WATER QUALITY OBSERVATIONS OF A HEADWATER WATERSHED IN THE RED RIVER BASIN AND VALUE OF AN INTERDISCIPLINARY MAJORS CAPSTONE COURSE IN THE NATURAL RESOURCE SCIENCES

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ABSTRACT

Understanding how change and adaptive management plays a role in natural resource sciences is key to preforming well in the field, as well as evaluating effects of management changes. Therefore, two studies were conducted: 1) to determine the value of skills taught in an interdisciplinary capstone course; and 2) to understand baseline water quality parameters in order to gauge subsurface drainage's role in alterations in water quality. Overall, participants surveyed in the capstone course agreed the interdisciplinary approach of the class and skills taught was helpful following graduation. The study also shed light on areas that could be improved to provide more skill building opportunity. Baseline water quality observations helped to identify significant differences within the study areas five drainage areas. These observations will act as quality comparisons in the future once subsurface drainage is installed within the study area.

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Zachary D. Anderson

DEDICATION

This thesis is dedicated to Norman Anderson, for it was the countless hours spent at your side that instilled in me the passion and respect for the natural world. Words cannot express how dear I hold those moments and because of that, this is for you Grandpa.

PREFACE

This thesis contains two different chapters, containing very different content. This is due to three different funding sources providing stipend money. The first was granted by The Red River Basin Commission and the North Dakota Soybean Council for water quality data collection. The second was granted by the School of Natural Resource Sciences at North Dakota State University to study the interdisciplinary capstone course.

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CHAPTER 1. LITERATURE REVIEW

1.1. Interdisciplinary Capstone Course

Today's world requires professionals to work in a continually changing and innovating workplace. Young professionals must be prepared to enter the work force with the ability to solve highly dynamic problems, while working within a team of experts to brainstorm solutions. In order to prepare students for the professional world, educators have adopted problem-centered learning environments to provide an opportunity to practice applying knowledge to real world problems, allowing for mock workplace collaboration and skill development (Dunlap, 2005). The adoption of problem-based learning (PBL) within universities hopes to provide these experiences for students so they are more comfortable when transitioning to the workforce, often utilizing capstone courses to ease the transition (Arthur and Thompson, 1999). The field of Natural Resource Management (NRM) is a perfect example of a field that requires graduates to be able to provide necessary expertise to answer the dynamic questions asked of NRM professionals.

Natural resources issues are by definition multidimensional and multidisciplinary (Arthur and Thompson, 1999). The course evaluated for this study includes four distinct disciplines of entomology, soil science, range science and natural resources management encompassing a variety of degrees and professions. In general, referring to NRM in this literature review is not specific to any one major, but the study of natural resources as a whole including all of the disciplines mentioned above. This capstone course puts heavy emphasis on NRM graduates ability to provide expertise to a variety of stakeholders with varied concerns. It also requires heightened teamwork ability as more than one expert is often needed to solve natural resource issues.

Traditionally, NRM curricula across universities has been primarily scientific in nature, and if other disciplines are presented, they are done so independently of one another (Berkson and Harrison, 2002). This leaves students with detached pieces of information and no way to connect them into a comprehensive understanding of how the process of how management of natural resources works. This opposes the reality of on the job situations. In NRM, science is rarely the sole factor managers must consider when making decisions (Berkson and Harrison, 2002). There is concern amongst professionals and universities that NRM graduates are not graduating with the necessary skills to provide the systems thinking, communication, and teamwork skills needed to provide effective employees (Noss and Cooperrider, 1995; Meffe, 1998; Cooper et al., 2016). This gap between professionals and new graduates is likely caused by the traditional teaching forms used in college NRM curricula. Without providing a course, or portions of multiple courses, that allow students to experience job like scenarios, this gap will continue to be present in the field. Sample et al. (1999) conducted a study to gauge employer's perspectives on recent graduate's knowledge gaps. They found that the largest gap, from the employer's perspective, lies in the ability to work in teams and the ability to address public concerns (Sample et al., 1999). Similarly, Prokopy (2009) found that employers from private firms and public agencies put ethics, working effectively with others, oral and written communication skills, and being able to define a problem in the top six needed skills when ranking twenty-two different skills. One way education institutions are answering the need for these skills is by implementing a required capstone course for graduation fulfillment. This course is often taken in the final semester(s) of the student's undergraduate degree (Arthur and Thompson, 1999; Nilsson and Fulton, 2002; Sargent et al., 2003; Dunlap, 2005; Habron et al., 2012; Pile et al., 2012).

