Institution: Eastern Connecticut State College  
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in contractual agreement with  
The University of Connecticut  

OWRT Project No.: A-068-CONN  
OWRT Agreement No.: 14-31-0001-6007  

Project Title: Analysis of Current Land-Use and Zoning Versus Selected Environmental Factors in Drainage Basins Containing Lakes or Ponds  

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and 21 students on independent study projects during school sessions.  

Project Began: July 1975  
Project Ended: September 1977  

PROJECT OBJECTIVES:  

Project objectives fall into two categories: research and educational.  

Research Objectives:  

1. To examine the relationship of selected environmental factors to current land-use and zoning in drainage basins containing standing bodies of water.  

2. To examine current land-use and zoning with respect to proposed future planning models.  

3. To define the most important environmental factors and land-use criteria for examination of existing and forecast of potential eutrophication and pollution problems.  

4. To study the chemistry of eastern Connecticut lakes and ponds on a reconnaissance basis with intense study of five or more specific lakes.
Educational Objectives:

1. To teach and train undergraduate students in the methodologies and techniques in chemical and physical analysis of lakes, lake waters, and lake drainage basins.

2. To develop research capabilities at Eastern Connecticut State College (ECSC) in land- and water-related studies.

3. To develop material and teaching techniques for existing classes and for new courses in the Earth & Physical Science Department, ECSC.

Achievement of Objectives:

During early work, it became apparent that the study of zoning was impractical for several reasons; therefore, the zoning aspects were not pursued. It also became obvious that there were limited recent chemical data for the lakes and ponds of eastern Connecticut, data essential for analysis of degree and rate of eutrophication of water bodies. Research Objective 4 was added to the original objectives to fulfill the lack of baseline data needed.

Specific achievements for each objective are as follows:

Research Objective 1: Methodologies and techniques for land-use versus environmental factors were developed. Relationship of land-use to Natural Soils Groups was emphasized and has been examined in 12 lake drainage basins (watersheds). Lake morphometric parameters, drainage basin morphometric parameters, lake water specific conductivities, and lake water chemistries have been gathered for examination and several interrelationships analyzed.

Research Objective 2: Future planning models in Connecticut consist of two categories: (1) Comprehensive Plans of Development at town, river basin, regional, and state levels; and (2) Individual plans based on eutrophication or pollution studies. Comprehensive plans are stated in general terms and include but do not discriminate watershed areas with lakes or ponds versus those without. Individual watershed plans are usually after-the-fact studies based on problems brought on by eutrophication, pollution, or nuisance types of algal blooms and usually are unrelated to other watersheds except for procedures or methodologies developed for the individual problem area.

Current land-use has been qualitatively analyzed with respect to the above and recommendations made for future zoning concepts.

Research Objective 3: Important environmental factors to be related to land-use for analysis and lake management must be practicable, attainable, rapid and inexpensive. Unfortunately, there is no single factor that can be used to examine and forecast the degree and rate of eutrophication or pollution. The relationship of land-use to soils based on standard land-use (SLUCONN) and Natural Soils Groups is a powerful, inexpensive and practicable methodology. Lake and drainage basin parameters and parameter ratios, lake water chemistry, and physical measurements of specific conductivity and Secchi Disc transparency are necessary adjuncts for complete analysis.

Interrelationships of several of the above factors have been analyzed.
Research Objective 4: Specific conductivity measurements were taken on 578 water samples from 108 lakes or ponds in Connecticut, 89 of which were in eastern Connecticut. Chemical analyses were made on 429 water samples from 95 lakes or ponds, 76 of which were in eastern Connecticut. The 19 lakes or ponds in central and western Connecticut were sampled for cross-correlation with other recent studies or were of interest to specific students. Intensive study on six lakes has been carried out for more than two years, and lakes in proximity to major highways have been sampled at shore or spillway points during the last year. The relationship of specific conductivity to major chemical constituents has been verified, and anion and cation dominance of lake waters has been analyzed. A potential method for calculating "original" water chemistry has been derived using current water chemistry and historical chloride and bicarbonate analyses.

