Water Quality in Utah Lake Tributaries over 40 Years

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WATER QUALITY IN UTAH LAKE TRIBUTARIES OVER 40 YEARS

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ABSTRACT: Utah Lake is a large, approximately 380 km^2, freshwater lake at an elevation of 1,400 m and an average depth of 2.7 m. Due to its size and depth, evaporation accounts for approximately 40% of the outflow and total dissolved solids (TDS) are a main concern. A predictive statistical model for TDS in the lake has been developed over the past 40 years, with data from the tributaries and the outlet that correlates TDS and ion concentrations with flow. This model was updated with extensive data collection from March 2009 through May 2011. The data included total dissolved solids, bicarbonate, sulfate, calcium, chloride, magnesium, potassium, sodium, water temperature, pH, conductivity, turbidity, dissolved oxygen, and flow rates. These data were used to develop new predictive statistical correlation equations. We compared the new correlation equations with the previous equations to determine how or if water quality had changed in the tributaries. Generally water quality has not changed significantly in the past 40 years. However, in tributaries that experienced heavy development, such as Hobble Creek, changes were identified but showed complex trends.

INTRODUCTION

Site Description. Utah Lake has a surface area of approximately 380 km^2, an average depth of 2.7 m, and is fed by approximately 50 tributaries (Rice, 1999; Miller, 1980). It is the largest freshwater lake in Utah and the second largest west of the Great Lakes. The Jordan River is the only natural, surface outflow which carries water to the Great Salt Lake (Miller, 1980).

The water in Utah Lake serves many purposes with a substantial portion used for irrigation. Economic losses would result if this water quality deteriorated (Brimhall, 1981). Utah Lake supports a host of recreational uses and wildlife including an endangered, endemic species of fish, the June Sucker, *Chasmistes liorus*. These uses depend on maintenance of the water quality (Marelli, 2010).

Purpose. Due to the size and depth, evaporation accounts for approximately 40% of the outflow and total dissolved solids (TDS) are a main concern. A predictive statistical model of Utah Lake for TDS was developed over the past 40 years, using data from the tributaries and the outlet. Land use in the watershed has changed greatly in 40 years. We updated this data collection and developed new correlation equations to predict lake conditions based on measured data. This study compares the new correlation equations to those developed over the past 40 years to assess changes and impacts from development.

Eight parameters were analyzed; total dissolved solids (TDS), bicarbonate (HCO_3), sulfate (SO_4), calcium (Ca), chloride (Cl), magnesium (Mg), potassium (K), and sodium (Na). These variables were grouped based on seasons (months of the year) and tributary flow rates.

