ASSOCIATION OF WATER QUALITY WITH LAND-COVER OF RIPARIAN ZONES IN THE FALL KILL CREEK IN DUTCHESS COUNTY, NY

AMANDA B. JACKSON MOJICA
University of Puerto Rico Mayagüez Campus, Mayagüez, PR 00681 USA

MENTOR SCIENTIST: DR. STUART E.G. FINDLAY
Cary Institute of Ecosystem Studies, Millbrook, NY 12545 USA

Abstract. Urban streams are a valuable resource and a necessity to the community around them. An increase in urbanization and impervious surfaces such as asphalt and cement, which do not allow water to permeate through, can lead to untreated runoff flowing into the stream with an abundance of pollutants. Vegetation buffer strips, known as riparian zones, alongside the stream have been considered an effective measure to retain some of the pollutants before arriving at the stream. In this study, pollutant concentrations were compared with width and impervious composition of riparian zones along the Fall Kill Creek in Dutchess County, NY. It was found that chloride and phosphate concentrations were lower at upstream sites with a wider riparian zone. The distance from the mouth of the stream to the site had a negative significant relationship with nitrate, but it is possible that this is only applicable for the highly urbanized downstream area of the creek. High chloride concentrations in riparian zones could be caused by salt application in the winter in reaches with a higher percentage of impervious surface. Pollutants such as nitrate and phosphate appeared to be retained by some of these riparian zones, while a possible point source of chloride was found. Dissolved oxygen concentrations were found to have a positive relationship with the impervious cover of the riparian zone, but a negative relationship with canopy cover. This research hopes to aid future planning and promote good stewardship of the Fall Kill creek and its riparian zones.

INTRODUCTION

The Fall Kill is an urban stream approximately 61 kilometers long including the main channel and its tributaries. The stream discharges into the Hudson River at the City of Poughkeepsie. The Fall Kill watershed is located entirely within Dutchess County, New York, USA and is approximately 50.5 square kilometers. It encompasses parts of Hyde Park, Clinton, Pleasant Valley and Poughkeepsie, and the City of Poughkeepsie. This stream provides a space for the community to interact with nature and has the potential to become a valuable cultural site, helping connect different neighborhoods through pocket parks and eco-urban corridors (Kim et al. 2012).

The Fall Kill Creek is currently classified by the New York State Department of Environmental Conservation (NYSDEC) as a “Class C” stream meaning that the stream can support fishing and other non-contact activities. The DEC has also listed the Fall Kill as having impaired aquatic life caused by urban runoff and suspended nutrients (NYSDEC, 2000). The conditions of a stream are reflective of those of the entire watershed that feeds it (Bean et al. 2006). The large impact in urban systems caused by humans includes substitution of vegetative surfaces with impervious surfaces that do not allow water to permeate to the ground. This can lead to untreated runoff from these surfaces making its way into the stream and has the potential to deteriorate its health. Although pollution conditions in the Fall Kill Creek in terms of nitrate and chloride are not detrimental to leaf decay and the macroinvertebrate community, the stream should be monitored to prevent worsening conditions (Sickinger et al. 2018).

Past work has found that using road salts leads to elevated levels of chloride in streams and even after application in the wintertime, the effects are still present throughout the year, showing high concentrations of chloride in the summer (Kelly et al. 2019). A study from 2006 found that chloride, nitrate and phosphate concentrations were high in the Fall Kill, with nitrate and phosphate exceeding recommended levels for healthy stream ecosystems (Bean et al. 2006). More recent research at some of the same research sites shows that chloride concentrations and specific conductance levels were related strongly to landcover (Grosskopft and Findlay 2017). This study shows that as the percentage of impervious surface area in the watershed increased, the chloride concentrations and levels of specific conductance were higher. On the other hand, some research suggests that urban land use can affect the nitrogen retention of nearby streams (Kaushal et al. 2008). This study in Baltimore, Maryland also found that concentrations for nitrate were higher in agricultural streams than urban streams. Lastly, phosphate is a known limiting nutrient for the growth of phytoplankton and eutrophication in freshwater systems (Cao et al. 2019), where eutrophication can have a negative impact on the health of a stream by causing excess algal growth, making the stream aesthetically unpleasing.