Educational Objective 1: By far the most satisfying achievement has been the teaching and training of eight undergraduates with grant finances and 21 other students by independent study and special studies. Currently, 21 students are enrolled in a Special Topics-Lakes Course, most students not having taken part previously. Most of the methodology and institutions used in teaching and training were developed with the students who were under grant financing.

Educational Objective 2: Basic field and laboratory instrumentation has been obtained through normal departmental funding. More sophisticated instrumentation, such as an Atomic Absorption unit and a Kail Reflecting Projector, are now considered high priority items. Work from this study has shown the utility of research in teaching and has been the philosophical basis for new courses in Environmental Earth Science Research starting in fall 1978.

Educational Objective 3: The methods and techniques developed from this grant have been and will be utilized in land- and water-related courses of study, including Hydrology, Chemical Methods in Environmental Earth Science, and Environmental Earth Science Research. Students have been taught aspects of lake water chemical analysis, graph overlay and planimeter measurement of land-use, soils, and drainage basins, and parameter and statistical measures. Student interest has also been shown in computer study of water chemistry data as well, leading to study in other courses such as Environmental Chemistry.

RESEARCH PROCEDURES USED:

RESEARCH PERIOD: Collection and collation of land use, zoning, and drainage basin outline maps commenced during the summer of 1975. Soil maps were collected at the same time but were pantographed to an appropriate scale during the summer of 1976. Chemical and physical measurements on Crystal Lake and Crystal Pond started in November 1975, with Alexander Lake added on the second sampling date in April 1976. During the summer of 1976, 17 lake or pond waters were sampled with specific conductivities measured for 35 lakes or ponds. In November 1976, a wide reconnaissance net for specific conductivities was undertaken for 47 lakes, most of which had previously been measured. This work was done to verify previous measurements and to widen our baseline. During the summer of 1977, specific conductance with concurrent chemical analyses were made on 77 lakes. During the fall semester of 1977, an additional 14 lakes were analyzed.

Map overlay work and parameter measurements were continuously carried out from 1975 throughout the grant period and continued on in current course work.
METHODS USED:

Map Overlay Technique: Land-use, soils, and drainage basin maps were collected from state and federal sources. Land-use and drainage basin outline maps were at a common scale of 1" = 2000'. Detailed soils maps or general soils maps on a 1" = 1320' scale were pantographed at a 1 1/2 reduction to 1" = 1980', compatible with the land-use and drainage basin maps and having an approximate areal error of two percent.

Lake and drainage basin outlines were traced onto several sheets of transparent paper. Individual tracings were then made for land-use for each watershed and for combined soil series based on Natural Soils Groups for each watershed. Areal computations were made for each drainage basin for land-use and soils by overlaying transparent 10 x 10 to 1 inch cross section paper on the individual maps and counting the squares; each square is equal to 0.918 acres. These areas were also measured with a compensated optical planimeter having one variable arm adjusted to read acres directly. In many cases graph and planimeter measurements were done by several students; these were then averaged.

Land-use maps were then overlain onto soils maps for measurement of housing on soils, agriculture on soils, etc. Again, multiple measurements were averaged.

Averaged measurements were then tabulated and percentages computed.

Lake and Drainage Basin Parameter Measures: Lake surface areas and drainage basin areas were measured by graph and planimeter techniques described above. Linear measurements were made with a map measurer (rotometer). Elevations were taken from standard U.S. Geological Survey 7 1/2 minute topographic quadrangle maps for computation of basin relief. Lake and drainage basin morphometric parameters and computations follow standard limnological texts and manuals and modifications by Dr. J. J. Kerekes, Department of Environment, Canadian Wildlife Service, c/o Biology Department, Dalhousie University, Halifax, N.S., Canada, in a series of papers from 1968 to the present.

