SWAMPLAND OR DRYLAND: THE EFFECT OF CLIMATE CHANGE ON THE LAKE LEVELS OF THE ETONIA CREEK WATER BASIN, FLORIDA

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ABSTRACT Protection of the environment is a theme being freely tossed about by the politicians in this presidential election year. But this attention to the environment underscores the increasing awareness of the environment by the people. The amount of attention being given to the effects of climate change on regional scales is intensifying. Potential climate changes may have a significant impact on the natural resources of a region, which in turn, may have a positive or negative impact on the activities and lifestyles of the population. The Upper Etonia Creek water basin is a region in north central Florida plagued with declining lake levels over the past fifteen years. In a region where the local economy is dependent on the use of lakes for recreation, lake levels and their variations are of paramount importance. This paper examines the possible linkages between climate variables (temperature and precipitation) and the levels of the lakes in the Upper Etonia Creek water basin in central Florida. Once the linkages have been developed, several climate scenarios will be examined in an effort to determine the possible effects on the future levels of the lakes.

Climate change is headline news today. This comes in a world caught up with increasing awareness of the environment. Concern has focused on the the "greenhouse effect" and the depletion of ozone in our atmosphere. These are global issues, however, and people are becoming more interested in how change will affect them directly. This has caused attention to shift to the regional impacts of climate change.

Individuals and groups in Florida are realizing that their region, or eco-system, is extremely fragile. Efforts are being made to understand development in environmental terms, now and in the future. Development impacts have been modelled and studied for some time, and construction projects such as the Cross-Florida Barge Canal have been stopped as a result. Climate change impacts are not understood as clearly and there is great interest to understand these at the regional scale.

Climate change can severely impact the lakes of north central Florida. Lakes are abundant this karst landscape and receive their water primarily from direct rainfall on he lakes, runoff and from the Floridan Aquifer. The lakes of the the Upper Etonia Creek Basin, are important to the residents as a source of water, recreation, tourism, income and beauty. The levels of these lakes have risen and lowered in the past, however there appears to be a downward trend in the past fifteen years which has outlasted past trends (Yobbi and Chappell, 1979). In this paper I will look at several climate scenarios in an effort to determine the possible effects on the future levels of the lakes.

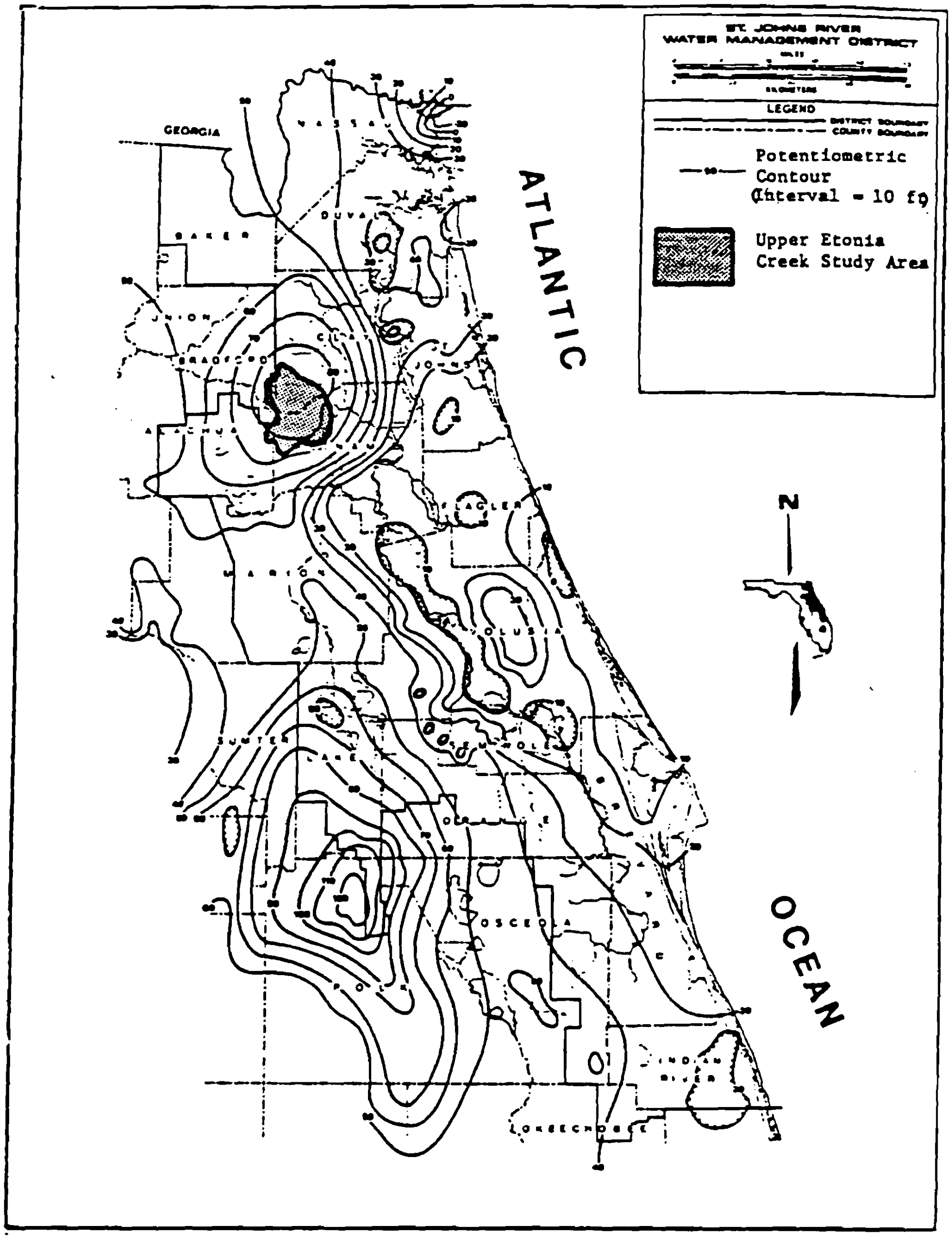
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT
LEGEND
DISTRICT BOUNDARY
COUNTY BOUNDARY
Potentiometric Contour (Interval = 10 ft)
Upper Etonia Creek Study Area
GEORGIA
ATLANTIC
OCEAN
N