The implementation of a multidisciplinary synthesis capstone course for NRM majors has been identified as a solution to help transition students from their “student” role to a “professional” role (Yeon-Su et al., 2007). Several criteria have been identified to measure quality in capstone course (Crunkilton et al., 1997) including: a planned learning experience, synthesizing previously learned subject material, integrating the material into a base for solving real world problems and providing a culminating experience which is carefully monitored so students achieve a stated objective (Knowles and Hoefler, 1995; Aupperle and Sarhan, 1995) Additionally, capstone courses should ease the transition between a student’s academic experience and career entry (Andreasen and Trede, 2000). These courses are utilized to help mold a student that is confident in their ability to apply their knowledge in the natural world all while being comfortable working on complex issues within a group of other experts.

Research about NRM capstone courses tend to focus around two different camps, the first camp being comprised of literature comparing problem-based learning to more traditional teaching styles in NRM, often outlining their given programs take on the capstone course (Arthur and Thompson, 1996; Piles et al., 2012). The second of the two methods involve surveying students who participated in a capstone course. Often these studies use pre and post surveys to gauge what the students feel they have gained from taking the course (Berkson and Harrison, 2002; Dunlap, 2005; Casper et al., 2016). While these studies provide valuable insight into how individual students trend from start to completion of the course, they might not be as useful to gauge the courses effectiveness in preparing the students for post-graduation careers. Few studies have evaluated capstones courses effectiveness in preparing students for post-graduation careers (Sample et al., 1999; Andreasen and Trede 2000; Sample et al., 2015). A 1999 survey conducted by Sample et al. asked recent forestry graduates what skills they found were most needed, and forestry employers to identify the level at which they require these skills for hires. A total of 257 employers who had hired a forestry school graduate within the last five years responded to the survey, and a total of 265 recent graduates responded to the survey, representing employers and forestry schools from across the United States (Sample et al., 1999). The interviewees were asked to rank out expected competency of 29 distinct skills for new hires on a scale of 1 to 10, 10 being the most competency expected (Sample et al., 1999). The primary focus of this survey was to identify areas to which both employers and recent graduates felt they lacked experience, and utilize that information for course design to ultimately better the function of capstone courses. The results from survey by Sample et al. (1999) showed that employers highly ranked competencies relating not to technical skills, but rather skills related to professionalism. Ranking the highest were written (9.2) and oral communication (9.1) skills along with ethics (9.3). Outranking technical skills such as forest ecology and forest inventory/biometry, ranking 8.0 and 7.8 respectively, were managerial leadership and collaborative problem solving, both ranking 8.2. Recent graduates tended to rank skills much differently than employers, with significant gaps in ratings of managerial and problem solving competencies. The greatest gaps occurring in managerial leadership, collaborative problem solving, human resource management, alternative dispute resolution, organizational development, government relations, ethics, and rural community development. Graduates also stated that technical skills were accessible within their given forestry school, but skills such as written and oral communication could only be found outside of the forestry school (Sample et al., 1999)

Adding to the Sample et al. (1999) work, Sample et al. (2015) again surveyed recent graduates and employers, adding forestry school educators to the sample population. This survey gauged forestry education across the United States on challenges they face along with the importance and preparedness of skill categories (for graduates) educators felt their curriculum provided (Sample et al., 2015). The two surveys results pointed to gaps in professional skills rather than technical skills. During the 1999 survey, the skills with highest importance for employers were ethics, written communication, and oral communication ranking; higher than all other technical skills including forest ecology (Sample et al., 1999). Collaborative problem-solving and managerial leadership also ranked higher than a number of technical skills, such as species identification and biometry (Sample et al., 1999). Similarly, to the 1999 survey, the Sample et al. (2015) study showed that employers valued professional skills to a higher degree than faculty and recent graduates. The survey also showed that employers top ranked competencies did not change drastically between 1999 and 2015. Communicating effectively within the office, ethics, and communicating effectively with clients/public averaged a response of 4.24, 4.02, and 4.16 respectively on a 0 to 5.0 Likert scale (Sample et al., 2015). Employers in both the 1999 and 2015 survey showed confidence in graduate's ability to meet their expectations in traditional skills such as forest science, wildlife, and ecology (Sample et al., 1999; Sample et al., 2015). The similar trends in skill gaps between graduates and employer expectation weighed heavily on professional skills, putting even more emphasis on the need to integrate real life learning situations to adequately prepare students for their careers post-graduation.

