walking and running, and the only recreational use of the lake is fishing. The lake water is murky and the bottom surface of the lake is rocky with a slimy texture.

III. Procedure

A. Setup

Each segment of this study was performed over a two-day period. Prior to going out in the field, the peepers were washed with phosphate free detergent and allowed to dry. Each compartment of the peepers was filled with deionized water by simply pouring the water from a beaker cleaned with phosphate free detergent. One piece of 75 micron monofilament mesh was cut to fit each peeper, and was placed directly over the water-filled peeper. The top portion of the peeper was then placed directly over the mesh and screws were inserted to hold the peeper together. Prior to inserting the screws, a sautering iron was used to make holes in the mesh for the smooth insertion of the screws. Once the peepers were assembled, they were laid flat and transported to the study site.

B. Field Work

The study area at each site was determined by prodding the sediment with a yard stick to find an area relatively free of obstructions for easy insertion of the peepers. The depth to which the peepers were inserted into the sediment was limited to the depth they could be physically placed into the sediment. In order to insert the peepers at a uniform depth throughout the sediment, the distance from the sediment to the top of the first peeper was determined by placing a yard stick next to the peeper. Subsequent peepers were then placed into the sediment approximately one foot apart at the determined depth. Once all of the peepers were in place, they were allowed to equilibrate for a two-hour period. During this period, water and sediment samples were collected within the area for further laboratory analysis. Once the two-hour equilibration period had elapsed, the peepers were carefully removed by pulling them vertically from the water. The peepers were laid flat and immediately transported to the laboratory.

C. Laboratory Analysis

Upon arrival at the lab, the peepers were immediately disassembled. In order to prevent cross contamination, the mesh was removed by rolling it from the left to the right of the peeper. The porewater samples were retrieved by the use of a separate sterile, plastic syringe for each level of sediment and water stratification. The pH and conductivity of the pooled porewater samples* were determined and the samples were placed in sterile, 60 ml plastic vials. Bacteria tests for Total Coliforms, *E. coli*, and Enterococci were conducted immediately on the samples using IDEX sample plates. Once the bacteria tests were completed, the samples were tested according to the following HACH standard methods tests:

Test Species	**Method Number**
Total Phosphorus (mg/L PO_4^{3-})	8190
Phosphate (mg/L PO_4^{3-})	8048
Total Nitrogen (mg/L N)	10071
Nitrite (mg/L NO_2^- - N)	8507
Nitrate (mg/L NO_3^- - N)	10020
Ammonia (mg/L NH_2Cl-N)	10045

The sediment samples collected were oven dried and tested for the carbonaceous oxygen demand and percent volatile solids**. The laboratory work was concluded by the use of a hydrometer to determine the particle size composition of the sediment for each site***.

*The stratification levels were determined by first subtracting the distance from the top of the sediment to the top of the peeper from the total length of the peeper. This resulting distance was the depth of the peeper into the sediment. The determined distance was then divided into various stratification levels relating to sediment depth, and the pore water cells were pooled together within the given distance. The remaining length of the peeper indicated the level of water stratification and was divided accordingly.

**Tests were conducted by members of University of Alabama at Birmingham's Environmental Lab.

***Test was conducted by Auburn University's Soil Testing Laboratory.

IV. Results

The numerical results of the study indicate that vertical stratification may be observed using the modified peepers. The numerical results of the study are found in appendix C.

A. Numerical Results for Study Site #1: Eastlake

1) Phosphorus Species

The results from the Eastlake study site indicate that the phosphorus concentrations varied between total phosphorus and phosphate concentrations. The total phosphorus concentration increased with increasing sediment depth from the sediment-water interface and increased as water levels approached the water surface. Phosphate concentrations were non-existent in the sediment, while they increased as the water level approached the surface.

2) Nitrogen Species

The total nitrogen concentrations were found to increase with increasing depth from the water surface to the bottom sediment, while free ammonia concentrations remained constant in the water column and increased with increasing sediment depth. Eastlake contained only minute concentrations of nitrite in both the water column and in the sediment. Nitrate concentrations varied throughout the water column, and were absent from the bottom and mid-sediment. The concentration of the nutrient jumped sharply from 0 to 0.2 at the mid-sediment and sediment-water interface, and was greatest at the water interface.

3) Bacteria Tests

The bacteria populations found in the lake all increased with increasing depth of the sediment. *E. coli* and Total Coliform concentrations increased from the water surface to the bottom sediment, while Enterococci concentrations increased from the sediment-water interface to the water's surface.

4) Physical Species

The pH of the lake was found to increase as the distance from the bottom of the sediment to the top of the water increased. The conductivity of the samples fluctuated with the highest levels found near the water's surface.

B. Numerical Results for Study Site #2: Oak Mountain

1) Phosphorus Species

Concentrations of phosphorus species varied significantly at the Oak Mountain study site. The total phosphorus concentrations rapidly increased from the sediment-water interface to the bottom sediment. The bottom-water total phosphorus concentration was 0.83 mg/L as PO_4^{3-}, while the concentration at the sediment-water interface was 4.98 mg/L as PO_4^{3-}. The total phosphorus concentration of the bottom sediment could not be determined because it was over the detection limit of the spectrophotometer. In contrast to the total phosphorus concentrations, phosphate concentrations at the study site were negligible in the sediment, while concentrations were found to be greatest at the bottom water stratification level.