Chemical and Physical Procedures: Variable sampling procedures have been used, starting with sampling from shore points convenient to roads or to boat launch areas. From 1977 on, however, samples were taken at or near spillways, when possible. On lakes, samples were taken from a small boat anchored at approximately the deepest point of the lake, verified by electronic depth recorders. Water samples for chemical analysis taken from surface waters were collected directly into polyethylene bottles held wrist deep below the surface (approx. 0.2 meters). Subsurface samples were taken from the bottom water (0.5 to 1.0 meters above the bottom) and from an intermediate depth (about one-half the maximum depth) with a 1.2 liter Kemmerer sampler (brass in 1975-76, non-metallic in 1977-78).

Chemical analyses for inorganic constituents such as Ca++, Mg++, HCO3-, SO4-, and Cl-, were taken to the Earth and Physical Science Department's laboratories at ECSC. Analyses were usually completed within 24 hours after sampling, many within 8 hours. Samples were raw water except for extremely turbid or algal-rich waters which were filtered through rapid-flow qualitative filter paper.
Chemical tests were run with a Hach DR-EL/2 Direct Reading Engineer's Laboratory. Alkalinity (HCO₃⁻), Hardness (Ca²⁺ & Mg²⁺), and Chloride (Cl⁻) tests were titrations; all others were spectrophotometric. High range Silica (0-15 mg/l) was substituted for the standard low range (0-2 mg/l), alleviating the need for sample dilutions in all but one lake. Distilled water has been used in the laboratory since the summer of 1976 when it became apparent that deionized water was reacting like silica-rich water; i.e., sample dilutions for low range tests all measured much greater than 2 mg/l. To avoid any possibility of interference by resins in deionized water, all final washing, rinsing, and sample dilutions use distilled water.

Dissolved oxygen, temperature, conductance, Secchi Disc transparency, and transmissivity (of light) were measured in situ. Dissolved oxygen and temperature measurements were taken at least at 1 meter intervals with a YSI-54ARC D.O.-Temperature meter. Some measurements were taken at 1/2 or 1/4 meter intervals, especially when values changed rapidly. Conductance and temperature were measured in situ with a YSI-33 Conductivity-Temperature meter as well as water samples being measured with a Lab-Line (Electronic Switchgear) Mark IV temperature compensating Conductivity Meter with a Sproule cell, K=0.1. The Secchi Disc was an 8-inch (20 cm.) disc with black and white quadrants. A Beckman Environeye Transmissivity Meter, EV3, was used in 1976; unfortunately, since then, it has been out of commission.

Educational Methods and Procedures: The following program has been developed through two years of work with students on independent studies and projects.

Step 1: All students are given a U.S. Geological Survey topographic map, scale 1 inch equals 2000 feet, with two lake areas specified for study. A short lecture is given on how to interpret drainage basin outlines. Students then make the drainage basin outlines on tracing paper and check their interpretation versus an interpretation made by U.S. Geological Survey, Water Resources Branch. If the student's map is not satisfactory, the work is repeated.

Step 2: U.S. Geological Survey drainage basin outline maps and land-use maps from the State of Connecticut are traced by the students, and land-use measurements are initially made by the graph paper (cross section paper, 10 x 10-inch) method. Data are checked against previous work. If estimates are high or low compared to previous data, students recount areas.

Step 3: Natural Soils Group maps for the same watershed as the land-use problem are traced onto another drainage basin outline overlay and areas graphed. Estimations are usually good at this stage; if not, the work is redone.

Step 4: Land-use is overlain onto Natural Soils Groups, and squares counted for each land-use versus underlying soils.

Step 5: All data from the above steps are calculated into acres; and charts on percentages of land-use, soils, and land-use on soils are derived for the watershed under study.

Step 6: Depending upon the progress of the student, another drainage basin is given as a problem using the graph method if the student needs further work, or the student is then taught how to use a planimeter for areal measurement. The procedures of Steps 2 through 5 are repeated.
Step 7: Students collect water samples from spillway areas of lakes near their hometowns or in proximity to the college. The student then chemically analyzes the sample(s) using Hach DR-EL/2 spectrophotometer and titration techniques. When possible, students go out onto lakes and take in situ measurements and sample lake waters at depth. On their first lake excursion, they are accompanied by either the instructor or an experienced student.