Riparian zones adjacent to streams can help act as buffers for pollutants or excess nutrients and prevent them from reaching the stream. Riparian areas connect the stream with the land and their plants and soil can help retain pollutants. Different types of vegetation and land use affect the efficiency of riparian zones in retaining pollutants (Cao et al. 2019). Land use varies along the Fall Kill stream length, ranging from wetlands, marshes and forested properties upstream to urban environments downstream in the City of Poughkeepsie (Bean et al. 2006). The efficiency of a riparian zone is also dependent on its width (Syversen 2005). A study from 2006 showed that the width of the riparian zone in the Fall Kill Creek shrinks as it goes downstream and then largely disappears in the City of Poughkeepsie where the stream was channelized with the construction of stone walls (Bean et al. 2006). The Fall Kill Watershed Committee made a plan to address the state of the Fall Kill, which included preserving the riparian zones that were unaltered and enhancing remaining riparian zones with trees, shrubs and grasses.

This study looked at nutrient and pollutant concentrations in surface water adjacent to different riparian zones along the Fall Kill Creek. By assuming that the input of pollutants was the same for the runoff into the stream and the water that permeated through the riparian zone, these concentrations were compared to the impervious cover in the riparian zones. The nutrient retention was expected to be greatest at locations with a lesser percentage of impervious cover in the riparian zone and for this to be negatively related to the shrinking riparian zone as the stream flows towards the Hudson River.

The Fall Kill Creek in its entirety has been affected negatively by human activity. The stream's condition has been impaired by significant quantities of trash and increasing impervious cover adjacent to the stream in the urbanized areas of the City of Poughkeepsie, where the deterioration is most noticeable (Bean et al. 2006). By studying the effects of urbanization near the stream and the riparian zone's efficiency at mitigating these, this study hopes to provide information for future planning and development along the Fall Kill Creek and promote good stewardship of riparian zones in the stream. With this, more conscious measures can be taken to rehabilitate the water quality and pollution problems of the Fall Kill.

METHODS

Eleven surface water sites were determined along the Fall Kill Creek at bridge crossings where it was possible to sample. The streets at the bridge crossings were the following (from mouth of river to upstream): N Water St, Mill St, Garden St, High St, 124 Mansion St, Hamilton St, 4 N Clinton St, N White St, 355 Mansion St, Howard St and Smith St. Their coordinates are shown in Table 1. The riparian zones upstream for each site were determined to start by the edge of the stream and go inland for 30 m.

These riparian zones stretched upstream from the sampling point of the site to the sampling point of the next upstream site. The data for the percentage of impervious surface in these riparian zones were obtained using GIS mapping data from the National Land Cover Data of 2016 (Multi-Resolution Land Characteristics Consortium 2016). Google Maps 2019 was also used to determine distance of miles upstream from the mouth of the stream to the site and the canopy cover at either side of the site (Both sides, one side or either).

Surface water grab samples were taken in duplicates at each site and as soon as the sample was taken, dissolved oxygen (DO) concentration (mg/L) was determined with a meter. Some sites had groundwater wells installed adjacent to the stream. These were sampled to compare with the surface water but not all sites had groundwater wells because a dry summer caused low water table and made it difficult to obtain groundwater samples using the wells at our disposal. Surface water samples were taken at two more upstream sites to compare, but the impervious cover data for these riparian zones was not used. Samples were stored in a cooler until returned to the laboratory, where they were filtered using 2.5 cm diameter glass fiber filler paper.

Samples were then tested for chloride (Cl) using a Fischer XL25 pH/Ion meter (mg/L) and for nitrate ($N\text{-}NO_3$) using a Satlantic SUNA V2 sensor (mg/L) – analytical triplicates were run for each sample. For phosphate ($P\text{-}PO_4$), the analysis was done as described in *Limnological Analysis* (Wetzel and Likens, 1979) using UV-Vis spectroscopy (µg/L). The procedure was adjusted to use only 15 mL of sample and 1.5 mL of composite reagent. For each of these measurements, standard curve calibrations were done and obtained $R^2 > 0.999$.

An analysis of linear regressions was used to determine the relationship between nutrient concentrations of surface water and the percentage of impervious cover in the riparian zone. Although not used in the statistical analysis, groundwater samples were compared to the surface water samples. Similarly, the nutrient concentrations for the surface water samples were compared to the miles upstream of the site from the Hudson River in Poughkeepsie through an analysis of linear regressions. The more upstream surface water samples were compared to these concentrations but were not used in the statistical analysis. Lastly, DO concentrations were compared to the canopy cover in the riparian zone at the sides of the stream.