2) Nitrogen Species

Nitrogen species noted for this site included nitrite, nitrate, and free ammonia. Nitrite concentrations were negligible in the water column, but increased rapidly in the sediment column. Sediment nitrite concentrations increased from 0.011 mg/L as NO_2^- to values over the range of detection of the spectrophotometer. Nitrate was found to be the nutrient in greatest concentration at the Oak Mountain site. Concentrations of nitrate ranged between 0.3 and 0.5 mg/L NO_3^- in both the water column and the sediment. Concentrations were found to be too small to be detected by the spectrophotometer in the bottom sediment layer. The concentration of free ammonia at the site varied among each layer of stratification. The level of free ammonia was greatest in the bottom sediment

layer, with a value of 0.45 mg/L NH_3 - N, while concentrations decreased from the bottom water stratification level through the entire water column.

3) Bacteria Tests

As seen with the Eastlake study site, Total Coliform and *E. coli* concentrations increased from the mid-water levels to the bottom sediment. A large number of total coliform, 9804 organisms, was found on the top level of stratification of the water column. Enterococci were not found in the water column, and only a small number of the organisms, were found in the sediment.

4) Physical Characteristics

Both the pH and the conductivity at the study site were found to decrease from the top of the water column through the sediment. The pH of the top level of the water column was found to be 7.37, while the pH of the bottom sediment was 6.37. The conductivity of the water column varied from 49 to 46 us/cm, while the conductivity was 42 us/cm throughout the sediment.

C. Numerical Results for Star Lake

1) Phosphorus Species

Total phosphorus levels of the lake were in highest concentration in the water column, with the greatest concentration found at the water interface. Total phosphorus levels found in the sediment increased with increasing depth of sediment. The concentration of phosphate was also greatest in the water column of the lake, with values ranging from 0.21 to 0.61 mg/L. Sediment levels of phosphate were minimal, with values under the range of detection of the spectrophotometer.

2) Nitrogen Species

The concentration of total nitrogen increased from 3 mg/L at the top of the water column to 6 mg/L at the sediment water interface. The concentration of total nitrogen was

greatest at the interface, but decreased throughout the remainder of the sediment column. Star lake was found to have only minute concentrations of nitrite, with the greatest concentration, 0.086 mg/L, found at the water interface. Both nitrite and free ammonia concentrations of the lake fluctuated throughout the water column. Nitrate concentrations ranged from 0.2 to 0.5 mg/L throughout both the sediment and water stratification levels. The highest nitrate concentrations were found in the mid-sediment stratification level. Free ammonia concentrations ranged from 0.1 to 0.44 mg/L. The concentration of free ammonia in the water column was much lower than the concentrations found in the sediment. The water column concentrations raged from 0.1 to 0.2 mg/L, while sediment concentrations ranged for 0.12 to 0.44mg/L. The concentration of free ammonia was greatest in the bottom sediment layer.

3) Bacteria Tests

The total coliform population Star lake behaved unlike any of the populations studied at Eastlake and Oak Mountain. The number of Total Coliform increased throughout upward, vertical stratification. The number of Total Coliform was greatest at the top layer of vertical stratification of the water column and was least in number in the bottom sediment. The population of *E. coli* varied throughout the stratification levels. *E. coli* were found to be in greatest number in the midwater stratification level. Enterococci were in small number at Star lake. The population of organisms did not exceed 20 in any level of stratification.

4) Physical Characteristics

Both the pH and the conductivity of the lake fluctuated throughout the various levels of stratification. pH values of the lake ranged from 7.47 to 8.01. The conductivity of the lake varied throughout the water column, but increased with downward, vertical stratification of the lake.

D. Statistical Results

The data was statistically analyzed to compare nutrient and bacteria concentrations of the water with those of the sediment. Two-tailed, t-tests with an alpha value of 0.05 were performed on Microsoft's Excel. Statistically significant points were those with t-values less than the alpha value of 0.05. The results of these tests are found in appendix D.

1) Phosphorus Species

Phosphate was the only phosphorus species found to be significant. The Star lake and Oak Mountain study sites were found to have statistically significant differences between the water and the sediment. Star Lake had a t-value of 0.01, while Oak Mountain was found to have a t-value of 0.05. The t-test did not reveal any statistically significant values for total phosphorus.

2) Nitrogen Species

The only nitrogen species for which statistically significant differences were found between the sediment and the water was total nitrogen. The total nitrogen concentration at Eastlake yielded a t-value of 0.03. The total nitrogen concentrations for Oak Mountain could not be determined due to lack of data for the study site.

3) Bacteria Species

The number of Total Coliforms found at the Oak Mountain site were determined to be statistically significant with a t-value of 0.01. Water and sediment concentrations of E. coli and Enterococci were not found to be statistically significant.

E. Graphical Results

Data collected was graphed on Sigma Plot and may be found in Appendix E.

V. Suggestions for Future Studies

Conducting a pilot study enabled me to discover and correct potential problems associated with the assembly and the use of the peepers. A problem encountered during the assembly of the instrument was with the insertion of the screws through the monofilament mesh layer. A sautering iron was used to form a hole in the mesh prior to inserting the screw. The mesh had a tendency to tangle up when the screw was inserted and drilled into place. The process was time consuming and very tedious. Prior to performing future studies with the peepers, a method should be developed of pre-fitting the mesh to better fit the size of the screw.

Proper sterilization of the peepers should also be considered prior to performing future studies. The peepers were cleaned with phosphate-free detergent and rinsed with deionized water. Though this method removed excess water and sediment from the instrument, it did not sterilize the instrument. This lack of sterilization may prove to interfere with bacteria and nutrient tests due to the deposition of samples on the peeper from previous studies. Autoclaving is not a possible technique for sterilization, because the Delrin™ material cannot withstand high temperatures associated with the method.