Step 8: Several sessions are used toward the end of each semester to discuss the overall project and individual findings.

RESULTS AND CONCLUSIONS:

Research Objective 1 - Selected Environmental Factors and Land-Use: Table 1 lists the lake and drainage basin morphometric parameters for 12 lakes studied in eastern Connecticut. Land-use, lake water chemistry, soils, and regional geological data were all essential for analysis of lake water - drainage basin relationships. Natural Soils Groups clustering from detailed soil series maps simplifies areal computations, and data analysis is rapid and is more useful than individual or combined soil series since the NSG system inherently combines soil characteristics, limitations and suitability common to a variety of member soils.

In the lake basins studied, past land-use practices in residential and agricultural siting have not been the prevalent cause of lake eutrophication in most of eastern Connecticut. The most adaptable land has been the most used in the past. This suggests, however, that further residential intensification will become a major contributing factor to accelerated eutrophication since the less adaptable "hardpan" and close to bedrock soils are left for development.

Recommendations for lake watersheds are:

1. Local or state purchase of land with limiting factors of severe or very severe for septic system or leach field design;

2. Variable high acreage (low density) zoning on limited capability soils;

3. Mandated engineering specifications for limited capability soils; and


Research Objective 2 - Future Planning Models: Connecticut planning processes show no specific concern for lake or pond watersheds. Town, regional and state plans formulated to date are general in nature and show concern for Inland Wetlands and "point source discharge to natural lakes" only. Strategies are based on phosphorus control measures.

It would be presumptuous to recommend panaceas in this area other than to suggest discontinuance of the use of road salt or other chemical additives during winter sanding and to emphasize air quality improvement for the State of Connecticut, since wet and dry fallout are major contributors of specific chemical constituents and plant nutrients to lake waters.

Individual lake and lake watershed studies are currently being carried out under 208 funding by various regional agencies in Connecticut. Lake management methodology developed from these studies emphasizes phosphorus control measures.
Table 1. List of lakes studied and selected lake and drainage basin morphometric parameters.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Location Town</th>
<th>County</th>
<th>Origin</th>
<th>Lake Surface Area ha.</th>
<th>Drainage Basin Area ha.</th>
<th>Mean Depth m.</th>
<th>Maximum Depth m.</th>
<th>Lake Perimeter Km.</th>
<th>Lake Volume $10^6$ m$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexander</td>
<td>Killingly</td>
<td>Windham</td>
<td>Nat.</td>
<td>77</td>
<td>235</td>
<td>7.4</td>
<td>16.2</td>
<td>5.7</td>
<td>5.7</td>
</tr>
<tr>
<td>Amos</td>
<td>Preston</td>
<td>New London</td>
<td>Nat.</td>
<td>43</td>
<td>218</td>
<td>5.8</td>
<td>14.6</td>
<td>3.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Columbia</td>
<td>Columbia</td>
<td>Tolland</td>
<td>Art.</td>
<td>114</td>
<td>788</td>
<td>5.1</td>
<td>7.8</td>
<td>6.0</td>
<td>5.8</td>
</tr>
<tr>
<td>Coventry (Wangumbaug)</td>
<td>Coventry</td>
<td>Tolland</td>
<td>Nat.</td>
<td>153</td>
<td>860</td>
<td>8.8</td>
<td>12.2</td>
<td>7.9</td>
<td>13.5</td>
</tr>
<tr>
<td>Crystal Lake</td>
<td>Ellington-Stafford Springs</td>
<td>Tolland</td>
<td>Nat.</td>
<td>81</td>
<td>720</td>
<td>6.0</td>
<td>15.2</td>
<td>4.2</td>
<td>4.9</td>
</tr>
<tr>
<td>Crystal Pond</td>
<td>Eastford-Woodstock</td>
<td>Windham</td>
<td>Nat.</td>
<td>61</td>
<td>215</td>
<td>4.4</td>
<td>13.4</td>
<td>4.4</td>
<td>2.7</td>
</tr>
<tr>
<td>Long Pond</td>
<td>Ledyard-No. Stonington</td>
<td>New London</td>
<td>Nat.</td>
<td>40</td>
<td>1181</td>
<td>4.6</td>
<td>21.9</td>
<td>6.2</td>
<td>1.8</td>
</tr>
<tr>
<td>Mond Pond</td>
<td>Columbia</td>
<td>Tolland</td>
<td>Art.</td>
<td>46</td>
<td>339</td>
<td>n/a</td>
<td>n/a</td>
<td>4.5</td>
<td>n/a</td>
</tr>
<tr>
<td>Moosup Pond</td>
<td>Plainfield</td>
<td>Windham</td>
<td>Nat.</td>
<td>39</td>
<td>300</td>
<td>2.8</td>
<td>7.9</td>
<td>2.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Red Cedar</td>
<td>Lebanon</td>
<td>New London</td>
<td>Art.</td>
<td>52</td>
<td>161</td>
<td>n/a</td>
<td>n/a</td>
<td>4.0</td>
<td>n/a</td>
</tr>
<tr>
<td>Terramuggus</td>
<td>Marlborough</td>
<td>Hartford</td>
<td>Nat.</td>
<td>34</td>
<td>140</td>
<td>6.5</td>
<td>13.1</td>
<td>2.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Wappaquassett</td>
<td>Woodstock</td>
<td>Windham</td>
<td>Art.</td>
<td>41</td>
<td>259</td>
<td>1.8</td>
<td>3.4</td>
<td>4.1</td>
<td>0.7</td>
</tr>
</tbody>
</table>