RESULTS

Miles upstream from mouth of stream

Linear regressions were done to compare the miles upstream to the pollutant concentrations and obtained a p-value < 0.05 for the chloride ion (Cl), indicating a significant relationship between the distance from the mouth of the stream and the Cl concentration in the surface water. In Figure 1, the concentration of the ion increases as the sampling site is closer to the mouth of the Fall Kill; a negative relationship. These surface water samples were also compared with two more upstream surface water samples and found that the upstream Cl concentrations were lower than for the more downstream sites used for the statistical analysis and although the upstream samples were not used for the analysis, they did not vary much from the expected trendline.

For the same analysis done for phosphate ($P\text{-}PO_4$), the analysis resulted in a p-value > 0.05, meaning that there was no significant relationship between the distance from the mouth of the stream to the site and the $P\text{-}PO_4$ concentration. As seen in Figure 2, the plot is mostly flat and when more upstream surface water samples were compared, it was found that the upstream $P\text{-}PO_4$ concentrations were lower than the downstream samples. The upstream surface water samples were not used in the statistical analysis and they did not fall within the expected trendline.

For nitrate ($N\text{-}NO_3$) analysis, a p-value < 0.05 was obtained, meaning there was a significant relationship between $N\text{-}NO_3$ concentration in surface water and the distance from the mouth of the stream to the site. In Figure 3, the negative relationship between these two variables is seen. The more upstream surface water samples that were not a part of the statistical analysis were then compared to the downstream ones that were and found that the $N\text{-}NO_3$ upstream concentrations were more variable than for Cl or $P\text{-}PO_4$ and they did not fall within the expected trendline.

Percentage of impervious surface area in the riparian zone

To see the relationship between the percentages of impervious cover in the riparian zone to the pollutant concentrations, linear regressions were done. For Cl a p-value < 0.05 was obtained, making it a significant relationship between the ion concentration and the impervious cover. The positive relationship between these two variables can be seen in Figure 4. These surface water samples were also compared to groundwater samples that were not used in the statistical analysis. There is one groundwater sample that had a much higher Cl concentration than the surface water sample at all sites.

Impervious cover of riparian zones was compared to the $P\text{-}PO_4$ concentration and a p-value > 0.05 was obtained, which means that there was no significant relationship between these variables. The plot in Figure 5 is shows this and is mostly flat. The groundwater $P\text{-}PO_4$ concentrations were also compared with the surface water ones used in the statistical analysis, it was found that the ground water samples had a lower $P\text{-}PO_4$ concentration than the surface water ones.

For $N\text{-}NO_3$, a p-value > 0.05 was obtained, which means that there was no significant relationship between the percentage of impervious cover and the $N\text{-}NO_3$ concentration in these sites. These surface water samples were later compared to the groundwater samples that were not used in the statistical analysis and, as shown in Figure 6, it found that most of the groundwater samples had concentrations lower than the surface water samples.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations in the surface water samples obtained were compared to the percentage of impervious cover and obtained a p-value < 0.05, meaning a significant relationship between these two variables. The positive relationship between these can be seen in Figure 7. DO concentrations in surface water were compared to the canopy cover at each side of the stream and it was found that there was a trend in which DO concentration increased as there was less canopy cover (as seen in Figure 8).

DISCUSSION

A significant negative relationship between the distance of the site from the mouth of the stream to the Cl concentration was found and can be seen in Figure 1. This could be caused by wider riparian zones in the upstream parts of the Fall Kill than in the urbanized downstream section where the stream is contained by stone walls and riparian zone mostly disappears, as mentioned in the Management Plan of 2006. Past research that included sites more upstream in the Fall Kill also found a significant negative relationship between the distance from the mouth of the stream and the Cl concentration (Grosskopft and Findlay 2017). The upstream surface water samples that were not used in the statistical analysis are consistent with this (Figure 1), since their concentrations are lower than the downstream ones used in the analysis and seem to be within the expected trendline.

A significant positive relationship between impervious surface cover of the riparian zone with the Cl concentration was also found. A similar relationship was found in past research in the Fall Kill but comparing the Cl concentration to impervious cover in the watershed that fed into the site (Grosskopft and Findlay 2017), not limited to only the riparian zone as our study did. However, another similar study found no significant relationship between the Cl concentration and the impervious cover within half mile radius, but they attributed this to taking into consideration the half mile radius above and below the site instead of only the part above the site (Sickinger et al. 2018). This indicates that the impervious cover of areas upstream of a point in the stream that feed into it can affect the Cl concentrations in it and that this relationship can be looked at in a watershed scale, not only limited to the riparian zone adjacent to that point in the stream.