Problems were also encountered during the actual insertion of the peeper into the sediment. Physically inserting the peepers into the sediment proved to be a problem. As discussed previously, the limiting factor in determining the depth to which the peepers were inserted into the sediment was found to be the physical strength of the person actually placing the instrument into the sediment. Insertion of the peeper caused lake sediment to be disrupted, therefore, interfering with the natural stratification layers of the lake. Disruption of bottom sediment experienced in the actual insertion of the peeper increased the tendency of the sediment to accumulate in the porewater slots. The sediment would clog various cells and make the removal of the water samples difficult. The presence of sediment within the samples also decreases the sample volume available for testing and increases the turbidity of the remaining sample volume. Because the spectrophotometer operates on a light-based analyzer, porewater samples containing large amounts of sediment could not be analyzed due to increased turbidity levels.

A possible solution to both of these encountered problems may be the addition of a metal sleeve to be placed around the peeper during insertion into the sediment. The sleeve would have a sharp tip that would aid in the actual insertion of the instrument through the various sediment layers. A sharp tipped addition to the peeper would facilitate placement into the sediment, and thus, reduce the amount of sediment disruption initially caused by insertion of the instrument. This would allow for the sediment to remain in natural stratification layers, and reduce the amount of mixing of bacteria and nutrients between the various layers. An added sleeve would also help to prevent clogging of the porewater cells by the disrupted sediment. The sleeve would be designed to be slipped on the peeper and would be removed upon insertion into the sediment.

A final factor to be taken into consideration prior to performing the experiment is the need for constant monitoring of the study site. The peepers need to be observed throughout the entire equilibration time to prevent outside interference on the study. During the pilot study, one of the peepers was removed from the sediment by a man near the chosen study site. This factor needs to be taken into consideration before beginning a study scheduled to have a lengthy equilibration time.

VI. Conclusions

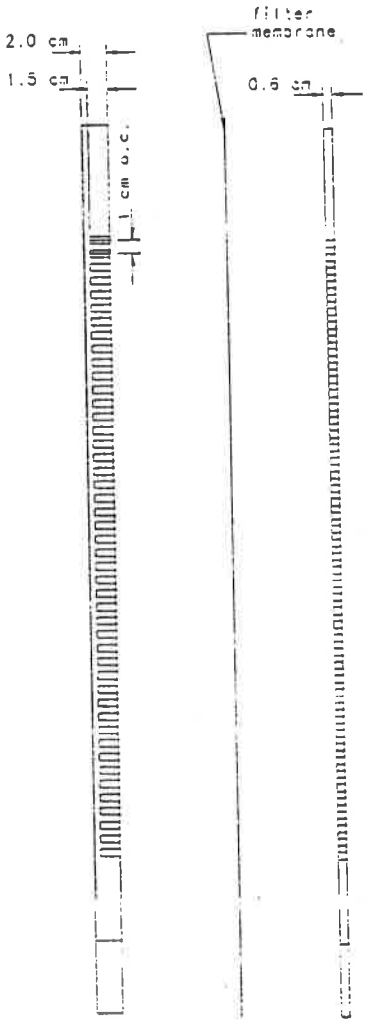
There were several conclusions drawn from this study. The first conclusion is that stratification of nutrients can be observed using the modified peepers. Though the statistical results of this study did not yield this conclusion, stratification was evident in the analysis of the numerical data, and was displayed by the graphical data. Thus, it may also be concluded that the modified peepers have sufficient resolution to show stratification of nutrients and bacteria within sediments.

The second main conclusion drawn from this study is that peepers allow for rapid testing of sediment and interstitial waters. Results of this study show that a two-hour equilibration time was sufficient to show vertical stratification of the lake sediment. A grab sample of lake water was collected at each study site and tested in the same manner as the porewater samples. The stratified porewater samples were often in higher concentrations of the nutrients and bacteria than the grab sample itself, thus, it is evident that a two-hour equilibration period is a sufficient amount of time to allow the equilibrium diffusion process to occur.

A final conclusion drawn from this study is that stratification of bacterial populations exists in sediments of shallow urban water bodies. As seen in the results section, bacteria concentrations remained high in sediments several centimeters deep, and often increased with increasing sediment depth.

Appendix A: Illustration of Peeper

Illustration of Peeper



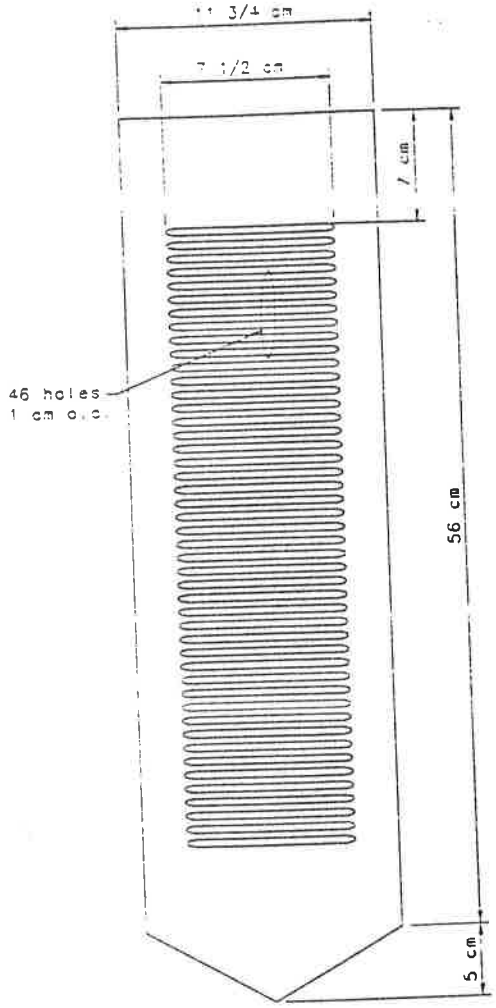


Figure A *Figure B* *Figure C*

Figure A: Main Body of the Peeper Consisting of Forty-Six Horizontal Slots Spaced One Centimeter Apart
Figure B: Seventy - Five Micron Filter Membrane
Figure C: Cover Piece

Illustration Taken from Wynn C. Echols, Jr.'s Graduate Non-Thesis Research Project at the University of Alabama at Birmingham.

