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SOIL AND SEDIMENT CHEMISTRIES IN
RELATION TO WATER QUALITY OF
COLORADO MOUNTAIN LAKES

by

Todd D. Margulies

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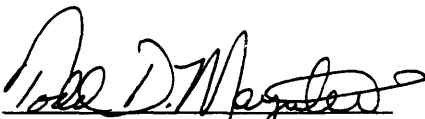
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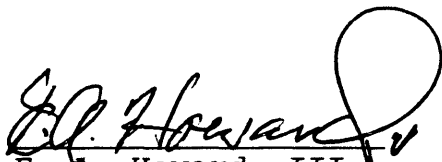
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A thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Master of Science (Mineral Resources Ecology)

Golden, Colorado

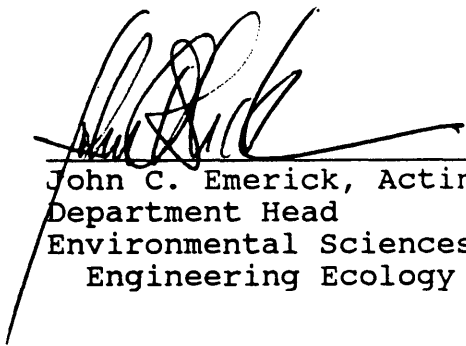
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ABSTRACT

Acid deposition has the potential to create a serious environmental problem in many parts of Colorado. Relatively few studies have been completed that have investigated the effects of acid deposition on soil and sediment chemistries and resulting water qualities. This study examines the ability of soils and sediments to neutralize incoming acidic inputs due to acid deposition. In turn, the data generated from the soils and sediments were shown to support a previously developed lake classification model based on water chemistries.

Ten basin soil and three lake sediment samples were collected from 35 target lakes in Colorado. Laboratory tests were conducted on the samples to determine pH, organic carbon, and cation exchange capacity. The resulting data were then used to examine soil and sediment chemistries in relation to surrounding geologic, vegetative and location (elevation) influences on the effects of acid deposition.

The raw data indicated that lakes situated in basins comprised predominantly of non-reactive igneous and metamorphic parent materials, are more susceptible to the effects of acid deposition than those lakes located in

basins comprised predominantly of more reactive sedimentary materials. It was also evident that lakes situated at higher elevations (>9000 ft) are more susceptible to the effects of acid deposition than those lakes situated at lower elevations (<9000 ft). This observation in many cases was directly related to the geologic environment in which the individual lakes were located.

Univariate analysis and analysis of variance (ANOVA) were performed on all soil and sediment data. Results of the univariate analysis supported the previously mentioned trends observed from the raw data. Results of the univariate analysis showed that the pH of all sediments was approximately 0.4 pH units higher than the mean pH of the soils. Results also showed that the mean cation exchange capacity of the soils was more than 10 meq/100 g higher than the mean cation exchange capacity of the sediments. ANOVA results on the soils indicated that the variance in all three measured variables can be attributed to differences between lake classes. Therefore, the soils data supported the lake classification model. ANOVA results on the sediments showed that only the variance in pH can be attributed to the differences between lake classes and thus, the only measured variable to support the lake classification model.

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Chapter 1

INTRODUCTION

Acid deposition has been studied extensively ever since it was first described by R. A. Smith in 1852 (1). However, until recently very little attention has been given to soil and sediment chemistries in relation to water qualities in lakes which may be susceptible to acidification. Colorado lakes in particular, possibly due to the lack of local industrialization, have only just begun to receive proper attention concerning acid deposition. Turk (2), Baron (3), Chappell (4) and others have shown that there are areas of Colorado which contain acid sensitive lakes. It is apparent that the acid sensitivity of these lakes is related to the geological, vegetative and climatic conditions found to predominate in these areas. Colorado is rather unique in that many different geologic, vegetative and climatic conditions exist. Due to the great variance of these parameters, acid deposition affects lakes throughout the state in varying degrees of magnitude.

Generally, lakes situated at lower elevations will be less severely impacted by acid deposition than those lakes found at higher elevations. Elevation appears to relate

directly to the geologic environment in which these lakes are located. These high mountain lakes are surrounded by granite, quartzite, or other non-reactive (unable to neutralize acidic pollutants) soils and rocks (5), thus making them more susceptible to acidification.

In 1984 a joint research project between the Colorado School of Mines and the University of Colorado, Denver was begun to investigate the acidification status of Colorado lakes. The research conducted in this investigation will be integrated within the joint project previously mentioned. The objective of this study is to determine the relative importance of soil and sediment chemistries in relation to the water quality of the lakes. The task of assessing impacts of acid deposition on individual lakes is not practical in terms of the entire state. This is due, in part, to the hydrology and chemistry of lakes and streams that are highly individualistic (6). In order to better understand the effects of acid deposition, an attempt is being made to classify the lakes according to certain measured chemical parameters found in: 1) soils or sediments surrounding the lakes and, 2) waters of the lakes. This paper will concentrate on the first of these two parameters. Correlation and interpretation of these parameters will help to group lakes, thus making it easier to assess possible effects of acid deposition.

Chapter 2

BACKGROUND

2.1 History

Until the 1950's, acid deposition was an environmental concern that was poorly understood and scarcely studied. During the 1950's Scandinavian countries began collecting samples of bulk precipitation (4). It was these initial actions that led to acid deposition becoming an important environmental issue. Studies have shown that certain lakes have been acidified in Scandinavia (7) and the northeastern United States (8, 9). The study of acid deposition progressed from Europe to the north-eastern United States and finally in the 1970's to the western United States. It was evident that physical characteristics unique to the western United States and Colorado in particular, required extensive study of acid deposition and its potential effects. Due in part to these characteristics, scientists and researchers began to suggest that the susceptibility of adverse effects due to acid deposition was extremely high in the western United States (2, 3).

These new ideas led to scientific studies which attempted to characterize acid deposition and its possible

consequences in the west (2, 10, 11). Results obtained from these studies indicate that acid deposition is occurring in certain areas of the west, but that the levels are far lower than those experienced in the northeastern United States (12, 13). However, the need for continued study of acid deposition in the western United States was firmly established.

Studies previously conducted on acid deposition have usually been oriented towards its effects on the terrestrial or aquatic environments. Usually, these studies had been designed to examine individual parameters connected with acid deposition. These parameters included effects on water quality, aquatic life, vegetation, soils and sediments, and some building materials. Ironically, very few of these individual parameters have been combined within past studies to evaluate the cumulative effects. An example would be to examine the influence of soil and sediment chemistries on resulting water qualities in relation to acid deposition.

Upon perusal of the literature it is readily apparent that only a minimal amount of study has been conducted dealing with the relationships between acid deposition, soil and sediment chemistries, and resulting water qualities. This is especially evident in Colorado and the

western United States. At the present time, only a few studies have been completed and a few more are currently in progress that study the specific parameters mentioned above. A discussion of the significant findings generated from these studies and others conducted elsewhere, will be presented in the following review.

2.2 Acid Deposition

Basically, acid deposition is the process through which acidic materials from the atmosphere interact with the natural processes embodied in the evolution of soils, the waters percolating through soil systems, and the resulting aquatic systems (10). Acid deposition is a combination of both precipitation and dry deposition. Wet precipitation includes both rain and snow. Dry deposition is composed of all other dust and particulate matter that falls to the earth's surface (14). Two of the main components of acid deposition which cause adverse effects, are sulfur compounds and nitrogen compounds. Combustion of fossil fuels is the principal pathway for these compounds to enter the atmosphere. Sulfur compounds (SO_2 and SO_3) originate from numerous sources but mainly from coal-powered electric plants and large copper smelters in the

west. Nitrogen oxides mostly come from the operation of internal combustion engines.

Once these sulfur and nitrogen oxides are emitted into the atmosphere, they will eventually be deposited onto the ground, either through precipitation or dry deposition. The sulfur oxides and nitrogen oxides combine with water to form sulfuric (H_2SO_4) and nitric (HNO_3) acids, respectively. It is these strong acids which cause adverse effects in soil and sediment processes and resulting water qualities.

2.3 Effects on Terrestrial Ecosystems

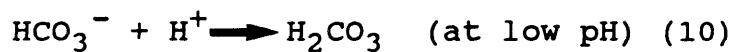
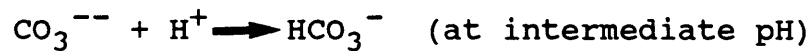
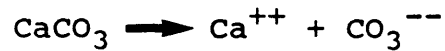
Soils and sediments play an extremely important role in neutralizing acidic inputs from the atmosphere. Yet, soils and sediments vary a considerable amount in their capacity to offset inputs of acids. Two of the major mechanisms responsible for neutralization are mineral weathering and cation exchange.

2.3.1 Mineral Weathering

The weathering of rocks and minerals is capable of neutralizing acidic inputs to soil and sediment systems.

The degree to which neutralization can occur is dependent upon the mineralogical and chemical composition of the parent material (10). In most cases however, weathering will neutralize incoming acidity entering a soil or sediment system (15). The exception is when neither cations or anions are released during weathering or when H^+ or OH^- ions are not involved in the reaction. Weathering processes are most important in buffering against slow acidification reactions although to a lesser degree, weathering does play a role in neutralizing sudden, heavy H^+ loads in solution (10). It is generally known that soils developed from crystalline parent material are more highly sensitive to increased deposition of acid, than soils developed from more reactive types of parent material (15). Crystalline parent materials such as granite, gneiss and schist have little ability to neutralize acidity introduced into a soil or sediment system. This factor is directly related to the parent material chemical composition. There are virtually no chemical constituents present in these parent materials that have the ability to neutralize acidic inputs. In contrast, soils and sediments developed from certain sedimentary parent materials constitute an important buffering mechanism. These sedimentary parent materials include calcareous rocks

(calcite and dolomite), which undergo dissolution of carbonate minerals. The primary reactions involved in buffering acid inputs are:



Local variations in geology notwithstanding, much of the mountainous part of Colorado may be treated as a regional unit composed mainly of crystalline granite, gneiss and schist (16). In many parts of Colorado this unique physical characteristic translates to the inability of soils and sediments to neutralize incoming acidity. This is not to say, however, that certain specific areas within Colorado do not possess the necessary geologic materials to help buffer against acid deposition.

2.3.2 Cation Exchange Capacity

The cation exchange capacity exhibited by a soil or sediment is also an integral mechanism through which incoming acidic inputs may be neutralized. Many soils or sediments take up hydrogen ions (acid component) supplied

by acid deposition via a rapid process called "cation exchange", in which base cations, usually calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^+), or potassium (K^+), are preferentially replaced by hydrogen ions (H^+) (17). Because cation exchange reactions are rapid, hydrogen ions in acid deposition could rapidly acidify soil by depleting exchangeable base nutrients (18). Calcium, magnesium, sodium and potassium are commonly referred to as "exchangeable bases", "base cations", or "bases", even though they are not proton acceptors, since acidity is neutralized when these substances exchange for hydrogen ions. In general, when a soil or sediment has a low cation exchange capacity and relatively few "exchangeable bases", the potential for acidification is greatly enhanced. Conversely, if a soil or sediment has a high cation exchange capacity and a relatively large number of "exchangeable bases", the potential for acidification is greatly reduced (19, 20). At this point it is worth noting that geological influences on acid neutralization can be loosely correlated with elevation differences. Soils and sediments developed at higher elevations in alpine or sub alpine environments, usually originate from non-reactive geologic material that exhibit relatively low cation exchange capacities. Therefore, these areas are most

susceptible to the adverse effects of acid deposition. In contrast, soils and sediments situated at lower elevations that are underlain by more reactive geologic material and are characterized by relatively high cation exchange capacities, have a much greater neutralization capability. It should also be noted that a hidden variable (vegetation) exists within the elevation characteristic. Certain vegetation types can indirectly affect the neutralization capability of a soil or sediment. This elevation characteristic will be examined in greater detail in the results section of this paper.

A relationship can also be demonstrated to exist between cation exchange capacity and pH. The ability of soils and sediments to store cations and to resist rapid changes in pH is due to their negatively charged particles, which behave like cation exchangers (19). Figure 2-1 illustrates this principal. The interaction of H^+ ions from acid deposition with the cation exchange capacity of the soils is what determines the effect of the additional acidity on soils and sediments. Decayed organic matter and silicate clays are almost exclusively responsible for soils or sediments cation exchange capacity (Table 2-1). Cation exchange capacities are most often expressed in milliequivalents per 100 grams of soil (meq/100 g) (See Table 2-1). Generally, the cation exchange capacity

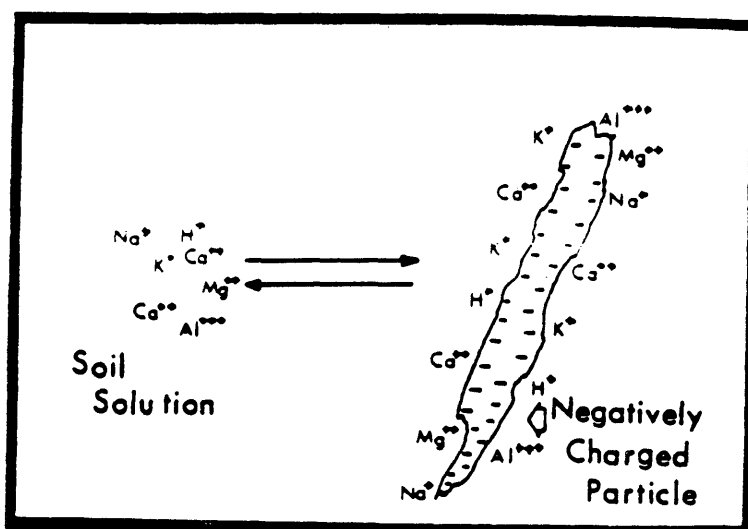


Figure 2-1 Equilibrium Between Cations in Solutions and Those Absorbed on Soil Colloids. From McFee (19)

Table 2-1 Typical Cation Exchange Capacities
of Soil Components

| | C.E.C. meq/100 g soil |
|---------------------|--------------------------|
| Organic Matter | 200* |
| Silicate Clays | |
| Vermiculite | 150 |
| Montmorillonite | 100 |
| Kaolinite | 10 |
| Illite | 30 |
| Hydrous Oxide Clays | 4 |
| Silts and Sands | negligible |

* variation is commonly 40% of these mean values
From McFee (19)

increases as the pH of the soil increases. The relationships between pH, cation exchange capacity, and organic matter (carbon) content will also be expanded upon in the discussion of results section of this paper.

2.4 Effects on Aquatic Ecosystems

The effects of acid deposition on aquatic ecosystems have been well documented. Adverse effects have been observed in aquatic biota, fish populations, birds and mammals and nutrient cycling (17). Since this investigation is mainly concerned with terrestrial ecosystems, only a brief overview of effects on aquatic ecosystems will be presented. However, it will be demonstrated that acid deposition can be extremely detrimental to surface water quality along with users of the potentially acidified water.

Surface water sensitivity to acid deposition is usually assessed in terms of alkalinity. Alkalinity measures the extent to which water is buffered against chemical changes caused when acidic substances enter it (21). Depletion of alkalinity in surface waters is a very rapid chemical reaction, whereas the processes that replenish alkalinity are much slower. In many cases, changes in alkalinity

correspond to an increase in sulfate and nitrate concentrations and a decrease in pH. Alkalinity is reduced by the reaction of H^+ ions with bicarbonate to form CO_2 . During the first phases of acidification, the pH of surface waters declines very slowly. When alkalinity is greatly reduced and begins to approach low values, the pH declines rapidly. This rapid pH decline is characterized by the fact that little or no bicarbonate is left in the surface waters to help neutralize incoming acidity. A common phenomenon that occurs in surface waters due to the rapid depletion of alkalinity is called "short-term" acidification. Short-term acidification usually happens during spring snowmelt or heavy rains. Declines of 0.5 to 1.5 pH units lasting from two to four days have been reported for surface waters in both the eastern and western United States (22). Consequences of short-term acidification include fish kills and increased mortality among invertebrates (23).

Acidification of surface waters also occurs over long periods of time resulting in chronic depressions of alkalinity. This type of acidification is not associated with rapid inputs of high concentrations of acidic components. Rather, chronic acidification occurs most readily in surface waters where the surrounding soils have

a low cation exchange capacity. These surface waters are situated in basins composed of slowly-weathering bedrock with thin soils that supply alkalinity and base cations at a limited rate (17). Due to the long periods of time over which chronic acidification occurs, it is extremely difficult to assess the direct harmful environmental effects. Yet, two areas in which acid deposition has been observed to cause changes are fish populations and nutrient cycling.