FIGURE 1

DATA AND DATA ANALYSIS

The Etonia Creek Basin is a kidney shaped area of 165 square miles in northern Florida, approximately 10 miles east of Gainesville and 30 miles southwest of Jacksonville. The topography varies from high sand hills with an elevation over 150 feet MSL in the northwestern part of the basin to a depression in the east known as the Florahome Valley at less than 100 feet MSL. There are numerous solution depressions in the area as a result of the dissolving and collapsing of the underlying limestone. Lakes have developed in many of these depressions (Yobbi and Chappell).

There are approximately 100 lakes in the study basin characterized by interior drainage at normal water levels. Some of the lakes are connected by intermittent or perennial streams and manmade canals through which water flows during periods of high lake levels. Most of the lakes in the basin are small, having surface areas less than 200 acres. The total combined surface area of the lakes is about 10% of the total basin area. A correlation of lake levels was done for 62 lakes in the basin by the St. Johns River Water Management District in a 1979 study. High correlation coefficients (>0.90) were obtained for 37 of the lakes (Yobbi and Chappell). This permits a generalization be made that the lakes of the study basin are in similar states, that is, in a rising or dropping state at the same time.

Rainfall is the major form of precipitation and is highly variable, both temporally and spatially. Summer rains are convective in nature and have large areal variation whereas the winter rains are more uniform being associated with frontal systems. The wettest months are July, August and September; the dryest are November and December (Water Resources, 1984). Mean monthly temperatures range from 46°F and 84°F with 75 to 100 days where temperatures exceed 90 degrees (Atlas of Florida, 1981).

Methodology

Stewart Cohen's study of the potential impacts of climatic change on Ontario, Canada (1988) suggests that climate variation will have effects on the water body levels of a region which in turn impacts on the activities of that region. In this study, I will discuss five climate scenarios: a change in annual mean temperature of ±4°F with no precipitation change, a change in annual precipitation totals on the order of ±20% with a constant annual mean temperature, and no changes or a scenario where temperature and precipitation are near the mean annual values. This approach is similar to the change scenarios used by Peter Gleick in his 1987 study. The scenario change values are similar to those predicted in empirical models such as the global circulation models run on a doubling of carbon dioxide in the atmosphere.

The water balance equation is a suitable means to relate the climatic variables to the lake levels:

$$LL = P - I - AET + RO \pm GWR$$

where LL = lake level, P = precipitation, I = interception, AET = Actual Evapotranspiration, RO = Runoff, and GWR = groundwater runoff (or leakage).