Appendix B: Pictures of Study Sites

Study Site # 1: Eastlake

Study Site # 2: Oak Mountain

Study Site # 3: Star Lake

Appendix C: Numerical Results

I. Eastlake

Nitrogen Species

Sample Type	Total Nitrogen	Nitrite	Nitrate	Ammonia
	(mg/L N)	(mg/L NO_2^-)	(mg/L NO_3^-)	(mg/L NH_2Cl-N)
lake water	1	0.005	0.1	0.26
lake water	1	0.005	0.2	0.26
lake water	1	0.003	0	0.26
top-water	1	0.008	0.2	0.27
mid-water	1	0.008	0.5	0.26
water interface	1	0	0.6	0.26
sediment interface	12	0	0.2	0.26
mid-sediment	13	0	0	0.28
bottom sediment	3	0.007	0	0.36
blank	0	0.001	0.4	0.25
standard actual value	10	0.23	4.9	OR
standard value	10	0.25	5	0.25

Phosphorus Species

Sample Type	Total Phosphorus	Phosphate
	(mg/L PO_4^{3-})	(mg/L PO_4^{3-})
lake water	0.85	0.2
lake water	0.55	0.09
lake water	0.39	0.05
top-water	0.21	0.06
mid-water	0	0.03
water interface	0.26	0.02
sediment interface	1.04	0.13
mid-sediment	1.26	0
bottom sediment	3.65	0
blank	0.31	0.04
standard actual value	OR	OR
standard value	2.5	2

I. Eastlake continued

Bacteria Species

Sample Type	Total Coliforms	*E. coli*	Enterococci
lake water	10462	364	156
top-water	>24192	121	85
mid-water	10462	86	30
water interface	12997	288	20
sediment interface	11192	262	41
mid-sediment	24192	537	52
bottom sediment	>24192	984	171
* per 100 ml			

Physical Species

Sample Type	pH	Conductivity
		(us/cm)
lake water	8.86	0.29
top-water	8.63	0.31
mid-water	8.63	0.22
water interface	8.63	0.26
sediment interface	8.45	0.23
mid-sediment	8.45	0.25
bottom sediment	7.82	0.26

II. Oak Mountain

Nitrogen Species

Sample Type	Total Nitrogen	Nitrite	Nitrate	Ammonia
	(mg/L N)	(mg/L NO_2^- N TNT)	(mg/L NO_3^-)	(mg/L NH_2Cl - N)
lake water	N/A	UR	0.2	0.01
lake water	N/A	UR	0.2	0.01
lake water	N/A	UR	0.4	0
top-water	N/A	0.002	0.3	0.03
mid-water	N/A	0.005	0.3	0.06
bottom water	N/A	0.011	0.4	0.13
sediment interface	N/A	0.136	0.5	0
bottom sediment	N/A	OR	UR	0.45
blank	N/A	0.003	0.1	0
standard actual value	N/A	0.223	5	0.25
standard value	N/A	0.25	5	0.25

Phosphorus Species

Sample Type	Total Phosphorus	Phosphate
	(mg/L PO_4^{3-})	(mg/L PO_4^{3-})
lake water	0.14	0.02
lake water	0.15	0.05
lake water	0.16	0.16
top-water	0.25	0.07
mid-water	0.19	0.08
bottom water	0.83	0.33
sediment interface	4.98	UR
bottom sediment	OR	UR
blank	0.1	0.06
standard actual value	OR	OR
standard value	2.5	2

II. Oak Mountain continued

Bacteria Species

Sample Type	Total Coliforms	*E. coli*	Enterococci
lake water	3654	74	0
top-water	9804	201	0
mid-water	4611	145	0
bottom water	15531	512	0
sediment interface	24192	1497	10
bottom sediment	24192	5475	905
* per 100 ml			

Physical Characteristics

Sample Type	pH	Conductivity (us/cm)
lake water	7.00	51
lake water	7.00	51
lake water	7.00	51
top-water	7.37	48
mid-water	7.28	49
bottom water	7.10	46
sediment interface	6.55	42
bottom sediment	6.37	42

III. Star Lake

Nitrogen Species

Sample Type	Total Nitrogen	Nitrite	Nitrate	Ammonia
	(mg/L N)	(mg/L NO_2^- N TNT)	(mg/L NO_3^-)	(mg/L NH_2Cl-N)
lake water	1	0.002	0.3	0.04
lake water	1	0.003	0.3	0.04
lake water	2	0	0.7	0.05
top water	3	0.048	0.4	0.1
mid-water	5	0.029	0.4	0.12
water interface	5	0.086	0.2	0.2
sediment interface	6	0.031	0.4	0.19
mid-sediment	2	0.021	0.5	0.12
bottom sediment	3	0.017	0.2	0.44
blank	0	0	0	0
standard actual value	2	0.227	5.2	0.23
standard value	10	0.25	5	0.25