A strong relationship between Cl concentration and impervious surface cover could be caused by road salt application. This is because in the winter time, when road salt is applied to impervious surfaces to avoid icy cover, the more impervious surface there is, the more salt is being applied and can be flushed into the stream by melting or a rain event. Although this takes place in the winter time, past research has shown that the effects of road salt application can still be evident in the summer time, long after the application to avoid icy roads (Kelly et al. 2019). There can also be other sources of Cl into the stream. In Figure 4, it can be seen how there is a groundwater sample with a Cl concentration much higher than any of the other surface water samples. If assumed that these sites have the same input of nutrients pre-riparian zone and pre-retention before arriving into the stream, this high Cl concentration could indicate that there is a point source of Cl in this riparian zone. A point source of Cl could be leaching into the stream but there is no knowledge that there used to be a deposit at this site or what circumstances in the past could have caused it to have this source of Cl. Just like this site, there could be other point source sites along the Fall Kill for Cl.

It was found that N-NO_3 concentrations did not have a significant relationship with the percentage of impervious cover in the riparian zone, consistent with past research done in the Fall Kill (Grosskopft and Findlay 2017). In Figure 6, the groundwater N-NO_3 concentration was lower for most samples than for the surface water samples used in the statistical analysis. If assumed that the input of nutrients pre-riparian zone and pre-retention for these sites is the same, then a lower groundwater N-NO_3 concentration could mean that the riparian zone is retaining this nutrient from arriving in high concentrations to the stream.

A significant negative relationship for N-NO_3 concentration and the distance from the mouth of the stream was found. Research done at the Fall Kill in 2017 showed that there was no significant relationship between these variables (Grosskopft and Findlay 2017). However, this research took into consideration for the statistical analysis surface water samples that were of more upstream sites than the ones used in this study. As seen in Figure 3, when looking at more upstream samples that were not used in the statistical analysis, their concentration is very variable and does not seem to be within where the expected trendline would continue. This could mean that if the statistical analysis were run with more upstream samples, a significant relationship might not be found, like what the study in 2017 found. This could be due to the fact that this significant relationship between N-NO_3 concentration and miles upstream is only evident in the downstream area that is in the more urbanized part of the Fall Kill.

By contrast, a significant relationship for P-PO_4 and the distance from the mouth of the stream was not found. The mostly flat plot seen in Figure 2 suggests that these P-PO_4 concentrations are very similar, but when comparing the upstream samples that were not used in the analysis, these concentrations are lower than the downstream sampling sites. The comparison of P-PO_4 concentration in stream water to groundwater samples seen in Figure 5 shows that the groundwater samples have lower concentrations. Assuming these sites have the same input of nutrients pre-riparian zone and pre-retention, the lower concentration of the groundwater samples could mean that some of the P-PO_4 is being retained and that's why the concentration would decrease as the water went through the riparian zone. Along with lower concentrations of surface water P-PO_4 in the more upstream samples that have a wider riparian zone, this could suggest that the riparian zone along the Fall Kill creek is helping retain the P-PO_4 and hence, lower concentrations as the water passes through the riparian zone and into the stream.

Finally, for DO concentration, a significant relationship with the percentage of impervious cover in the riparian zone was found, as seen in Figure 7. When the DO concentrations were compared with the canopy cover in the riparian zone in Figure 8, it was seen that the sites that had less canopy cover had higher DO concentrations. A possible explanation is that for sites that have a higher percentage of impervious cover in the riparian zone, it is harder for the sites to have canopy cover, since impervious cover may preclude substantial tree cover. The lack of canopy cover then leads to more light arriving in the stream, which could be absorbed by the vegetation in the stream to produce more dissolved O_2 in the water.

The findings from this study vary a lot between the different pollutants that were analyzed and the different riparian zone conditions of each site. Research supports some of the possible drivers for increase in pollutants, such as road salt application in the wintertime for Cl concentrations. Although a possible point source of pollutant (Cl) was found, more could be present in the stream. However, other pollutants, such as N-NO_3 and P-PO_4, appear to be retained by the riparian zone as the water passes through it into the stream. These findings also helped shed light that some relationships of these pollutants vary if the whole stream is being considered or if only the urbanized areas are being looked at. Simply put, urbanization and shrinking of riparian zone have affected the Fall Kill Creek and the pollutant concentration in the surface water. Wider riparian zones could help retain some of these pollutants from arriving into the stream and less urbanized areas appear to have lower concentrations of some of the pollutants, although it could cause less canopy cover which would lead to an increase in DO concentration. Future research could focus on comparing groundwater samples throughout more of the Fall Kill since low water table conditions did not allow this, or it may look at plant or soil composition in the riparian zone to help guide future planning and restoration along the Fall Kill.