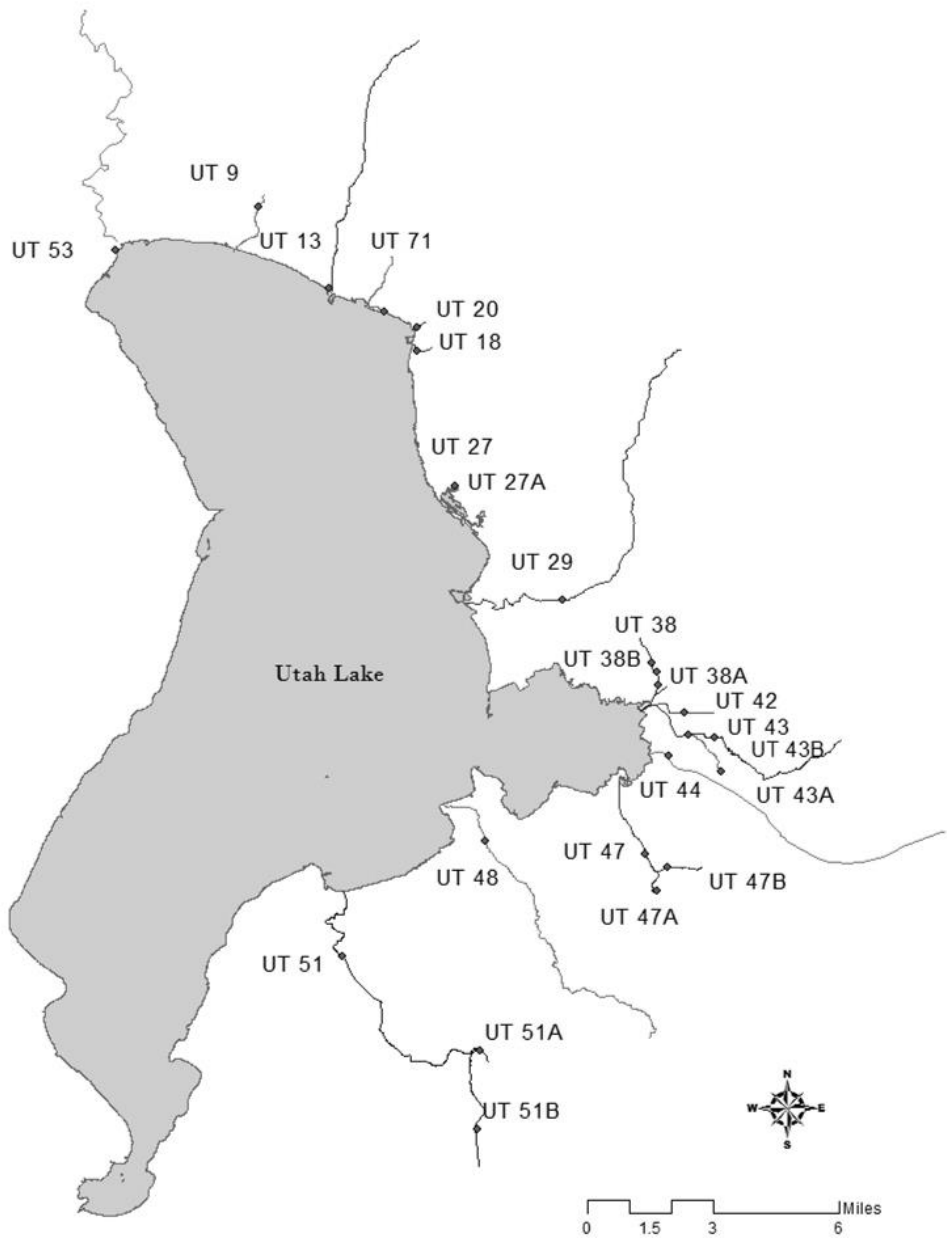

FIGURE 1. The location of the sampling sites for the tributaries and the outlet.

METHODOLOGY

Data Acquisition. From March 2009 to May 2011, monthly samples were collected at 18 different sites from the Utah Lake major tributaries and the Jordan River (UT 53). During high flow periods, from April to June of each year, samples were taken twice a month.

Of the 14 original sites, 4 were located downstream from waste water treatment plants (WWTPs). Beginning in October 2009 to May 2011, additional data were collected upstream of these WWTPs. Field measurements of water temperature, pH, conductivity, turbidity, and dissolved oxygen were taken with a Hach HydroLab DS 5 water probe. Weather conditions were also noted. The water samples were sent to the Utah Unified State Laboratory for TDS and ion concentrations measurements.

Flow rates were measured simultaneously with the samples. The flow rates for the Provo River (UT 29) and Hobble Creek (UT 44) were taken from the United States Geological Survey gaging records. Jordan River flow rates were provided by the Jordan River/Utah Lake Commissioner (Dye, 2012).

Flow was calculated by measuring the depth and velocity at three or four subsections within the cross section. The velocity was measured using a Flo-Mate Model 2000 Portable Flow Meter, (Marsh-McBinney, Inc). The velocity was measured at 0.4 (from the bottom) of the surface depth to obtain the average of the velocity profile for each subsection. Flow was computed by multiplying the sub-section area by the average velocity. The total tributary flow rate is the sum of the subsection flows (Dye, 2012).

From November 2009 to May 2011, data for the various wastewater treatment plants (WWTP) and the Geneva Steel Site (UT 20) were acquired directly from the State of Utah. Prior to November 2009, the values for the flow rates and ion concentrations at the Geneva Steel Site were measured by the study team.

Data Analysis. Data were organized by site locations and matched with flow measurements. We then computed averages, standard deviations, and maximum, and minimum values for each sample set. We then removed the outliers in the data sets.

The data sets were separated by seasons. Past projects characterized the seasons in different ways (O'Neill, 1992). We divided the year into three seasons: March through June (spring), July through September (summer), and October through February (winter) which produced the most logical and consistent results.

Each TDS and ion concentration was plotted against flow. The data were then fitted with trend lines; linear, exponential, power, logarithmic, or polynomial. The trendline type chosen was based mainly on which type produced the best coefficient of determination ($\boldsymbol{r^2}$). However, the number of available data points was limited. Therefore, if a trendline produced a high r^2 value, but did not realistically project values that went beyond those of the available data points, that trendline was not selected. Any r^2 value less than 0.4 was deemed unacceptable to maintain consistency with past studies (Marelli, 2010).
If an equation could not accurately predict TDS and ion concentrations, then mean values were used. In past reports, both overall mean values and seasonal mean values were used to predict TDS and ion concentrations. We calculated seasonal and overall mean values and used them to predict TDS and ion concentrations, if no reliable trendline equation could be determinedTrendlines and concentration values were plotted so a visual verification of accuracy could be done.