2.4.1 Fish Populations

It is generally known that certain fish species are extremely sensitive to increased acidic inputs. Investigations have shown that reproduction will be reduced for sensitive species at pH levels below 6.0, either as a result of failure to spawn or through failure of the eggs to hatch (23). Although the surviving adults will grow faster, the eventual result will be a reduction in the number of species native to the particular body of water. Acid waters also suppress primary productivity which in turn affects the species diversity of certain invertebrates and phytoplankton. The reduction of potential food sources may lead to a reduction in fish populations. Fish larvae

are particularly vulnerable to acid water, and unusually high mortalities can occur following short-term flushes of a low-pH water during spring snowmelt (23).

2.4.2 Nutrient Cycling

Acidification of both terrestrial and aquatic ecosystems has been shown to have a prominent effect on nutrient cycling. Increased amounts of heavy metals being released into a system have been suggested to be directly related to acidification (increase in H^+ ions). Many acidified natural waters have elevated concentrations of aluminum, manganese, and zinc, although only aluminum usually occurs in levels considered toxic to aquatic biota (11). Within the pH range critical to many aquatic species, aluminum effectively acts as an acid (24). Many fish cannot reproduce in acid lakes, which may be due to the high concentrations of soluble aluminium rather than to the concentrations of free acids (25). However, it is difficult to separate the effects of trace metal toxicity from effects of hydrogen ion toxicity among fish species in natural waters. Trace metal toxicity affects more mature individuals within species whereas hydrogen ion toxicity affects younger individuals within species and potential food sources (10).

Chapter 3

METHODOLOGY

The work performed in this study originates from a joint investigation between the University of Colorado, Denver and the Colorado School of Mines. The investigation was designed to determine the acidification status of Colorado Lakes. Since it was virtually impossible to sample the more than 4000 named lakes and reservoirs in Colorado, a method was established to select a representative number of lakes that exemplified the varying geologic, climatic and vegetative characteristics found within the state. A brief overview of this selection process will be presented here. A detailed discussion of this process can be found in Chappell (4).

In 1984, phase I of the investigation began by assembling a list of Colorado lakes. Two sources were used to assemble a list of named lakes in Colorado: the 1972 Colorado Fish and Wildlife Inventory and the USGS Geographic Names Information System of the Lakes and Tanks (reservoirs) of Colorado. A master list of 4069 lakes

was divided into twelve different drainage basins (4) (See figure 3-1).

The twelve basins in Colorado are:

- | | |
|--------------------------------|------------------------------|
| 1 Colorado | 7 Rio Grande |
| 2 Yampa | 8 Arkansas (>6000 feet) |
| 3 Eagle/Roaring Fork | 9 Arkansas (<6000 feet) |
| 4 Gunnison | 10 North Platte/Laramie |
| 5 Dolores/San Miguel | 11 South Platte (<6000 feet) |
| 6 San Juan/Las Animas/La Plata | 12 South Platte (>6000 feet) |

The next task was to select a number of lakes from each basin that represented the previously mentioned characteristics. Three different sets of twenty randomly selected lakes were chosen from each basin. A final lake sampling list containing at least 12 usable lakes per basin was compiled based on accessibility and ownership. The 1984 sampling program included 175 lakes which were sampled for water quality characteristics. A complete list of water

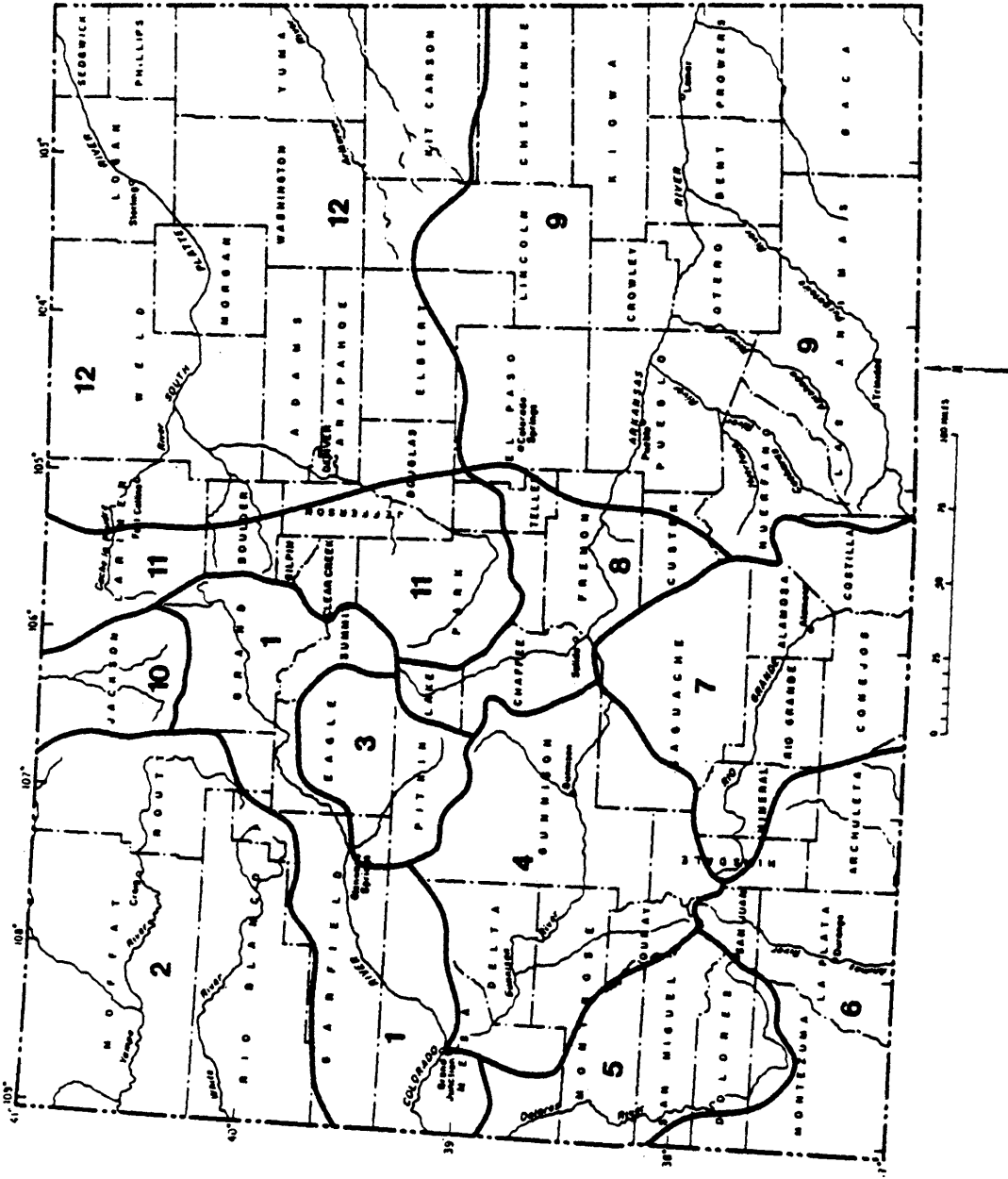


Figure 3-1 Drainage Basin Divisions for Sampling of Colorado Lakes. U.S.D.I. (26)

quality characteristics can be found in Chappell (4). This first phase established a classification system for Colorado lakes (4). The classification model resulted in nine categories which appeared related to the geologic and biologic characteristics of the drainage basin. Table 3-1 shows the 1984 classification categories.

The 1985 sampling program consisted of 106 lakes sampled for water quality characteristics. As part of 1985 sampling, 33 target lake basins were designated for collection of soil samples surrounding the lake, lake bottom sediments, (this study) and vegetation mapping. Two additional lakes basins were added after the final water sampling was completed in the fall of 1985. Table 3-2 gives a complete list of lake basins that were sampled for soils and sediments. The 35 target lake basins represent all nine lake classes identified in 1984 (Table 3-1). Between two and six lakes from each class were sampled.

The primary objective of the soil and sediment sampling was to determine whether the chemical characteristics of targeted lake waters and the classification model could be quantitatively linked to soil and sediment composition (27). Even though one would logically expect that, in pristine environments, the geologic and vegetation community would

Table 3-1 1984 Classification Categories
(Geological and Vegetation Characteristics)

| <u>CLASS</u> | <u>GEOLOGICAL</u> | <u>VEGETATION</u> | <u>LAND USE/COMMENTS</u> |
|--------------|---|---|--|
| 1 | Precambrian metamorphic | below timberline - coniferous includes Engelmann spruce, lodge- pole pine, aspen | Oligotrophic - little to moderate human use |
| 2 | Precambrian metamorphic Precambrian igneous Tertiary igneous Pennsylvanian sedimentary | alpine tundra - shrub, grass, meadow | Small drainage basin. Isolated - little usage. Exposed bedrock |
| 3 | Tertiary igneous | below timberline - mixed includes Engelmann spruce, lodgepole pine, aspen shrub, meadow, grassland | Broad, pervasive group |
| 4 | Tertiary & lower Cretaceous sedimentary | arid lowlands - includes grassland, shrub, sagebrush, aspen | High human activity and agricultural use |
| 5 | Cretaceous upper sedimentary | arid lowlands - includes grassland, shrub, sagebrush, aspen | High human activity and agricultural use |

(continued)

Table 3-1 (continued)

| CLASS GEOLOGICAL | VEGETATION | LAND USE/COMMENTS |
|--|--|--|
| 6 Tertiary, Cretaceous sedimentary (includes upper & lower Cretaceous & Tertiary sediments) | coniferous - includes Engelmann spruce, lodgepole pine, ponderosa pine, aspen | Intermittent lakes, or intermittent inlet/outlet |
| 7 Pennsylvanian sedimentary (includes Triassic, Permian, Pennsylvanian, Pre-pennsylvanian Paleozoic sediments) | below timberline - Engelmann spruce | Small drainage basin Intermittent or no inlet/outlet |
| 8 Pennsylvanian sedimentary (same as Class 7) | below timberline - mixed includes Engelmann spruce, ponderosa pine, aspen, shrub grasslands | Large, permanent inlet/outlet, or intermittent lake |
| 9 Precambrian igneous (includes granitic rocks) | below timberline - mixed includes Engelmann spruce, lodgepole pine, ponderosa pine, aspen, grassland | Oligotrophic Isolated, or little usage |

Chappell, (27)

Table 3-2 List of Target Lakes

| LAKE ID# | LAKE NAME | BASIN | SIZE acre | ALT. ft. | COUNTY | LAT. deg/min/sec | LONG. deg/min/sec | CAT. # |
|----------|------------------------------|-------|-----------|----------|--------|------------------|-------------------|--------|
| 3.1 | DIEMER LAKE | C | 40 | 8500 | PIT | 39 20 05 | 106 36 25 | 1 |
| 10.10 | BIG CREEK Lake (UPPER) | NP | 113 | 9009 | JAC | 40 55 10 | 106 36 40 | 1 |
| 11.22 | MAMMOTH CREEK RESERVOIR | SP | 21 | 9650 | GIL | 39 52 51 | 105 37 02 | 1 |
| 11.4 | CRATER LAKE (UPPER #1) | SP | 8.5 | 11020 | GIL | 39 53 51 | 105 40 35 | 2 |
| 11.9 | ARAPAHOE LAKE #3 | SP | 10 | 11165 | GIL | 39 54 27 | 105 40 51 | 2 |
| 3.8 | MORMAN LAKE | C | 9.6 | 11500 | PIT | 39 19 39 | 106 30 27 | 2 |
| 8.15 | VENABLE LAKE (UPPER) | A | 5 | 12080 | CUS | 38 04 00 | 105 37 05 | 2 |
| 8.20 | GRIZZLY LAKE (sub 8.14) | A | 15 | 11202 | CHA | 38 40 00 | 106 19 56 | 2 |
| 1.3 | BULL CREEK RESERVOIR (#1) | C | 12.8 | 10184 | MES | 39 03 59 | 108 01 03 | 3 |
| 1.21 | TWIN BASIN RESERVOIR | C | 17 | 9800 | MES | 39 05 08 | 108 02 38 | 3 |
| 4.2 | CARP LAKE | G | 11.5 | 10280 | DEL | 39 02 27 | 107 59 13 | 3 |
| 4.5 | HOWARD RESERVOIR | G | 7.15 | 9920 | DEL | 39 01 16 | 107 57 12 | 3 |
| 7.14 | SPENCER LAKE | RG | 9.1 | 9800 | CON | 37 21 43 | 106 23 40 | 3 |
| 10.16 | FINGER LAKE | NP | 1.5 | 9400 | JAC | 40 23 37 | 106 21 22 | 3 |
| 6.4 | STEVENS | SJ | 25 | 7100 | ARC | 37 18 00 | 107 04 30 | 4 |
| 10.2 | ADDISON RESERVOIR | NP | 14 | 8260 | JAC | 40 30 57 | 106 20 53 | 4 |
| 2.6 | MC HATTON RESERVOIR | W | 4.7 | 6720 | RB | 40 04 15 | 107 49 08 | 5 |
| 6.8 | CHAPMAN LAKE | SJ | 26.8 | 6880 | LP | 37 10 00 | 106 45 43 | 5 |

(continued)

Table 3-2 (continued)

| LAKE ID# | LAKE NAME | BASIN | SIZE acre | ALT. ft. | COUNTY | LAT. deg/min/sec | LONG. deg/min/sec | CAT. # |
|----------|-----------------------|-------|-----------|----------|--------|------------------|-------------------|--------|
| 4.3 | FISHER RESERVOIR | G | 7.35 | 9740 | DEL | 39 01 04 | 107 43 04 | 6 |
| 4.4 | OWENS RESERVOIR | G | 15.76 | 9920 | DEL | 39 00 53 | 107 44 48 | 6 |
| 6.6 | O CONNELL LAKE | SJ | 9.7 | 7960 | ARC | 37 23 35 | 107 11 43 | 6 |
| 2.8 | CLOCK LAKE | W | 10 | 10400 | GAR | 39 47 41 | 107 19 21 | 7 |
| 6.9 | MOLAS LAKE (LITTLE) | SJ | 10 | 10905 | SJ | 37 44 45 | 107 41 01 | 7 |
| 7.5 | RITO ALTO | RG | 12 | 12000 | SAG | 38 05 18 | 105 40 34 | 7 |
| 2.10 | SEVENTH LAKE | W | 2.4 | 8082 | RB | 39 54 46 | 107 38 49 | 8 |
| 3.17 | NOECKER RESERVOIR | C | 11.1 | 8320 | EAG | 39 43 07 | 106 49 31 | 8 |
| 10.7 | THREE MILE RESERVOIR | NP | 7.3 | 8180 | JAC | 40 57 28 | 106 25 32 | 8 |
| 8.18 | WRIGHTS RESERVOIR | A | 168 | 8080 | TEL | 38 47 37 | 105 16 19 | 9 |
| 8.19 | UPPER RESERVOIR | A | 11.5 | 7720 | EP | 30 06 47 | 104 56 15 | 9 |
| 10.14 | RAINBOW LAKE #2 | NP | 7 | 9814 | JAC | 40 38 55 | 106 37 25 | 9 |
| 10.24 | RAINBOW LAKE UPPER #1 | NP | 101 | 9854 | JAC | 40 38 55 | 106 38 02 | 9 |

Chappell (27)

exert the primary influence on water quality, this has not been previously demonstrated in Colorado (27). If the hypothesized geologic and vegetation controls are confirmed, we may conclude that chemical composition of lake waters represents the integrated influence of the surrounding drainage basin (27). In addition, soil and sediment data would support the natural lake classification schemes based on lake water chemistry.

3.1 Field Data Collection

Target lake basins were sampled between July 3, 1985 and October 21, 1985. Due to access problems the lake basins sampled for soils and sediments do not perfectly match the lake basins where vegetation characteristics were mapped. A detailed description of the vegetation mapping is presented in Chappell (27). Jumbo Reservoir, Rito Alto Lake and Grizzly Lake were not mapped for vegetative cover.

Ten soil samples were collected from around each lake representing all the geologic and vegetation types observed in the basin. Sampling sites were chosen to maximize the range of soils sampled in each basin (27). Samples were taken six to eight inches below the surface or in the

B-horizon, if there was adequate soil development to identify horizons. The samples were then sieved in the field to less than 2 mm using a stainless steel sieve. After sieving, soil samples were stored in labeled Kraft high wet-strength paper bags. Three bottom sediment samples were obtained from the shore. If inlet and outlet streams could be identified, sediment samples were collected near these two points. The third sediment sample would then be collected at a randomly selected site in between the first two sediment samples. When no inlet or outlet stream could be identified, all three sediment samples were collected at randomly selected sites. It was attempted, however, to choose sites that were evenly spaced around the lake and that would also represent of the varying geologic and vegetative environments. Shore sampling may not have been the best method for obtaining sediment samples representative of the varying geologic and vegetative characteristics of each basin. This is due, in part, to processes occurring within each lake such as sediment focussing. These sediment samples were then sieved and stored in the same manner as the soil samples. Additional field observations were made to record human impact, livestock and farming influences, geology, and

vegetation of the area surrounding each lake and its surrounding environment.