1 ha. = 2.47 acres; 1 m. = 3.28 feet; 1 cubic meter = 35.3 cubic feet = 264.2 gallons (U.S. Liq.).
Analytical techniques appear to be sound and could be expanded for analysis of nutrients other than phosphorus. Strategies are based on cost-effectiveness and should also be of value in analysis of nutrient and pollution sources other than phosphorus. These studies, although valuable, are overly simplistic, restricted to the study of nitrogen and phosphorus, and limited in their views as to the need for baseline data acquisition and the need for monitoring.

Efforts made in both areas of planning, the broad area and the specific lake area are respected; however, cookbook methodology to solve the problems of lakes with different chemistry, bottom sediments, nutrient content, etc., are viewed pessimistically.

Research Objective 3 - Environmental Factors and Land-Use Criteria:
Unfortunately, neither single nor paired factors can be used to examine and forecast eutrophication or pollution potential or rate. Direct measurement and modeling techniques have both been used to develop concepts and techniques for eutrophication plans. Natural Soils Groups surrounding land-use, major chemical content, and specific conductivity of lake water are minimal parameters necessary for analysis of lake water quality in relationship to the lake watershed.

In retrospect to the study done, it has been found that the relationship of Natural Soils Groups versus land-use is a good guide for initial management judgment. Indepth studies for particular situations should not stop with this simplistic reference, nor should studied be restricted to one or two intensely studied parameters. The crux in solving any problem is first in defining the problem. In the case of lake watersheds, it is too often stated that the "problem" consists of point and non-point sources of nutrients in the eutrophication process. The "problem", as seen here, is the potential malpractice of using soils that are not suitable for the use proposed. Natural Soils Groups are suited for rapid computation, are easily obtained from either detailed or general soils maps, and can be readily analyzed for land-use capability. The relationship of this parameter to current land-use, therefore, is practicable, attainable, and most importantly, correlatable with areas not necessarily having the same soil series, but having similar capabilities.

Currently there are many working tools for obtaining a multitude of parameters that are useful in lake and lake watershed analysis. There are topographic and soils maps for slope measurement; topographic maps for elevations, relief and lake surface parameters; soils maps and land-use maps for all of Connecticut; drainage basin maps and published data on drainage basin areas; bathymetric maps and depth data for more than 160 lakes and ponds; historical chemical data on many lakes and ponds; and a multitude of equations and models interrelating parameters that are measurable from the above.

The need is for: current chemical analyses of lake waters, not only for nutrients, but also for trace metals and organic material that may be hazardous to health; extension of lake mapping for depth data and bathymetric maps; and commitment to a long-term water quality monitoring program.