The original predictive model assumed flows from WWTPs discharged into Utah Lake separate from their tributaries. Realistically effluent from the WWTPs is carried by tributaries. We treated tributaries which carried WWTP effluent differently from those without WWTP effluent.

Only four tributaries carry WWTP effluent: Millrace (UT 38B), Spring Creek (UT 43), Dry Creek (UT 47), and Benjamin Slough (UT 51). The effluent flow rates from these WWTPs were obtained from plant operators, with the flow rate for the Salem WWTP (UT 51C) assumed to be constant at 1.2 cfs. This was justified since the effluent from this WWTP is discharged from ponds with small fluctuations. The Timpanogos WWTP Ponds (UT 71) and Orem WWTP (UT 27A) both discharge directly into Utah Lake.

For Millrace, Spring Creek, and Dry Creek the water quality data upstream from the WWTP were used in the original predictive model with the flow rate values downstream set equal to the flows minus the WWTP discharge flow rates. If the WWTP discharge was not available, the seasonal mean discharge was used. This assumption was made since the difference in flow rates between the upstream measurements and the downstream measurements were within 3 cubic feet per second (cfs). Benjamin

Slough (UT 51) sustained a greater difference and the influence of the Payson WWTP (UT 51A) and Salem WWTP (UT 51C) on UT 51 was removed using a mass balance equation.

Limitations. In past, similar studies trendline equations with high r^2 values, often greater than 0.9 were produced. In this study the average r^2 values were about 0.6. Since the collected data for this study only span a 26 month period, the lower r^2 values were deemed to be reasonable.

We noted that the equations and averages might be considerably different if data had also been collected during average and low runoff years, instead of the three high runoff years of 2009 - 2011. For example, the average 47 year Provo River flow at the Woodland station is 211 cfs, where the average flow rate for the past three years is 257 cfs, and the average 83 year Spanish Fork River flow at the Castilla station is 237 cfs, where the average flow rate for the past three years is 287 cfs. The average precipitation for the past 30 years at the Provo/BYU station is 20.13 inches, where the average precipitation for the past three years is 23.14 inches.The average Spanish Fork precipitation for the past 30 years is 21.55 inches, where the average for the past three years is 25.74 inches.

The trendline equations likely work best at predicting lake TDS and ion concentrations when the flow rates are within the maximum and minimum flow rates measured in the 26 month period. Beyond these flow rates, the predicted concentration values may be significantly inaccurate.

RESULTS AND DISCUSSION

Results. The data collected from each site were plotted similar to those shown in Figure 2. If the overall r^2 value was less than 0.4, then mean values were plotted (as shown for the SO_4 plots in Figure 3).