Evaporation plays a key role in lake levels. Estimates of annual lake evaporation for this area averaged 48.6 inches per year for the years 1954 through 1976. Temperature will be used as a surrogate variable for evapotranspiration. This is not the optimal solution since evaporation is the result of the total energy available for evaporation, by cloud cover, absorption, reflectance, air and water temperature, water vapor pressure of the atmosphere and at the water surface, and wind speed to name a few factors. Evaporation is the primary water loss mechanism.

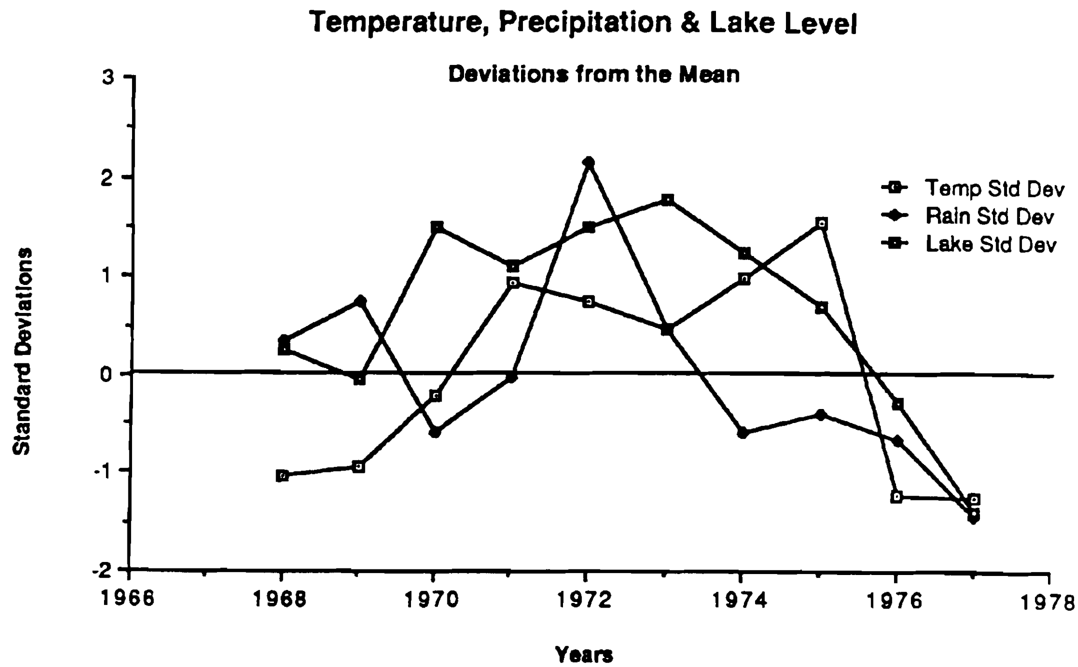

FIGURE 2

Several assumptions were used in this study. First, Brooklyn Lake is representative of all lakes in the region. The validity of this assumption was discussed earlier. Two assumptions were made concerning precipitation: the rainfall in Palatka is representative for the immediate area around Brooklyn Lake (15 miles away), and the rainfall is continuous and uniform over the study area. Lake levels are affected by precipitation through direct rainfall over the lake and by runoff from the surrounding watershed. Since the lakes are numerous and watersheds are small, runoff has not been considered in this study though runoff has been estimated to be 2-6 inches per year by Motz and Heaney (1991). This removes the need to consider changes in the watershed over time, particularly due to urbanization, and assumes that the basin characteristics have remained stable. Lake levels may be affected by draw down of the surficial and Floridan aquifers by wells or by increased demands by vegetation during extended hot, dry periods. However, I assumed that leakage from the lakes to the aquifers was minimal and was thus ignored.

Thus the water balance equation simplifies to:

$$LL = P - AET$$

Thus I regressed temperature and precipitation against lake level stages in simple regressions separately.

Data

Ten years of daily temperature and precipitation data (1968-1977) were obtained for Palatka. More recent data was available but is more difficult to work with due to a lack of completeness. Mean daily temperatures were averaged into a monthly mean temperature which was used for analysis. Daily precipitation was summed to give monthly and annual total rainfall. Coverage for both variables was near 90% for the time period.