In detailed, studied familiar to the author, phosphorus impact on two lakes in eastern Connecticut was analyzed by a set of models using measured and estimated values and data from literature searches. The analysis was based on: (1) Erosion-Related Sources; (2) Contribution from Septic Systems; (3) Atmospheric Contribution; (4) Livestock Contribution; (5) Motor Vehicle Contribution; and (6) the Dillon-Rigler Phosphorus Analysis equation. The two studies - Connecticut 208 Special Lake Study
Columbia Lake, and Wangumbaug (Coventry) Lake - will be available from the Windham Regional Planning Agency, 21 Church Street, Willimantic, Connecticut 06226. The comprehensive methodology developed in these studies, although restricted to phosphorus analysis, could be modified for a number of other elements, either nutrient sources leading to eutrophication or metals and organics detrimental to health.

Alternative methodologies to the above should be developed to check the validity of estimates made. Kerekes (1974) suggested the ratio of shore length to lake volume as a meaningful morphometric index, while Rawson (1960) noted that lakes with high total solids have relatively heavy biological crops. These references are illustrative of the view that morphometric parameters, lake water chemistry, and soils and land-use information are all necessary for intelligent analysis.

One point that must be emphasized, however, is that the factors of time and timing are the weakest link in our understanding of lake processes. The rate of removal of nutrients may limit organic production as well as the lack of nutrients. Inversely, the rate of input at optimum growth periods would enhance production even though yearly averages show submoderate amounts of nutrients available in a lake. There is an apprehension, therefore, of the subordinate role of seasonal dwellings in proximity to lake shores in the analysis of phosphorus control. The concerns are: first, that seasonal occupation of these dwellings contributes septic system leachate near or at peak times for algal growth; and second, that the seasonal dwellings of today will become year-round dwellings in the near future, thereby contributing leachate on a continual basis.

Research Objective 4 - Lake Water Chemistry: Lake waters of eastern Connecticut vary from extremely soft to medium hard. The breakdown is as follows:

- Extremely soft ($\text{HCO}_3^- < 10 \text{ ppm}$) 41
- Soft ($\text{HCO}_3^- 10-28 \text{ ppm}$) 33
- Medium Hard ($\text{HCO}_3^- 28-84 \text{ ppm}$) 1 (man-made farm pond)

Versailles Pond, a paper mill pond formed by damming a river, varied from medium hard to extremely soft water, prior to and after artificial agitation, respectively. This could be anticipated since eastern Connecticut is primarily underlain by granitic and gneissic bedrock and probably the major components of the glacial deposits within which the lakes and ponds lie. The total dissolved material and the specific conductance of the waters do not conform to this simplistic categorization, however.

A total of 108 lakes were measured for specific conductivity, 90 of these from eastern Connecticut. The following table summarizes these data.
Table 2. Specific Conductivity

<table>
<thead>
<tr>
<th></th>
<th>No. of Lakes</th>
<th>Arithmetic Mean</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern CT. (not obviously altered)</td>
<td>85</td>
<td>68</td>
<td>62</td>
<td>34-154.5</td>
</tr>
<tr>
<td>Eastern CT. - Total</td>
<td>89</td>
<td>73</td>
<td>64</td>
<td>34-252</td>
</tr>
<tr>
<td>Central &amp; Western CT. - non-limestone</td>
<td>16</td>
<td>134</td>
<td>94</td>
<td>40.5-361</td>
</tr>
<tr>
<td>Central &amp; Western CT. - Total</td>
<td>19</td>
<td>152</td>
<td>97</td>
<td>40.5-361</td>
</tr>
<tr>
<td>Western CT. - Limestone Lakes</td>
<td>3</td>
<td>251</td>
<td>--</td>
<td>227-292</td>
</tr>
<tr>
<td>All Lakes &amp; Ponds</td>
<td>108</td>
<td>86</td>
<td>67</td>
<td>34-361</td>
</tr>
</tbody>
</table>