Phosphorus Species

Sample Type	Total Phosphorus	Phosphate
	(mg/L PO_4^{3-})	(mg/L PO_4^{3-})
lake water	0.15	N/A
lake water	0.12	N/A
lake water	0.16	0.49
top-water	1.14	0.51
mid-water	1.05	0.61
water interface	2	0.21
sediment interface	0.24	UR
mid-sediment	0.66	UR
bottom sediment	0.75	0.08
blank	0.08	0.04
standard actual value	0.1	0.19
standard value	2.5	2

III. Star Lake continued

Bacteria Species

Sample Type	Total Coliforms	*E. coli*	Enterococci
lake water	8164	63	0
top-water	>24192	20	20
mid-water	24192	111	10
water interface	24192	41	0
sediment interface	15531	96	20
mid-sediment	17329	63	0
bottom sediment	9804	74	10
* per 100 ml			

Physical Characteristics

Sample Type	pH	Conductivity (us/cm)
lake water	8.01	147
lake water	8.01	147
lake water	8.01	147
top-water	7.92	139
mid-water	7.74	147
water interface	7.47	124
sediment interface	7.56	128
mid-sediment	7.61	143
bottom sediment	7.56	144

COD and Volatile Solids

Sample Location	**COD**	**Volatile Solids**
	g COD/kg dry sediment	Percent
Eastlake	50400	2.3
Oak Mountain	110000	6.5
Star Lake	112200	12.5

Appendix D: Statistical Results

Statistical Tests: Two-Tailed T-test with an alpha value of 0.05

The following are calculated t-values:

Nitrogen Species

Sample Location	Total Nitrogen	Nitrate	Ammonia
Eastlake	0.03	0.13	0.34
Oak Mountain	Not Available	0.87	0.56
Star Lake	0.59	0.89	0.26

Phosphorus Species

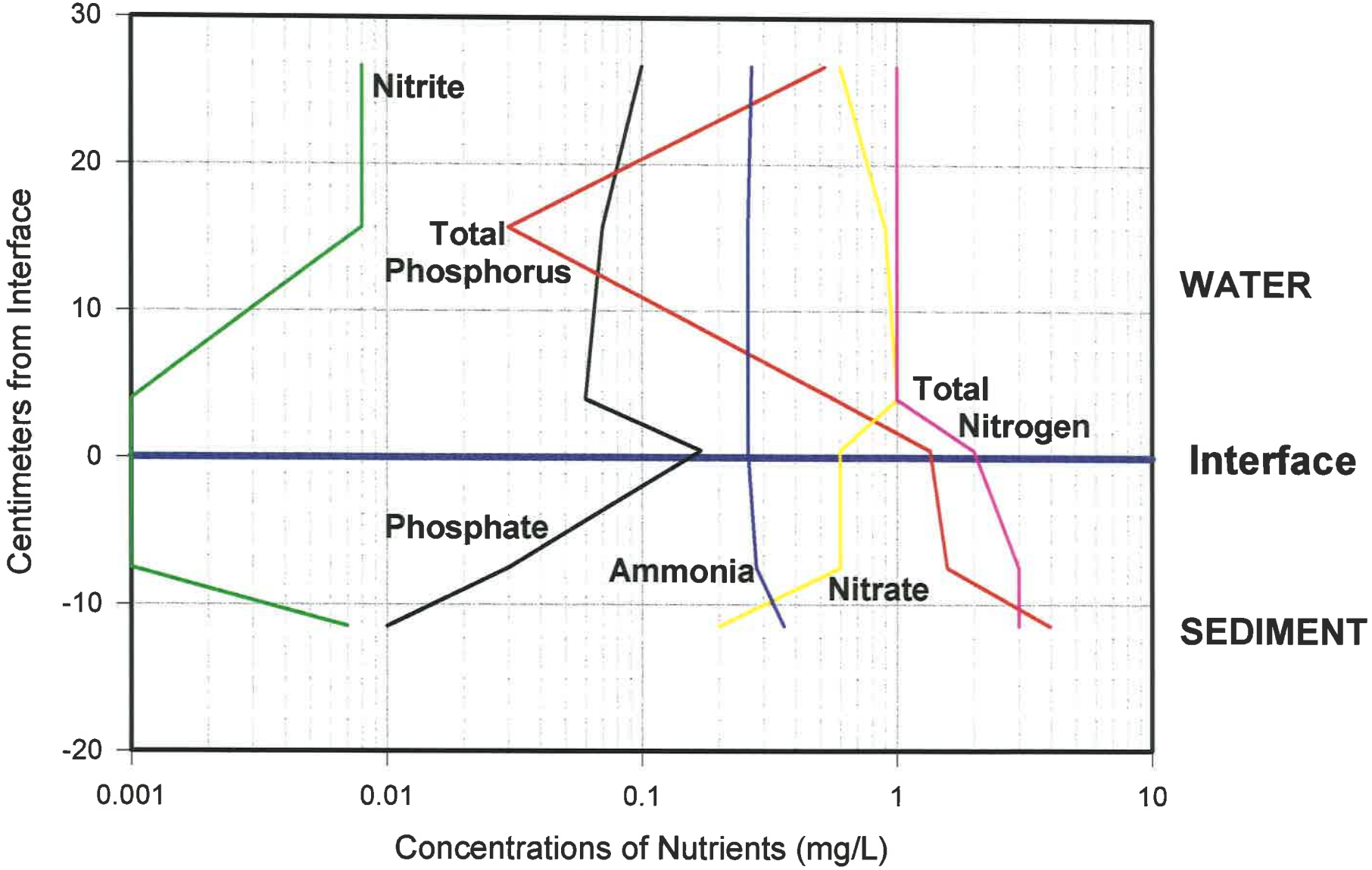
Sample Location	Total Phosphorus	Phosphate
Eastlake	0.2	0.57
Oak Mountain	0.12	0.05
Star Lake	0.55	0.11