3.2 Sample Preparation

Samples were allowed to dry at ambient laboratory temperature and then split using a mechanical splitter. One half of each sample was returned to the Kraft paper bag and the other half was ground for two minutes in a Spex Mixer Mill using an alumina canister and two small (1/4" diameter) alumina balls. The bulk of the ground sample was less than 200 mesh (0.15 mm) after grinding was completed. The ground portion of each sample was placed in a labeled glass container.

Due to the large number of samples (455) collected for this study, only three parameters were determined: pH, organic carbon content (%), and cation exchange capacity. These parameters provide a quantitative measure of soil characteristics (27). In other words, these parameters allow general soil characteristics to be determined.

3.3 Soil and Sediment pH Determination

The pH or hydrogen-ion activity of the soil and

sediment samples was determined by the McLean (28) procedure with a slight modification. The slight modification was to determine the pH on a saturated paste rather than a 1:1 ratio of soil or sediment to water. The unground portion of each sample was used for pH measurements. Enough soil or sediment was placed in a 100 ml beaker to allow sufficient immersion of the electrode for a stable reading. Deionized water was added to each sample in small increments and stirred with a glass rod in between each addition. The deionized water was added until a "saturation paste" was formed. Samples were then covered lightly with plastic wrap and allowed to stand for 24 hours. The pH reading for each sample was then taken using a Sargent Welch Model IP pH meter. The pH meter was calibrated approximately every ten samples using standard buffer solutions of pH 4.0 and 8.0. Repeats were performed randomly on 10-15% of the samples with a range of ± 0.1 pH units.

3.4 Organic Carbon Content Determination

The organic carbon content of each sample was determined by the Walkley-Black method (29). A 0.25-0.50 g portion of ground sample was placed in a 500 ml wide mouth Erlenmyer flask. Ten ml of 1.000 N $K_2Cr_2O_7$ were then added and

mixed thoroughly. Twenty ml of concentrated H_2SO_4 were then added. The flask was swirled and then allowed to stand on an asbestos pad for about 30 minutes. Next, 200 ml of deionized water were added and then 3 drops of o-phenanthroline indicator. The solution was then titrated with 0.5000 N $FeSO_4$ to the end point. Calculation of organic carbon content was obtained through the following equation:

$$OC \% = \frac{(\text{meq } K_2Cr_2O_7 - \text{meq } FeSO_4) \times 0.003 \times 100 \times 1.33}{\text{grams of air dry soil}}$$

Replicate analyses of 10-15% were randomly performed on the samples. The range was $\pm 5\%$.

3.5 Cation Exchange Capacity Determination

The cation exchange capacity (CEC) was determined by sodium saturation (30). A 4-6 g sample of ground soil or sediment was weighed and placed in a 50 ml centrifuge tube. Thirty-three ml of 1.000 N NaOAc solution were added. The tube was then capped and shaken in a mechanical shaker for five minutes. The tube was then centrifuged

until the supernatant liquid was clear (approximately seven minutes). The supernatant liquid was decanted and the extraction was repeated three more times. The sample was then washed in an identical manner with three 33-ml portions of 99% isopropyl alcohol.

Using the shaking and centrifuging procedure outlined above, the adsorbed Na is replaced using three 33-ml portions of NH_4OAc reagent, decanting each washing into a 100 ml volumetric flask. The solution was diluted to volume with NH_4OAc . The Na concentration was determined by Inductively Coupled Plasma Emission Spectrometry (ICP-ES). Calcium and magnesium were simultaneously determined on the extracting solution, although this is not part of the usual procedure. Calcium and magnesium represent loosely-bound alkaline earth elements which are easily replaced by sodium, providing the sodium is high enough in concentration. The CEC results are reported as meq/100 g of sample. Replicates were performed on approximately 10% of the samples and had a range of $\pm 4.5\%$.

Chapter 4

DISCUSSION OF RESULTS

The results obtained in this study will be discussed from two major viewpoints. First, data from the soils and sediments analyses were interpreted separately. Hypotheses and observations are presented based on the results between the soils and sediments and groups of soils and sediments. An attempt was also made to correlate these results with possible relationships with geologic influences, vegetative cover, location (elevation), and resulting water quality. Second, statistical analyses of the soils and sediments were shown to support hypotheses generated from the raw data and the lake classification model previously developed.

4.1 Analysis of Raw Data

All of the raw data was analyzed before any statistical analyses were performed. This was done to determine if any trends could be shown to exist between soils and sediments or groups of soils and sediments. The potential

relationships between the soils and sediments in relation to geologic influences, vegetative cover, and location (elevation) were also examined. Once these tasks were completed, statistical analyses were performed on the data to test any hypotheses that were generated. A discussion of the findings is presented in the following section.

Due to the large number of soil and sediment samples (350 and 105 respectively) collected in this study, it was virtually impossible to detect relationships between individual data points. For this reason soils and sediments were grouped through various parameters. It was hoped that trends and relationships not detectable through the individual numbers, would be apparent through the groupings. Raw data for the soils and sediments are presented in Appendices A and B. After studying the data, it was apparent that without performing any statistical analysis, only one of the three measured parameters was useful in comparing the soils and sediments. This also appeared to be the case when the soils and sediments were compared with their surrounding physical characteristics. The measured parameter best suited for these purposes was pH.

The first noticeable trend that appeared was that the pH of the sediments appeared to be slightly higher overall

than the pH of the soils. A number of mechanisms could be responsible for this trait. It is possible that a minimal buffering capacity exists within waters that are in contact with the sediments. A second mechanism that could be responsible for the increased pH is mineral weathering. If the sediments have undergone an increased amount of weathering relative to the soils, the end result could be a higher pH. The additional weathering would remove a larger portion of the acidic components resulting in a higher overall pH. The degree of mineral weathering is related to the geologic environment from which the soils and sediments originated. A third mechanism that could be related to the increased pH in the sediments is organic carbon content. Many of the basins have a forest cover which can result in a high organic carbon content and therefore a lower pH in the soils relative to the sediments. All of the lakes, and therefore their respective soils and sediments, have been put into classes based in part on the geology of each basin. Soils and sediments were grouped by similar classes of geological materials to see if, in fact, geology or parent material played a role in determining the pH of the soils and sediments.

Referring to Table 3-1, there appeared to be a logical way to group the classes based on geology. Soils and

sediments in classes 1, 2, 3 and 9 all originated from predominantly igneous and metamorphic parent materials. These four classes were put into a single group referred to as Group A. Soils and sediments found in the remaining five classes (4, 5, 6, 7, 8), originated from predominantly sedimentary parent materials. These five classes were put into a single group referred to as Group B. It was anticipated that the soils and sediments in group A would have a lower pH than the soils and sediments found in group B. One reason behind this hypothesis was that soils and sediments derived from less reactive parent materials (igneous and metamorphic), should have lower pH values than those soils and sediments originating from more reactive parent materials (sedimentary). The results of this test are presented in section 4.2.1. Another reason that soils and sediments of Group A might have a lower pH is vegetation cover. Vegetation cover high in organic carbon can result in a lower pH, independent of igneous/metamorphic versus sedimentary differences.

A second trait was also apparent after studying the raw data. In general, it seemed that location (elevation) could be indirectly related to pH. The basis for this indirect relationship is that the geologic environment can be directly related to elevation. Once again using the grouping technique from the previous test (geology vs pH)

it was thought that the soils and sediments found in Group A should have lower pH values than those soils and sediments in Group B. The majority of soils and sediments in Group A come from lake basins located above 9000 feet and situated on virtually non-reactive geologic materials. Conversely, most of the soils and sediments in Group B come from lake basins located below 9000 feet that are situated on much more reactive geologic materials. As stated, the direct relationship is observed between geologic environment and elevation. Yet, both of these physical characteristics may be combined to help determine the pH of the soils and sediments collected from their respective lake basins. Table 4-1 illustrates these general relationships.

4.2 Statistical Analysis of Data

Upon completion of the field and laboratory requirements and analysis of the raw data, all data were split into soils and sediments computer files. Distribution histograms were then constructed for each of the three measured parameters to illustrate the relative distribution of the samples. All of the histograms except pH, yielded a positively-skewed distribution. For this reason the data for both organic carbon content and cation exchange capacity were logarithmically transformed. The

Table 4-1 General Relationships Observed from Raw Data

| Group A | Group B |
|-------------------------|-------------------------|
| (classes 1, 2, 3, 9) | (classes 4, 5, 6, 7, 8) |
| pH: lower overall | pH: higher overall |
| elevation: > 9000 feet | elevation: < 9000 feet |
| geological material: | geological material: |
| igneous and metamorphic | sedimentary |

results of these transformations were slightly negatively-skewed distributions. The resulting histograms all appeared to have a near-normal distribution. Since pH is a logarithmic measurement, the data were left in their original form.

The Kolmogorov-Smirnov (K-S) test was used to quantitatively compare the original data distributions with normal curves. By taking the logarithms of the original data, this test confirmed the positive skewness observed and supported the decision to logarithmically transform organic carbon content and cation exchange capacity data for both soils and sediments.

4.2.1 Univariate Analysis

In order to test hypotheses generated from the raw data, univariate analysis was applied to the data. The univariate analysis performed on the data yielded results supporting general patterns originally detected from the raw data between the soils and sediments. The mean pH of all sediments was approximately 0.4 pH units higher than the mean pH for all soils (See Table 4-2 and 4-3). This confirmed that a slight buffering capacity of the waters that were in contact with these sediments does exist.

Table 4-2 Summary of Univariate Analysis of Data for Soils

| Measured <u>Variable</u> | <u>Mean</u> | <u>Range</u> | Standard <u>Deviation</u> | <u>Skewness</u> |
|-----------------------------|-------------|--------------|------------------------------|-----------------|
| pH | 5.876 | 3.50-8.60 | 0.982 | 0.406 |
| Organic Carbon Content | 3.637 | 0.20-13.75 | 2.527 | 1.358 |
| Cation Exchange Capacity | 42.835 | 6.19-159.34 | 22.712 | 1.410 |

Table 4-3 Summary of Univariate Analysis of Data for Sediments

| Measured <u>Variable</u> | <u>Mean</u> | <u>Range</u> | Standard <u>Deviation</u> | <u>Skewness</u> |
|-----------------------------|-------------|--------------|------------------------------|-----------------|
| pH | 6.305 | 4.30-8.30 | 1.014 | 0.127 |
| Organic Carbon Content | 2.934 | 0.80-12.20 | 2.936 | 1.131 |
| Cation Exchange Capacity | 32.358 | 0.40-211.13 | 26.818 | 3.103 |

Another reason the mean pH of the sediments was higher is that these sediments may have been exposed to a higher degree of weathering.

A comparison of the mean cation exchange capacities showed that the soils exhibited a cation exchange capacity more than 10 meq./100 g higher than the sediments. This indicated that once a soil comes in contact with the water, a small decrease in the ability to exchange cations is experienced. Another explanation is that the cation exchange capacity is partially consumed by the more weathered sediments.

Univariate analysis was also performed on the data of the nine classification categories, in the hopes that the results would support any hypotheses generated from the analysis of the raw data. Table 4-4 presents the results of the analyses. The results indicated that the grouping techniques suggested in section 4.1 were valid. It can be seen that the overall pH values of Group A (classes 1, 2, 3, and 9) were indeed lower than the overall pH values of Group B (classes 4, 5, 6, 7, and 8). Most of the soils and sediments in Group A originated from non-reactive igneous and metamorphic parent materials, while a majority of the soils and sediments in Group B originated from more reactive sedimentary parent materials. The results suggested that

Table 4-4 Summary of Univariate Analysis on Classification Categories

| Category | | Mean | Range | Standard Deviation | Skewness |
|------------|-------|--------|--------------|--------------------|----------|
| 1 Soils | pH* | 5.270 | 4.30-6.10 | 0.483 | -0.224 |
| | OC* | 1.974 | 0.20-8.52 | 1.879 | 2.418 |
| | CEC** | 28.917 | 6.19-115.52 | 23.791 | 2.659 |
| Sediments | pH | 5.233 | 4.30-6.00 | 0.548 | -0.367 |
| | OC | 3.926 | 0.19-7.76 | 3.297 | -0.207 |
| | CEC | 28.573 | 1.78-56.48 | 22.538 | 0.044 |
| 2 Soils | pH | 5.037 | 3.50-6.10 | 0.584 | -0.288 |
| | OC | 4.870 | 0.68-10.90 | 2.624 | -0.475 |
| | CEC | 48.863 | 16.05-159.34 | 28.718 | 1.734 |
| Sediments | pH | 5.461 | 4.80-6.50 | 0.505 | 0.801 |
| | OC | 2.978 | 0.08-8.59 | 3.038 | 0.759 |
| | CEC | 26.788 | 5.71-82.90 | 23.107 | 1.516 |

* OC = Organic Carbon Content
 ** CEC = Cation Exchange Capacity

(continued)

Table 4-4 (continued)

| Category | Mean | Range | Standard Deviation | Skewness |
|------------|------|--------------|--------------------|----------|
| 3 Soils | pH | 4.20-7.20 | 0.630 | 0.419 |
| | OC | 0.76-13.40 | 2.362 | 2.010 |
| | CEC | 15.46-138.72 | 21.458 | 1.093 |
| Sediments | pH | 4.70-7.60 | 0.761 | 0.418 |
| | OC | 0.52-12.20 | 3.631 | 0.880 |
| | CEC | 17.49-211.13 | 37.988 | 3.408 |
| 4 Soils | pH | 6.10-8.60 | 0.765 | 0.157 |
| | OC | 0.42-2.94 | 0.570 | 0.441 |
| | CEC | 12.58-42.08 | 9.439 | 0.323 |
| Sediments | pH | 7.20-7.90 | 0.288 | 0.000 |
| | OC | 0.59-3.56 | 1.142 | 2.176 |
| | CEC | 10.86-29.72 | 8.082 | -0.749 |

Table 4-4 (continued)

| Category | Mean | Range | Standard Deviation | Skewness |
|------------|------|--------|--------------------|----------|
| 5 Soils | pH | 7.590 | 0.324 | -0.724 |
| | OC | 1.564 | 0.772 | 1.472 |
| | CEC | 26.123 | 6.365 | -0.573 |
| Sediments | pH | 7.783 | 0.376 | 0.700 |
| | OC | 1.720 | 1.554 | 0.052 |
| | CEC | 25.422 | 20.669 | 0.245 |
| 6 Soils | pH | 5.770 | 0.681 | -0.643 |
| | OC | 2.865 | 1.279 | 0.452 |
| | CEC | 30.761 | 9.007 | 0.562 |
| Sediments | pH | 6.217 | 0.845 | 1.228 |
| | OC | 2.298 | 1.119 | -0.106 |
| | CEC | 31.287 | 3.553 | 0.388 |

Table 4-4 (continued)

| Category | Mean | Range | Standard Deviation | Skewness |
|------------|------|-------------|--------------------|----------|
| 7 Soils | pH | 4.20-6.60 | 0.596 | 0.574 |
| | OC | 0.24-13.95 | 3.117 | 1.081 |
| | CEC | 14.09-85.48 | 18.235 | 0.700 |
| Sediments | pH | 5.40-7.50 | 0.793 | 0.048 |
| | OC | 0.30-8.19 | 3.167 | 1.210 |
| | CEC | 0.40-67.45 | 24.274 | 1.023 |
| 8 Soils | pH | 6.00-8.00 | 0.478 | 0.632 |
| | OC | 0.39-9.87 | 2.129 | 0.717 |
| | CEC | 16.00-88.84 | 17.503 | 0.334 |
| Sediments | pH | 7.30-8.00 | 0.215 | 0.656 |
| | OC | 0.13-7.63 | 2.090 | 2.542 |
| | CEC | 6.33-48.54 | 13.500 | 0.211 |

Table 4-4 (continued)

| Category | Mean | Range | Standard Deviation | Skewness |
|------------|------|-------------|--------------------|----------|
| 9 Soils | PH | 4.70-7.20 | 0.766 | -0.163 |
| | OC | 0.64-13.00 | 2.781 | 1.505 |
| | CEC | 12.66-88.65 | 17.967 | 1.027 |
| Sediments | PH | 5.40-7.50 | 0.706 | -0.463 |
| | OC | 0.12-7.21 | 2.619 | 0.864 |
| | CEC | 4.27-70.41 | 22.212 | 0.727 |

geology does in fact play a role in determining the pH of soils and sediments. The results also help to support the location (elevation) hypothesis generated in Section 4.1. Table 3-2 shows that the 80% of basins in Group A are situated above 9000 feet while the 67% of basins in Group B are located below 9000 feet. It is therefore possible that both these physical parameters (geology and location) interact to help determine the pH of soils and sediments.

As stated previously in this section, the mean pH of all sediments was approximately 0.4 pH units higher than the mean pH of all soils. Univariate analysis on the nine categories showed that in all the categories except number 1, the mean pH of the sediments was higher than the mean pH of the soils. These results support the interpretation that a slight buffering capacity exists when the sediments are in contact with the waters.