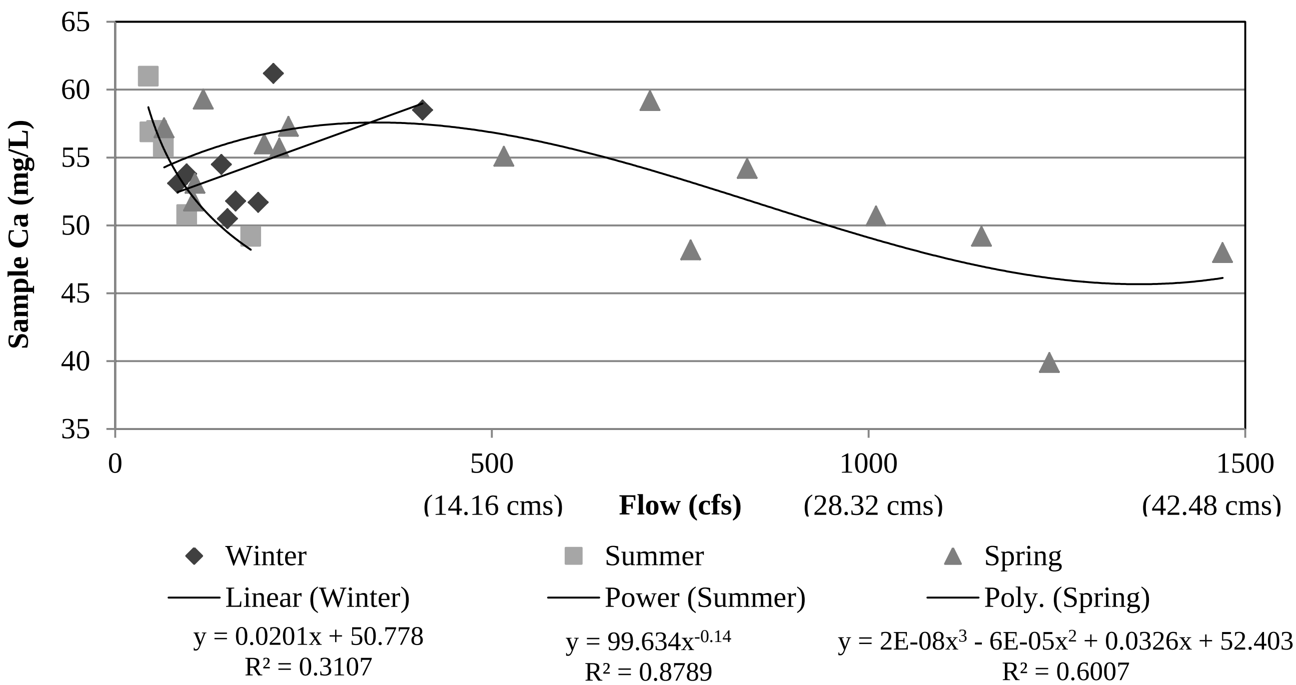

FIGURE 2. The trendlines that were found to have the reasonably best fit were used to predict concentrations of Ca in UT 29, lower Provo River.

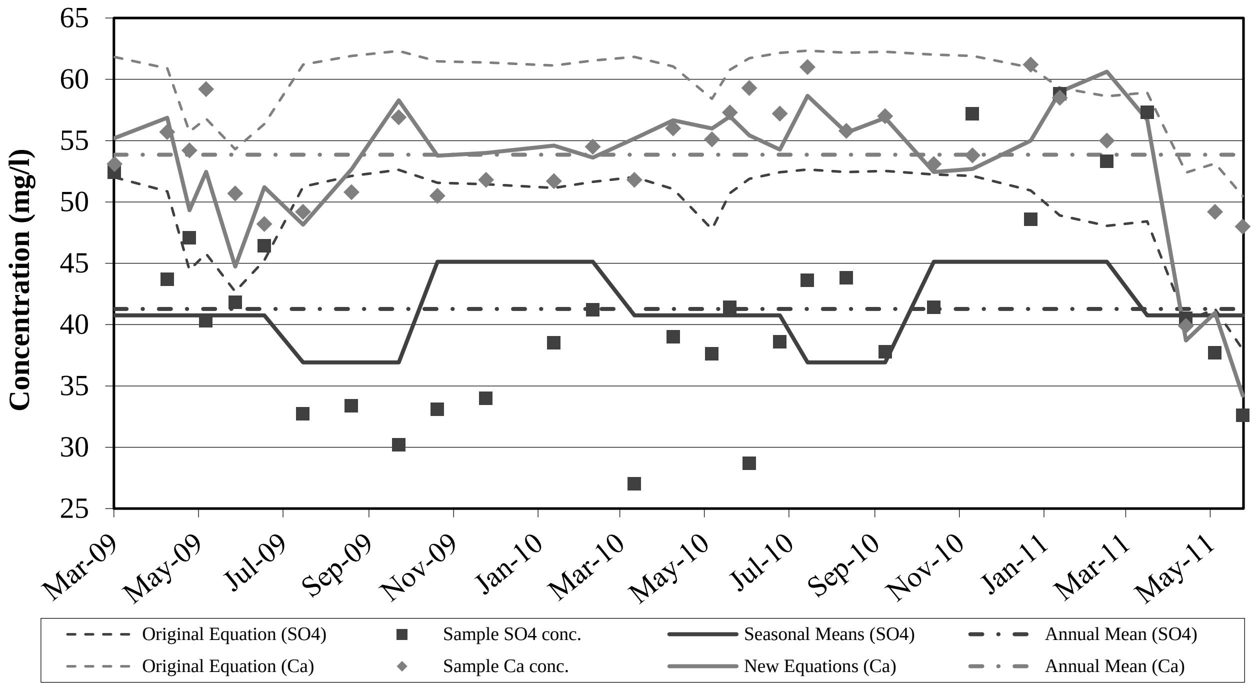

FIGURE 3. A predictive equation for Ca concentrations was found, but seasonal mean values were used to predict SO_4 concentrations in UT 29, lower Provo River.