Bacteria Species

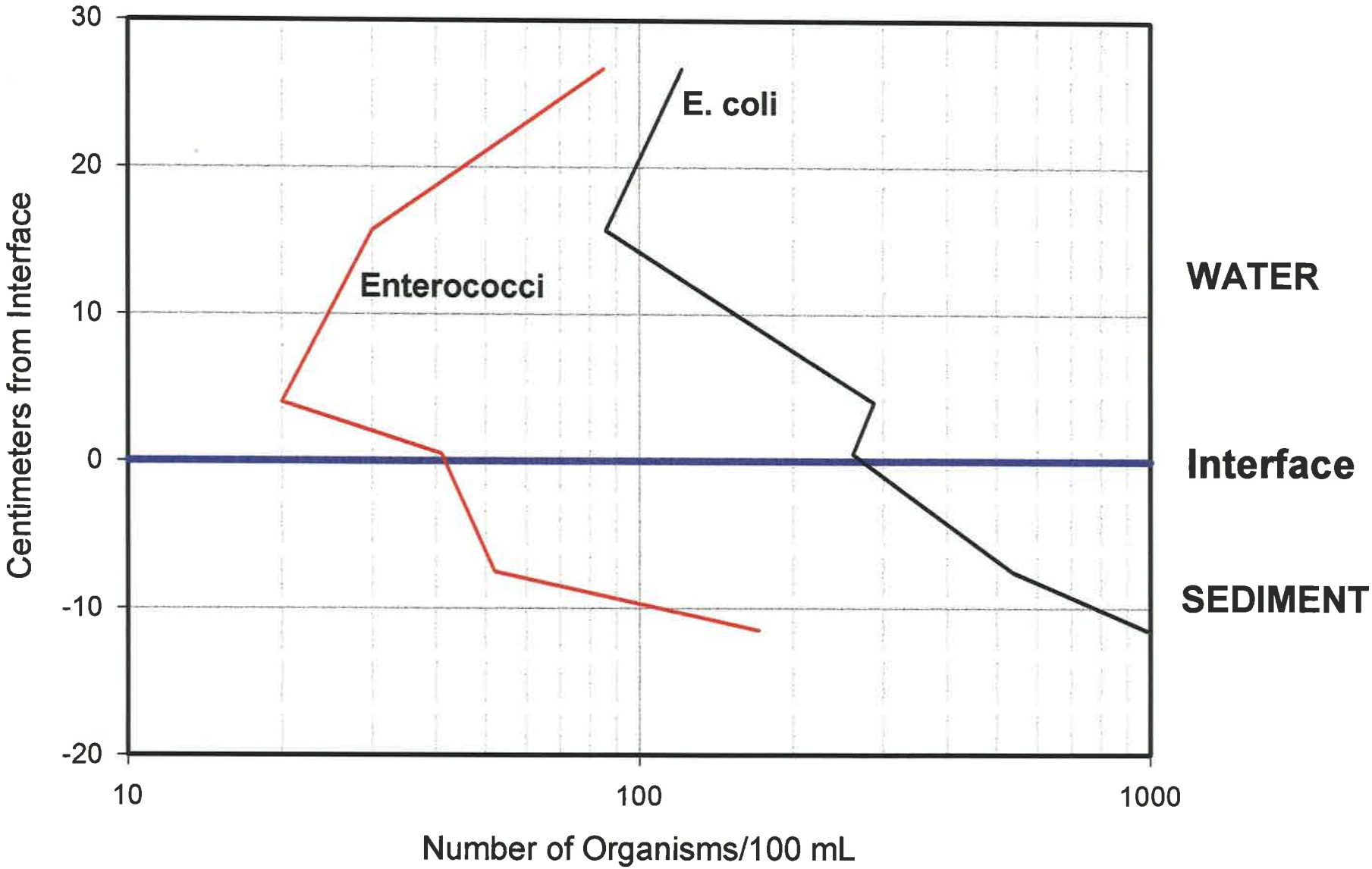
Sample Location	Total Coliforms	*E. coli*	Enterococci
Eastlake	0.38	0.23	0.78
Oak Mountain	0.01	0.35	0.49
Star Lake	Not Available	0.43	0.76