Specific conductivity measurements reflect the amount of total dissolved solids in the lake waters. The measured values of Ca++, Mg++, HCO₃⁻, SO₄²⁻, and Cl- and calculated Na+ and K+ were summed and divided by the specific conductance (25°C); a common method of analysis with typically expected values of 0.6 to 0.7 in fresh waters. Results were as follows:

Table 3. Sum of Major Ions

<table>
<thead>
<tr>
<th></th>
<th>No. of Lakes</th>
<th>SUM OF MAJOR IONS (p.p.m.)</th>
<th>Specific Cond. (@25°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Arithmetric Mean</td>
<td>Median</td>
</tr>
<tr>
<td>Eastern CT.</td>
<td>76</td>
<td>.63</td>
<td>.63</td>
</tr>
<tr>
<td>Central &amp; Western CT.</td>
<td>19</td>
<td>.69</td>
<td>.74</td>
</tr>
<tr>
<td>Total CT.</td>
<td>95</td>
<td>.64</td>
<td>.64</td>
</tr>
</tbody>
</table>

Considering that there is seasonal variability in bicarbonate and sulfate, an effect from high equivalent conductance of H⁺, Cl⁻, and dissolved metals (especially iron and manganese not considered in this summation), and another effect from the low equivalent conductance of HCO₃⁻, it is observed, with pleasure, that these results are comparable to commonly expected values.
Major cation dominance based on equivalent percentage is as follows:

Table 4. Major Cation Dominance

<table>
<thead>
<tr>
<th></th>
<th>EASTERN CONNECTICUT</th>
<th>ALL LAKES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>Na &gt; Ca &gt; Mg &gt; K</td>
<td>39</td>
<td>51.3</td>
</tr>
<tr>
<td>Ca &gt; Na &gt; Mg &gt; K</td>
<td>19</td>
<td>25.0</td>
</tr>
<tr>
<td>Ca &gt; Mg &gt; Na &gt; K</td>
<td>14</td>
<td>18.4</td>
</tr>
<tr>
<td>Mg &gt; Ca &gt; Na &gt; K</td>
<td>2</td>
<td>2.6</td>
</tr>
<tr>
<td>Na &gt; Mg &gt; Ca &gt; K</td>
<td>2</td>
<td>2.6</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>76</td>
<td>99.9</td>
</tr>
</tbody>
</table>

These relationships should be considered preliminary since Na and K were calculated from millequivalent balancing of cations with anions. Values of potassium (K) ranged from 0.08 to 2.5 p.p.m. (mean 1.24, median 1.2) in 31 analyses of Norvell and Frink (1975) and E. Jokinen (Univ. of Conn. Biology Dept. files, 1978). Cation millequivalence for K was assumed to be 0.03 with K being the last dominant of the four major cations.

Anion dominance based on equivalent percentage was also calculated from the measured values of HCO\(_3\), SO\(_4\), and Cl\(^-\), the major constituents in these waters. Anion values with a difference of less than 0.02 meq. were considered approximately equal.

Table 5. Anion Dominance

<table>
<thead>
<tr>
<th></th>
<th>EASTERN CONNECTICUT</th>
<th>ALL LAKES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>HCO(_3) &gt; SO(_4) &gt; Cl(^-)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HCO(_3) &gt; Cl(^-) &gt; SO(_4)</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>HCO(_3) ≈ Cl(^-) &gt; SO(_4)</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>HCO(_3) ≈ Cl(^-) ≈ SO(_4)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Cl(^-) &gt; HCO(_3) &gt; SO(_4)</td>
<td>21</td>
<td>28</td>
</tr>
<tr>
<td>Cl(^-) &gt; HCO(_3) ≈ SO(_4)</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Cl(^-) &gt; SO(_4) &gt; HCO(_3)</td>
<td>23</td>
<td>30</td>
</tr>
<tr>
<td>Cl(^-) = SO(_4) &gt; HCO(_3)</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>SO(_4) &gt; Cl(^-) &gt; HCO(_3)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>76</td>
<td>100</td>
</tr>
</tbody>
</table>
Fresh water inland lakes would have expected dominance of Ca > Mg > Na > K and HCO₃ > SO₄ > Cl (Rawson, 1960). Na and Cl could be predominant ions in lakes nearest ocean areas (Kerekés, 1973) and presumably may have Mg and SO₄ also contributed by sea water spray and precipitation from ocean sources. Na and Cl alone could be added constituents from road salt. Several precipitation samples analyzed from 1976 through 1978 show high H⁺, Cl and SO₄ with negligible Ca and Mg content. The variety of lake waters found implies that original Ca and HCO₃ dominant waters have been heavily influenced by precipitation and humanly induced chemical input (road salt, water conditioning effluent, automobile emissions, etc.).