It was difficult to determine any specific or conclusive trends in relation to organic carbon content of the soils and sediments, however, one general trend was evident. In six of the nine categories (2, 4, 6, 7, 8, and 9), the organic carbon content was greater in the soils than in the sediments. These results suggested that when the soils come in contact with the waters, it is possible that organic carbon materials are reworked, broken down, or dispersed,

and corresponding levels of organic carbon decrease.

Univariate analysis on the classification categories also produced supportive results in connection with the cation exchange capacities. All of the categories except category 6 exhibited higher cation exchange capacities in the soils than in the sediments. This supported the idea that when soils come in contact with the waters, a decrease in the ability to exchange cations takes place.

After completing the previously mentioned analyses it was apparent that statistical tests were needed in order to determine the relationships between measured parameters in both the soils and sediments. The two tests that were chosen to effectively illustrate these relationships were the Spearman Rank Correlation Test and the Pearson Correlation Test. Tables 4-5 through 4-8 illustrate these relationships. All of the correlations appeared to be significant. The two correlation tests yielded similar results in the magnitude of the individual correlations and that the highest correlation was between organic carbon and cation exchange capacity. This was true for both soils and sediments. Since all of the individual correlations are similar in magnitude, it is possible that the relationships between the individual parameters are of approximately equal importance in both soils and sediments.

Table 4-5 Spearman Rank Correlation Coefficients for Soils

| (N=346)* | pH | Organic Carbon | Cation Exchange Capacity |
|--------------------------|-------------------------------|----------------------------|----------------------------|
| Organic Carbon | -0.270 Sig. \leq 0.001** | | |
| Cation Exchange Capacity | -0.212 Sig. \leq 0.001 | 0.780 Sig. \leq 0.001 | 1.000 Sig. \leq 0.001 |

* = number of cases
** = significance

Table 4-6 Spearman Rank Correlation Coefficients for Sediments

| (N=103)* | pH | Organic Carbon | Cation Exchange Capacity |
|--------------------------|-------------------------------|----------------------------|----------------------------|
| Organic Carbon | -0.405 Sig. \leq 0.001** | | |
| Cation Exchange Capacity | -0.264 Sig. \leq 0.001 | 0.866 Sig. \leq 0.001 | 1.000 Sig. \leq 0.001 |

* = number of cases
** = significance

Table 4-7 Pearson Correlation Coefficients for Soils

| (N=346)* | pH | Organic Carbon | Cation Exchange Capacity |
|--------------------------|-----------------------|--------------------|--------------------------|
| Organic Carbon | -0.254 P ≤ 0.001** | | |
| Cation Exchange Capacity | -0.200 P ≤ 0.001 | 0.717 P ≤ 0.001 | 1.000 P ≤ 0.001 |

* = number of cases
 ** = significance

Table 4-8 Pearson Correlation Coefficients for Sediments

| (N=103)* | pH | Organic Carbon | Cation Exchange Capacity |
|--------------------------|-----------------------|--------------------|--------------------------|
| Organic Carbon | -0.408 P ≤ 0.000** | | |
| Cation Exchange Capacity | -0.268 P ≤ 0.001 | 0.750 P ≤ 0.001 | 1.000 P ≤ 0.001 |

* = number of cases
 ** = significance

4.2.2 Analysis of Variance for Soils and Sediments

Analysis of variance (ANOVA) was applied to the data to test hypotheses generated from the raw data and to see if the data supports the lake classification model. ANOVA partitions the total observed variance of a set of measurements into individual components (26). This experiment was designed to determine the effect of one variable on a response (dependent variable). In this study, ANOVA partitions the variance for a dependent variable such as the measured variable cation exchange capacity (CEC), from an independent variable such as lake category. If there are several variables of interest, additional levels may be introduced. When there is more than one level in ANOVA, it is possible that interactions among variables can be determined.

Applying ANOVA to this investigation, the variance of CEC in the target lakes was partitioned between lake classification categories and between lakes within a single lake classification category. This partitioning approach would determine the effectiveness of the lake classification model developed previously, using lake water quality. The lake classification model was based on the hypothesis that lake water chemistry is determined by the integration of all the geologic, weathering, and vegetation processes in the

drainage basin. If this hypothesis was correct, it was anticipated that the soil variability would reflect similar category distinctions based on lake water chemistry (26). ANOVA performed on the soil and sediment data allows the testing of alternative formulations of categories, by testing to see if a single measured variable supports hypothesized categories.

Before presenting the results of ANOVA it is necessary to describe the protocol used in computation. The total observed variance for each measured variable was partitioned into three contributions, "between lake classes", "within lake classes", and residuals (unexplained variance). The "within lake classes" variance may, in turn, be partitioned into two portions, "between individual lakes" and "within individual lakes". The significance of the variance contributions in the ANOVA were determined using the F-test. The higher the F-value the more significant the particular source of variance is in determining the value of the dependent variable such as; CEC, pH, etc. The "significance of F" listed in the last column of the tables is an estimate of the probability that the F value could be the result of chance. For example, a significance of 0.010 indicates that there is one chance in 100 of the F value being due to chance (26).

Tables 4-9, 4-10, and 4-11 show the ANOVA results on soils for pH, organic carbon and cation exchange capacity. All three variables had a high F-value for the "class" level. The high F-values indicate that the variance in the

Table 4-9 ANOVA of pH in Soils

| <u>Source of Variation</u> | <u>Sum of Squares</u> | <u>DF</u> | <u>Mean Square</u> | <u>F</u> | <u>Significance of F</u> |
|----------------------------|-----------------------|-----------|--------------------|----------|--------------------------|
| Main Effects | 212.3 | 13 | 13.339 | 70.1 | ≤ 0.001 |
| Class | 196.3 | 8 | 24.535 | 150.3 | ≤ 0.001 |
| Lake | 10.0 | 5 | 1.999 | 8.58 | ≤ 0.001 |
| Two-way Interactions | 43.03 | 18 | 2.390 | 10.2 | ≤ 0.001 |
| Class-Lake | 43.03 | 18 | 2.390 | 10.2 | ≤ 0.001 |
| Explained | 255.4 | 31 | 8.240 | 35.4 | ≤ 0.001 |
| Residual | 68.49 | 294 | 0.233 | | |
| TOTAL | 323.9 | 325 | 0.997 | | |

Table 4-10 ANOVA of Organic Carbon in Soils

| <u>Source of Variation</u> | <u>Sum of Squares</u> | <u>DF</u> | <u>Mean Square</u> | <u>F</u> | <u>Significance of F</u> |
|-----------------------------|-----------------------|------------|--------------------|-------------|--------------------------|
| Main Effects | 8.919 | 13 | 0.686 | 11.2 | ≤0.001 |
| Class | 6.550 | 8 | 0.819 | 13.4 | ≤0.001 |
| Lake | 0.280 | 5 | 0.056 | 0.92 | 0.470 |
| Two-way Interactions | 6.398 | 18 | 0.355 | 5.82 | ≤0.001 |
| Class-Lake | 6.398 | 18 | 0.355 | 5.82 | ≤0.001 |
| Explained | 15.32 | 31 | 0.494 | 8.09 | ≤0.001 |
| Residual | 17.95 | 294 | 0.061 | | |
| TOTAL | 33.26 | 325 | 0.102 | | |

Table 4-11 ANOVA of Cation Exchange Capacity in Soils

| <u>Source of Variation</u> | <u>Sum of Squares</u> | <u>DF</u> | <u>Mean Square</u> | <u>F</u> | <u>Significance of F</u> |
|----------------------------|-----------------------|-----------|--------------------|----------|--------------------------|
| Main Effects | 4.098 | 13 | 3.315 | 12.2 | ≤ 0.001 |
| Class | 3.167 | 8 | 0.396 | 15.4 | ≤ 0.001 |
| Lake | 0.226 | 5 | 0.045 | 1.76 | 0.122 |
| Two-way Interactions | 3.825 | 18 | 0.212 | 8.25 | ≤ 0.001 |
| Class-Lake | 43.03 | 18 | 0.212 | 10.2 | ≤ 0.001 |
| Explained | 7.923 | 31 | 0.256 | 9.93 | ≤ 0.001 |
| Residual | 7.568 | 294 | 0.026 | | |
| TOTAL | 15.49 | 325 | 0.048 | | |

three variables can be attributed to differences between the lake classes. Low F-values would have indicated that the differences between the lake classes could have been due to chance. A relatively large F-value was observed for pH at the "lake" level, indicating significant "between lake" (within class) differences. Organic carbon and cation exchange capacity data did not support the differences at the "lake" level. All three variables showed class differences to be the main factor. Therefore, the soils data supported the lake classification model. ANOVA of the soils also showed that the amount of variance explained by the "class-lake" interactions was large compared to the residuals. This means that the amount of variance due to sampling and analytical error was small (26).

Tables 4-12, 4-13, and 4-14 show ANOVA results on sediments for pH, organic carbon and cation exchange capacity. Only pH had a large F-value for the "class" level and thus was the only variable to support the lake classification model. Organic carbon and cation exchange capacity data for sediments did not support the lake classification model. The results between lake (within class) differences and "class-lake" interactions were similar to those observed in soils. The amount of variance

Table 4-12 ANOVA of pH in Sediments

| <u>Source of Variation</u> | <u>Sum of Squares</u> | <u>DF</u> | <u>Mean Square</u> | <u>F</u> | <u>Significance of F</u> |
|----------------------------|-----------------------|-----------|--------------------|----------|--------------------------|
| Main Effects | 68.96 | 13 | 5.305 | 35.7 | ≤ 0.001 |
| Class | 65.86 | 8 | 8.232 | 55.5 | ≤ 0.001 |
| Lake | 4.278 | 5 | 0.856 | 5.76 | ≤ 0.001 |
| Two-way Interactions | 15.89 | 18 | 0.883 | 5.95 | ≤ 0.001 |
| Class-Lake | 15.89 | 18 | 0.883 | 5.95 | ≤ 0.001 |
| Explained | 84.86 | 31 | 2.737 | 18.4 | ≤ 0.001 |
| Residual | 9.647 | 65 | 0.148 | | |
| TOTAL | 94.51 | 96 | 0.984 | | |

Table 4-13 ANOVA of Organic Carbon in Sediments

| <u>Source of Variation</u> | <u>Sum of Squares</u> | <u>DF</u> | <u>Mean Square</u> | <u>F</u> | <u>Significance of F</u> |
|-----------------------------|-----------------------|-----------|--------------------|-------------|--------------------------|
| Main Effects | 4.054 | 13 | 0.312 | 1.35 | 0.207 |
| Class | 2.745 | 8 | 0.343 | 1.49 | 0.179 |
| Lake | 1.677 | 5 | 0.335 | 1.456 | 0.217 |
| Two-way Interactions | 8.353 | 18 | 0.464 | 2.01 | 0.021 |
| Class-Lake | 8.353 | 18 | 0.464 | 2.01 | 0.021 |
| Explained | 12.31 | 31 | 0.400 | 1.73 | 0.031 |
| Residual | 14.99 | 65 | 0.231 | | |
| TOTAL | 27.40 | 96 | 0.285 | | |

Table 4-14 ANOVA of Cation Exchange Capacity in Sediments

| <u>Source of Variation</u> | <u>Sum of Squares</u> | <u>DF</u> | <u>Mean Square</u> | <u>F</u> | <u>Significance of F</u> |
|----------------------------|-----------------------|-----------|--------------------|----------|--------------------------|
| Main Effects | 2.846 | 13 | 0.219 | 1.95 | 0.040 |
| Class | 2.274 | 8 | 0.284 | 2.54 | 0.018 |
| Lake | 0.836 | 5 | 0.167 | 1.49 | 0.205 |
| Two-way Interactions | 5.332 | 18 | 0.296 | 2.64 | 0.002 |
| Class-Lake | 5.332 | 18 | 0.296 | 2.64 | 0.002 |
| Explained | 8.178 | 31 | 0.264 | 2.36 | 0.002 |
| Residual | 7.280 | 65 | 0.112 | | |
| TOTAL | 156.46 | 96 | 0.161 | | |

explained compared to residuals is small, indicating that soils may be inherently better for classifying lakes.

4.2.3 Multiple Range Tests for Soils and Sediments

One method of testing whether one class can be distinguished from another class for a given parameter is the multiple range test. Two different multiple range tests were applied to the three measured parameters in the soils and sediments. The two tests applied in this study were the least-squares-difference test and the Duncan multiple range test. Results of both tests were presented here to illustrate the similarities and differences found to exist. It was hypothesized that these tests would not only show which classes were significantly different from other classes, but also, which of the three measured variables best discriminated among the nine classes based on water chemistries. Both of these general hypotheses were supported.

Figures 4-1 and 4-2 summarize the results of the least-squares-difference test as it was applied to the three measured parameters for soils and sediments

| pH Class | | | | | | | | | | Organic Carbon Class | | | | | | | | | |
|----------|---|---|---|---|---|---|---|---|---|----------------------|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 7 | 3 | 6 | 9 | 8 | 4 | 5 | | 4 | 5 | 1 | 6 | 9 | 3 | 7 | 8 | 2 | |
| 2 | 0 | | | | | | | | | 4 | 0 | | | | | | | | |
| 1 | 0 | | | | | | | | | 5 | 0 | | | | | | | | |
| 7 | | 0 | | | | | | | | 1 | | 0 | | | | | | | |
| 3 | * | * | | 0 | | | | | | 6 | * | * | * | 0 | | | | | |
| 6 | * | * | * | | 0 | | | | | 9 | * | * | * | | 0 | | | | |
| 9 | * | * | * | | | 0 | | | | 3 | * | * | * | | | 0 | | | |
| 8 | * | * | * | * | * | * | 0 | | | 7 | * | * | * | | | | 0 | | |
| 4 | * | * | * | * | * | * | | 0 | | 8 | * | * | * | | | | | 0 | |
| 5 | * | * | * | * | * | * | * | | 0 | 2 | * | * | * | * | | | | | 0 |

| Cation Exchange Capacity Class | | | | | | | | | |
|--------------------------------|---|---|---|---|---|---|---|---|---|
| 4 | 1 | 5 | 6 | 9 | 7 | 2 | 8 | 3 | |
| 4 | 0 | | | | | | | | |
| 1 | | 0 | | | | | | | |
| 5 | | | 0 | | | | | | |
| 6 | | | | 0 | | | | | |
| 9 | * | * | * | | 0 | | | | |
| 7 | * | * | * | | | 0 | | | |
| 2 | * | * | * | * | | | 0 | | |
| 8 | * | * | * | * | * | | | 0 | |
| 3 | * | * | * | * | * | * | | | 0 |

* Indicates a significant difference between classes at the 0.01 level

Figure 4-1 Least-Squares-Difference Multiple Range Classification of Soils

| pH Class | | | | | | | | | | Organic Carbon Class | | | | | | | |
|----------|---|---|---|---|---|---|---|---|---|----------------------|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 6 | 7 | 9 | 8 | 4 | 5 | 8 | 5 | 4 | 2 | 9 | 7 | 1 | 6 | 3 |
| 1 | 0 | | | | | | | | 8 | 0 | | | | | | | |
| 2 | * | 0 | | | | | | | 5 | 0 | | | | | | | |
| 3 | * | | 0 | | | | | | 4 | | 0 | | | | | | |
| 6 | * | | | 0 | | | | | 2 | | | 0 | | | | | |
| 7 | * | * | | | 0 | | | | 9 | | | | 0 | | | | |
| 9 | * | * | * | | | 0 | | | 7 | | | | | 0 | | | |
| 8 | * | * | * | * | * | * | 0 | | 1 | | | | | | 0 | | |
| 4 | * | * | * | * | * | * | | 0 | 6 | | | | | | | 0 | |
| 5 | * | * | * | * | * | * | | | 3 | * | | | | | | | 0 |

Cation Exchange Capacity Class

| 7 | 1 | 5 | 9 | 2 | 4 | 8 | 6 | 3 |
|---|---|---|---|---|---|---|---|---|
| 7 | 0 | | | | | | | |
| 1 | | 0 | | | | | | |
| 5 | | | 0 | | | | | |
| 9 | | | | 0 | | | | |
| 2 | | | | | 0 | | | |
| 4 | | | | | | 0 | | |
| 8 | | | | | | | 0 | |
| 6 | | | | | | | | 0 |
| 3 | * | * | | * | * | | | 0 |

* Indicates a significant difference between classes at the 0.01 level

Figure 4-2 Least-Squares-Difference Multiple Range Classification of Sediments

respectively. Classes which were significantly different at the 0.01 level from other classes are designated by asterisks in the comparison matrix (26). If two classes were not significantly different at the 0.01 level the cell is blank. Zeros fill the diagonal because this represents comparison of an individual class against itself and therefore no class difference exists. All of the individual matrices are symmetrical and for this reason, only the lower half of each matrix has been completed. In order to properly interpret the figures an example is presented here from figure 4-1. It can be seen that the pH of the soils was not significantly different between classes 1 and 2, but was significantly different between classes 1 and 3. The results of these tests indicated that pH was the best discriminator between lake classes of the three measured parameters. In both the soils and sediments, organic carbon and cation exchange capacity had less ability to distinguish differences between classes. It should be noted, however, that all three parameters were better discriminators between classes in the soils than in the sediments. This may be due to the large number of soil samples taken in comparison to the number of sediment samples taken. Another possibility is that the soils may be inherently better than the sediments for the purpose of

classifying lakes. It is also worth noting that in sediments only pH was able to effectively distinguish between classes.