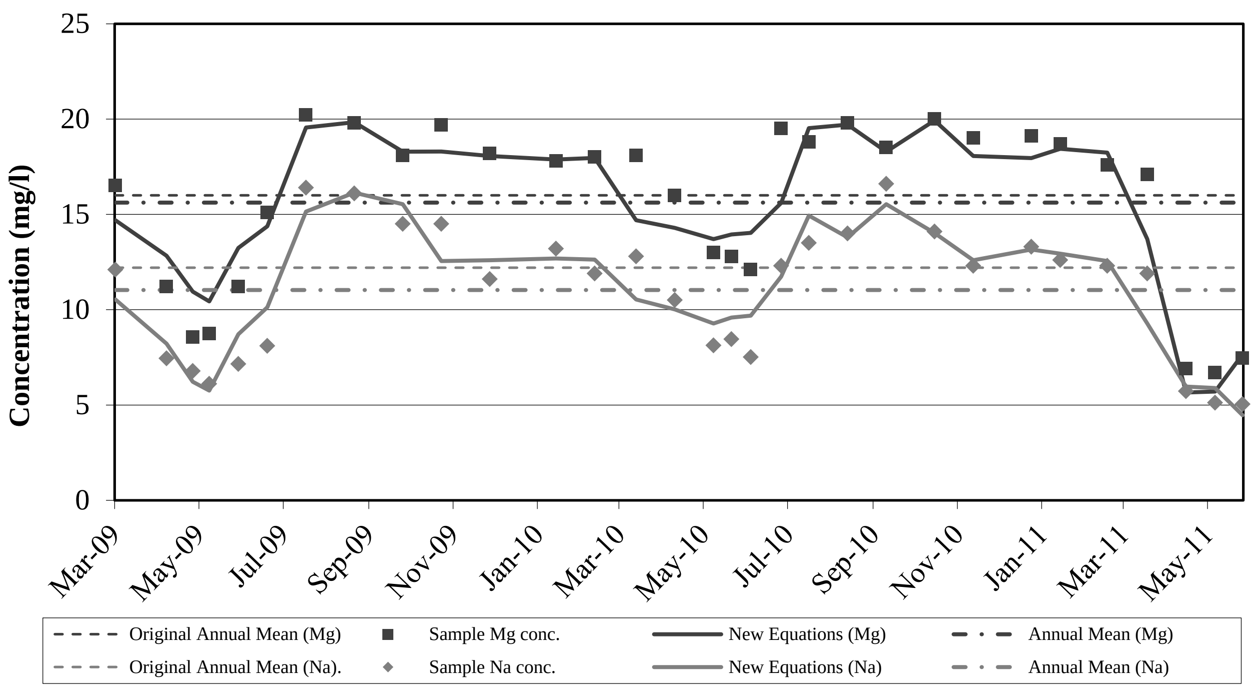

FIGURE 4. The original predictive model used annual means from 40 years ago, but recent data have produced predictive equations for both Mg and Na in UT 44, Hobble Creek.

Discussion. No equation was developed to predict the varying SO_4 concentrations, so a seasonal mean was used (Figure 3). However, in many cases the seasonal means could not accurately simulate the SO_4 trends. The annual mean concentrations of Mg and Na decreased over the past 40 years with the difference in Na being greater than that of Mg (Figure 4). Complex trends exist among these seasonal concentrations. Both of these tributaries, Provo River and Hobble Creek, have experienced heavy development over the past 40 years which may have contributed to the changes observed between the new and old data sets.

For every station, the new data proved more accurate than the previous model. Among the 21 sites analyzed in this study, new equations were found for 67 percent of the TDS and ion concentrations. However, the data from the seven WWTPs generated fewer equations, overall, than the 13 Utah Lake tributaries and the Jordan River. Only 55 percent of the TDS and ion concentration values for the WWTPs could be simulated with an acceptable equation. Conversely, 75 percent of the TDS and ion concentrations for the Utah Lake tributaries and the Jordan River could be simulated with an acceptable equation.

The poor percentage of acceptable equations for the various WWTPs may have occurred because there was a comparatively low variation among the flow rates. For example, the Salem WWTP (UT 51C) had a relatively constant flow of 1.2 cfs. Thus, no acceptable trendline equations were produced to correlate flow with the TDS and ion concentrations.In this case, the seasonal mean values were used and seem to be sufficient to predict TDS and ion concentrations.

About 64 percent of the trendlines were polynomial equations. Although the data points that had polynomial trends were best described by this type of equation, polynomial equations are poor at data extrapolation and results outside the sample range are suspect.

CONCLUSION

The water quality of Utah Lake is of great importance to agriculture, recreation, and wildlife. We compared new correlation equations developed from recently gathered data over a 26 month period to those that were developed over the past 40 years . We found that few significant changes in water quality have occurred in the past 40 years. However, the new equations developed by this study, more accurately predict water quality of Utah Lake using tributary flow rates of the tributaries and the time of the year

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