Appendix E: Graphical Results

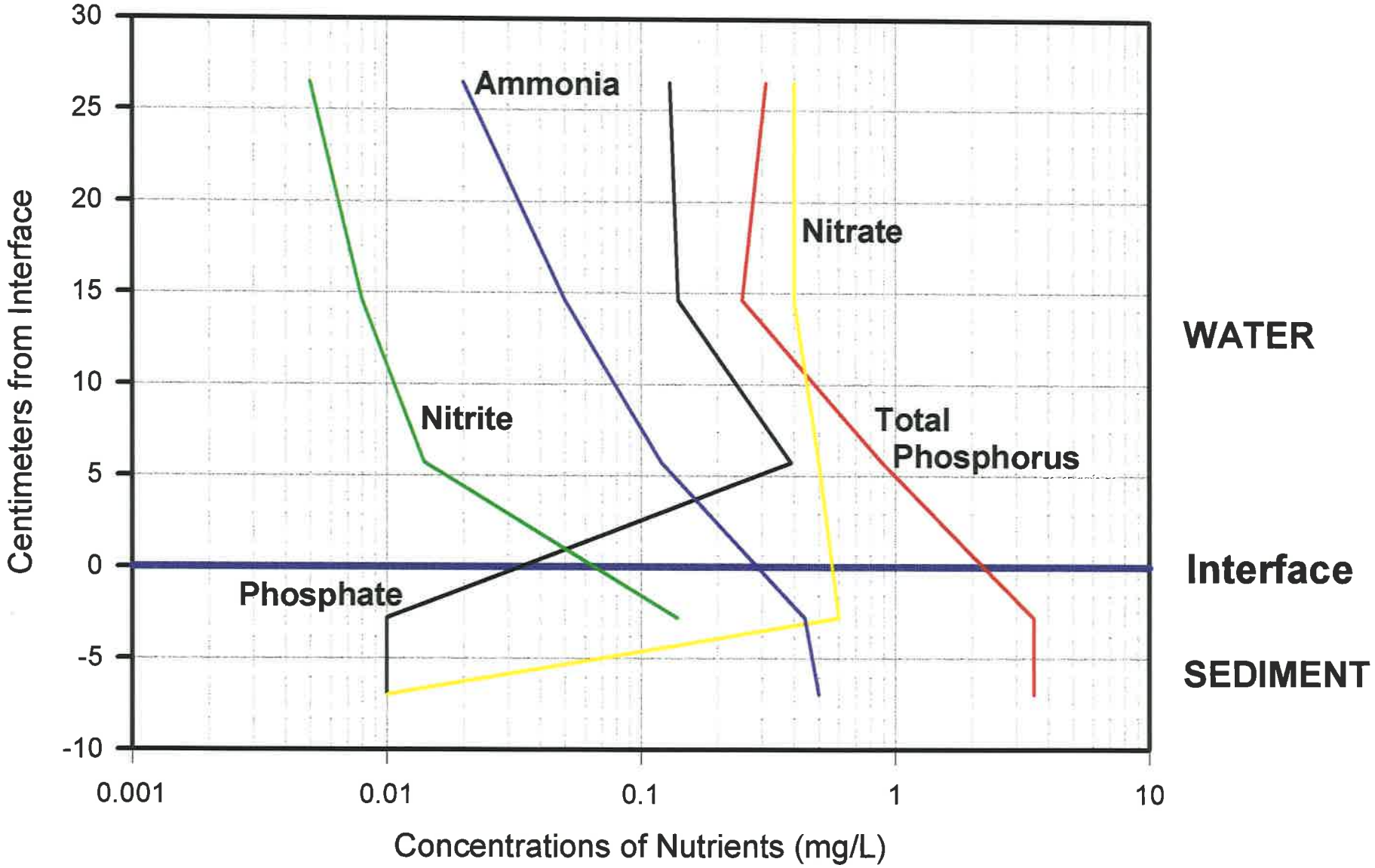
Nutrient Profile in East Lake



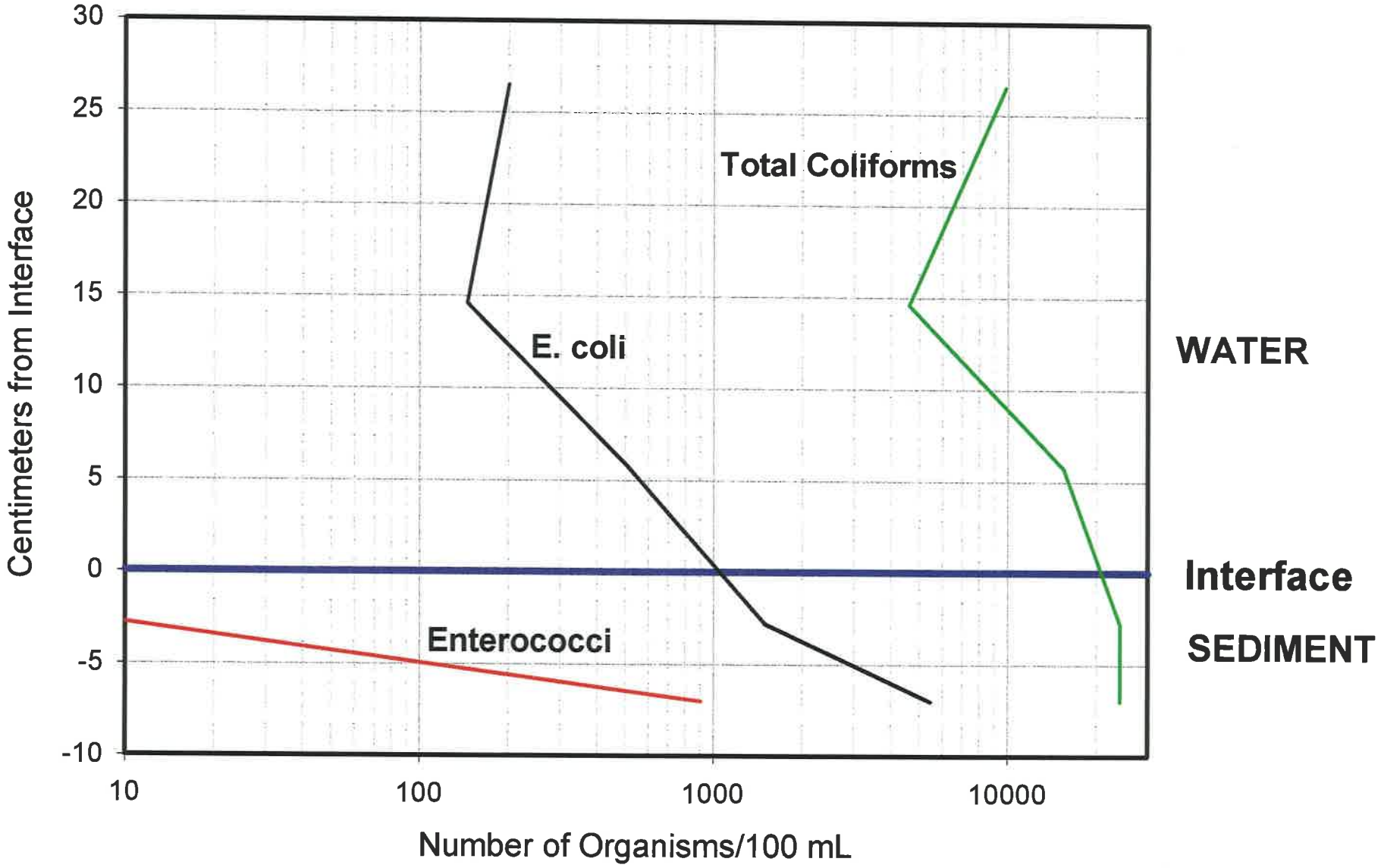
Bacteria Profile in East Lake