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APPENDIX

TABLE 1. Coordinates of streets at bridge crossings of the Fall Kill Creek where it was sampled.

Street at Bridge Crossing	**Coordinates (decimal)**
Smith St.	41.714282, -73.903939
Howard St.	41.709518, -73.905315
355 Mansion St.	41.703955, -73.912058
N White St.	41.701901, -73.914696
4 N Clinton St.	41.702733, -73.921030
Hamilton St.	41.704577, -73.922196
124 Mansion St.	41.706505, -73.924254
High St.	41.708603, -73.921857
Garden St.	41.710769, -73.923750
Mill St.	41.708511, -73.935694
N Water St.	41.709084, -73.938787

Figure Legend:

- Surface Water used in Statistical Analysis
- Upstream Surface Water
- Ground Water

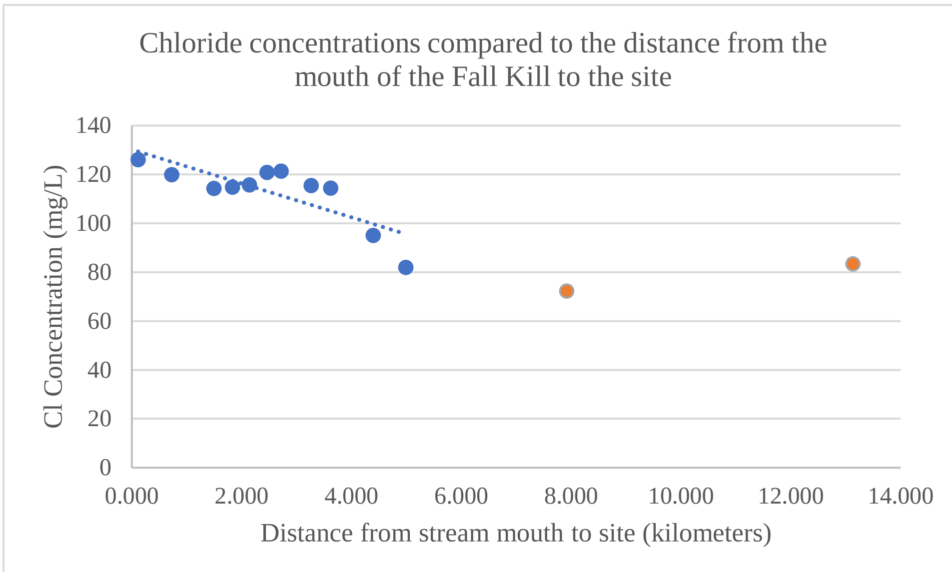

FIGURE 1. Chloride concentration in the Fall Kill compared to distance of site from mouth of stream (linear regression, df =10, p = 0.0031).