Figures 4-3 and 4-4 summarize the results of the Duncan multiple range test as it was applied to the three measured variables for soils and sediments, respectively. The matrices are set up in the same design as the least-squared-difference test matrices. The results are almost the same as those yielded from the least-squared-difference tests. The results again indicated that pH was the best discriminator between lake classes of the three measured parameters in both soils and sediments. Organic carbon and cation exchange capacity had less ability to distinguish between classes in the sediments. It is interesting to note that both multiple range tests showed significant differences between similar lake classes, in both the soils and sediments. This confirmed that these differences are in fact legitimate.

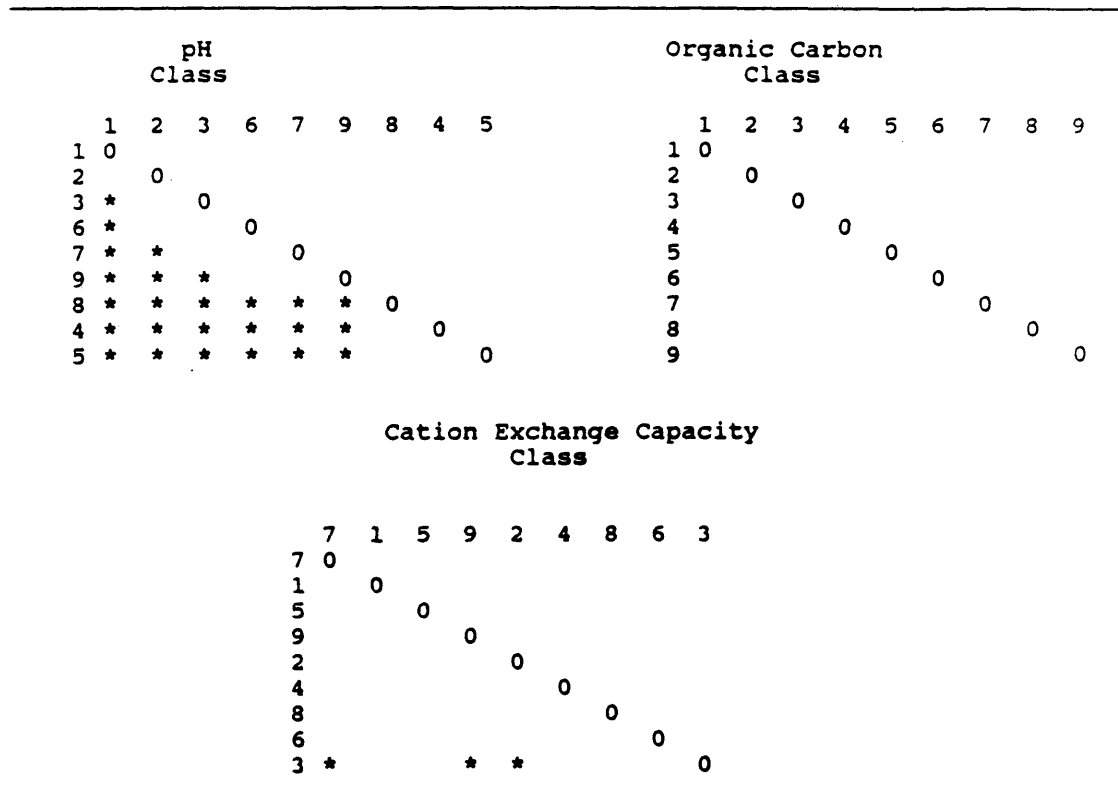
| pH Class | | | | | | | | | Organic Carbon Class | | | | | | | | |
|----------|---|---|---|---|---|---|---|---|----------------------|---|---|---|---|---|---|---|---|
| 2 | 1 | 7 | 3 | 6 | 9 | 8 | 4 | 5 | 4 | 5 | 1 | 6 | 9 | 3 | 7 | 8 | 2 |
| 2 | 0 | | | | | | | | 4 | 0 | | | | | | | |
| 1 | 0 | | | | | | | | 5 | 0 | | | | | | | |
| 7 | | 0 | | | | | | | 1 | | 0 | | | | | | |
| 3 | * | * | | 0 | | | | | 6 | * | * | * | 0 | | | | |
| 6 | * | * | | | 0 | | | | 9 | * | * | * | | 0 | | | |
| 9 | * | * | * | | | 0 | | | 3 | * | * | * | | | 0 | | |
| 8 | * | * | * | * | * | * | 0 | | 7 | * | * | * | | | | 0 | |
| 4 | * | * | * | * | * | * | | 0 | 8 | * | * | * | | | | | 0 |
| 5 | * | * | * | * | * | * | * | 0 | 2 | * | * | * | | | | | 0 |

Cation Exchange Capacity Class

| 4 | 1 | 5 | 6 | 9 | 7 | 2 | 8 | 3 |
|---|---|---|---|---|---|---|---|---|
| 4 | 0 | | | | | | | |
| 1 | | 0 | | | | | | |
| 5 | | | 0 | | | | | |
| 6 | | | | 0 | | | | |
| 9 | * | * | * | | 0 | | | |
| 7 | * | * | * | | | 0 | | |
| 2 | * | * | * | * | | | 0 | |
| 8 | * | * | * | * | | | | 0 |
| 3 | * | * | * | * | * | * | | 0 |

* Indicates a significant difference between classes at the 0.01 level

Figure 4-3 Duncan Multiple Range Classification of Soils



* Indicates a significant difference between classes at the 0.01 level

Figure 4-4 Duncan Multiple Range Classification of Sediments

Chapter 5

SUMMARY

The results presented in the previous chapter indicated that soils and sediments do play a role in determining resulting water quality. General trends observed from the raw data and through statistical analyses were shown to be valid. It was apparent that overall, soils data was more informative and useful than sediments data. This was evident when comparing relationships between the soils and sediments themselves, and in support of the lake classification model based on lake water chemistries.

Upon examination of the raw data it was evident that only pH was useful in looking at relationships between soils and sediments. It appeared that the overall pH values of the sediments were slightly greater than the overall pH values of the soils. This trend may be the result of a slight buffering capacity of water in contact with the sediments or that the sediments may have undergone an increased amount of mineral weathering relative to the soils. From the raw data, it was also thought that both geology and location (elevation) would play a role in determining soil and sediment pH. In order to investigate

these hypotheses, soils and sediments data from the nine classes were divided into two groups (Group A and Group B). Group A was comprised of classes 1, 2, 3, and 9 while Group B was comprised of classes 4, 5, 6, 7, and 8. Physical characteristics of samples in Group A included mainly igneous and metamorphic geologic materials, which were generally situated in basins at an elevation of 9000 ft or higher. Conversely, Group B samples were composed mainly of sedimentary geologic materials situated in basins lower than 9000 ft. Statistical analyses performed later showed these general trends to be valid.

Statistical analysis was begun by splitting the data into soils and sediments computer files. Distribution histograms were constructed for all the measured variables for both soils and sediments. All of the histograms except pH were positively skewed. Therefore, it was decided to logarithmically transform the data for organic carbon and cation exchange capacity. The resulting histograms all appeared to have near-normal distributions. The Kolmogorov-Smirnov (K-S) goodness of fit test confirmed the positive skewness observed and supported the decision to logarithmically transform organic carbon and cation exchange capacity data.

The next step was to conduct univariate analysis on the

soils and sediments data, Group A and Group B subdivisions within the two main files, and finally on the nine individual classes.

Results of the univariate analysis on the soils and sediments files showed that the mean pH of the sediments was approximately 0.4 pH units higher than the soils. These results confirmed the general trend observed from the raw data. The results also helped to support the idea that waters in contact with the sediments do, in fact, slightly buffer the sediments. A second result yielded through univariate analysis of the soils and sediments, was that the mean cation exchange capacity of the soils was more than 10 meq/100 g higher than the sediments. This was not observed from the raw data. This result suggested that once a soil comes in contact with water, the ability to exchange cations was somewhat decreased. The decrease in cation exchange capacity may also be due to increased mineral weathering that occurred previously.

Univariate analysis was then performed on soils and sediments in Group A and Group B. The results showed that the grouping techniques explained above were indeed valid. Group A was shown to have lower pH values than Group B. These results support the ideas suggested from the raw data in that geology plays a direct role in determining soil and

sediment pH, while location (elevation) plays an indirect role in determining soil and sediment pH.

The final univariate analysis experiment was carried out on the nine individual classes. The results showed that in all classes except number 1, the mean pH of the sediments was higher than the mean pH in the soils. No specific results were evident for the organic carbon data, although one general trend was observed. In six of the nine classes (2, 3, 6, 7, 8, 9), organic carbon content was higher in soils than in sediments. This indicated that it was possible for organic carbon materials to be broken down or dispersed after coming in contact with water, resulting in decreased measurable organic carbon contents. Results of univariate analysis on the nine classes using cation exchange capacity, also supported the results obtained from the analysis on the soils and sediments files. It was seen that in all classes except number 6, the cation exchange capacity was higher in the soils than in the sediments. These results also help to confirm the idea that soils experience a decrease in their ability to exchange cations when they come in contact with water.

The Spearman Rank and Pearson Correlation Tests were used to determine relationships between the measured parameters (pH, organic carbon, and cation exchange

capacity). All correlations appeared to be significant, possibly due to the large number of samples. The two tests yielded similar results in the magnitude of the individual correlations and showed that the highest correlation was between organic carbon and cation exchange capacity in both soils and sediments.

Analysis of variance (ANOVA) was performed on both the soils and sediments. The results for the soils showed that all three parameters had high F values at the "class" level. This indicated that the main differences were between lake classes. The parameter pH also had a high F value at the "lake" level indicating differences between lakes (within classes). Therefore, these results were interpreted to support the previously developed lake classification model. The "class-lake" interactions explained were large versus residuals, which indicated that sampling and analytical errors were small.

Results of ANOVA on sediments showed that only pH had a large F value at the "class" level. This indicated that only pH was able to support the lake classification model. Results of between lake (within class) and "class-lake" interactions were similar to those observed in soils. The amount of variance explained is small compared to residuals indicating that soils may be inherently better for classifying lakes.

Multiple range tests were applied to the data to test if one class could be distinguished from another for a given parameter. The two tests used were the least-squares-difference test and the Duncan multiple range test. Both tests showed which classes were significantly different from other classes and which measured parameter best discriminated between the water-based classes. In both the soils and sediments, pH was shown to be the best discriminator between classes, although all three parameters were better discriminators in the soils than in the sediments. The two tests also showed differences between similar lake classes indicating that the differences were legitimate.

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APPENDIX A
CHEMICAL ANALYSES OF SEDIMENT SAMPLES

| LAKE | SAMPLES | CATEGORY | PH | ORGANIC | | | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|------------|---------|----------|-----|--------------------------|-------|------|-------------------------------|--------------------------------|-----------------------|------------------|
| | | | | CARBON CONTENT (%) | | | | | | |
| Crater | 11.04A | 2 | 4.8 | 7.35 | 5.43 | 1.21 | 76.62 | 3.1226 | | |
| | 11.04B | 2 | 5.2 | 6.86 | 1.58 | 0.37 | 54.15 | 3.3739 | | |
| | 11.04C | 2 | 4.9 | 0.56 | 0.13 | 0.06 | 15.31 | 5.7587 | | |
| Arapahoe | 11.09A | 2 | 5.0 | 0.49 | 0.10 | 0.02 | 12.63 | 6.3010 | | |
| | 11.09B | 2 | 5.6 | 0.45 | 0.10 | 0.03 | 7.21 | 4.2206 | | |
| | 11.09C | 2 | 5.0 | 8.15 | 0.39 | 0.05 | 41.31 | 4.7488 | | |
| Mammoth | 11.22A | 1 | 6.0 | 0.69 | 0.11 | 0.01 | 7.48 | 5.7000 | | |
| | 11.22B | 1 | 4.3 | 6.50 | 0.41 | 0.03 | 56.48 | 5.1753 | | |
| | 11.22C | 1 | 5.3 | 0.75 | 0.13 | 0.01 | 17.19 | 6.3003 | | |
| Noecker | 3.17A | 8 | 7.6 | 2.85 | 20.89 | 0.46 | 36.88 | 5.0713 | | |
| | 3.17B | 8 | 7.3 | 0.85 | 36.78 | 0.45 | 20.85 | 5.2772 | | |
| | 3.17C | 8 | 7.8 | 0.59 | 31.85 | 0.46 | 24.16 | 5.4200 | | |
| Carp | 4.02A | 3 | 5.4 | 12.20 | 1.76 | 0.15 | 69.18 | 5.3136 | | |
| | 4.02B | 3 | 5.3 | 7.27 | 1.05 | 0.11 | 58.11 | 5.2929 | | |
| | 4.02C | 3 | 6.2 | 0.98 | 0.22 | 0.09 | 25.39 | 5.2194 | | |
| Howard | 4.05A | 3 | 5.7 | 1.76 | 0.26 | 0.05 | 26.80 | 5.2428 | | |
| | 4.05B | 3 | 6.2 | 0.74 | 0.18 | 0.07 | 24.89 | 5.3473 | | |
| | 4.05C | 3 | 5.8 | 3.04 | 0.59 | 0.07 | 38.14 | 5.1665 | | |
| Twin Basin | 1.21A | 3 | 6.7 | 0.76 | 0.39 | 0.18 | 34.45 | 5.5435 | | |
| | 1.21B | 3 | 6.2 | 3.72 | 1.15 | 0.28 | 60.66 | 5.0129 | | |
| | 1.21C | 3 | 6.2 | 3.63 | 1.01 | 0.27 | 50.07 | 4.9173 | | |
| Jumbo | 0.00A | 3 | 6.2 | 2.07 | 0.58 | 0.11 | 36.58 | 5.2087 | | |
| | 0.00B | 3 | 5.6 | 9.64 | 1.55 | 0.18 | 75.96 | 5.3889 | | |
| | 0.00C | 3 | 5.5 | 10.69 | 1.52 | 0.19 | 69.08 | 5.5474 | | |
| Owens | 4.04A | 6 | 6.2 | 2.71 | 0.75 | 0.14 | 35.72 | 5.5162 | | |
| | 4.04B | 6 | 7.7 | 0.80 | 20.07 | 0.51 | 35.15 | 5.2139 | | |
| | 4.04C | 6 | 6.6 | 1.44 | 0.35 | 0.12 | 27.75 | 5.3606 | | |
| Lake Molas | 6.09A | 7 | 5.5 | 7.75 | 2.03 | 0.09 | 7.29 | 5.2484 | | |
| | 6.09B | 7 | 6.6 | 0.37 | 0.10 | 0.21 | 67.54 | 5.1526 | | |
| | 6.09C | 7 | 6.6 | 0.30 | 0.16 | 0.10 | 0.40 | 5.5011 | | |
| Haviland | 6.15A | 8 | 7.5 | 0.31 | 1.20 | 0.15 | 8.94 | 5.4018 | | |
| | 6.15B | 8 | 7.5 | 1.43 | 1.34 | 0.22 | 21.48 | 5.2258 | | |
| | 6.15C | 8 | 7.3 | 0.96 | 0.52 | 0.14 | 14.65 | 5.1683 | | |
| Chapman | 6.08A | 5 | 7.7 | 0.44 | 4.28 | 0.21 | 4.85 | 5.3818 | | |
| | 6.08B | 5 | 8.2 | 0.31 | 3.40 | 0.23 | 8.71 | 5.2926 | | |
| | 6.08C | 5 | 8.3 | 0.19 | 3.55 | 0.23 | 7.97 | 5.6219 | | |

* - Basin
 ** - Lake No.
 *** - Sample No.

| LAKE | SAMPLES | CATEGORY | pH | ORGANIC CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|---------------|---------|----------|-----|-------------------------------------|-------------------------------|--------------------------------|-----------------------|------------------|
| Stevens | 6.04A | 4 | 7.9 | 0.59 | 16.36 | 0.41 | 24.98 | 5.1544 |
| | 6.04B | 4 | 7.8 | 1.33 | 23.95 | 0.34 | 29.72 | 5.2150 |
| | 6.04C | 4 | 7.3 | 0.67 | 0.77 | 0.08 | 27.33 | 5.4754 |
| | 6.06A | 6 | 5.8 | 1.84 | 0.36 | 0.04 | 28.69 | 5.5031 |
| O'Connell | 6.06B | 6 | 5.6 | 3.59 | 0.81 | 0.05 | 32.07 | 5.1550 |
| | 6.06C | 6 | 5.4 | 3.41 | 0.59 | 0.03 | 28.34 | 5.1729 |
| | 7.05A | 7 | 6.3 | 1.94 | 0.33 | 0.04 | 21.09 | 5.5885 |
| Rito Alto | 7.05B | 7 | 5.4 | 1.00 | 0.07 | 0.02 | 9.43 | 5.5490 |
| | 7.05C | 7 | 5.4 | 8.19 | 0.90 | 0.04 | 57.58 | 5.1223 |
| | 8.02A | 2 | 5.0 | 8.59 | 1.81 | 0.06 | 82.90 | 5.5199 |
| Grizzly | 8.02B | 2 | 5.7 | 2.13 | 0.59 | 0.04 | 26.76 | 5.2347 |
| | 8.02C | 2 | 5.1 | 5.14 | 0.48 | 0.06 | 25.29 | 5.4861 |
| | 8.19A | 9 | 6.7 | 3.71 | 2.19 | 0.16 | 42.06 | 5.1300 |
| Upper | 8.19B | 9 | 7.0 | 0.65 | 0.47 | 0.08 | 14.42 | 5.0975 |
| | 8.19C | 9 | 7.3 | 1.41 | 1.07 | 0.14 | 21.55 | 5.1065 |
| | 7.14A | 3 | 7.6 | 1.70 | 3.59 | 0.54 | 33.05 | 5.1459 |
| Spencer | 7.14B | 3 | 7.2 | 9.52 | 4.34 | 0.49 | 64.76 | 5.1790 |
| | 7.14C | 3 | 6.9 | 1.89 | 0.94 | 0.22 | 30.87 | 5.5793 |
| | 8.15A | 2 | 5.9 | 0.45 | 0.09 | 0.03 | 12.48 | 5.5065 |
| Upper Venable | 8.15B | 2 | 6.5 | 0.51 | 0.20 | 0.07 | 12.94 | 5.4458 |
| | 8.15C | 2 | 6.5 | 0.08 | 0.09 | 0.06 | 8.95 | 5.2004 |
| | 8.18A | 9 | 6.8 | 0.53 | 0.15 | 0.02 | 11.53 | 5.2076 |
| Wrights | 8.18B | 9 | 6.4 | 0.80 | 0.44 | 0.04 | 28.52 | 5.5367 |
| | 8.18C | 9 | 7.1 | 2.39 | 0.35 | 0.11 | 18.17 | 5.1953 |
| | 3.08A | 2 | 5.8 | 1.79 | 0.27 | 0.03 | 14.77 | 5.4792 |
| Morman | 3.08B | 2 | 5.3 | 3.87 | 0.24 | 0.02 | 28.47 | 5.4402 |
| | 3.08C | 2 | 5.2 | 2.63 | 0.17 | 0.02 | 16.49 | 5.4083 |
| | 3.01A | 1 | 4.8 | 6.66 | 0.82 | 0.10 | 53.33 | 5.3266 |
| Diemer | 3.01B | 1 | 4.7 | 6.07 | 0.40 | 0.05 | 37.68 | 5.2761 |
| | 3.01C | 1 | 5.2 | 7.76 | 0.74 | 0.11 | 52.87 | 5.3481 |
| | 10.24A | 9 | 6.3 | 0.12 | 0.06 | 0.02 | 4.27 | 5.6016 |
| Rainbow | 10.24B | 9 | 5.5 | 7.21 | 0.52 | 0.02 | 41.90 | 5.4511 |
| | 10.24C | 9 | 5.7 | 0.93 | 0.07 | 0.01 | 4.76 | 5.4816 |
| | 10.14B | 9 | 5.8 | 0.37 | 0.06 | 0.02 | 4.74 | 5.4167 |
| M. Painbow | 10.14A | 9 | 5.4 | 0.81 | 0.06 | 0.01 | 6.47 | 5.4454 |

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| LAKE | SAMPLES | CATEGORY | PH | ORGANIC | | | | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|----------------|---------|----------|-----|--------------------------|------------------------------|--------------------------------|-----------------------|--------------------------------|-----------------------|------------------|
| | | | | CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | | | |
| Mc Hatton | 2.06A | 5 | 7.4 | 2.96 | 34.57 | 2.16 | 37.88 | 5.3401 | | |
| | 2.06B | 5 | 7.6 | 2.95 | 28.91 | 1.46 | 52.89 | 5.2478 | | |
| | 2.06C | 5 | 7.5 | 3.47 | 28.82 | 1.80 | 40.23 | 5.4717 | | |
| Seventh | 2.10A | 8 | 7.3 | 1.14 | 1.17 | 0.11 | 37.78 | 5.2625 | | |
| | 2.10B | 8 | 7.6 | 2.49 | 24.10 | 0.60 | 38.16 | 5.5293 | | |
| Clock | 2.10C | 8 | 7.7 | 0.39 | 0.83 | 0.10 | 31.17 | 5.4854 | | |
| | 2.08A | 7 | 6.9 | 2.11 | 0.21 | 0.07 | 16.14 | 5.1750 | | |
| Threemile | 2.08B | 7 | 7.5 | 2.22 | 0.60 | 0.26 | 26.86 | 5.5063 | | |
| | 10.07A | 8 | 8.0 | 0.26 | 4.62 | 0.32 | 6.33 | 5.0682 | | |
| Upper Bigcreek | 10.07B | 8 | 7.4 | 7.63 | 21.32 | 1.30 | 48.54 | 5.2426 | | |
| | 10.07C | 8 | 7.6 | 0.13 | 3.70 | 0.20 | 11.18 | 5.2528 | | |
| | 10.10A | 1 | 5.5 | 0.32 | 0.03 | 0.01 | 1.78 | 5.3486 | | |
| Finger | 10.10B | 1 | 5.8 | 0.19 | 0.05 | 0.01 | 2.00 | 5.3265 | | |
| | 10.10C | 1 | 5.5 | 6.39 | 0.42 | 0.02 | 28.35 | 5.2788 | | |
| | 10.16A | 3 | 6.9 | 1.26 | 0.52 | 0.06 | 26.11 | 5.2650 | | |
| Addison | 10.16B | 3 | 6.1 | 0.52 | 0.17 | 0.03 | 17.49 | 5.3233 | | |
| | 10.16C | 3 | 5.9 | 1.80 | 0.42 | 0.03 | 29.25 | 5.6222 | | |
| | 10.02A | 4 | 7.2 | 0.90 | 12.25 | 0.72 | 12.01 | 5.2528 | | |
| | 10.02B | 4 | 7.4 | 3.56 | 16.66 | 0.95 | 24.62 | 5.2131 | | |
| Upper Pomeroy | 10.02C | 4 | 7.7 | 0.71 | 3.35 | 0.74 | 10.86 | 5.3694 | | |
| | 8.14A | 2 | 5.7 | 0.13 | 0.14 | 0.02 | 5.71 | 5.4081 | | |
| | 8.14B | 2 | 5.7 | 0.19 | 0.09 | 0.03 | 8.56 | 5.3382 | | |
| Shingle | 8.14C | 2 | 5.4 | 4.24 | 0.37 | 0.02 | 31.63 | 5.5143 | | |
| | 3.26A | 9 | 7.0 | 4.86 | 1.60 | 0.07 | 48.80 | 5.4646 | | |
| | 3.26B | 9 | 7.2 | 7.18 | 3.47 | 0.15 | 70.41 | 5.3191 | | |
| Fisher | 3.26C | 9 | 7.5 | 5.87 | 2.75 | 0.13 | 61.20 | 5.2670 | | |
| | 4.03A | 3 | 5.6 | 6.35 | 1.39 | 0.15 | 57.02 | 5.6381 | | |
| | 4.03B | 3 | 5.2 | 4.82 | 0.85 | 0.11 | 48.17 | 5.4187 | | |
| Bull Creek | 4.03C | 3 | 4.9 | 1.63 | 0.32 | 0.07 | 35.06 | 5.7198 | | |
| | 1.03A | 3 | 4.8 | 1.08 | 0.41 | 0.07 | 54.32 | 5.6214 | | |
| | 1.03B | 3 | 5.2 | 8.57 | 8.15 | 0.52 | 211.13 | 5.4187 | | |
| | 1.03C | 3 | 4.7 | 6.00 | 2.76 | 0.16 | 62.01 | 5.2963 | | |

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APPENDIX B
CHEMICAL ANALYSES OF SOIL SAMPLES

| LAKE | SAMPLES | CATEGORY | pH | ORGANIC | | | | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|----------|---------|----------|------|--------------------------|------------------------------|--------------------------------|-----------------------|--------------------------------|-----------------------|------------------|
| | | | | CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | | | |
| CRATER | 11.04D | 2 | 3.5 | 3.13 | 0.07 | 0.01 | 35.06 | 5.2733 | | |
| | 11.04E | 2 | 4.0 | 4.69 | 0.68 | 0.09 | 69.11 | 5.3753 | | |
| | 11.04F | 2 | 4.0 | 3.30 | 0.18 | 0.02 | 40.83 | 5.0176 | | |
| | 11.04G | 2 | 4.2 | 5.22 | 0.22 | 0.04 | 46.99 | 4.4717 | | |
| | 11.04H | 2 | 4.5 | 1.43 | 0.13 | 0.02 | 29.06 | 4.7154 | | |
| | 11.04I | 2 | 4.9 | 2.16 | 0.16 | 0.02 | 19.17 | 5.4221 | | |
| | 11.04J | 2 | 5.2 | 2.84 | 0.34 | 0.04 | 33.45 | 5.5406 | | |
| | 11.04K | 2 | 4.7 | 2.67 | 0.24 | 0.03 | 33.06 | 5.4071 | | |
| | 11.04L | 2 | 4.5 | 3.54 | 0.72 | 0.11 | 43.98 | 5.5781 | | |
| | 11.09D | 2 | 5.2 | 8.20 | 0.59 | 0.08 | 47.80 | 5.4275 | | |
| | 11.09E | 2 | 4.3 | 3.82 | 0.16 | 0.03 | 41.80 | 5.9425 | | |
| ARAPAHOE | 11.09F | 2 | 4.4 | 2.78 | 0.12 | 0.04 | 29.21 | 5.5850 | | |
| | 11.09G | 2 | 4.6 | 1.11 | 0.09 | 0.02 | 16.05 | 5.5472 | | |
| | 11.09H | 2 | 4.5 | 5.46 | 0.41 | 0.11 | 53.46 | 5.4194 | | |
| | 11.09I | 2 | 4.3 | 4.40 | 0.15 | 0.04 | 42.61 | 5.5539 | | |
| | 11.09J | 2 | 4.8 | 1.86 | 0.18 | 0.05 | 27.65 | 5.8208 | | |
| | 11.09K | 2 | 4.6 | 2.16 | 0.26 | 0.05 | 26.83 | 6.0305 | | |
| | 11.09L | 2 | 4.1 | 2.20 | 0.06 | 0.02 | 25.01 | 5.7055 | | |
| | 11.22D | 1 | 5.2 | 1.96 | 0.32 | 0.03 | 29.45 | 5.6862 | | |
| | 11.22E | 1 | 5.4 | 2.74 | 0.56 | 0.08 | 29.05 | 5.2566 | | |
| | 11.22F | 1 | 5.4 | 1.62 | 0.38 | 0.03 | 26.38 | 6.0022 | | |
| | 11.22G | 1 | 5.4 | 2.21 | 0.38 | 0.02 | 25.35 | 5.7304 | | |
| MAMMOTH | 11.22I | 1 | 5.1 | 8.52 | 0.96 | 0.14 | 115.52 | 4.2515 | | |
| | 11.22J | 1 | 4.4 | 7.29 | 0.77 | 0.17 | 100.12 | 4.7358 | | |
| | 11.22K | 1 | 5.1 | 1.66 | 0.26 | 0.05 | 35.99 | 5.8493 | | |
| | 11.22L | 1 | 4.9 | 2.19 | 0.22 | 0.03 | 30.05 | 5.8734 | | |
| | 11.22M | 1 | 5.4 | 1.22 | 0.48 | 0.03 | 34.54 | 5.6424 | | |
| | 11.22N | 1 | 4.5 | 2.86 | 0.58 | 0.03 | 40.12 | 5.1829 | | |
| | 3.17D | 8 | 6.8 | 4.16 | 2.02 | 0.20 | 52.04 | 5.6927 | | |
| | 3.17E | 8 | 7.0 | 4.38 | 2.09 | 0.23 | 52.30 | 5.0074 | | |
| | 3.17F | 8 | 6.6 | 4.39 | 1.85 | 0.13 | 48.96 | 5.1353 | | |
| | 3.17G | 8 | 6.7 | 2.84 | 1.63 | 0.15 | 43.98 | 5.1565 | | |
| | 3.17H | 8 | 7.2 | 5.80 | 5.32 | 0.45 | 81.04 | 5.4430 | | |
| 3.17I | 8 | 7.1 | 3.35 | 1.61 | 0.10 | 35.66 | 5.5747 | | | |
| NOECKER | | | | | | | | | | |
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* - Basin

** - Lake No.

*** - Sample No.

| LAKE | SAMPLES | CATEGORY | pH | ORGANIC CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|------------|----------|----------|-----|-------------------------------------|-------------------------------|--------------------------------|-----------------------|------------------|
| | * ** *** | | | | | | | |
| | 3.17J | 8 | 6.6 | 3.98 | 1.58 | 0.11 | 41.64 | 5.0455 |
| | 3.17K | 8 | 6.9 | 5.00 | 2.64 | 0.22 | 59.27 | 5.2917 |
| | 3.17L | 8 | 7.9 | 2.10 | 36.35 | 0.77 | 34.98 | 5.0245 |
| | 3.17M | 8 | 6.9 | 3.94 | 2.38 | 0.24 | 51.13 | 5.1471 |
| CARP | 4.02D | 3 | 5.6 | 8.52 | 2.63 | 0.14 | 81.51 | 5.2142 |
| | 4.02E | 3 | 4.8 | 3.16 | 1.02 | 0.11 | 55.56 | 5.1130 |
| | 4.02F | 3 | 5.2 | 3.74 | 1.32 | 0.09 | 62.75 | 5.2828 |
| | 4.02G | 3 | 4.2 | 2.88 | 0.38 | 0.04 | 56.81 | 5.2376 |
| | 4.02H | 3 | 4.4 | 2.18 | 0.67 | 0.08 | 63.62 | 5.3125 |
| | 4.02I | 3 | 4.8 | 4.07 | 0.89 | 0.09 | 50.31 | 5.2573 |
| | 4.02J | 3 | 5.5 | 4.14 | 0.96 | 0.11 | 59.79 | 4.8528 |
| | 4.02K | 3 | 5.7 | 4.29 | 1.07 | 0.09 | 61.78 | 5.3796 |
| | 4.02L | 3 | 6.0 | 2.36 | 0.67 | 0.08 | 46.11 | 5.4148 |
| | 4.02M | 3 | 5.9 | 2.78 | 0.83 | 0.08 | 49.59 | 5.3942 |
| HOWARD | 4.05D | 3 | 5.6 | 3.71 | 0.81 | 0.09 | 50.85 | 5.5771 |
| | 4.05E | 3 | 5.5 | 3.14 | 0.59 | 0.06 | 37.59 | 5.5315 |
| | 4.05F | 3 | 5.4 | 2.40 | 0.53 | 0.05 | 36.97 | 5.4366 |
| | 4.05G | 3 | 5.4 | 2.31 | 0.41 | 0.05 | 33.74 | 5.4537 |
| | 4.05H | 3 | 5.6 | 2.59 | 0.59 | 0.04 | 38.35 | 5.3309 |
| | 4.05I | 3 | 4.8 | 3.96 | 0.73 | 0.13 | 51.38 | 5.5790 |
| | 4.05J | 3 | 5.4 | 3.23 | 0.72 | 0.07 | 39.24 | 5.2326 |
| | 4.05K | 3 | 5.4 | 2.68 | 0.56 | 0.06 | 44.47 | 5.4000 |
| | 4.05L | 3 | 5.6 | 2.93 | 0.71 | 0.07 | 39.97 | 5.3981 |
| | 4.05M | 3 | 4.7 | 5.31 | 0.72 | 0.08 | 55.08 | 5.2754 |
| TWIN BASIN | 1.21D | 3 | 5.8 | 3.64 | 0.99 | 0.17 | 50.66 | 5.1948 |
| | 1.21E | 3 | 5.6 | 3.10 | 0.91 | 0.18 | 45.13 | 5.1183 |
| | 1.21F | 3 | 5.5 | 3.52 | 1.02 | 0.15 | 51.75 | 5.3207 |
| | 1.21G | 3 | 5.8 | 3.98 | 1.42 | 0.17 | 57.84 | 5.4830 |
| | 1.21H | 3 | 5.7 | 3.77 | 0.95 | 0.15 | 49.88 | 6.1655 |
| | 1.21I | 3 | 6.1 | 3.96 | 1.44 | 0.17 | 54.21 | 5.1275 |
| | 1.21J | 3 | 6.1 | 3.76 | 1.30 | 0.17 | 48.57 | 5.3915 |
| | 1.21K | 3 | 5.8 | 4.04 | 0.93 | 0.16 | 49.59 | 5.0877 |
| | 1.21L | 3 | 5.8 | 3.25 | 0.85 | 0.14 | 43.34 | 5.3592 |
| | 1.21M | 3 | 5.4 | 3.15 | 0.68 | 0.13 | 45.11 | 5.3905 |

| LAKE | SAMPLES | CATEGORY | pH | ORGANIC | | | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|-------|---------|----------|------|--------------------------|------------------------------|--------------------------------|--------------------------------|-----------------------|------------------|
| | | | | CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | | | |
| JUMBO | 0.00D | 3 | 6.9 | 10.62 | 12.18 | 0.30 | 79.27 | 5.1200 | |
| | 0.00E | 3 | 6.0 | 4.70 | 0.51 | 0.12 | 31.17 | 5.5268 | |
| | 0.00F | 3 | 6.0 | 3.71 | 1.08 | 0.14 | 49.57 | 5.2743 | |
| | 0.00G | 3 | 5.3 | 6.74 | 1.01 | 0.15 | 65.39 | 5.4083 | |
| | 0.00H | 3 | 5.4 | 1.90 | 1.22 | 0.07 | 52.77 | 5.3247 | |
| | 0.00I | 3 | 5.3 | 13.40 | 4.80 | 0.19 | 89.13 | 5.5152 | |
| | 0.00J | 3 | 5.8 | 5.23 | 1.52 | 0.13 | 50.86 | 5.4052 | |
| | 0.00K | 3 | 7.1 | 4.12 | 1.43 | 0.13 | 49.54 | 5.2070 | |
| | 0.00L | 3 | 7.1 | 2.96 | 1.69 | 0.29 | 53.39 | 5.5888 | |
| | 0.00M | 3 | 6.7 | 3.49 | 1.24 | 0.19 | 43.13 | 5.2847 | |
| | 4.04D | 6 | 6.1 | 2.12 | 0.55 | 0.13 | 33.13 | 5.1992 | |
| | 4.04E | 6 | 5.7 | 4.33 | 0.74 | 0.11 | 34.11 | 5.3772 | |
| | 4.04F | 6 | 4.8 | 2.74 | 0.40 | 0.09 | 28.89 | 5.4663 | |
| | 4.04G | 6 | 5.3 | 3.16 | 0.74 | 0.11 | 33.00 | 5.4712 | |
| | 4.04H | 6 | 5.4 | 5.49 | 0.84 | 0.14 | 44.67 | 5.1519 | |
| 4.04I | 6 | 5.8 | 3.53 | 0.73 | 0.12 | 35.41 | 5.1220 | | |
| 4.04J | 6 | 5.5 | 3.00 | 0.65 | 0.11 | 33.83 | 5.4904 | | |
| 4.04K | 6 | 6.1 | 1.08 | 0.44 | 0.14 | 35.82 | 5.2104 | | |
| 4.04L | 6 | 5.1 | 1.50 | 0.30 | 0.09 | 24.69 | 5.4094 | | |
| 4.40M | 6 | 5.6 | 3.61 | 0.44 | 0.10 | 30.38 | 5.0400 | | |
| 6.09D | 7 | 5.0 | 2.45 | 0.37 | 0.11 | 33.72 | 5.8569 | | |
| 6.09E | 7 | 4.9 | 0.24 | 0.15 | 0.08 | 26.04 | 5.8182 | | |
| 6.09F | 7 | 4.8 | 1.33 | 0.18 | 0.09 | 27.51 | 5.0923 | | |
| 6.09G | 7 | 5.3 | 2.65 | 0.52 | 0.18 | 37.02 | 5.0644 | | |
| 6.09H | 7 | 4.5 | 7.25 | 0.87 | 0.12 | 66.33 | 5.2330 | | |
| 6.09I | 7 | 5.2 | 2.65 | 0.32 | 0.11 | 26.95 | 5.4228 | | |
| 6.09J | 7 | 5.6 | 1.60 | 0.50 | 0.12 | 28.65 | 5.4820 | | |
| 6.09K | 7 | 4.9 | 3.24 | 0.38 | 0.13 | 38.17 | 5.3338 | | |
| 6.09L | 7 | 5.9 | 1.62 | 0.53 | 0.10 | 26.59 | 5.1965 | | |
| 6.09M | 7 | 5.3 | 0.35 | 0.12 | 0.09 | 14.09 | 5.2490 | | |
| 6.15D | 8 | 6.6 | 2.21 | 1.09 | 0.15 | 36.59 | 5.2422 | | |
| 6.15E | 8 | 7.0 | 4.01 | 2.31 | 0.21 | 44.54 | 5.1953 | | |
| 6.15F | 8 | 6.8 | 2.03 | 0.74 | 0.14 | 27.22 | 5.2420 | | |

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LAKE MOLAS

HAVILAND

| LAKE | SAMPLES | CATEGORY | pH | ORGANIC CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|-----------|----------|----------|-----|-------------------------------------|-------------------------------|--------------------------------|-----------------------|------------------|
| | * ** *** | | | | | | | |
| | 6.15G | 8 | 6.8 | 1.43 | 0.39 | 0.16 | 16.00 | 5.0835 |
| | 6.15H | 8 | 7.2 | 4.09 | 1.79 | 0.30 | 31.70 | 5.1458 |
| | 6.15I | 8 | 7.7 | 6.07 | 7.97 | 0.71 | 61.51 | 5.0071 |
| | 6.15J | 8 | 7.6 | 9.87 | 8.18 | 1.13 | 81.41 | 5.6749 |
| | 6.10K | 8 | 7.8 | 7.51 | 16.97 | 0.91 | 85.89 | 5.5171 |
| | 6.15L | 8 | 7.8 | 4.60 | 20.01 | 0.48 | 57.59 | 5.2875 |
| | 6.15M | 8 | 7.2 | 3.55 | 2.21 | 0.18 | 37.74 | 5.4282 |
| CHAPMAN | 6.08D | 5 | 7.9 | 0.76 | 21.81 | 0.29 | 28.4 | 5.4841 |
| | 6.08E | 5 | 7.5 | 0.72 | 3.86 | 0.27 | 26.31 | 5.4229 |
| | 6.08F | 5 | 7.6 | 1.56 | 18.19 | 0.44 | 18.28 | 5.2122 |
| | 6.08G | 5 | 7.7 | 1.33 | 1.31 | 0.19 | 25.41 | 5.1745 |
| | 6.08H | 5 | 7.7 | 1.52 | 2.25 | 0.22 | 24.71 | 5.3174 |
| | 6.08I | 5 | 7.4 | 1.49 | 9.38 | 0.26 | 15.64 | 5.0528 |
| | 6.08J | 5 | 7.7 | 0.64 | 20.26 | 0.45 | 11.59 | 5.4439 |
| | 6.08K | 5 | 7.7 | 1.58 | 1.09 | 0.14 | 19.82 | 5.3321 |
| | 6.08L | 5 | 7.3 | 3.12 | 0.96 | 0.15 | 22.51 | 5.1600 |
| | 6.08M | 5 | 7.3 | 2.07 | 1.05 | 0.14 | 22.77 | 5.4837 |
| STEVENS | 6.04D | 4 | 7.4 | 0.42 | 0.40 | 0.08 | 31.28 | 5.2841 |
| | 6.04E | 4 | 6.6 | 2.07 | 0.64 | 0.09 | 26.84 | 5.5436 |
| | 6.04F | 4 | 6.2 | 1.93 | 0.62 | 0.06 | 38.08 | 5.4945 |
| | 6.04G | 4 | 7.6 | 1.46 | 23.57 | 0.16 | 36.83 | 5.3418 |
| | 6.04H | 4 | 7.5 | 2.27 | 4.42 | 0.16 | 36.39 | 5.0797 |
| | 6.04I | 4 | 6.4 | 1.70 | 0.65 | 0.08 | 42.08 | 5.4893 |
| | 6.04J | 4 | 6.3 | 1.82 | 0.59 | 0.11 | 29.60 | 5.4667 |
| | 6.04K | 4 | 7.0 | 1.39 | 0.84 | 0.24 | 30.75 | 5.1771 |
| | 6.04L | 4 | 6.7 | 1.43 | 0.64 | 0.15 | 28.73 | 5.2999 |
| | 6.04M | 4 | 6.7 | 1.63 | 0.65 | 0.1 | 29.03 | 5.1848 |
| O'CONNELL | 6.06D | 6 | 6.0 | 1.49 | 0.41 | 0.04 | 22.66 | 5.2591 |
| | 6.06E | 6 | 4.0 | 5.32 | 0.42 | 0.03 | 54.41 | 5.1971 |
| | 6.06F | 6 | 5.4 | 3.58 | 0.53 | 0.05 | 28.26 | 5.4330 |
| | 6.06G | 6 | 6.0 | 3.46 | 0.90 | 0.07 | 31.69 | 5.5723 |

| LAKE | SAMPLES | CATEGORY | pH | ORGANIC CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|------|----------|----------|-----|-------------------------------------|------------------------------|--------------------------------|-----------------------|------------------|
| | * ** *** | | | | | | | |
| | 6.06H | 6 | 6.2 | 1.77 | 0.70 | 0.05 | 24.05 | 5.2811 |
| | 6.06I | 6 | 6.6 | 1.31 | 0.22 | 0.03 | 12.54 | 5.3075 |
| | 6.06J | 6 | 7.1 | 1.17 | 0.41 | 0.10 | 19.92 | 5.5894 |
| | 6.06K | 6 | 6.0 | 2.72 | 0.33 | 0.04 | 21.29 | 5.1492 |
| | 6.06L | 6 | 6.3 | 3.01 | 1.22 | 0.08 | 33.76 | 5.3087 |
| | 6.06M | 6 | 6.4 | 2.91 | 1.13 | 0.08 | 32.71 | 5.1461 |
| | 7.05D | 7 | 4.9 | 8.93 | 0.58 | 0.05 | 66.61 | 5.1134 |
| | 7.05E | 7 | 5.2 | 5.76 | 0.64 | 0.06 | 47.41 | 5.5146 |
| | 7.05F | 7 | 4.7 | 3.80 | 0.17 | 0.04 | 40.43 | 5.4339 |
| | 7.05G | 7 | 4.2 | 13.95 | 0.62 | 0.09 | 85.48 | 5.2684 |
| | 7.05H | 7 | 5.3 | 6.74 | 0.89 | 0.06 | 58.47 | 5.2229 |
| | 7.05I | 7 | 5.4 | 10.10 | 2.04 | 0.10 | 78.41 | 5.5980 |
| | 7.05J | 7 | 4.7 | 6.98 | 0.43 | 0.05 | 45.97 | 5.3941 |
| | 7.05K | 7 | 4.8 | 6.63 | 0.49 | 0.04 | 65.48 | 5.4671 |
| | 7.05L | 7 | 4.6 | 3.32 | 0.15 | 0.04 | 29.98 | 5.3683 |
| | 7.05M | 7 | 5.2 | 5.10 | 0.41 | 0.05 | 43.61 | 5.0671 |
| | 8.02D | 2 | 5.6 | 8.59 | 10.00 | 0.07 | 159.34 | 5.4181 |
| | 8.02E | 2 | 5.6 | 8.04 | 0.95 | 0.08 | 40.66 | 5.2310 |
| | 8.02F | 2 | 5.5 | 6.69 | 0.77 | 0.07 | 34.63 | 5.5897 |
| | 8.02G | 2 | 5.4 | 3.92 | 0.33 | 0.05 | 25.95 | 5.2631 |
| | 8.02H | 2 | 5.1 | 10.68 | 1.10 | 0.12 | 67.98 | 5.4522 |
| | 8.02I | 2 | 5.1 | 10.27 | 3.44 | 0.05 | 118.00 | 5.2200 |
| | 8.02J | 2 | 5.1 | 7.45 | 0.69 | 0.06 | 56.71 | 5.1620 |
| | 8.02K | 2 | 5.8 | 7.92 | 1.98 | 0.09 | 73.25 | 5.3031 |
| | 8.21L | 2 | 5.9 | 8.21 | 1.98 | 0.10 | 74.47 | 5.0529 |
| | 8.19D | 9 | 6.9 | 1.07 | 0.61 | 0.09 | 18.67 | 5.5675 |
| | 8.19E | 9 | 6.5 | 1.09 | 0.51 | 0.06 | 14.25 | 5.5237 |
| | 8.19F | 9 | 6.4 | 3.11 | 0.61 | 0.08 | 18.80 | 5.5752 |
| | 8.19G | 9 | 6.4 | 0.64 | 0.26 | 0.06 | 12.66 | 5.5680 |
| | 8.19H | 9 | 6.5 | 2.81 | 1.23 | 0.12 | 28.29 | 5.2732 |
| | 8.19I | 9 | 6.0 | 3.26 | 0.65 | 0.08 | 23.58 | 5.2382 |
| | 8.19J | 9 | 6.2 | 2.54 | 1.11 | 0.09 | 26.35 | 5.3975 |
| | 8.19K | 9 | 6.0 | 2.38 | 0.92 | 0.11 | 29.17 | 5.2501 |

RITO ALTO

GRIZZLY

UPPER

| LAKE | SAMPLES | CATEGORY | pH | ORGANIC CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|---------------|---------|----------|------|-------------------------------------|-------------------------------|--------------------------------|-----------------------|------------------|
| | * | ** | *** | | | | | |
| SPENCER | 8.19L | 9 | 6.5 | 6.12 | 2.24 | 0.16 | 46.21 | 5.1211 |
| | 8.19M | 9 | 6.2 | 6.53 | 2.28 | 0.14 | 46.73 | 5.4643 |
| | 7.14D | 3 | 6.7 | 1.64 | 0.78 | 0.13 | 41.91 | 5.2623 |
| | 7.14E | 3 | 5.7 | 1.39 | 0.36 | 0.03 | 30.51 | 5.6035 |
| | 7.14F | 3 | 6.4 | 2.45 | 1.21 | 0.14 | 45.71 | 5.3580 |
| | 7.14G | 3 | 7.2 | 1.30 | 1.10 | 0.17 | 33.76 | 5.4246 |
| | 7.14H | 3 | 6.5 | 5.12 | 2.57 | 0.19 | 60.19 | 5.2466 |
| | 7.14I | 3 | 6.7 | 0.76 | 0.68 | 0.24 | 72.16 | 5.2326 |
| | 7.14J | 3 | 6.6 | 1.24 | 1.90 | 0.19 | 52.19 | 5.2515 |
| | 7.14K | 3 | 5.7 | 2.38 | 0.47 | 0.06 | 35.60 | 5.2171 |
| UPPER VENABLE | 7.14L | 3 | 5.8 | 6.46 | 2.70 | 0.26 | 88.21 | 5.1698 |
| | 7.14M | 3 | 5.6 | 5.49 | 2.05 | 0.16 | 69.33 | 5.1071 |
| | 8.15D | 2 | 5.4 | 2.84 | 0.24 | 0.05 | 35.74 | 5.2212 |
| | 8.15E | 2 | 5.5 | 3.49 | 0.37 | 0.08 | 33.59 | 5.1806 |
| | 8.15F | 2 | 5.5 | 2.74 | 0.36 | 0.08 | 35.31 | 5.4815 |
| | 8.15G | 2 | 6.0 | 3.79 | 0.59 | 0.06 | 39.08 | 5.2201 |
| | 8.15H | 2 | 5.8 | 3.89 | 0.54 | 0.09 | 30.86 | 5.6098 |
| | 8.15I | 2 | 6.1 | 2.08 | 0.31 | 0.07 | 24.26 | 5.3074 |
| | 8.15J | 2 | 5.6 | 3.25 | 0.18 | 0.05 | 23.10 | 5.2468 |
| | 8.15K | 2 | 5.4 | 4.63 | 0.61 | 0.08 | 45.47 | 5.3480 |
| WRIGHTS | 8.15L | 2 | 5.2 | 1.07 | 0.27 | 0.06 | 22.98 | 5.3768 |
| | 8.15M | 2 | 5.3 | 0.99 | 0.05 | 0.02 | 17.50 | 5.3688 |
| | 8.18D | 9 | 6.9 | 1.34 | 0.74 | 0.13 | 25.88 | 5.3952 |
| | 8.18E | 9 | 6.5 | 1.84 | 0.64 | 0.06 | 24.76 | 5.5699 |
| | 8.18F | 9 | 5.8 | 1.22 | 0.46 | 0.04 | 22.89 | 5.5310 |
| | 8.18G | 9 | 6.1 | 1.31 | 0.39 | 0.04 | 21.63 | 5.2294 |
| | 8.18H | 9 | 7.2 | 1.97 | 0.78 | 0.09 | 23.90 | 5.3325 |
| | 8.18I | 9 | 6.9 | 1.55 | 0.66 | 0.09 | 27.12 | 5.3737 |
| | 8.18J | 9 | 7.0 | 2.06 | 1.43 | 0.15 | 44.64 | 5.2137 |
| | 8.18K | 9 | 6.9 | 2.02 | 0.92 | 0.08 | 30.06 | 5.4114 |
| 8.18L | 9 | 6.8 | 2.12 | 1.06 | 0.24 | 53.86 | 5.2013 | |
| 8.18M | 9 | 6.7 | 1.79 | 0.68 | 0.12 | 36.09 | 5.2914 | |