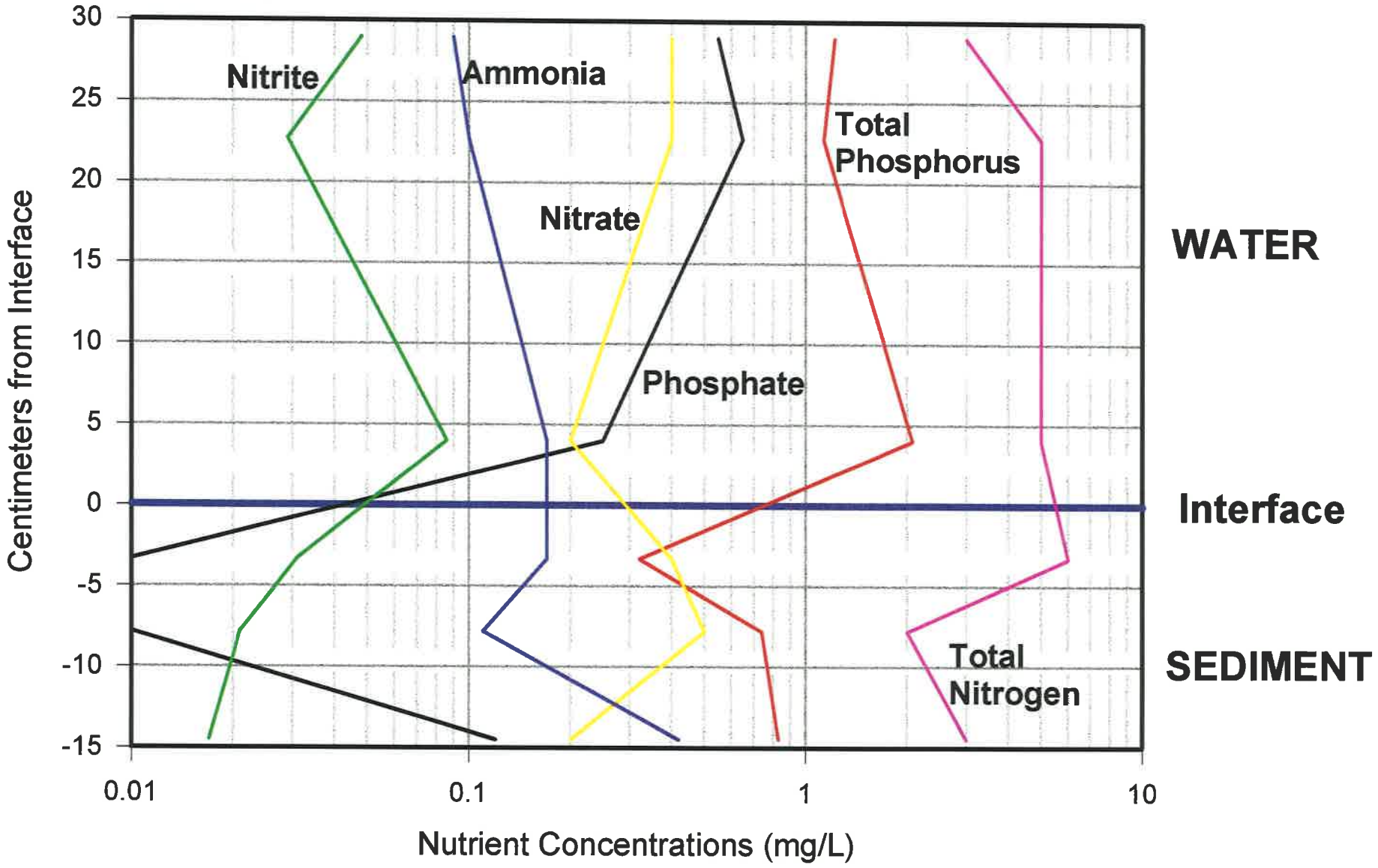
Nutrient Profile in Oak Mountain



Bacteria Profile in Oak Mountain



Nutrient Profile for Star Lake



Bibliography