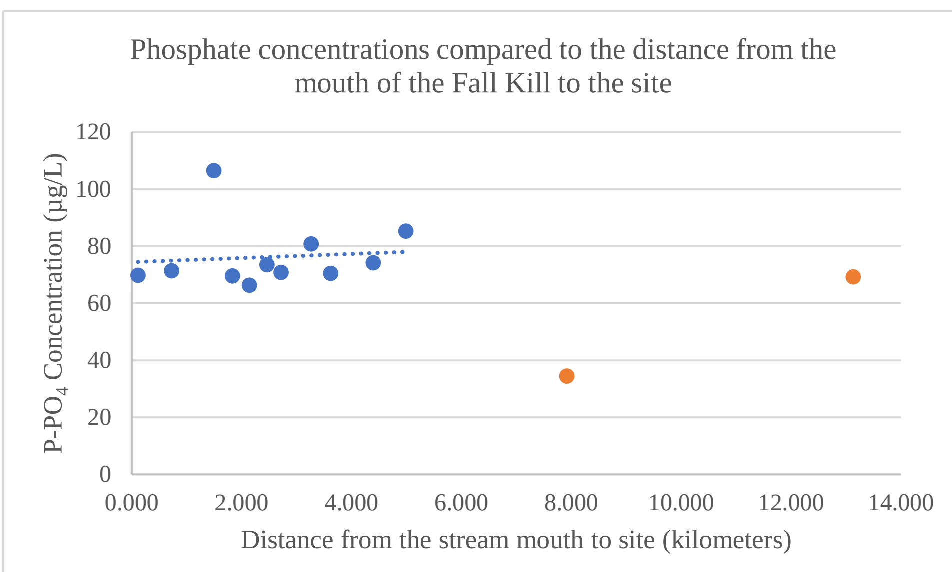

FIGURE 2. Phosphate concentration in the Fall Kill compared to distance of site from mouth of stream (linear regression, df =10, p = 0.7830).

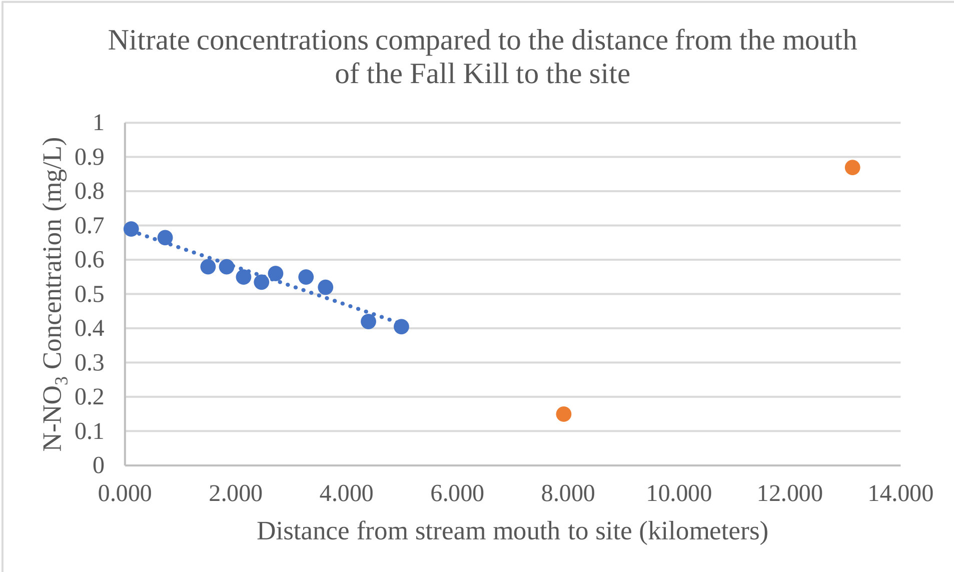

FIGURE 3. Nitrate concentration in the Fall Kill compared to distance of site from mouth of stream (linear regression, df =10, p = 2.65E-06).

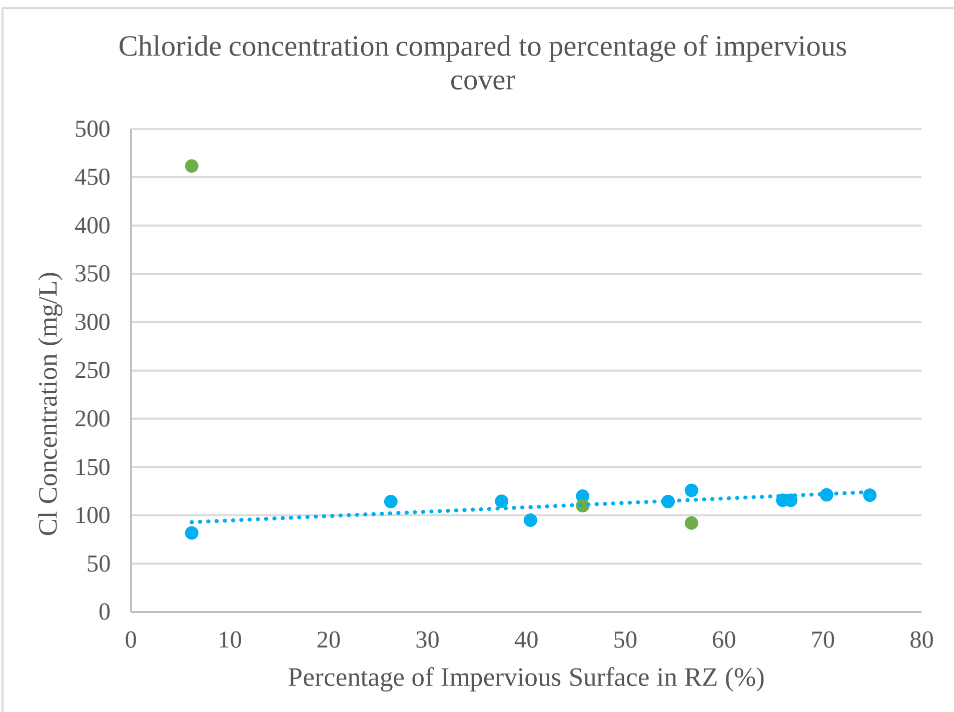

FIGURE 4. Chloride concentration in the Fall Kill compared to percentage of impervious cover in the riparian zone adjacent to the site (linear regression, df =10, p = 0.0094).

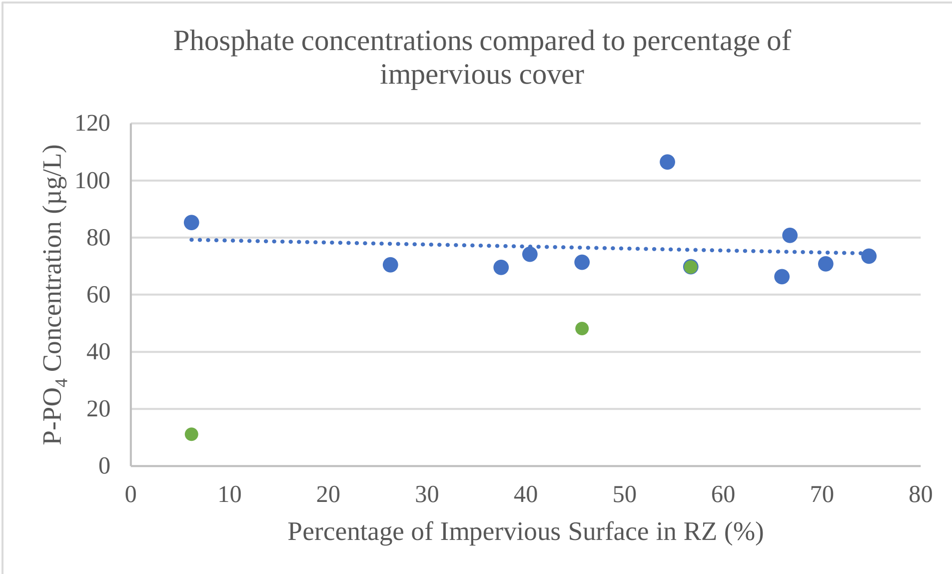

FIGURE 5. Phosphate concentration in the Fall Kill compared to percentage of impervious cover in the riparian zone adjacent to the site (linear regression, df =10, p = 0.7076).

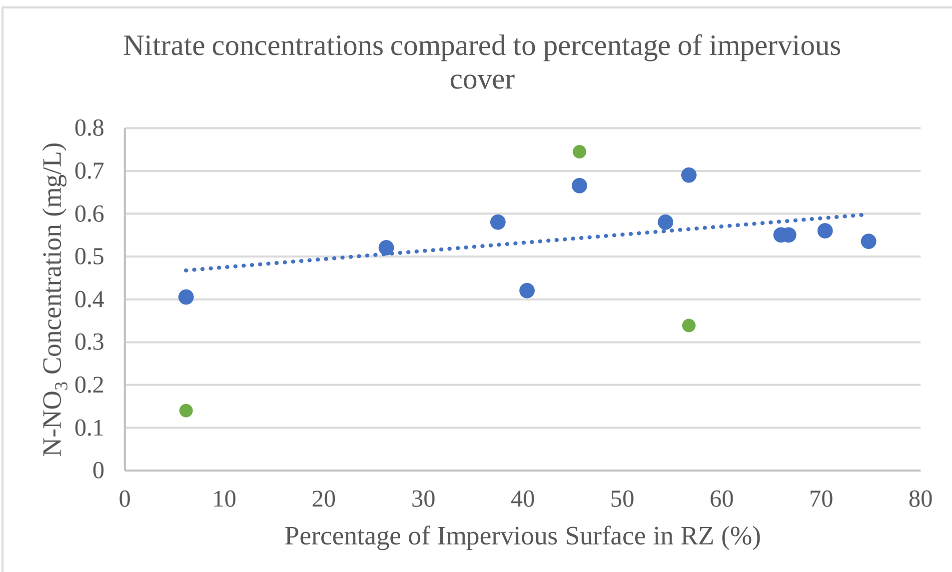

FIGURE 6. Nitrate concentration in the Fall Kill compared to percentage of impervious cover in the riparian zone adjacent to the site (linear regression, df =10, p = 0.1499).

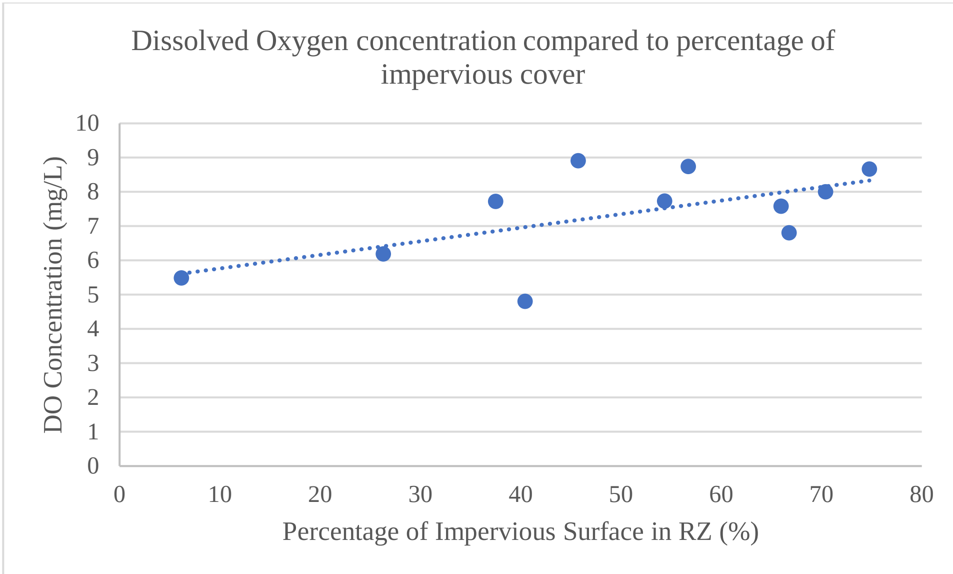

FIGURE 7. Dissolved Oxygen concentration in the Fall Kill compared to percentage of impervious cover in the riparian zone adjacent to the site (linear regression, df =10, p = 0.0459).

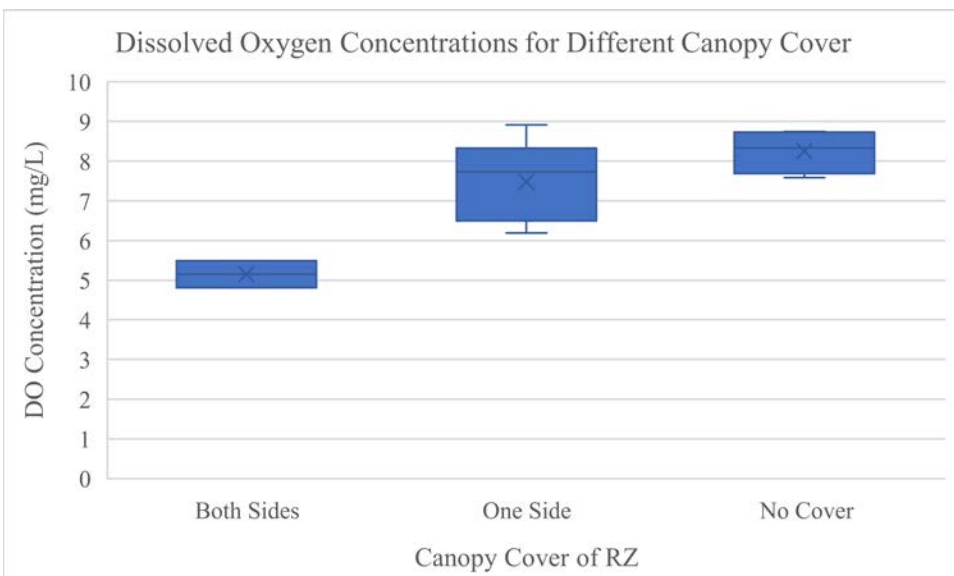

FIGURE 8. Dissolved Oxygen concentration in the Fall Kill compared to canopy cover in the riparian zone adjacent to the site.