Lake level data was obtained for Brooklyn Lake from the St. Johns River Water Management District in Palatka, Florida. Brooklyn Lake is located in the northwest portion of the study basin. Coverage was available for 1968-1989.

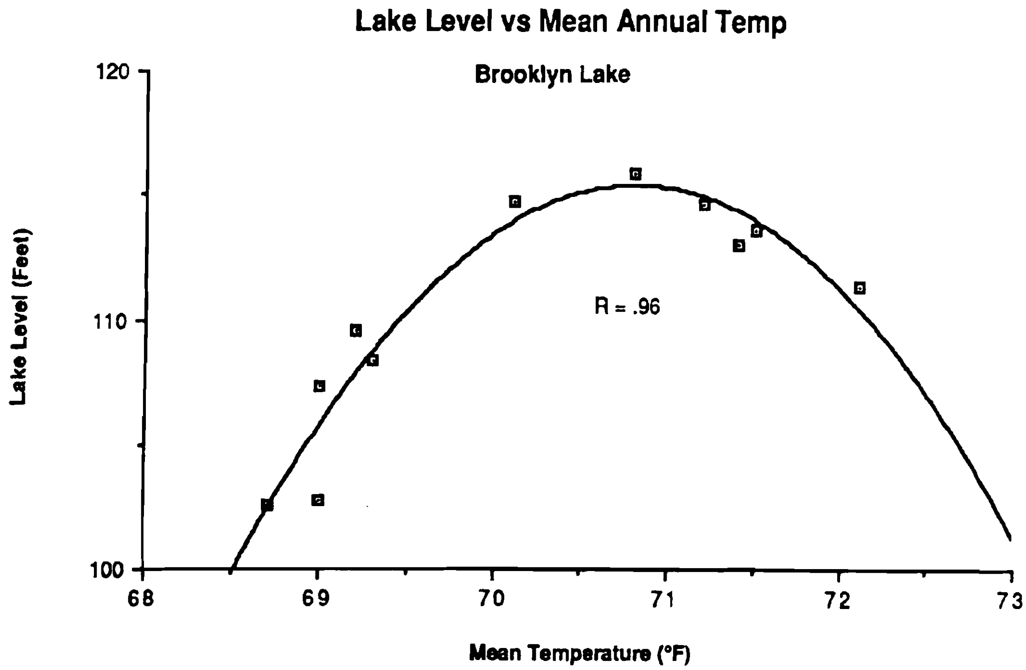

FIGURE 3

RESULTS

Deviations from mean values were plotted for temperature, precipitation and lake levels. All have shown a similar pattern for the study period. The mean annual lake level is 108.50 feet with a standard deviation of 4.13 feet. Temperatures showed the same cyclical pattern. The mean annual temperature for the period was 70.4 degrees and the variation never exceeded 1.8 degrees from the mean. Rainfall had a more varied pattern but the cycle is still present. The mean total precipitation was 50.68 inches with a standard deviation of 8.10 inches.

The variance in terms of standard deviation are plotted at Figure 2. These plots show that all three variable followed the same cyclical pattern but were rarely in close agreement until 1977 when all three variables were one standard deviation below the norm. The change in lake level has always lagged changes in precipitation patterns by nearly a year and this close agreement shows a downward trend in the lake levels. Plotting temperature against the levels of Brooklyn Lake for 1968 to 1977, it is apparent that a relationship exists between the two variables (Figure 3). A regression analysis resulted in a correlation coefficient of 0.92 using a second order polynomial. Likewise, precipitation shows a similar relationship to lake levels (Figure 4) and a correlation coefficient of 0.49 was obtained with a linear regression equation. There is little relationship between the precipitation received in the area and temperature. When regressed against each other, a correlation coefficient of 0.05 was obtained. Thus, I have used temperature or precipitation to predict lake level change.