Ca and Mg analyses using 10 ml aliquots for titration of this study were checked versus Atomic Absorption work of Norvell and Frink (1975) on 14 lakes. Of the 28 analyses checked (14 for each Ca and Mg), 79 percent were within one p.p.m. and all were within two p.p.m. HCO₃ analysis from 10 ml aliquot titrations were compared with Total Inorganic Carbon analyses from the University of Connecticut's Biology Department, 9 or 11 being within 2 p.p.m. Equipment and chemicals for titrametric analysis are inexpensive and portable, and careful titrations result in data comparable with major analytical instrumentation.

Educational Objective 1 - Teaching and Training: A total of 21 undergraduate students were taught methods in drainage basin analysis, chemical analysis techniques, and physical and chemical lake water measurement methods. Eight of these undergraduates were financed during the summer months from 1976 through 1977; two in 1975; three in 1976; and four in 1977 (one student being on the project in 1976 and 1977). Student participation and interest has been outstanding.

Educational Objective 2 - Research Capabilities: Basic chemical and lake testing equipment has been obtained. More elaborate equipment has been ordered or has been placed on a high priority for future purchase. Work from this grant has been used as part of the rationale for a grant proposing the purchase of an Atomic Absorption Spectrophotometer.

Educational Objective 3 - Techniques and Courses: Techniques and methods of teaching and training developed during tenure of this grant are currently being used in a course, Special Topics - Lakes. A future series of courses in Environmental Earth Science Research using the work of this grant as a basis of teaching will begin in September 1978.

Materials, concepts and data will continue to be used in courses in Hydrology, Chemical Methods in Environmental Earth Science and Environmental Chemistry, as well as in the preceding research courses.

LIST OF PUBLICATIONS:


ACKNOWLEDGEMENTS:

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REFERENCES CITED:


ABSTRACT:

Land use, soils, and lake water chemistry were studied in 12 lake drainage basins in eastern Connecticut. Housing and agriculture are the most prevalent uses of land in the lake watersheds; however, the percentage of use varies substantially. Soil studies were based on Natural Soils Groups which also varied from basin to basin. In general, the most adaptable land for urban development has been the first used for residential subdivision. Further residential intensification, especially on hardpan soils, could become a major factor in eutrophication acceleration and water pollution. The relationship of land use and soils to water chemistry is complex and must consider regional differences in waters prior to examination for change.

Connecticut planning processes do not specifically differentiate lake watersheds from other land areas. Strategies are based on phosphorus control only. Baseline data acquisition and a monitoring system are recommended additions for future planning models.

Environmental factors of land use, soils and water chemistry can be augmented with lake and drainage basin morphometric parameters for analysis of sources and rates of eutrophication and pollution. These indices may be useful for moderate to long-range estimation, but must be modified to cover seasonal changes.

Eastern Connecticut lakes are mostly soft and extremely soft with respect to bicarbonate content. Specific conductivities of lake water range from 34 to 154.4, with a mean of 68 and median of 62 micromhos/cm. for 76 lakes sampled. An approximation of total dissolved solids in p.p.m. or mg/l can be made by multiplying specific conductance by 0.63. Major cation and anion dominance vary.
"Original" water dominated by calcium and bicarbonate ions has been changed mainly by addition of sodium and chloride ions.

Educational objectives of teaching and training of undergraduates, growth of research capabilities, and development of curriculum including material and techniques are summarized.

KEY WORDS: