# Improvements of Atmospheric Deposition Sampling and Further Analysis of its Impact on Utah Lake

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## ABSTRACT


Improvements of Atmospheric Deposition Sampling Procedures and
Further Analysis of its Impact on Utah Lake



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This study focused on Atmospheric Deposition (AD) loading on Utah Lake. Utah Lake is susceptible to Harmful Algal Blooms (HABs) because of its large surface area to volume ratio, proximity to Great Basin dust sources, and various wind patterns from close mountain ranges that blow AD towards the lake. In this study, we continued the collection and analysis of AD samples that started in 2017 and 2018, while reporting additional 2019 and 2020 data. We constructed a sampler on Utah Lake itself, which allowed us to better estimate how AD loads were distributed over the lake. An interpolation assumption was made in the previous studies that the amount of AD decreases exponentially as it passes onto the lake from the shore. Results from 5 months of Bird Island AD sampling on Utah Lake indicate that this assumption was incorrect.

We performed statistical comparison tests on 2 variables: (1) the difference in AD between 2 table heights at the same site and (2) the difference in AD between a filtered sample and an unfiltered sample. We were able to statistically conclude that there was no difference in AD between 1-meter and 2-meter tall sample tables and that filtered AD samples had as much as 3 times lower concentration than unfiltered AD samples.

In 2017, the total AD loading was estimated to be, on the high end, approximately 350 tons of total phosphorous (TP) and 160 tons of dissolved inorganic nitrogen (DIN) (Olsen JM, 2018). After making some changes to the interpolation methods, Joshua Reidhead in 2018 estimated AD loads of 162 tons of TP and 124 tons of DIN (Reidhead, 2019). With no changes to the 2018 sampling methods, but using an updated interpolating method, we determined the AD results for Utah Lake in 2019 to be 392 tons of TP and 1659 tons of DIN. After adjustments to the sampling tables, the buckets, and incorporating the Bird Island sampler results, we calculated the 2020 AD loading totals to be 133 tons of TP and 482 tons of DIN on the lake.



**Keywords**: Utah Lake; atmospheric deposition; total phosphorus; dissolved inorganic nitrogen; eutrophic; harmful algal blooms

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# 1 INTRODUCTION

## 1.1 Background

It is generally assumed that the loading of nutrients to a lake ecosystem occurs mainly through point sources like wastewater treatment plants effluent, ground water, and surface water or non-point water sources such as overland flow and runoff. Most point sources are easy to identify and sample, while non-point sources can be estimated. Atmospheric Deposition (AD) has proven to be a difficult nutrient source to measure. Most of the research on AD has been associated with other elements associated with acidic deposition such as sulfur, mercury, and chloride (Hicks, 1986). Recently, research has been performed regarding other nutrient components of AD such as Phosphorus and Nitrogen in an attempt to understand how they impact algae growth on bodies of water. Utah Lake is a eutrophic freshwater lake that sustains a rich and nutrient heavy ecosystem, which often leads to algal blooms and cyanobacteria growth. Recent studies have shown that AD provides significant nutrient loads to the lake (Olsen JM, 2018).

The National Atmospheric Deposition Program (NADP) has 5 AD monitoring stations throughout Utah, but none in Utah Valley, where Utah Lake is located. NADP, however, is more focused on measuring and understanding global atmospheric deposition. Because of this, their stations are sited to minimize AD loads from local sources, focusing on long-range transport. Since this study is focused on any potential AD that could enter Utah Lake, all sources, both global and local, are considered legitimate contributions to AD. Thus, our stations were sited to measure AD loads locally on the lake.

A study measuring the atmospheric deposition of total phosphorus (TP) and dissolved inorganic nitrogen (DIN) on Utah Lake began in 2017. That study originated from questions over the feasibility and necessity of reducing the nutrient loadings from wastewater treatment plants (Olsen JM, 2018). These questions led to studies being performed to better understand all the potential nutrient sources that could enter the Utah Lake ecosystem and be used for algal growth. With help from the South Davis Sewer District, Jacob Olsen constructed AD sampling tables and set them up at various locations around Utah Lake (Olsen JM, 2018). These tables were constructed with guidance from the NADP (Lehmann, 2011) and these tables were used from 2017 to 2019 with no changes. Feedback from the Utah Science Panel (USP) about the samplers used for data collection raised several questions about the validity of the data. Three of the concerns raised by the panel are (1) does the height of the table holding the sample buckets bias the measurements, (2) does using a filter, which protects the samples from bugs and debris, make a significant difference on the measurements, and (3) how well do these measurements from the shores of the lake represent the actual deposition across the water surface? These questions are of interest to the USP, NADP, and other AD research projects moving forward because it will help determine the validity of the already collected data and provide guidelines for future AD sampling methods.

To address these concerns, we made modifications to the sampling tables to determine the effect of changing the height of the sampler and the effect that a filter inside the sampling buckets would have on measured AD. Additionally, we installed a sampler on Bird Island (Figure 1), which is located in the southern portion of Utah Lake. This station was constructed in an effort to evaluate interpolation methods and analyze the correlations that might exist among the samplers around the lake. Previous studies (Olsen JM, 2018, Reidhead, 2019) had assumed different distribution patterns for AD on the lake. Since this new sampler measures AD on the lake itself, we were able to use this data to perform better spatial interpolations in estimating total AD loads. The Bird Island sampler data also helped determine the accuracy of previous years' data interpolation methods.

*Figure 1 – Bird Island Sampler, Winched Halfway Down*

This report will present a statistical analysis of the data collected to compare the effect of (1) sampler table heights and (2) filters in the sample buckets, as well as (3) an analysis of correlations among the existing sampler locations and the Bird Island sampler. An estimate of the total amounts of AD for 2019 and 2020 will also be provided to remain consistent with previous years' research.

## 2 MATERIALS AND METHODS

The sampling procedure followed the same NADP protocols outlined in Jacob Olsen's publication (Olsen JM, 2018). During my regular weekly sample runs, I procured a wet-deposition sample and dry-deposition sample from each site. In order to simulate the collecting properties of a wet lake surface, the dry-deposition sample bucket at each site was loaded with 3 liters of deionized water (Jassby AD, 1994, Anderson KA, 2006). During the weekly sampling, all buckets were replaced with clean ones. I collected samples at 5 sites around and in Utah Lake seen in Figure 2. I then allocated 500 mL of each sample into clean bottles that then could be analyzed by the Environmental Analytical Laboratory on the campus of Brigham Young University.

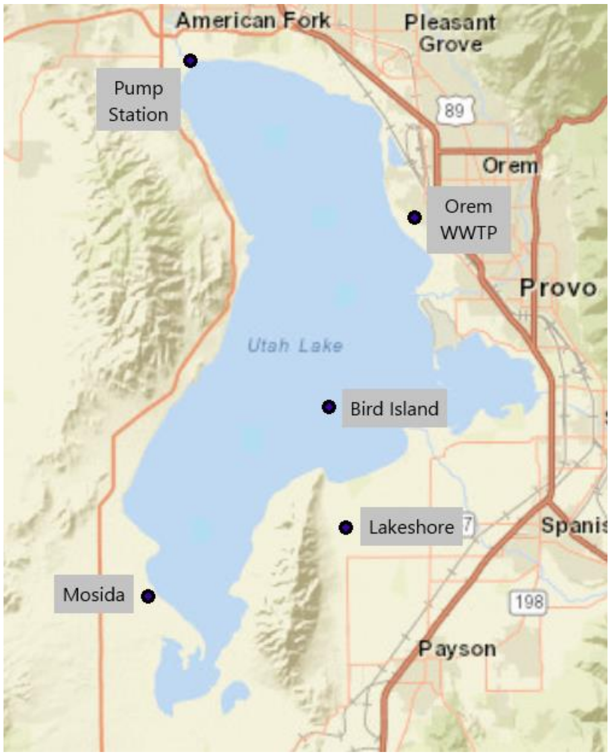


*Figure 2 – Utah Lake Sampling Sites*

I followed the same calculation process as has been followed in previous years' work: I multiplied the nutrient concentration of each sample (mg/L) by the volume of the sample (L) which resulted in mg of nutrients deposited in the sample bucket (Olsen JM, 2018, Reidhead, 2019). Deionized water was added to bring samples up to analytical volume if necessary, but any measurable nutrient concentration in the distilled, deionized water was subtracted. After receiving the results from the lab, I calculated unit area deposition rates by dividing the total deposition mass in milligrams by the surface area of the sample bucket (0.0615 $m^2$) and the time represented by the sample (usually 1 week).

In this section, I will discuss the changes made to the tables and sampling methods in 2020.

### 2.1 High vs Low Tables

One of the requirements for official NADP samplers is that the table should be 1 to 2 meters from the ground. Tables previously constructed have steel legs which meet this requirement but are only about 1-meter tall. I installed four 1-meter tall steel legs to each of the existing tables using four bolts, washers, and nuts which gave the tables approximately a 2-meter height. The goal of doing this was to provide greater probability that all the nutrients in each sample resulted from AD only, and not from local vegetation or windswept dust from around the tables.

In order to understand the effectiveness of the higher tables, while also minimizing the impact of geographical variability, I set up two tables, one with the original 1-meter table legs and one with the new 2-meter table legs, at the Central Davis Wastewater Treatment Plant location and the Ambassador Duck Club location. Both sites are located near Farmington, Utah for similar research being done on Farmington Bay, part of the Great Salt Lake. Figure 3 shows the location of those samplers and Figure 4 shows a tall sampler next to a short sampler at the Ambassador Duck Club location.

*Figure 3 – The two AD sampling locations around Farmington Bay*


*Figure 4 – High vs Low tables at the Ambassador Duck Club near Farmington Bay, Utah*

## 2.2 Filter vs No Filter

One of the major challenges of direct AD measurement involves contamination by insects, plant matter, or bird excrement (Newman, 1995, Ahn H, 2001). Attempts have been made in other AD studies to solve this problem by installing additional samplers at one location to increase the chance of collecting enough uncontaminated samples for analysis (Anderson KA, 2006). Our study is primarily focused on amounts of AD being deposited on Utah Lake per year. Therefore, installing multiple samplers at a location to try to obtain uncontaminated samples would not be cost or time efficient. Other attempts have been made (Tamatamah, 2005) to control for large outlier samples by removing contaminated samples, but this strategy leads to frequent missing data. Ultimately, there is still not a universal agreement on whether or not to include these local contaminants as part of the deposition (Graham, 1979). Olsen and Reidhead included these sources as they reasoned these contaminated samples still represented contributions to the nutrient load on the lake (Olsen JM, 2018).

Within the last three years of AD sampling around Utah Lake, large amounts of bugs, both terrestrial and aquatic, have been found in the samples, especially at the Mosida location. We attempted to answer the question: are the bugs found in the samples an accurate representation of bugs falling and dying in the lake, or just an anomaly? For example, during the 2019 sampling year, from July to August, I counted about 100+ bugs per sample at the Mosida location for 5 weeks, mostly the terrestrial bee *Halictidae Lasioglossum*. We installed stainless steel, 50-micron mesh filters in each of the buckets as shown in Figure 5. We observed the results to determine the impact of filters on the samples. Immediately, the Mosida site had zero bugs the first week the filters were installed and resulted in zero bugs or vegetation in the sample the following weeks. We installed filters at each of the locations and every sample at each site proceeded to show no indication of large bug or plant contamination.

*Figure 5 – Mosida Sample w/o Filter After 2 Days (left). Mosida Sample w/Filter After 1 Week (right)*

Our hypothesis was that the buckets without a filter would have more nutrients than the buckets with a filter. We performed a statistical analysis on the difference over 7 months between filtered and unfiltered samples in Section 3.2.

## 2.3 Bird Island Sampler

After a year's worth of discussion, planning, and fabricating, we installed an AD sampler in the south end of Utah Lake, about 50 m east from the middle of Bird Island. We placed the frame with spikes into the gravelly soil, screwed the 10-foot tall poles with the wenches onto the frame, and slid the raising frame onto the apparatus. We installed 50 feet worth of dynamic rope from each corner of the sampler onto 2 cinder blocks connected to a chain and an anchor. For extra support, we shoveled gravel and large rocks on top of the frame for foundational stability. We bolted a standard 1-meter sampling table on top of the frame that gets winched up. We bolted a steel L-bracket to the side of the table with the solar panel on one end to charge the electronics battery and a beacon light on the other end for boater safety at night. A picture of the sampler can be seen in Figure 6 below.

*Figure 6 – Bird Island Sampler*

Having results from a known point inside Utah Lake greatly assisted in the interpolation of total AD on the lake, as will be discussed later in Section 3.3.

We also wanted to answer the question of whether or not we could predict the nutrient content at the Bird Island location based on some combination of the other 4 sites (Lakeshore, Mosida, Pump Station, and Orem). The statistical analysis we performed can be found in Section 3.3.

### 2.4 Total Utah Lake Atmospheric Deposition

The purpose of the research in 2017 began as an attempt to quantify the amount of AD being deposited on Utah Lake per year. In 2017, Olsen simply interpolated between the shoreline samplers to 5 selected fake points inside the lake and reported the total. An assumption made was that the AD deposition rate at these fake points in Utah Lake was at background levels of

0.019 mg $m^{-2}$ $day^{-1}$ (Olsen JM, 2018). His report indicated that sampling sites near the lake center would be required to answer the question about deposition patterns on the lake.

Reidhead did more research into the interpolation methods used by other studies and settled on using a geometrical interpolation method with the conservative assumption that the AD values were zero at the center of the lake (Reidhead, 2019).

After a 5-month period of sampling on Bird Island in 2020, the AD results at this location were consistently higher or about the same as the shoreline samplers. More samplers would need to be set up throughout the lake in order to truly understand the spatial and temporal variation from the shoreline to Utah Lake. However, having this known data point gives an idea of the AD throughout the lake so we used the results anyway when performing the interpolation needed to determine the total amount of AD on Utah Lake in 2020.

I used the same 2020 TP and DIN regression equations for the 2019 data as well. Even though AD fluctuates greatly depending on seasonal variation or other weather patterns, we decided to use the regression equation anyway because it gave a better idea of the AD on the lake than not using it. In order to get a clearer idea of the spatial and temporal fluctuations over Utah Lake, there would need to be multiple samplers set up in the lake, as well as a statistical analysis during each seasonal period, to have strong confidence that interpolations over the lake are more accurate. However, for the scope and purpose of the research at this time, having one sampler in the lake is enough to provide some evidence of the AD regression over the entire lake.

I only had sample results from the Bird Island location for 5 months of 2020 (July to November). The values for the other 7 months of the year (January to June and December) were created from the TP and DIN regression equation generated from the 5-month statistical analysis.

I used simple kriging with a standard variogram to interpolate between the sample points. While the interpolation method performed here is the same as performed by Olsen (Olsen JM, 2018), the understanding of deposition dispersion rates is different. Our method used on the 2019 and 2020 data means that the estimated deposition rates generally increased or remained the same as it progressed towards the center of the lake. In 2017, Olsen used decreasing dispersion rates as it progressed towards the center of the lake from the shore. I used the geostatistical software found in ArcGIS Pro for the spatial analysis.

For sites that had missing values for a given week, I used the mean of the remaining sites for that week. If one of the sites had a high outlier, I excluded the high outlier and used the mean of the remaining sites. I loaded the sampling results for each site to each point around the lake. I then created a random raster within the extents of the Utah Lake layer. I used the Kriging tool within ArcGIS Pro, following the kriging steps described earlier, to load interpolated values onto the Utah Lake raster. I then extracted just the cells within the Utah Lake layer using the "Extract by Mask" tool. I finally summed every cell within the Utah Lake raster to compute the total nutrient loading for the whole lake in milligrams for that week. I repeated this process for each week in 2019 and 2020 for both TP and DIN. I then converted the results from milligrams to tons.

## 2.5 Other Changed Items

### 2.5.1 Solar Panel Locations

One of the critiques regarding the previous sampling tables was that the solar panels used to charge the battery were too close to the samplers. The reasoning behind this criticism was that the solar panels and steel L-bracket it was attached to could leach off nutrients from the steel during a rain event and fall into the sample, resulting in a contaminated AD sample. I retrofitted the samplers at each location by removing the solar panel and the L-bracket post attached to the table, moving the panel 15 feet away from the table, and then bolting the panel down to a T-post that was pounded into the ground. I heat shrank the ends of 10-gauge wire and spliced them to the existing wires from the solar panel to ensure a minimum of 15 feet from the table and that proper electrical powering of the battery could still be accomplished. The solar panels were attached to the T-posts using a circular steel base welded to a cylindrical pipe that would fit around a T-post as seen in Figure 7 below.

*Figure 7 – Tables with Solar Panel Attached (left) and Table with Solar Panel 15 feet away (right)*

### 2.5.2 Miners Moss Installation

Along the same vein of minimizing contamination when there is a rain event, there was a question from the USP about contamination that could occur from rain that bounced off the top of the tabletop covering, and into the wet deposition sample bucket. We glued green miners moss on top of the tabletop coverings after we performed some basic experiments to see how well the miners moss absorbed water. It performed better than any other material we tested.

# 3 RESULTS

## 3.1 High vs Low Tables Comparison

We performed a paired t-test on 38 pairs of table height sample data over 7 months, collected from the Central Davis and Ambassador locations. We had 21 pairs from the Central Davis site and 17 from the Ambassador site.

Figure 8 and Figure 9 below show the graphical comparison and the Box and Whisker Plot comparison of TP between the heightened tables and the original lower tables over the course of 8 months in 2020. The data table used to create these figures can be found in the Appendix in Table 12.

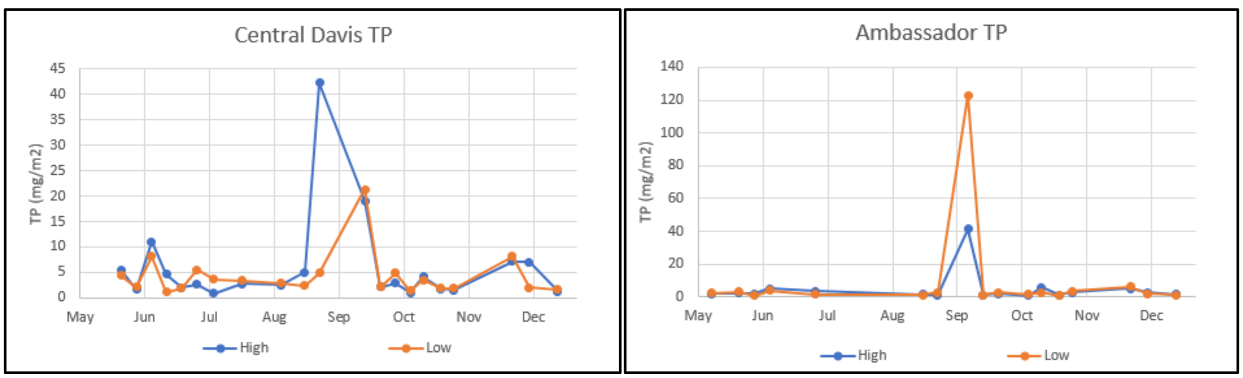


*Figure 8 – TP Comparison Between High and Low Sampling Samplers*

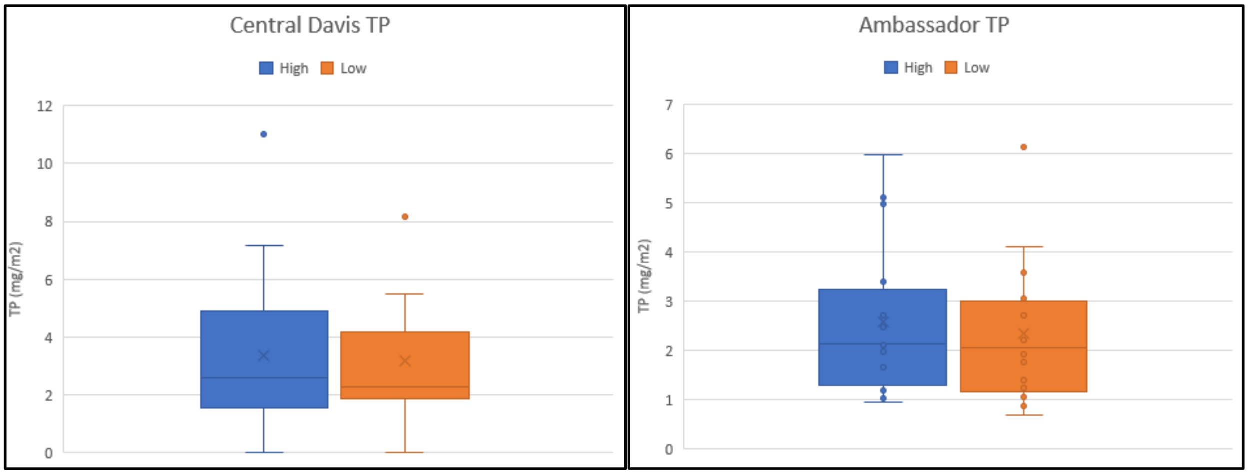


*Figure 9 –TP Box and Whisker Plot Comparison Between High and Low Samplers*
**Note – the outlier values above 40 mg/m² have been removed to see the difference better between tables.*

Figure 10 and Figure 11 below show the graphical comparison and the Box and Whisker Plot comparison of DIN between the heightened tables and the original lower tables over the course of 8 months in 2020. The data table used to create these figures can be found in the Appendix in Table 13.

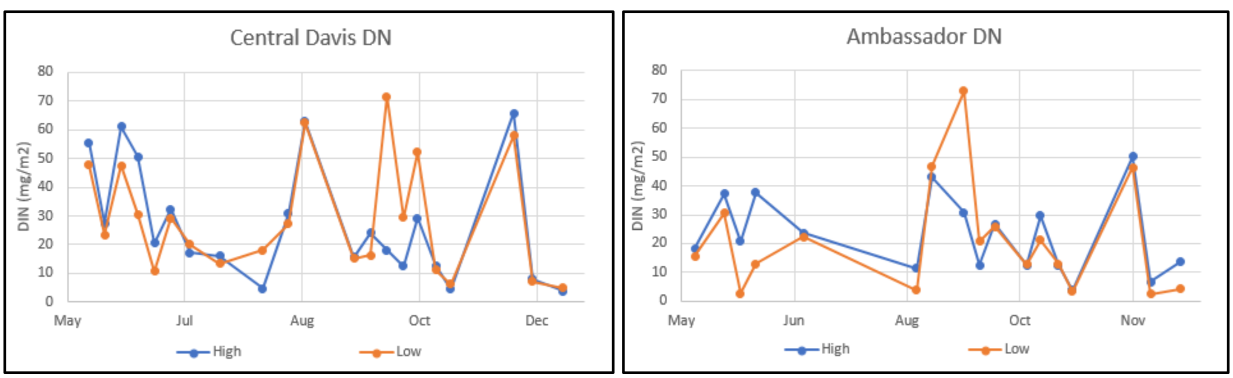


*Figure 10 – DIN Graphical Comparison Between High and Low Samplers*

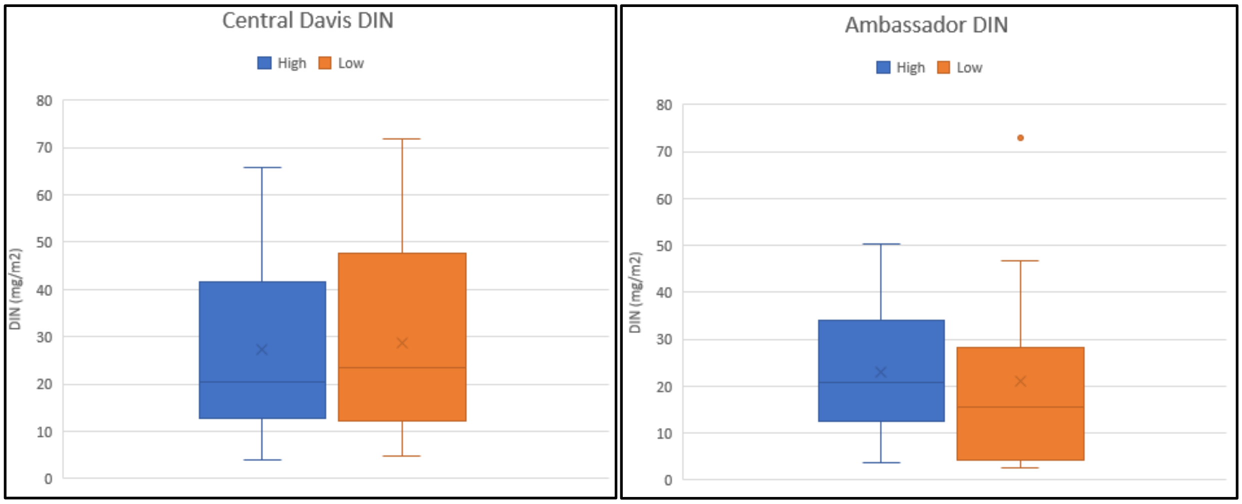

*Figure 11 – DIN Box and Whisker Plot Comparison Between High and Low Samplers*
**Note – No outliers were removed from the data for this plot.*

The distribution of data collected was significantly skewed and had a few measurements that came back as zero, so the data were transformed with a Ln(x+1) transformation. After the back transformation, the TP measurements had an average median difference of 1.09 mg/m$^2$, a 95% confidence interval of (0.85, 1.34), and a 1 tailed p-value of 0.264. Because of the transformation, the average difference and confidence interval values represent a multiplicative difference. Thus, the low samplers for TP, on average, were 8% of the high sampler's value. The low table DIN measurements were on average 12% lower than the high table AD results and a 1 tailed p-value of 0.116.

The low p-values for both TP and DIN indicate that there is not strong evidence that higher tables result in lower AD loadings. However, these results do not prove that there is no difference between low and high tables. Further experiments will need to be performed in order to have more evidence that table height does not have an impact on AD. For the purposes of this study, the data we retrieved and analyses performed indicate that the tables built previously are sufficient at the 1-meter height.

### 3.2 Filter vs No Filter

In previous years' sample data, a question we have had was how much the bugs found in the samples contributed to the AD nutrient totals in the samples. We decided to do a comparison between 2019 and 2020 and see if installing filters had any effect on the AD concentration outliers. I considered a value an outlier if it was greater than 1 mg/l for TP or 8 mg/l for DIN. Both of these outlier values are about 3 standard deviations above the mean for each respective nutrient. I recorded the number of outliers and average weekly concentration with and without the outliers for 2019 and 2020 in Table 1. As discussed above, we installed bucket filters at the beginning of May 2020. As seen in Table 1, there are 6 TP outliers at all the sites for the 2020 samples. Of these 6 outlier samples, 3 of them occurred before the installation of the filters. The remaining 3 outliers occurred during high wind days with large amounts of visible dust in the sample. There were 2 outliers in the 2020 DIN data compared to 9 outliers in the 2019 DIN data.

*Table 1 – 2019 vs 2020 TP and DIN Average Weekly Concentration Comparison (Units in mg/l)*

| 2020 TP Data | | | | |
|---|---|---|---|---|
| Location | Avg w/ Outliers | Avg w/o Outliers | # of Samples | # of Outliers |
| Lakeshore | 0.181 | 0.12 | 35 | 2 |
| Mosida | 0.532 | 0.088 | 39 | 2 |
| Pump Station | 0.12 | 0.12 | 40 | 0 |
| Orem | 0.15 | 0.113 | 32 | 1 |
| Bird Island | 0.376 | 0.255 | 18 | 1 |

| 2020 DIN Data | | | | |
|---|---|---|---|---|
| Location | Avg w/ Outliers | Avg w/o Outliers | # of Samples | # of Outliers |
| Lakeshore | 0.785 | 0.451 | 35 | 0 |
| Mosida | 1.935 | 0.458 | 39 | 2 |
| Pump Station | 0.398 | 0.32 | 40 | 0 |
| Orem | 0.553 | 0.352 | 32 | 0 |
| Bird Island | 0.82 | 0.642 | 18 | 0 |

| 2019 TP Data | | | | |
|---|---|---|---|---|
| Location | Avg w/ Outliers | Avg w/o Outliers | # of Samples | # of Outliers |
| Lakeshore | 0.219 | 0.137 | 35 | 2 |
| Mosida | 3.13 | 0.129 | 35 | 9 |
| Pump Station | 0.155 | 0.155 | 36 | 0 |
| Orem | 0.265 | 0.154 | 36 | 2 |

| 2019 DIN Data | | | | |
|---|---|---|---|---|
| Location | Avg w/ Outliers | Avg w/o Outliers | # of Samples | # of Outliers |
| Lakeshore | 2.07 | 0.59 | 35 | 1 |
| Mosida | 10.097 | 0.489 | 35 | 6 |
| Pump Station | 1.134 | 0.432 | 36 | 0 |
| Orem | 1.572 | 0.575 | 36 | 2 |

Including the outliers for all data, the average concentration for TP for 2020 was approximately 77% lower than the TP for 2019 while the average concentration for DIN for 2020 was about 81% lower than the 2020 DIN (Table 2). There is evidence that the lack of high outlier AD concentrations can be attributed to the installation of these filters.

*Table 2 – Average Percentage Difference between TP and DIN for 2020 and 2019*

| | TP (mg/l) | DIN (mg/l) |
|---|---|---|
| 2020 | 0.272 | 0.898 |
| 2019 | 0.942 | 3.718 |
| % Diff | 78% | 81% |

Figure 12 and Figure 13 below show the graphical comparison and the Box and Whisker Plot comparison of TP between the filtered samplers and the unfiltered samplers over the course of 6 months in 2020. It is important to note that the comparison between filtered and unfiltered samplers occurred with 2-meter tall tables. The data table used to create these figures can be found in the Appendix in Table 14.

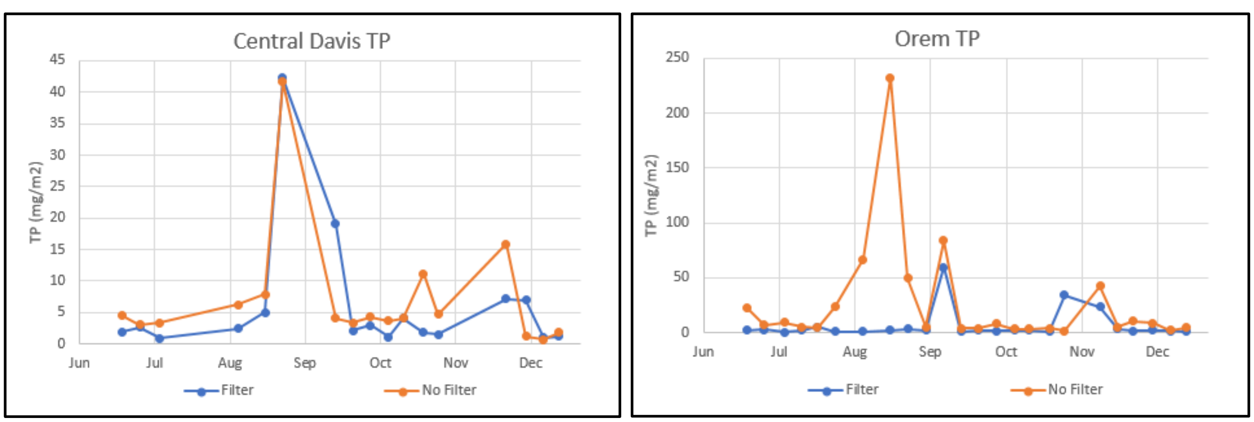


*Figure 12 – TP Graphical Comparison Between Filtered and Unfiltered Samplers*

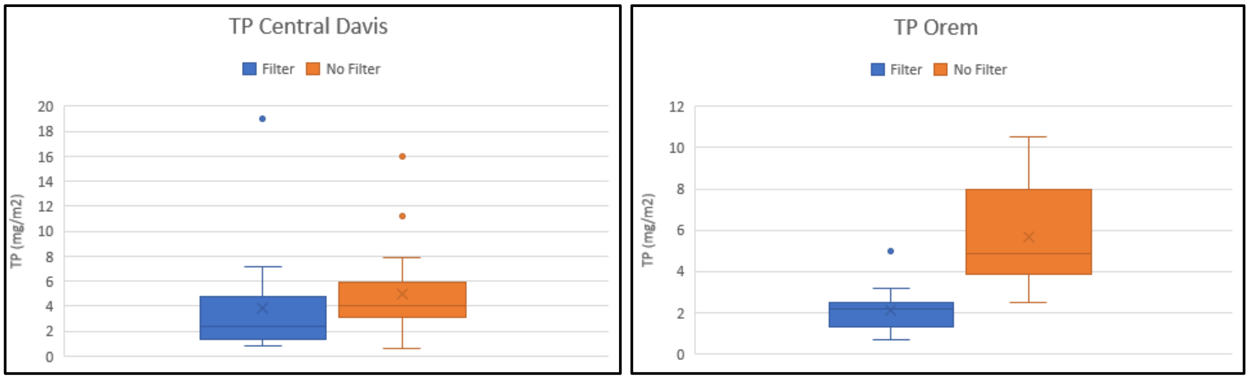


*Figure 13 – TP Box and Whisker Plot Comparison Between Filtered and Unfiltered Samplers*
**Note – 8 Pairs of outlier samples were removed from the data to see the difference more clearly.*

Figure 14 and Figure 15 show the graphical comparison and the Box and Whisker Plot comparison of DIN between the filtered samplers and the unfiltered samplers over the course of 6 months in 2020. The data table used to create these figures can be found in the Appendix in Table 15.

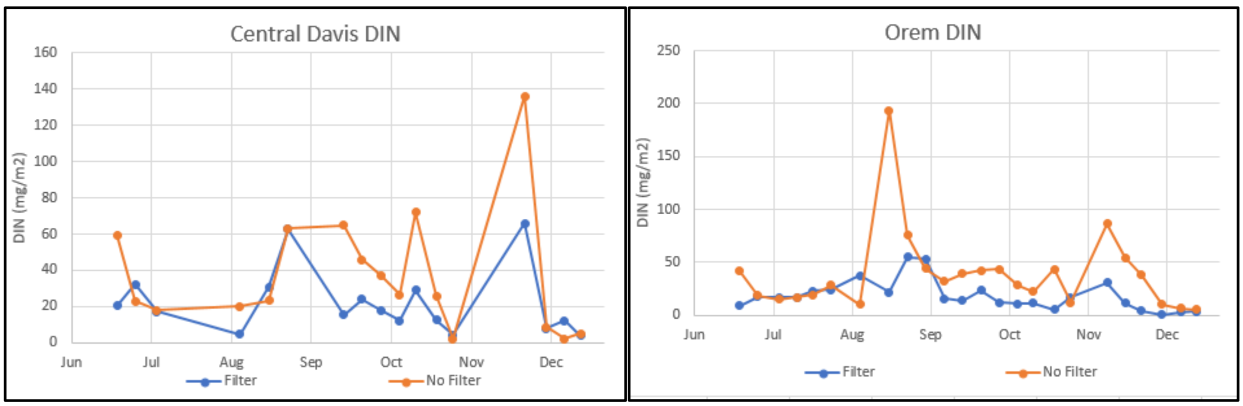


*Figure 14 – DIN Graphical Comparison Between Filtered and Unfiltered Samplers*

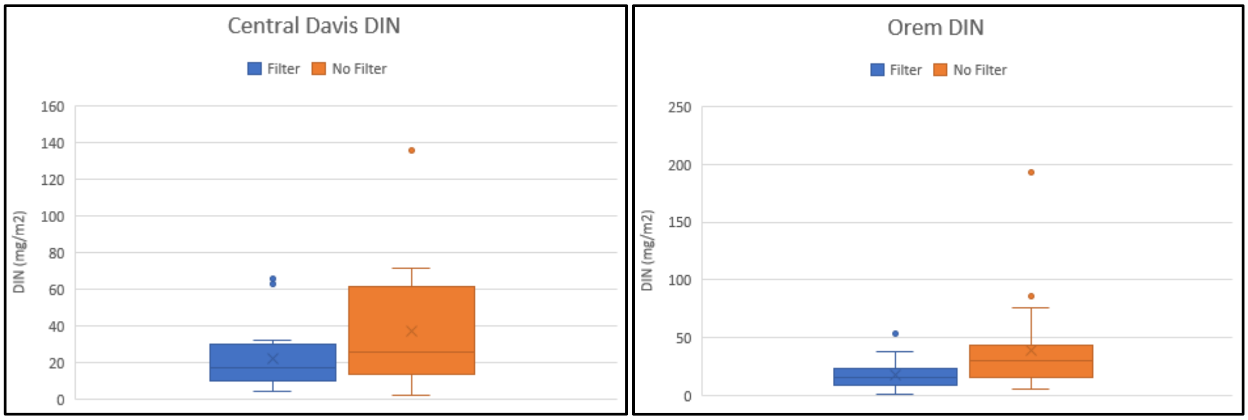

*Figure 15 – DIN Box and Whisker Plot Comparison Between Filtered and Unfiltered Sampling Tables*
**Note – No pairs of outlier samples were removed from the data.*

The unfiltered data sites generally had higher nutrient concentrations than the filtered data. There are a few times where that is not the case; for example, the TP results from 10/29/2020 showed the filtered Orem data to be 34.498 mg/m$^2$ while the unfiltered sampler at Orem for the same day was only 1.606 mg/m$^2$. The reason for this big of a discrepancy is not apparent. However, the results for most other samples showed the filtered data to be lower in AD concentration than the unfiltered data.

Between two sites, Orem and Central Davis, there were 41 different pairs of samples collected, 17 at the Central Davis site and 24 at the Orem site. I compared the differences in concentrations of TP and DIN using a paired t-test. The distributions of the differences for the two nutrients were skewed, so a natural log transformation was performed on each sample value. I used the one-sided p-value since the hypothesis was directional.

I statistically analyzed the paired data using JMP and for TP, the average difference between filtered and unfiltered data on the log scale was 0.823, with a 95% confidence interval of 0.398 to 1.249 and a p-value of 0.0004. Back-transforming these values ($e^x$) gives a multiplicative difference in the medians of 2.488, with a 95% confidence interval of 1.488 to 3.488. For DIN, the average difference on the log scale was 0.555 with a 95% confidence interval of 0.266 and a p-value of 0.0116. The multiplicative difference in the medians was 1.816 with a 95% confidence interval of 1.305 to 2.326. Table 3 below summarizes the statistical difference between filtered and unfiltered samples. See Figure 24 and Figure 25 in the Appendix for JMP difference scatterplots.

*Table 3 – Summary of Statistical Results for Filter vs Nonfilter Comparison*

| Nutrient | Log Scale | | | p-value | Multiplicative Difference | | |
|---|---|---|---|---|---|---|---|
| | Diff. | 95% Conf. Int. | | | **Diff.** | 95% Conf. Int. | |
| TP | 1.112 | 0.405 | 1.819 | **0.0018** | **3.04** | 1.50 | 6.17 |
| DIN | 0.412 | 0.062 | 0.763 | **0.0116** | **1.51** | 1.06 | 2.14 |

The low p-value of 0.0018 indicates that there is a statistically significant difference between the filtered and unfiltered samples for TP. The unfiltered samples in mg/m$^2$ had on average 3 times the amount of TP as the filtered samples. There is moderate evidence for a difference in the amount of DIN, with the unfiltered samples having 1.5 times the amount of the filtered samples.

Overall, it appears that the filters installed in the samplers provided a barrier that previous contamination (insects, vegetation, etc.) could not get through. Whether or not this means that filtered samples are the most accurate report of AD is still debatable. However, filtered samples provide a conservative estimate of AD at a location.

### 3.3 Bird Island Prediction

Results show that the Bird Island samples were generally higher in AD content than the other samplers. If the 31.29 mg/m$^2$ data point from the Pump Station on 9/4/2020 is removed, Bird Island generally has a higher or about the same AD value as the other samplers on the shores of Utah Lake for the 5 months that the sampler was available (July to November). These results run contrary to previous years' assumption that the amount of AD would be less on the lake interior compared to the shore samplers. All previous years' interpolations assumed a decreasing correlation from the shore samplers to the middle of the lake. Table 4 and Table 5 show this phenomenon of the Bird Island sampler recording higher amounts of AD than the shoreline samplers. The only instance where the Bird Island site was higher in TP than the shoreline samplers was in October of 2020, it was only about 64% lower than the average of that month. The only time when the Bird Island sampler was lower than the average for DIN was in August of 2020 and it was only 19% lower than the August average.

*Table 4 – Bird Island Sampler Monthly TP Results*

| 2020 Total Phosphorus (mg/m²) | | | | | | |
|---|---|---|---|---|---|---|
| **Month** | **Bird Island** | **Lakeshore** | **Mosida** | **Pump Station** | **Orem** | **Avg of 4 shore sites** |
| **Jul** | 5.35 | 6.62 | 7.40 | 2.56 | 3.73 | 5.08 |
| **Aug** | 9.37 | 2.55 | 3.13 | 4.36 | 2.31 | 3.09 |
| **Sep** | 36.25 | 3.75 | 6.17 | 19.91 | 16.45 | 11.57 |
| **Oct** | 1.73 | 4.70 | 3.36 | 2.49 | 8.42 | 4.74 |
| **Nov** | 33.34 | 6.01 | 2.89 | 3.34 | 9.51 | 5.44 |

*Table 5 -- Bird Island Sampler Monthly DIN Results*

| 2020 Dissolved Nitrogen (mg/m²) | | | | | | |
|---|---|---|---|---|---|---|
| **Month** | **Bird Island** | **Lakeshore** | **Mosida** | **Pump Station** | **Orem** | **Avg of 4 shore sites** |
| **Jul** | 31.93 | 24.91 | 21.25 | 17.28 | 19.84 | 20.82 |
| **Aug** | 28.87 | 35.50 | 38.31 | 30.02 | 37.94 | 35.44 |
| **Sep** | 52.29 | 35.47 | 25.28 | 20.21 | 26.40 | 26.84 |
| **Oct** | 16.39 | 16.84 | 15.37 | 9.58 | 11.14 | 13.23 |
| **Nov** | 27.17 | 14.51 | 13.24 | 2.62 | 15.36 | 11.43 |

To answer the question of whether or not we could predict the nutrient content at the Bird Island location based on the other 4 sites (Lakeshore, Mosida, Pump Station, and Orem), I performed a general linear F-test on the data from the 5 Utah Lake sample sites. The TP results were log-transformed because the nutrient data formed a cluster and seemed random (Figure 28 and Figure 27).

I performed a general linear F-test on the data to determine whether or not the Bird Island results could be predicted by the shoreline samplers. The full model in this F-test refers to the model created by using all 4 shoreline sample sites in predicting the Bird Island sampler results. The reduced models in the F-test refer to the models created by removing some of the parameters (sample sites) in predicting the Bird Island sampler results (Ramsey, 2012). JMP produces sets of equations for the full model and reduced models, along with p-values to help determine which model is best at determining the linear prediction equation. Each model was compared using the extra sum of squares test. In this instance, I ran reduced models, removing sites at different times to see if there was more of a correlation with just the sites closest to the Bird Island sampler.

The results of the AD content at the Bird Island location compared to the other four sites around Utah Lake were calculated to determine the regression equation between shoreline samples and the AD content on the lake. The analysis showed some influential outlier observations; however, considering that there are only 16 samples recorded over this time, I did not remove any points. The TP analysis shows that there is no evidence for Lakeshore (p-value 0.3867) and non-conclusive evidence for Orem (0.0175) being related to Bird Island TP. However, there is convincing evidence that the Mosida TP is related to Bird Island TP. A comparison between models with an extra sum of squares F-test presents non-conclusive evidence that the models are different from each other with a two-sided p-value of 0.023. This matches prevailing winds, where the Bird Island site is more similar to the Mosida station than to the stations further north or east.

In the case of DIN, the analysis shows similar results for both the reduced (Mosida and Lakeshore) and full (all sites) models. There is not strong evidence that any of the sites are linearly related for DIN with the Bird Island, with p-values greater than 0.5. The extra sum of squares test has a high p-value so there is not strong evidence that the full and reduced models are different. There is no strong statistical evidence that Orem, Pump Station, and Mosida are linearly related for DIN to Bird Island. There is nonconclusive evidence that the Lakeshore site for DIN is linearly related to Bird Island DIN, based on only one of the reduced models.

Even though the statistical results do not indicate that we can confidently and accurately predict the AD at the Bird Island site based on the shoreline sites, I used the reduced linear regression equations from this exercise to give an approximate value for the other 7 months of 2020 for Bird Island. More samplers in Utah Lake itself will need to be constructed and more data over the next few years will need to be collected before an accurate dispersion and prediction model can be created.

### 3.4 Scope of Inference

Each of these analyses was based on observational studies. The experiments were not randomized. Thus, causality cannot be established, and the conclusions may not confidently apply to other AD sampling locations or times.

### 3.5 Total Utah Lake Atmospheric Deposition Results

Even though the linear regression performed on the Bird Island sampler compared with the other samplers did not return strong evidence that the Bird Island AD could be predicted by the other samplers, we proceeded to use the results from the regression analysis anyways because it provided a better picture of the AD on the lake than previous years. We used the results from the full model in Table 6 while determining the total amount of TP over the entirety of Utah Lake for

2019 and 2020, and we used a reduced model in Table 7 when determining the total amount of DIN over Utah Lake for 2019 and 2020. In situations where either the full or reduced model resulted in a negative value or a value that did not fit with the rest of the data when creating the weekly values for the interpolation, I entered a mean value that fit within the rest of that week's AD results.

*Table 6 – Full Model TP Results*

| Indicator Function Parameterization | | | | | | |
|---|---|---|---|---|---|---|
| **Term** | **Estimate** | **Std Error** | **t Ratio** | **Prob>\|t\|** | **Lower 95%** | **Upper 95%** |
| Intercept | 2.1952956 | 0.213912 | 10.26 | 0.0094* | 1.2749082 | 3.115683 |
| Log[Orem] | 0.7870785 | 0.144942 | 5.43 | 0.0323* | 0.1634416 | 1.4107153 |
| Log[Lakeshore] | -0.99595 | 0.179052 | -5.56 | 0.0308* | -1.766349 | -0.225551 |
| Log[Mosida] | -0.549934 | 0.17492 | -3.14 | 0.0880 | -1.302556 | 0.2026871 |
| Log[Pump Station] | 0.5818599 | 0.065296 | 8.91 | 0.0124* | 0.3009135 | 0.8628063 |

*Table 7 – Reduced Model DIN Results*

| Indicator Function Parameterization | | | | | | |
|---|---|---|---|---|---|---|
| **Term** | **Estimate** | **Std Error** | **t Ratio** | **Prob>\|t\|** | **Lower 95%** | **Upper 95%** |
| Intercept | 11.100706 | 15.95262 | 0.70 | 0.5175 | -29.90682 | 52.108228 |
| Orem | -0.209478 | 0.355154 | -0.59 | 0.5810 | -1.122432 | 0.703475 |
| Lakeshore | 1.0071501 | 0.39013 | 2.58 | 0.0493* | 0.0042888 | 2.0100113 |

Following the interpolation explained in Section 2.4, I performed a weekly AD interpolation in ArcGIS Pro for each of the weeks in 2020. I then summed each of the weeks' total AD to report the yearly TP and DIN for 2019 and 2020. Figure 16 shows a map of interpolated DIN for the week of 8/23/2020. Other examples of weekly interpolated maps throughout the year can be seen in Figure 21, Figure 22, and Figure 23 in the Appendix.

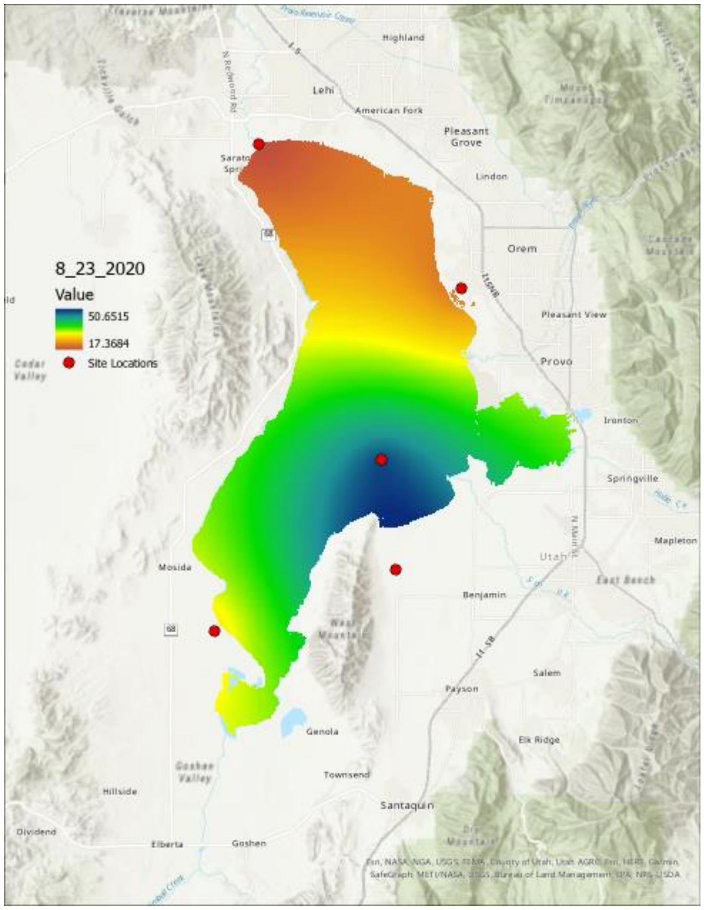


*Figure 16 – 8/23/2020 DIN Interpolation Results Map*

Each week's interpolation resulted in a different spatial interpolation map, making it difficult to notice any clear pattern of AD distribution on the lake. Some weeks showed each of the sites having more of a linear relationship to the Bird Island site. Another sampler on the west side of the lake would be helpful with this spatial interpolation. The interpolation could be better since there is only one sampling point in Utah Lake, but it provides a better picture of the AD on the lake than previous years.

The interpolation resulted in a total 2020 TP DIN loading estimation of 133 tons and a total 2020 DIN loading estimation of 482 tons (see Table 8).

*Table 8 -- 2019 and 2020 Yearly Tons of AD*

| Yearly Tons of AD | | |
|---|---|---|
| Year | TP | DIN |
| 2019 | 392 | 1659 |
| 2020 | 133 | 482 |

Figure 17 shows the weekly loading of TP and DIN for 2020 while Figure 18 shows the 2019 weekly AD loading. Data used to create these figures can be found in the Appendix (Table 16 and Table 17). There is much seasonal variation in both the 2019 and 2020 data. The winter months were generally distributed so that they correlated with the minimum amounts of AD for their respective year. The summer months generally related to the maximum amounts of AD for the year. It is important to remember that the spike in the 2020 data occurred in May prior to the installation of filters. As explained in a prior section, there is strong evidence that suggests that the number of bugs that usually found their way into the sample would be filtered out and the peaks would most likely not reach 80 tons of DIN and 27 tons of TP like it does in this instance.

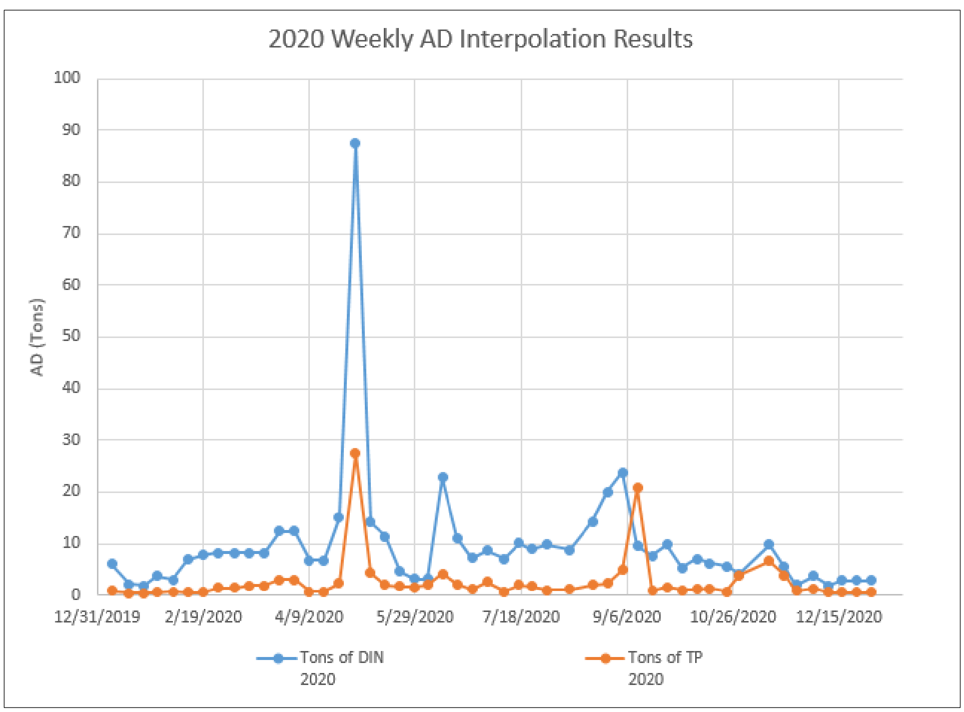


*Figure 17 – 2020 Weekly AD Interpolation Results*

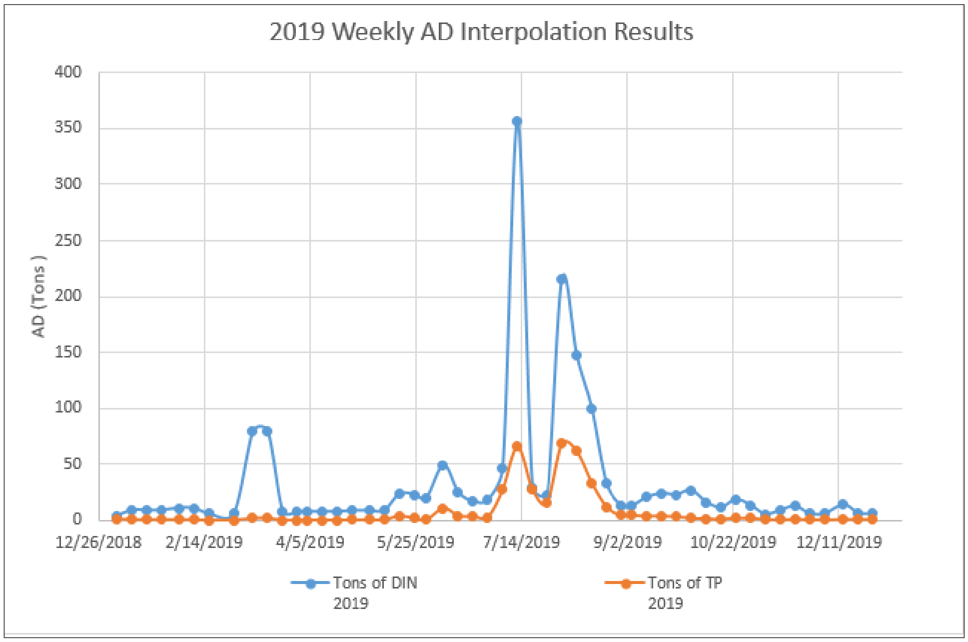


*Figure 18 – 2019 Weekly AD Interpolation Results*

## 3.6 Yearly Sample Comparison

There has been a question of what other AD weekly loading totals look like on Utah Lake over the course of several years. I compiled average monthly AD sample data from 2017 and 2018 and then incorporated monthly AD data I collected from 2019 and 2020 in an effort to get a snapshot of AD monthly variance. I did a simple average calculation from each site for each month and then did an average of those results to get a total monthly average for all the sites. These monthly averages are shown in Table 9 and Figure 19 below.

It is apparent that the changes to the sampling apparatus in 2020 had an impact on the summer data. In 2017 and 2019, Figure 19 shows a spike of TP occurring in July. The 2020 data never showed a spike as high as that in any of the months.

*Table 9 – Comparison of Average Monthly TP For All Sites($mg/m^2$)*

| Month | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|
| Jan | N/A | N/A | 4.08 | 1.66 |
| Feb | N/A | N/A | 2.36 | 1.80 |
| Mar | N/A | N/A | 10.97 | 2.86 |
| Apr | N/A | 4.25 | 3.29 | 12.57 |
| May | 10.91 | 36.43 | 5.15 | 24.82 |
| Jun | 99.32 | 12.20 | 13.13 | 6.56 |
| Jul | 17.82 | 22.02 | 102.40 | 3.97 |
| Aug | 10.15 | 16.85 | 122.43 | 3.09 |
| Sep | 7.09 | 9.91 | 11.31 | 11.25 |
| Oct | 4.58 | 6.38 | 4.54 | 3.65 |
| Nov | N/A | 4.55 | 2.16 | 4.57 |
| Dec | N/A | 2.90 | 2.44 | 1.84 |

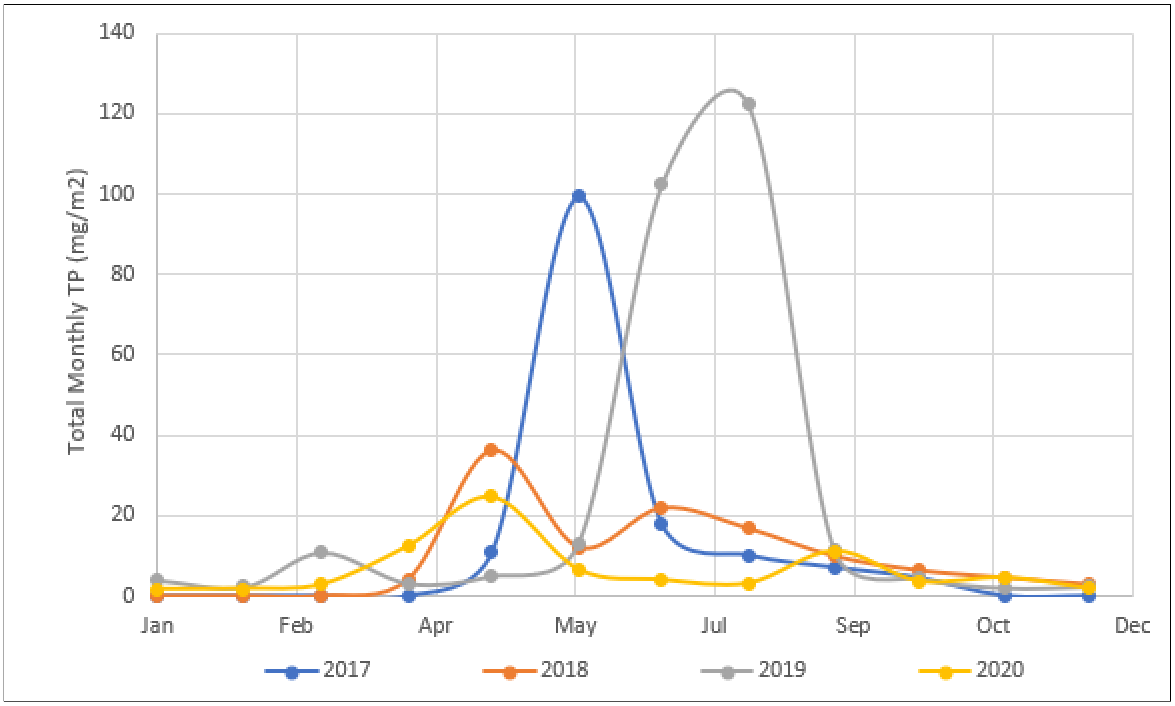


*Figure 19 – Monthly Average TP for All Sites Comparison*

I performed the same analysis on DIN data for 2017 to 2020. While 2020's average DIN data did peak around middle of April, Figure 20 shows that it did not reach the same crest as any of the other years. This has more to do with the sampling changes to the tables, adding bucket filters specifically, rather than stating that 2020 was maybe a low monthly AD loading year for Utah Lake. The general trend of increasing AD during the summer months and decreasing AD during the winter months was confirmed with this analysis.

*Table 10 – Comparison of Monthly Average DIN for All Sites (mg/m²)*

| Month | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|
| Jan | N/A | N/A | 54.88 | 17.34 |
| Feb | N/A | N/A | 32.13 | 5.72 |
| Mar | N/A | N/A | 251.57 | 36.20 |
| Apr | N/A | 38.84 | 88.89 | 63.50 |
| May | 25.96 | 334.52 | 55.17 | 73.58 |
| Jun | 63.16 | 29.56 | 67.20 | 27.24 |
| Jul | 44.26 | 50.71 | 414.19 | 19.23 |
| Aug | 34.10 | 52.27 | 342.39 | 35.44 |
| Sep | 36.12 | 33.94 | 53.46 | 26.84 |
| Oct | 19.77 | 44.42 | 39.03 | 13.23 |
| Nov | N/A | 40.94 | 19.25 | 11.43 |
| Dec | N/A | 13.58 | 24.51 | 4.28 |

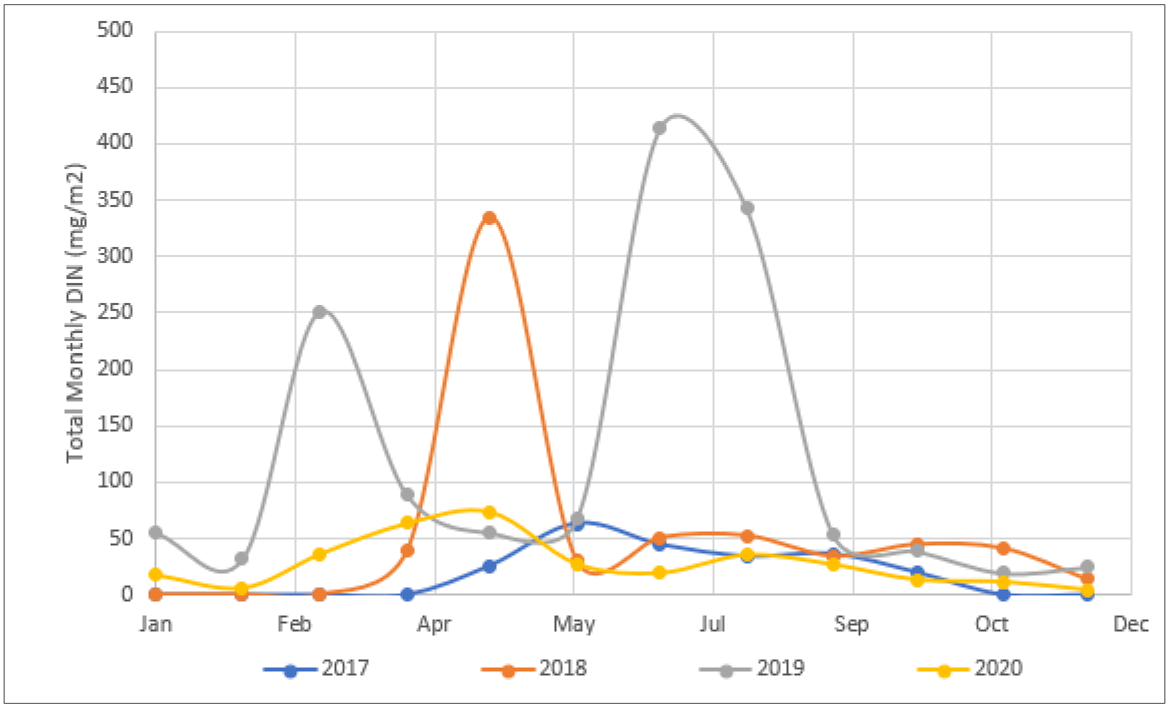


*Figure 20 – Monthly Average TP for All Sites Comparison*

The same trends found for monthly TP are true for DIN as shown in Figure 20. The DIN peaks for 2017-2019 were approximately 250, 330, and 415 mg/m$^2$, while the 2020 peak was about 75 mg/m$^2$. It is important to remember that some of the 2017 data was removed due to an incorrect understanding of sample contamination. The general trend of increasing DIN during the summer months and decreasing DIN during the winter months was again confirmed with this analysis, except for a smaller DIN peak of 250 in 2019 that occurred in February.

# 4 FURTHER RESEARCH

## 4.1 Atmospheric Deposition

As more sites are added, there will be better representation of the AD entering Utah Lake. Specifically, constructing a table somewhere on the west side of Utah Lake, perhaps near the old Pelican Point site (called Saratoga Springs in previous studies), could provide a better interpolation for the AD between the sites. The previous studies showed that the Pelican Point site had more local contribution from dust (Olsen JM, 2018) likely due to the large gravel pit and agricultural practices on that side of the lake. A better understanding of the total deposition could be determined with a site on the west side combined with the analysis results from this study that the distribution of AD across Utah Lake does not decrease, but rather in some situations, increases.

The comparison tests of having two tables at a few sites performed as part of this research have been informative and enlightening, but the extra tables might be more useful at new sites.

A comparison of the different types of interpolation could be performed and could provide a range of AD weekly values depending on the type of interpolation (kriging, IDW, or Thiessen Polygons) and the different variograms (Gaussian, exponential, semivariate, or linear).

## 4.2 Site Local Soil Comparison

A potential concern surrounding this research is that the samplers are not exactly on the Utah Lake shoreline. Some sites are 50 meters away from the closest shoreline and some samplers are 5 meters away. The reason some samplers are further away is purely logistical as we could not find a more secure or a more accessible property to place the sampler at the time. Something that could be done to assist in stating more confidently that the results are representative of actual AD would be to perform a serial extraction on the soil around each of the sampler tables. Dust samples from the top of the tables could be collected and be compared to the results of the soil extraction and analyzed.

## 4.3 Wind Patterns or Other Weather Analysis

We set up two weather stations in 2020: one at the Mosida site and the other at the Orem WWTP site. These weather stations have the ability to measure rainfall, temperature, humidity, wind velocity, and wind direction. Wind roses could be built from the wind velocity and direction data. If data were collected over the entire year, analyses could be performed in an effort to determine the relationship between wind patterns and AD. The relationship between AD and other weather variables (rain, temperature, or humidity) could be studied also.

# 5 ANALYSIS AND CONCLUSIONS

First, this analysis suggests that there is not enough evidence of a difference between high and low tables for both TP and DIN. The lower buckets had, on average, smaller concentrations of both nutrients than the higher buckets; the opposite of what our original hypothesis stated. Additional trials with much taller tables, e.g. 2 to 4 meters, could theoretically more firmly settle the debate about sample contamination from short tables.

Second, there is strong evidence that the filtered samples have significantly less nutrients than the unfiltered samples. Thanks to a monthly comparison from previous years, there is evidence to support the fact that the 50-micron mesh filters prevented contamination (bugs, local vegetation, etc.) in the samples. However, this analysis did not address whether the filtered or the unfiltered sample is the most accurate representation of Atmospheric Deposition. The filters might be filtering out larger particles of AD that would result in a representative sample. It is plausible that the actual value of AD is higher than the reported filtered value in 2020.

The 2017 through the 2019 data showed a period of time where the data would “spike” to sometimes 10 times the average AD values. Filters brought that spike down to about only 3 times the yearly average of AD. For example, the Central Davis unfiltered sample in November indicated a DIN value of approximately 135 $mg/m^2$ while the Central Davis filtered sample for the same date returned a DIN value of about 60 $mg/m^2$, a 225% reduction.

Third, there is not strong evidence that the AD nutrients at the four shoreline sites are related to the nutrients at Bird Island for both reduced and full statistical regression models. However, it is worth pointing out that there are only 16 observations associated with this exercise. One potential concern might be that each sample site is influenced by different wind patterns which affect the transport of AD. There is some evidence that the Mosida site is most closely related to the Bird Island site. Early preliminary analysis of the wind roses at the Mosida site indicate that the majority of the winds come from the southwest, which is the direction that leads almost directly to the Bird Island site. Further research on site-specific wind patterns that likely influence the AD on Utah Lake should be conducted.

Finally, the results from interpolating the sample values across Utah Lake can be seen in Table 11. There was approximately 392 tons of TP added to Utah Lake in 2019 and 133 tons of TP in 2020, while 1659 tons of DIN were added in 2019 and 482 tons of DIN in 2020. Dry TP deposition represents the majority of deposition that occurs seasonally.

*Table 11 – Summary of 2017-2020 AD Data on Utah Lake (tons)*

| Year | TP | DIN |
|---|---|---|
| 2017 | 350 | 160 |
| 2018 | 162 | 124 |
| 2019 | 392 | 1659 |
| 2020 | 133 | 482 |

The algal growth is greatest during the summer, so it is important to note that the Utah Lake AD correlates with the time when algal growth generally increases the most. To reaffirm, it takes about 17 tons of phosphorus per year and 200 tons of nitrogen per year to support constant algal growth on Utah Lake (Merritt LB, 2016). The amount of TP and DIN determined by this study and previous years' studies is enough AD alone to support eutrophic conditions on the lake. While this study was specific to Utah Lake, this analysis should be a foundation on which water managers at other locations could use as reason to start their own AD monitoring project.

## APPENDIX

*Table 12 – Weekly TP Comparison Table Between High and Low Samplers*

| Total Phosphorus (mg/m$^2$) | | | | |
|---|---|---|---|---|
| **Date** | **Central Davis High** | **Central Davis Low** | **Ambassador High** | **Ambassador Low** |
| **5/15/2020** | N/A | N/A | 2.1019 | 2.2019 |
| **5/28/2020** | 5.5211 | 4.3844 | 2.4699 | 3.0559 |
| **6/4/2020** | 1.6591 | 2.1910 | 2.1392 | 0.6789 |
| **6/11/2020** | 11.0077 | 8.1681 | 4.9910 | 4.1117 |
| **6/18/2020** | 4.6052 | 1.1592 | N/A | N/A |
| **6/25/2020** | 1.9736 | 1.8912 | N/A | 2.0518 |
| **7/2/2020** | 2.6770 | 5.5142 | 3.3861 | 1.7758 |
| **7/10/2020** | 0.8675 | 3.6073 | N/A | N/A |
| **7/17/2020** | N/A | N/A | N/A | N/A |
| **7/23/2020** | 2.7951 | 3.3811 | N/A | N/A |
| **7/30/2020** | N/A | N/A | 6.3890 | N/A |
| **8/10/2020** | 2.4922 | 2.9497 | N/A | N/A |
| **8/21/2020** | 5.0232 | 2.3520 | 1.7534 | 1.0470 |
| **8/28/2020** | 42.2723 | 4.8558 | 1.1744 | 2.7162 |
| **9/11/2020** | N/A | 95.0565 | 41.4456 | 122.9775 |
| **9/18/2020** | 19.0458 | 21.3333 | 1.0806 | 1.2422 |
| **9/25/2020** | 2.1758 | 2.2004 | 1.9871 | 2.7481 |
| **10/2/2020** | 2.9420 | 4.8666 | N/A | N/A |
| **10/9/2020** | 1.0739 | 1.3719 | 0.9570 | 1.4054 |
| **10/15/2020** | 4.0970 | 3.5867 | 5.9876 | 2.8122 |
| **10/23/2020** | 1.7816 | 1.8972 | 1.0262 | 0.8696 |
| **10/29/2020** | 1.5314 | 1.8779 | 2.8117 | 3.5793 |
| **11/25/2020** | 7.1850 | 8.1438 | 5.1187 | 6.1318 |
| **12/3/2020** | 6.9812 | 2.0605 | 2.7071 | 1.9200 |
| **12/10/2020** | 0.9690 | 1.3493 | N/A | N/A |
| **12/16/2020** | 1.2232 | 1.6993 | 1.6509 | 1.1216 |

*Table 13 – Weekly DIN Comparison Table Between High and Low Samplers*

| Dissolved Nitrogen (DIN) ($mg/m^2$) | | | | |
|---|---|---|---|---|
| **Date** | **Central Davis High** | **Central Davis Low** | **Ambassador High** | **Ambassador Low** |
| **5/15/2020** | N/A | N/A | 18.3505 | 15.6802 |
| **5/28/2020** | 55.5805 | 47.8516 | 37.1800 | 30.5609 |
| **6/4/2020** | 27.3853 | 23.4786 | 20.6964 | 2.6625 |
| **6/11/2020** | 61.0313 | 47.5235 | 37.7698 | 12.9051 |
| **6/18/2020** | 50.7340 | 30.5800 | N/A | N/A |
| **6/25/2020** | 20.4300 | 10.6777 | N/A | 30.8692 |
| **7/2/2020** | 32.4111 | 29.1291 | 23.6510 | 22.3738 |
| **7/10/2020** | 17.1983 | 20.0588 | N/A | N/A |
| **7/17/2020** | N/A | N/A | N/A | N/A |
| **7/23/2020** | 16.0371 | 13.3301 | N/A | N/A |
| **7/30/2020** | N/A | N/A | 37.6854 | N/A |
| **8/10/2020** | 4.6574 | 18.1426 | N/A | N/A |
| **8/21/2020** | 30.7045 | 27.1392 | 11.4268 | 3.9072 |
| **8/28/2020** | 62.8473 | 62.5003 | 43.1570 | 46.8427 |
| **9/11/2020** | N/A | 60.0307 | 30.7545 | 72.9678 |
| **9/18/2020** | 15.6639 | 15.0998 | 12.5794 | 20.8336 |
| **9/25/2020** | 24.0713 | 16.2298 | 26.8603 | 25.9990 |
| **10/2/2020** | 18.1224 | 71.7225 | N/A | N/A |
| **10/9/2020** | 12.4450 | 29.4181 | 12.4538 | 12.8069 |
| **10/15/2020** | 29.1751 | 52.1308 | 29.5834 | 21.2767 |
| **10/23/2020** | 12.8071 | 11.2148 | 12.4538 | 12.9849 |
| **10/29/2020** | 4.5165 | 6.3549 | 3.7474 | 3.3032 |
| **11/25/2020** | 65.8802 | 57.9917 | 50.2586 | 46.3789 |
| **12/3/2020** | 8.0681 | 7.1911 | 6.6332 | 2.4917 |
| **12/10/2020** | 12.1626 | 11.6605 | N/A | N/A |
| **12/16/2020** | 3.8923 | 4.8168 | 13.5444 | 4.3525 |

*Table 14 – Weekly TP Comparison of Filtered vs Unfiltered Tables*

| Total Phosphorus ($mg/m^2$) | | | | |
|---|---|---|---|---|
| **Date** | **Central Davis Filter** | **Central Davis Unfiltered** | **Orem Filter** | **Orem Unfiltered** |
| **6/25/2020** | 1.9736 | 4.4820 | 2.0095 | 22.9642 |
| **7/2/2020** | 2.6770 | 3.0465 | 2.6660 | 7.0593 |
| **7/10/2020** | 0.8675 | 3.3352 | 0.6988 | 9.4431 |
| **7/17/2020** | N/A | N/A | 2.4678 | 5.4925 |
| **7/23/2020** | 2.7951 | N/A | 4.9859 | 4.5119 |
| **7/30/2020** | N/A | N/A | 0.9500 | 23.7307 |
| **8/10/2020** | 2.4922 | 6.2892 | 1.0434 | 66.5338 |
| **8/21/2020** | 5.0232 | 7.9270 | 2.3631 | 232.5352 |
| **8/28/2020** | 42.2723 | 41.6804 | 3.5383 | 49.7937 |
| **9/4/2020** | N/A | N/A | 2.4220 | 5.2501 |
| **9/11/2020** | N/A | 5.6627 | 59.9064 | 83.9371 |
| **9/18/2020** | 19.0458 | 4.0492 | 1.2663 | 4.2267 |
| **9/25/2020** | 2.1758 | 3.3842 | 2.1909 | 4.0811 |
| **10/2/2020** | 2.9420 | 4.3022 | 1.6954 | 8.2823 |
| **10/9/2020** | 1.0739 | 3.6930 | 2.1695 | 3.4091 |
| **10/15/2020** | 4.0970 | 4.0859 | 2.5183 | 3.6299 |
| **10/23/2020** | 1.7816 | 11.1853 | 1.2217 | 3.7653 |
| **10/29/2020** | 1.5314 | 4.7025 | 34.4981 | 1.6064 |
| **11/12/2020** | N/A | N/A | 23.8514 | 42.5714 |
| **11/19/2020** | N/A | N/A | 3.1592 | 5.3603 |
| **11/25/2020** | 7.1850 | 15.9369 | 1.5063 | 10.5526 |
| **12/3/2020** | 6.9812 | 1.1643 | 2.3049 | 8.6842 |
| **12/10/2020** | 0.9690 | 0.6500 | 1.5589 | 2.5119 |
| **12/16/2020** | 1.2232 | 1.8235 | 1.2048 | 4.3610 |

*Table 15 – Weekly DIN Comparison of Filtered vs Unfiltered Tables*

| Dissolved Nitrogen (DIN) (mg/m$^2$) | | | | |
|---|---|---|---|---|
| **Date** | **Central Davis Filter** | **Central Davis Unfiltered** | **Orem Filter** | **Orem Unfiltered** |
| **6/25/2020** | 20.4300 | 59.5340 | 8.8608 | 41.6556 |
| **7/2/2020** | 32.4111 | 22.8556 | 17.4130 | 18.7116 |
| **7/10/2020** | 17.1983 | 18.0469 | 16.8853 | 15.0733 |
| **7/17/2020** | N/A | N/A | 16.8511 | 16.9373 |
| **7/23/2020** | 16.0371 | N/A | 22.8224 | 19.2995 |
| **7/30/2020** | N/A | N/A | 23.9317 | 28.0458 |
| **8/10/2020** | 4.6574 | 20.2561 | 37.3610 | 9.8357 |
| **8/21/2020** | 30.7045 | 23.3195 | 21.4038 | 193.4824 |
| **8/28/2020** | 62.8473 | 62.9133 | 55.0607 | 75.6913 |
| **9/4/2020** | N/A | N/A | 53.2993 | 44.0598 |
| **9/11/2020** | N/A | 40.1728 | 15.4110 | 31.7135 |
| **9/18/2020** | 15.6639 | 64.8115 | 13.5924 | 39.1779 |
| **9/25/2020** | 24.0713 | 45.8080 | 23.2990 | 42.4242 |
| **10/2/2020** | 18.1224 | 37.2950 | 11.8829 | 43.3193 |
| **10/9/2020** | 12.4450 | 26.5728 | 10.5837 | 28.3383 |
| **10/15/2020** | 29.1751 | 71.8249 | 11.4560 | 22.3484 |
| **10/23/2020** | 12.8071 | 25.9082 | 5.3034 | 43.1498 |
| **10/29/2020** | 4.5165 | 2.4101 | 16.4699 | 11.7305 |
| **11/12/2020** | N/A | N/A | 30.6879 | 86.2924 |
| **11/19/2020** | N/A | N/A | 11.0848 | 54.5141 |
| **11/25/2020** | 65.8802 | 135.9862 | 4.3066 | 37.7897 |
| **12/3/2020** | 8.0681 | 8.8403 | 0.6518 | 10.2957 |
| **12/10/2020** | 12.1626 | 2.2210 | 2.9760 | 6.1784 |
| **12/16/2020** | 3.8923 | 5.3047 | 3.4658 | 5.3441 |

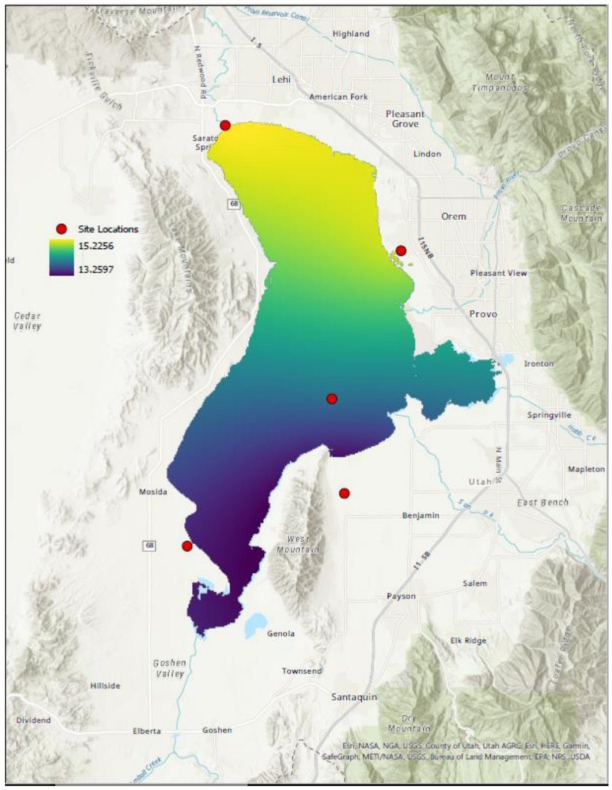


*Figure 21 – 1/7/2020 DIN Interpolation Results Map*

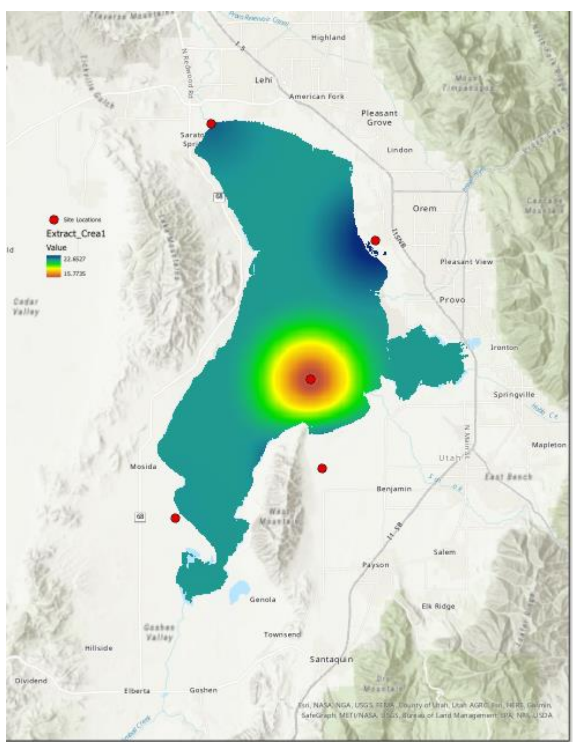


*Figure 22 – 7/23/2020 DIN Interpolation Results Map*

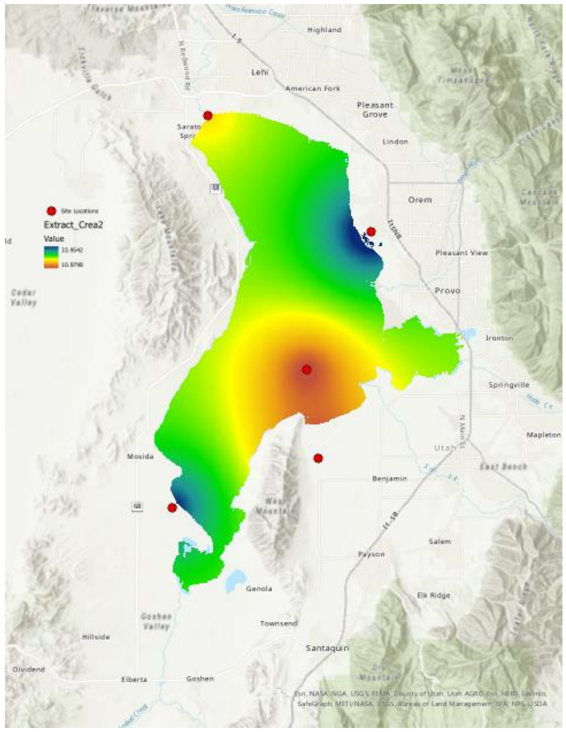


*Figure 23 – 8/10/2020 DIN Interpolation Results Map*

*Table 16 – 2020 Weekly AD Interpolation Results*

| Date | Tons of DIN 2020 | Tons of TP 2020 |
|---|---|---|
| 1/7/2020 | 6.06 | 0.95 |
| 1/15/2020 | 2.24 | 0.48 |
| 1/22/2020 | 1.94 | 0.48 |
| 1/28/2020 | 3.83 | 0.60 |
| 2/5/2020 | 3.03 | 0.76 |
| 2/12/2020 | 6.92 | 0.57 |
| 2/19/2020 | 7.78 | 0.57 |
| 2/26/2020 | 8.27 | 1.53 |
| 3/5/2020 | 8.27 | 1.53 |
| 3/12/2020 | 8.27 | 1.96 |
| 3/19/2020 | 8.27 | 1.96 |
| 3/26/2020 | 12.46 | 3.09 |
| 4/2/2020 | 12.46 | 3.09 |
| 4/9/2020 | 6.86 | 0.74 |
| 4/16/2020 | 6.86 | 0.73 |
| 4/23/2020 | 14.95 | 2.28 |
| 5/1/2020 | 87.41 | 27.49 |
| 5/8/2020 | 14.21 | 4.28 |
| 5/15/2020 | 11.36 | 2.04 |

| | | |
|---|---|---|
| 5/22/2020 | 4.57 | 1.76 |
| 5/29/2020 | 3.13 | 1.65 |
| 6/4/2020 | 3.25 | 2.02 |
| 6/11/2020 | 22.84 | 4.14 |
| 6/18/2020 | 11.13 | 2.19 |
| 6/25/2020 | 7.18 | 1.16 |
| 7/2/2020 | 8.73 | 2.65 |
| 7/10/2020 | 7.04 | 0.69 |
| 7/17/2020 | 10.14 | 1.97 |
| 7/23/2020 | 8.96 | 1.75 |
| 7/30/2020 | 9.77 | 0.97 |
| 8/10/2020 | 8.87 | 1.11 |
| 8/21/2020 | 14.29 | 2.10 |
| 8/28/2020 | 20.07 | 2.32 |
| 9/4/2020 | 23.81 | 4.94 |
| 9/11/2020 | 9.50 | 20.79 |
| 9/18/2020 | 7.62 | 0.92 |
| 9/25/2020 | 9.84 | 1.55 |
| 10/2/2020 | 5.37 | 1.03 |
| 10/9/2020 | 7.06 | 1.12 |
| 10/15/2020 | 6.28 | 1.26 |
| 10/23/2020 | 5.64 | 0.76 |
| 10/29/2020 | 4.20 | 3.91 |
| 11/12/2020 | 9.88 | 6.60 |
| 11/19/2020 | 5.46 | 3.91 |
| 11/25/2020 | 1.98 | 0.82 |
| 12/3/2020 | 3.74 | 1.26 |
| 12/10/2020 | 1.95 | 0.65 |
| 12/16/2020 | 2.84 | 0.60 |
| 12/23/2020 | 2.84 | 0.60 |
| 12/30/2020 | 2.84 | 0.60 |
| TOTALS | 482.29 | 132.96 |

*Table 17 – 2019 Weekly AD Interpolation Results*

| Date | Tons of DIN 2019 | Tons of TP 2019 |
|---|---|---|
| 1/4/2019 | 4.33 | 1.55 |
| 1/11/2019 | 9.05 | 0.72 |
| 1/18/2019 | 9.05 | 0.72 |
| 1/25/2019 | 9.05 | 0.72 |
| 2/2/2019 | 10.98 | 0.71 |
| 2/9/2019 | 10.98 | 0.71 |

| | | |
|---|---|---|
| 2/16/2019 | 6.05 | 0.38 |
| 2/28/2019 | 6.05 | 0.38 |
| 3/9/2019 | 79.16 | 2.12 |
| 3/16/2019 | 79.16 | 2.12 |
| 3/23/2019 | 7.73 | 0.34 |
| 3/30/2019 | 7.73 | 0.34 |
| 4/4/2019 | 7.73 | 0.34 |
| 4/11/2019 | 7.73 | 0.34 |
| 4/18/2019 | 7.73 | 0.34 |
| 4/25/2019 | 8.70 | 0.63 |
| 5/3/2019 | 8.70 | 0.63 |
| 5/10/2019 | 8.70 | 0.63 |
| 5/17/2019 | 23.32 | 4.09 |
| 5/24/2019 | 23.04 | 2.08 |
| 5/30/2019 | 20.10 | 0.68 |
| 6/7/2019 | 49.14 | 11.04 |
| 6/14/2019 | 24.86 | 4.19 |
| 6/21/2019 | 16.90 | 3.73 |
| 6/28/2019 | 18.16 | 3.04 |
| 7/5/2019 | 46.19 | 27.52 |
| 7/12/2019 | 356.73 | 66.26 |
| 7/19/2019 | 29.08 | 27.45 |
| 7/26/2019 | 22.52 | 15.87 |
| 8/2/2019 | 215.58 | 68.78 |
| 8/9/2019 | 147.08 | 61.95 |
| 8/16/2019 | 99.84 | 33.67 |
| 8/23/2019 | 32.60 | 12.12 |
| 8/30/2019 | 13.01 | 4.48 |
| 9/4/2019 | 13.01 | 4.48 |
| 9/11/2019 | 20.46 | 3.93 |
| 9/18/2019 | 24.04 | 4.01 |
| 9/25/2019 | 22.67 | 3.42 |
| 10/2/2019 | 26.86 | 2.05 |
| 10/9/2019 | 16.38 | 1.63 |
| 10/16/2019 | 11.39 | 1.06 |
| 10/23/2019 | 18.65 | 2.25 |
| 10/30/2019 | 13.71 | 2.11 |
| 11/6/2019 | 5.49 | 0.88 |
| 11/13/2019 | 8.97 | 0.57 |
| 11/20/2019 | 12.61 | 1.06 |
| 11/27/2019 | 5.91 | 0.57 |
| 12/4/2019 | 5.91 | 0.57 |
| 12/13/2019 | 13.96 | 0.88 |
| 12/20/2019 | 6.28 | 0.96 |

| | | |
|---|---|---|
| 12/27/2019 | 6.28 | 0.96 |
| TOTALS | 1659.37 | 392.02 |

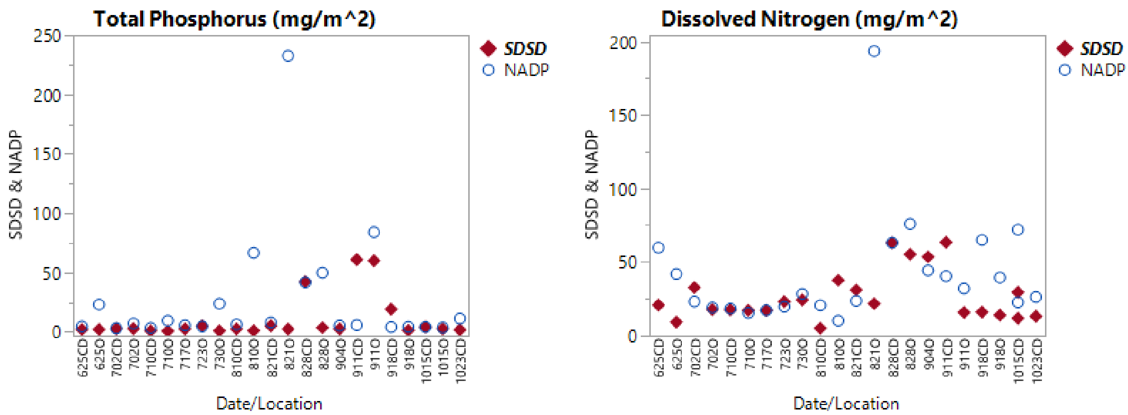


*Figure 24 –Filtered vs Nonfiltered Scatterplot of TP and DIN*

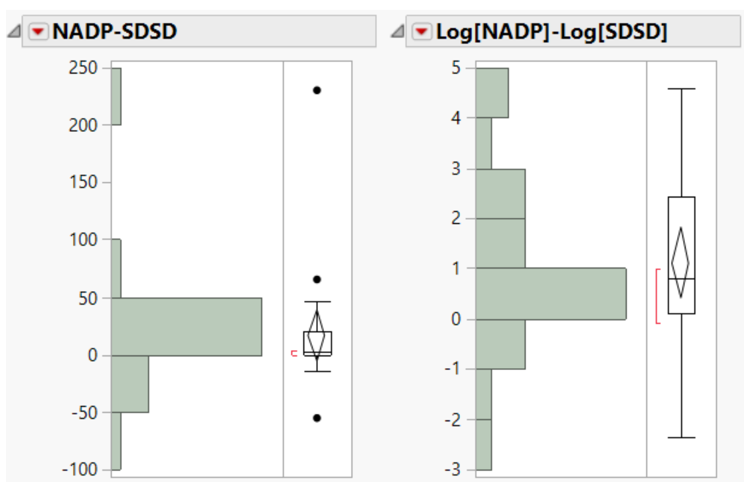


*Figure 25 – Difference and Log Difference of TP Between Filtered and Nonfiltered*

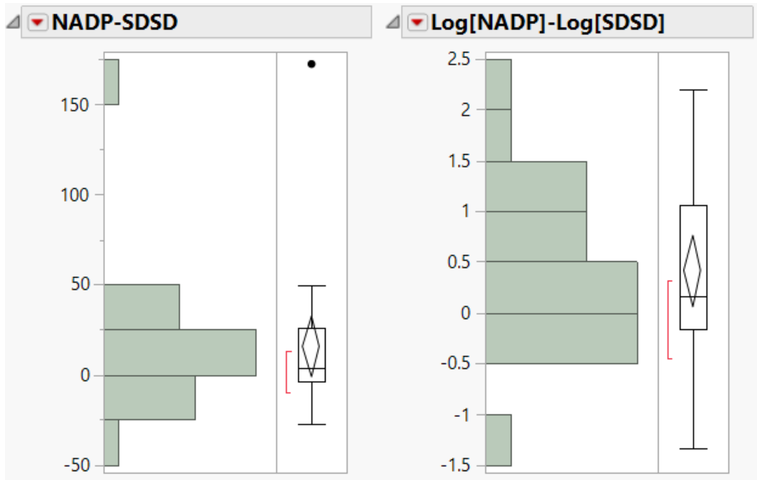


*Figure 26 – Original and Transformed Distributions of DIN Difference Filtered vs Nonfiltered*

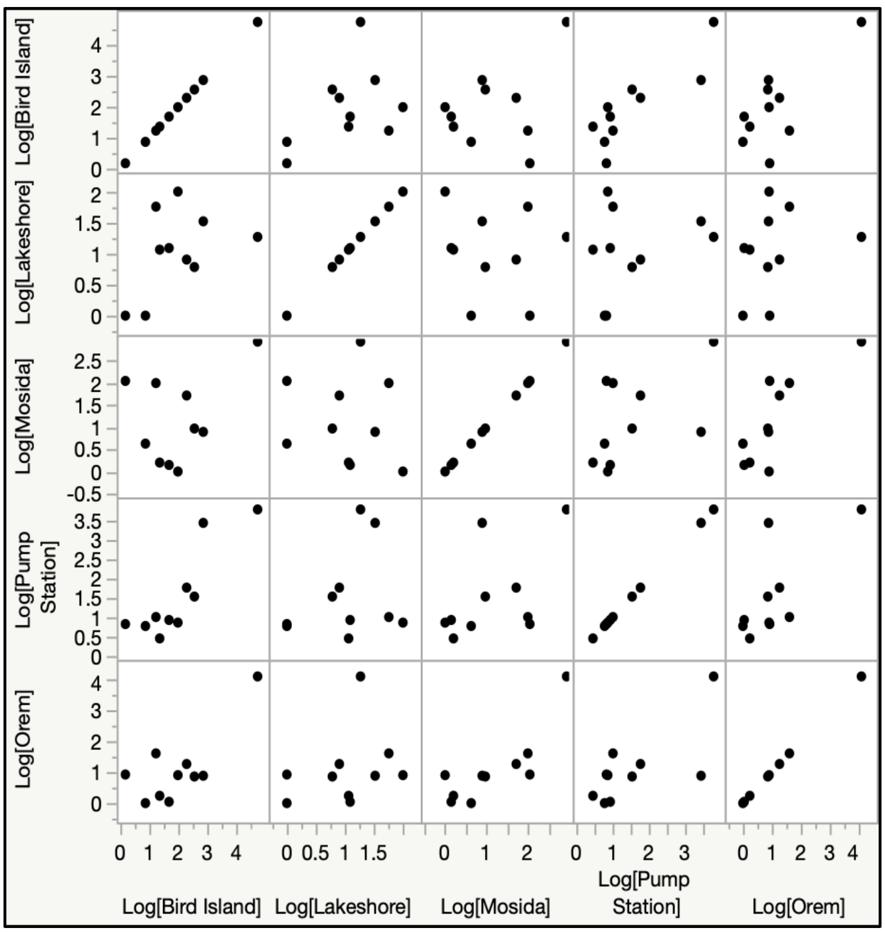


*Figure 27 – TP Scatterplot Matrix (Log Transformed Data)*

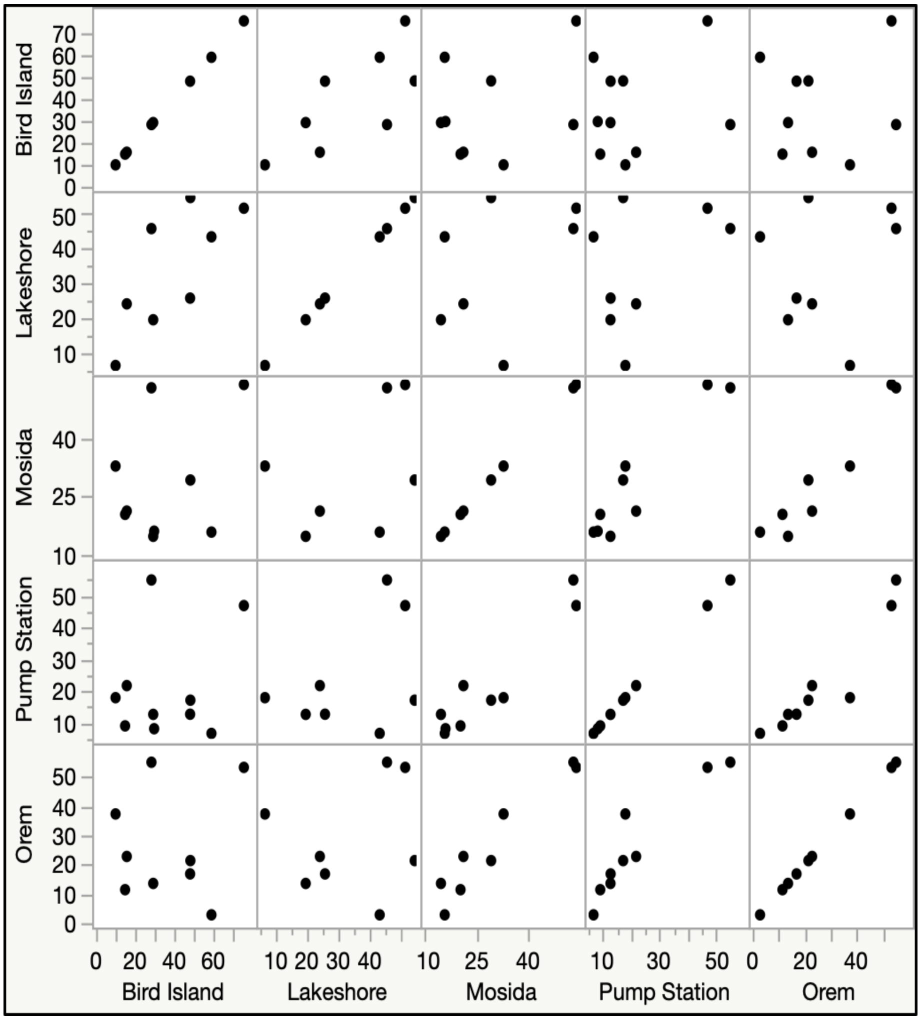


*Figure 28 – TP Scatterplot Matrix Before Transformation*

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