| LAKE | SAMPLES | CATEGORY | pH | ORGANIC CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|------|----------|----------|-----|-------------------------------------|------------------------------|--------------------------------|-----------------------|------------------|
| | * ** *** | | | | | | | |
| | 10.14F | 9 | 5.5 | 3.75 | 0.66 | 0.07 | 35.02 | 5.1795 |
| | 10.14G | 9 | 5.4 | 3.50 | 0.45 | 0.06 | 36.90 | 5.4111 |
| | 10.14H | 9 | 4.8 | 9.57 | 0.75 | 0.10 | 76.41 | 5.2031 |
| | 10.14I | 9 | 5.5 | 3.70 | 0.58 | 0.07 | 29.50 | 5.4557 |
| | 10.14J | 9 | 4.8 | 4.99 | 0.51 | 0.04 | 39.14 | 5.1685 |
| | 10.14K | 9 | 4.7 | 6.31 | 0.40 | 0.05 | 57.22 | 5.1620 |
| | 10.14L | 9 | 4.9 | 2.92 | 0.29 | 0.05 | 34.69 | 5.1164 |
| | 10.14M | 9 | 5.0 | 5.24 | 0.61 | 0.09 | 51.36 | 5.1415 |
| | 2.06D | 5 | 7.9 | 1.12 | 21.78 | 0.91 | 29.71 | 5.3150 |
| | 2.06E | 5 | 7.9 | 1.10 | 23.36 | 1.07 | 33.70 | 5.3182 |
| | 2.06F | 5 | 8.0 | 1.05 | 16.39 | 0.83 | 30.70 | 5.4793 |
| | 2.06G | 5 | 7.4 | 2.06 | 0.92 | 0.19 | 28.30 | 5.5487 |
| | 2.06H | 5 | 7.7 | 1.27 | 6.08 | 0.60 | 30.51 | 5.2186 |
| | 2.06I | 5 | 6.9 | 1.26 | 0.69 | 0.17 | 30.22 | 5.3833 |
| | 2.06J | 5 | 7.7 | 1.49 | 1.89 | 0.94 | 25.38 | 5.1580 |
| | 2.06K | 5 | 8.1 | 1.13 | 1.81 | 1.07 | 27.30 | 5.2107 |
| | 2.06L | 5 | 7.5 | 2.33 | 0.95 | 0.24 | 34.50 | 5.3846 |
| | 2.06M | 5 | 6.9 | 3.68 | 1.08 | 0.13 | 36.67 | 5.0177 |
| | 2.10N | 8 | 6.5 | 3.91 | 1.36 | 0.15 | 49.41 | 5.2642 |
| | 2.10D | 8 | 6.5 | 6.50 | 2.59 | 0.24 | 65.21 | 5.2095 |
| | 2.10E | 8 | 6.4 | 3.01 | 1.42 | 0.13 | 50.08 | 5.4291 |
| | 2.10F | 8 | 6.7 | 3.36 | 2.03 | 0.14 | 49.29 | 5.1633 |
| | 2.10G | 8 | 6.0 | 5.60 | 1.85 | 0.12 | 56.55 | 5.2234 |
| | 2.10H | 8 | 6.7 | 2.39 | 1.11 | 0.18 | 45.01 | 5.4801 |
| | 2.10I | 8 | 6.8 | 2.92 | 1.48 | 0.19 | 43.30 | 5.6062 |
| | 2.10J | 8 | 6.5 | 4.26 | 1.74 | 0.14 | 47.40 | 5.2037 |
| | 2.10K | 8 | 6.8 | 7.22 | 4.27 | 0.35 | 88.84 | 5.3371 |
| | 2.10L | 8 | 6.5 | 3.34 | 2.02 | 0.13 | 65.36 | 5.2713 |
| | 2.10M | 8 | 6.7 | 5.29 | 2.02 | 0.18 | 52.87 | 5.5704 |
| | 2.08D | 7 | 5.4 | 4.96 | 0.43 | 0.07 | 42.31 | 5.1410 |
| | 2.08E | 7 | 6.6 | 6.87 | 0.27 | 0.02 | 21.37 | 5.0676 |
| | 2.08F | 7 | 5.8 | 1.79 | 0.20 | 0.03 | 19.76 | 5.2400 |

MC HATTON

SEVENTH

CLOCK

| LAKE | SAMPLES | CATEGORY | pH | ORGANIC CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|------|---------|----------|-----|-------------------------------------|------------------------------|--------------------------------|-----------------------|------------------|
| | * | | | | | | | |
| | ** | | | | | | | |
| | *** | | | | | | | |
| | **** | | | | | | | |
| | 2.08G | 7 | 6.3 | 2.42 | 0.32 | 0.04 | 24.16 | 5.3834 |
| | 2.08H | 7 | 6.2 | 3.11 | 0.60 | 0.15 | 40.85 | 5.3248 |
| | 2.08J | 7 | 6.5 | 4.72 | 0.91 | 0.17 | 44.44 | 5.3637 |
| | 2.08K | 7 | .2 | 5.59 | 0.53 | 0.11 | 55.18 | 5.2656 |
| | 2.08L | 7 | 5.5 | 5.38 | 0.94 | 0.11 | 60.28 | 5.0150 |
| | 2.08M | 7 | 5.6 | 1.59 | 0.27 | 0.04 | 30.43 | 5.5031 |
| | 10.07D | 8 | 7.7 | 0.39 | 2.17 | 0.15 | 16.61 | 5.2900 |
| | 10.07E | 8 | 7.3 | 1.13 | 8.55 | 0.15 | 26.00 | 5.3704 |
| | 10.07F | 8 | 7.0 | 2.50 | 5.76 | 0.18 | 36.41 | 5.5438 |
| | 10.07G | 8 | 6.9 | 6.43 | 2.08 | 0.47 | 51.02 | 5.2779 |
| | 10.07H | 8 | 7.7 | 3.66 | 2.08 | 0.50 | 54.14 | 5.3991 |
| | 10.07I | 8 | 8.0 | 4.14 | 23.28 | 1.87 | 40.66 | 5.2740 |
| | 10.07J | 8 | 6.4 | 8.27 | 3.60 | 0.19 | 58.28 | 5.1352 |
| | 10.07K | 8 | 6.6 | 8.67 | 3.04 | 0.21 | 55.56 | 5.2609 |
| | 10.07L | 8 | 7.0 | 1.69 | 1.20 | 0.06 | 17.91 | 5.3909 |
| | 10.07M | 8 | 6.7 | 1.54 | 1.93 | 0.11 | 22.64 | 5.3553 |
| | 10.10D | 1 | 5.8 | 0.44 | 0.09 | 0.01 | 7.90 | 5.3416 |
| | 10.10E | 1 | 5.4 | 1.44 | 0.17 | 0.01 | 16.66 | 5.1686 |
| | 10.10F | 1 | 6.1 | 0.20 | 0.08 | 0.01 | 6.19 | 5.3367 |
| | 10.10G | 1 | 4.5 | 1.98 | 0.33 | 0.01 | 18.89 | 5.2511 |
| | 10.10H | 1 | 5.9 | 1.42 | 0.28 | 0.02 | 12.69 | 5.2096 |
| | 10.10I | 1 | 5.2 | 0.41 | 0.10 | 0.01 | 11.82 | 5.5590 |
| | 10.10J | 1 | 5.5 | 0.79 | 0.16 | 0.02 | 9.76 | 5.5259 |
| | 10.10K | 1 | 5.2 | 1.01 | 0.13 | 0.01 | 19.01 | 5.2640 |
| | 10.10L | 1 | 5.4 | 4.95 | 0.76 | 0.04 | 51.04 | 5.3097 |
| | 10.10M | 1 | 4.3 | 0.81 | 0.08 | 0.01 | 9.38 | 5.3778 |
| | 10.16D | 3 | 5.5 | 2.91 | 0.44 | 0.04 | 27.88 | 5.5232 |
| | 10.16E | 3 | 4.9 | 2.15 | 0.25 | 0.03 | 21.16 | 5.2021 |
| | 10.16F | 3 | 6.1 | 2.54 | 0.63 | 0.08 | 30.34 | 5.1908 |

THREEMILE

UPPER BIGCREEK

FINGER

| LAKE | SAMPLES | CATEGORY | pH | ORGANIC CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|------|----------|----------|-----|-------------------------------------|-------------------------------|--------------------------------|-----------------------|------------------|
| | * ** *** | | | | | | | |
| | 10.16G | 3 | 6.4 | 4.08 | 1.47 | 0.11 | 36.62 | 5.4412 |
| | 10.16H | 3 | 6.5 | 4.53 | 1.35 | 0.10 | 34.48 | 5.3993 |
| | 10.16I | 3 | 6.1 | 2.47 | 0.67 | 0.04 | 32.29 | 5.1329 |
| | 10.16J | 3 | 4.8 | 2.78 | 0.36 | 0.03 | 29.72 | 5.3719 |
| | 10.16K | 3 | 4.6 | 2.79 | 0.45 | 0.03 | 31.54 | 5.2273 |
| | 10.16L | 3 | 5.1 | 1.78 | 0.36 | 0.03 | 36.71 | 5.5333 |
| | 10.16M | 3 | 5.9 | 0.99 | 0.22 | 0.02 | 15.46 | 5.4868 |
| | 10.02D | 4 | 7.7 | 1.11 | 1.40 | 0.26 | 13.07 | 5.1596 |
| | 10.02E | 4 | 8.6 | 0.57 | 0.77 | 0.94 | 12.58 | 5.1876 |
| | 10.02F | 4 | 7.8 | 1.03 | 0.50 | 0.09 | 16.86 | 5.2623 |
| | 10.02G | 4 | 8.0 | 2.94 | 11.12 | 0.57 | 21.75 | 5.1600 |
| | 10.02H | 4 | 7.9 | 1.13 | 0.97 | 0.08 | 14.50 | 5.3700 |
| | 10.02I | 4 | 7.8 | 1.26 | 1.07 | 0.07 | 15.75 | 5.1929 |
| | 10.02J | 4 | 6.3 | 1.44 | 0.29 | 0.03 | 16.91 | 5.1453 |
| | 10.02K | 4 | 6.4 | 1.65 | 0.30 | 0.04 | 19.12 | 5.3246 |
| | 10.02L | 4 | 6.1 | 1.66 | 0.24 | 0.04 | 16.62 | 5.1473 |
| | 10.02M | 4 | 8.1 | 1.08 | 0.44 | 0.13 | 15.15 | 5.1972 |
| | 8.14D | 2 | 4.8 | 10.90 | 0.51 | 0.11 | 46.22 | 5.3839 |
| | 8.14E | 2 | 5.5 | 0.68 | 0.10 | 0.02 | 19.77 | 5.3243 |
| | 8.14F | 2 | 5.6 | 1.63 | 0.24 | 0.03 | 21.43 | 5.2988 |
| | 8.14G | 2 | 5.2 | 4.58 | 0.30 | 0.07 | 37.04 | 5.4256 |
| | 8.14H | 2 | 5.4 | 5.81 | 0.47 | 0.09 | 33.37 | 5.5534 |
| | 8.14I | 2 | 4.9 | 7.70 | 2.33 | 0.20 | 111.40 | 5.3496 |
| | 8.14J | 2 | 5.8 | 6.18 | 4.33 | 0.51 | 101.01 | 5.2968 |
| | 8.14K | 2 | 5.7 | 7.60 | 5.00 | 0.49 | 110.64 | 5.3866 |
| | 8.14L | 2 | 5.8 | 5.40 | 3.45 | 0.36 | 85.74 | 5.4285 |
| | 8.14M | 2 | 5.6 | 5.61 | 3.43 | 0.32 | 95.41 | 5.3800 |
| | 3.26D | 9 | 5.7 | 13.00 | 3.74 | 0.17 | 83.95 | 5.3368 |
| | 3.26E | 9 | 5.8 | 0.82 | 0.21 | 0.02 | 17.10 | 5.2146 |
| | 3.26F | 9 | 5.9 | 7.49 | 2.00 | 0.07 | 67.42 | 5.4842 |
| | 3.26G | 9 | 6.2 | 12.04 | 4.77 | 0.12 | 88.65 | 5.2994 |

ADDISON

UPPER POMEROY

SHINGLE

| LAKE | SAMPLES | CATEGORY | PH | ORGANIC | | | | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | SAMPLE WEIGHT |
|------|---------|----------|-----|--------------------------|------------------------------|--------------------------------|-----------------------|--------------------------------|-----------------------|------------------|
| | | | | CARBON CONTENT (%) | EXTRACTED CALCIUM (Ca) | EXTRACTED MAGNESIUM (Mg) | CEC SODIUM (Na) | | | |
| | * | | | | | | | | | |
| | ** *** | | | | | | | | | |
| | 3.26H | 9 | 6.1 | 1.98 | 0.77 | 0.04 | 35.47 | 5.5065 | | |
| | 3.26I | 9 | 6.8 | 2.80 | 1.24 | 0.06 | 42.41 | 4.8619 | | |
| | 3.26J | 9 | 6.7 | 2.02 | 0.54 | 0.05 | 30.42 | 5.2867 | | |
| | 3.26K | 9 | 6.3 | 7.29 | 3.65 | 0.10 | 68.73 | 5.3290 | | |
| | 3.26L | 9 | 5.9 | 6.43 | 1.04 | 0.07 | 42.08 | 5.2824 | | |
| | 4.03D | 3 | 5.2 | 3.29 | 2.32 | 0.14 | 71.25 | 5.2749 | | |
| | 4.03E | 3 | 6.1 | 3.19 | 2.12 | 0.17 | 64.96 | 5.3641 | | |
| | 4.03F | 3 | 5.8 | 3.34 | 2.20 | 0.21 | 97.14 | 5.4183 | | |
| | 4.03G | 3 | 5.2 | 8.33 | 1.99 | 0.15 | 58.73 | 5.6293 | | |
| | 4.03H | 3 | 5.1 | 5.53 | 2.16 | 0.16 | 63.74 | 5.1871 | | |
| | 4.03I | 3 | 5.2 | 6.11 | 4.42 | 0.23 | 70.91 | 5.6561 | | |
| | 4.03J | 3 | 5.3 | 3.98 | 2.12 | 0.11 | 49.34 | 5.2188 | | |
| | 4.03K | 3 | 4.9 | 1.17 | 2.11 | 0.15 | 62.04 | 5.3287 | | |
| | 4.03L | 3 | 4.8 | 1.39 | 1.12 | 0.11 | 50.26 | 5.3223 | | |
| | 4.03M | 3 | 5.0 | 1.33 | 1.18 | 0.09 | 37.17 | 5.4185 | | |
| | 1.03D | 3 | 6.0 | 5.53 | 3.04 | 0.17 | 89.06 | 5.6952 | | |
| | 1.03E | 3 | 5.5 | 3.49 | 3.34 | 0.19 | 97.82 | 5.1849 | | |
| | 1.03F | 3 | 5.1 | 7.33 | 2.26 | 0.10 | 75.72 | 5.7446 | | |
| | 1.03G | 3 | 5.6 | 3.40 | 3.08 | 0.18 | 90.32 | 5.6156 | | |
| | 1.03H | 3 | 5.6 | 5.22 | 3.04 | 0.13 | 102.28 | 5.1461 | | |
| | 1.03I | 3 | 5.2 | 2.87 | 0.90 | 0.06 | 59.70 | 5.8149 | | |
| | 1.03J | 3 | 4.9 | 6.31 | 3.98 | 0.22 | 83.27 | 5.2761 | | |
| | 1.03K | 3 | 5.3 | 1.56 | 2.90 | 0.19 | 138.72 | 5.4877 | | |
| | 1.03L | 3 | 5.7 | 13.16 | 3.29 | 0.19 | 96.43 | 5.2598 | | |
| | 1.03M | 3 | 5.1 | 6.86 | 4.83 | 0.21 | 82.06 | 5.5660 | | |

FISHER

BULL CREEK