Using Figures 3 and 4, the five climate scenarios show that the lake levels in the region decrease for all scenarios except normal and wet years:

SCENARIO	VARIABLE CHG	LAKE LEVEL RESULT
1. Hot Year	+4 deg	Decrease 10+ ft
2. Cold Year	-4 deg	Decrease 10+ ft
3. Wet Year	+20% Precip	Increase 2.5 ft
4. Dry Year	-20% Precip	Decrease 2.5 ft
5. Normal Year	No Change	Increase

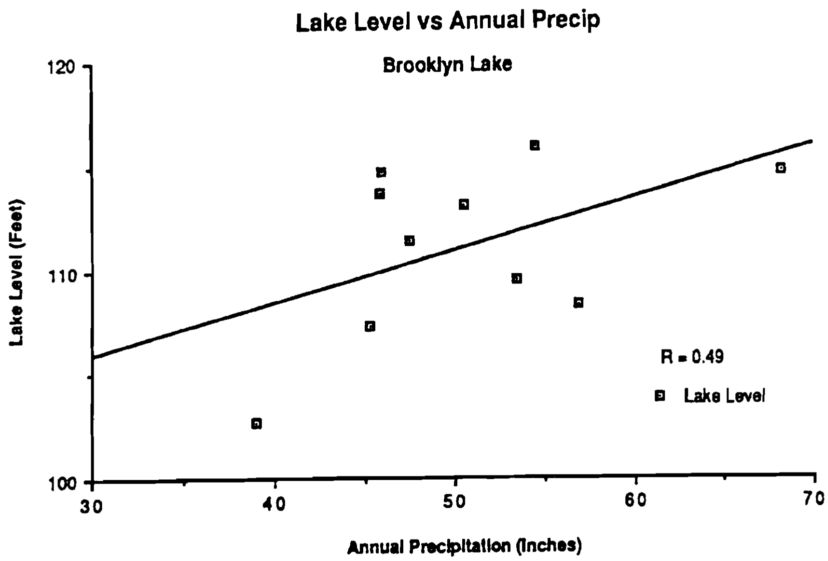

FIGURE 4

Normal year lake levels should show an increase of 3 to 6 feet except that it appears that seepage keeps the mean lake level lower. Many of the lakes are interconnected and as lake levels rise, water begins to flow between between them in the chains mentioned earlier. This will keep lakes from reaching theoretical maximums.

In the scenarios where the temperature and precipitation variables were changed, precipitation increased only in the scenario where the increase was the hypothesized result from the global circulation model (GCM). In all other change scenarios, precipitation declines. In the precipitation change scenarios, temperature increases in wetter years and decreases in dryer years.

CONCLUSIONS

Based on this study, it is apparent that lake levels in north central Florida are more sensitive to mean annual temperature changes than to changes in total annual precipitation.

Temperature changes of the magnitude expected from GCMs will produce a large drop in the lake levels. A drop of ten feet or more is significant to lakes whose depths are rather shallow. Lowering lakes will leave docks high and dry. Access to the lakes may change since lake bottoms are privately owned in many cases, and not necessarily by the original lake front property owners. Many lakes are small but still suitable for recreational boating and a drop in level will decrease the navigable area, perhaps to the point where pleasure boating is no longer possible. A drop would certainly decrease the variety of possible uses of the lakes, the attractiveness and desirability of lake property, and land values. Such a large drop would probably harm the businesses of the small communities in the area which depend on the appeal of the lakes to attract vacation residents from the nearby major urban centers.

A decrease in precipitation will also cause lake levels to drop, but only by 2.5 feet. Many of the effects mentioned above will occur but the smaller magnitude is one which the residents have dealt with during the varying lake level cycles in the past. An increase in precipitation will cause a rise of 2.5 feet. This is a small increase but may cause different types of problems: high water and wave action can erode beaches and damage sea walls; flooding may occur. The magnitude of the potential problems is reduced since many of the lakes are interconnected and other lakes have man-made devices to control maximum levels.

Timing of precipitation during the year plays an important role in lake levels. A wet spring appears to cause lakes to rise and puts them in a better position to withstand high evaporation rates later in the year. Years in which precipitation levels were high are also characterized by a more even monthly distribution of the rainfall though the summer totals are still highest. Lack of a wet spring and well distributed pattern appears to result in a net loss of lake level. Plots of typical scenario years showed a pattern of lake level decrease through the summer and fall except for the wet year. This indicates the significance of evaporative processes. Evaporation has a net reducing effect in hot years as well as cold years though the rate is greater for hot years.

Further research is needed to clarify the magnitude of lake level change and the relationships between the variables. Evaporation estimates can be calculated and water demand data included.

This study has shown a correlation between temperature and lake levels, and between precipitation and lake levels. It has also shown the direction and expected magnitude of change of lake levels given typical climate variable changes as predicted by global circulation models.

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