Andreason and Trede (2000) surveyed past graduates of the agriculture capstone course at Iowa State University with a similar goal of evaluating the capstones course effectiveness. The survey had 90 respondents, all who had been enrolled in the course at one time and had since graduated with an undergraduate degree and were currently employed in a professional role. The surveyed population were asked to indicate perceived benefits from a number of capstone course activities, as they related to their first professional position, then rank them using a five-point Likert scale with five being the highest degree of agreement to the statement. Results showed that the course was providing adequate support for students based on the pre-existing goals of applying knowledge gained from other courses, preparing and presenting reports, developing respect for different ideas, variety of assessment procedures, and seeking information from Iowa State University extension (Andreason and Trede, 2000). Studies such as this are the cornerstone for evaluating if a capstone course is providing adequate opportunity for students to become familiar with professional expectations and roles.

1.2. Water Quality and Tile Drainage

Tile drainage, otherwise known as subsurface drainage is utilized extensively in North American and Europe to lower the water table in soils that are seasonally or perpetually wet. This practice is necessary for water management in agricultural fields with naturally poorly drained soil; however, it contributes to water quality issues (Saadat et al., 2018). Without artificial drainage, agricultural production on poorly drained soils would not be economically feasible (King et al., 2016). Estimates suggest that greater than 37% of agricultural land in the US Midwest benefits from subsurface drainage (Zucker and Brown, 1998), though the extent is thought to be much greater (Blann et al., 2009). Tile drainage infrastructure includes privately owned perforated pipes installed in parallel configurations at a field scale. These pipes eventually discharge into ditches and streams (Ikenberry et al. 2014). These systems have significantly impacted watershed hydrology, nutrient fate, and transport over the past 50 years (Blann et al., 2009; Christianson et al., 2016; King et al., 2015). Nitrogen (N) and Phosphorous (P) are the most common and troublesome nutrients brought on by these changes as tile drainage provides a significant pathway for these nutrients to exit agricultural fields and enter adjacent waterways (King et al., 2016).

Aquatic ecosystems can be sensitive to anthropogenic additions of N and dissolved P, which are major contributors to the environmentally degrading processes of eutrophication and hypoxia (Nash et al., 2014). Phosphorus, which exists in aquatic environments as phosphate, organic P compounds, or sediment-bound P, is one of the primary contributors to harmful algal blooms in lakes (Davis et al., 2009; Downing et al., 2001) such as those observed in the western basin of Lake Erie and Lake Winnipeg. Between 1990 and 2000 the phosphorus concentration of Lake Winnipeg doubled (McCullough et al., 2012), one possible explanation for this rapid increase is expansion and intensification of agriculture in the southern part of the lake's catchment, both Canada and the United States (Schindler et al., 2012). Nitrogen exports from headwater watersheds has been directly linked to the water quality conditions in downstream waters (Alexander et al., 2007). High profile cases such as the seasonal hypoxic zone in the Gulf of Mexico are linked to non-point source pollution in the Mississippi Basin. Expansion and improvement of existing tile drainage continue in the present day (Schilling et al., 2015). Understanding how tile drains alter both water quality and watershed hydrology is necessary if we are to development management systems to mitigate nutrient loss.

It is well understood that tile drainage is the primary N loss pathway from agricultural fields (Amado et al., 2017; Goswami et al., 2009), because of this many studies exploring nutrient transport via tile drainage focus on N exports. Nitrogen is highly mobile in the soil surface, and is commonly applied as fertilizer for crop plant uptake which eliminates a percentage of N applied, leaving excess N to normal denitrification or nitrification processes (Goswami et al., 2009). Denitrification is of particular interest as it is an anaerobic process normally caused by water logged soil (Hillel, 1998). Tile drainage lowers the water table limiting what denitrification can take place. This residual N is soluble and moves into tile drains during precipitation events. Rainfall volume has shown to be correlated to N exports from tile systems, with large exports occurring during large events and vice versa, unless other factors favor N export during smaller events (David et al., 1997; Goswami et al., 2009; Mager et al., 2004). It has been observed that these exports can account for significant percentages of N loads for the given watershed. Williams et al. (2015) found that 14-100% ($\bar{x} = 29\%$) of NO_4-N in the watershed originated from tile drainage. In a more recent study Amado et al., (2017), found that at least 50% of N load measured in an Iowa watershed originated from tile drains. To truly understand N movement within a watershed onsite monitoring is necessary. In a 2017 study, Amado et al. observed that tile lines within a watershed in Iowa, USA contributed 80% of the streams N load, while only providing 15-43% of the water. The United States Environmental Protection Agency suggests a drinking water standard of 10.0 mg/l nitrogen to insure no health threats from the nutrient levels. In a 2018 study, Saadat et al. compared free draining tile lines to tile lines that were controlled via outlet risers. They observed an annual nitrogen export from free draining tile line to be 8.4 mg/L (Saadat et al., 2018). Williams et al. (2015) found a similar annual nitrogen export of 9.77 mg/L from two tile drained fields in an Ohio, USA watershed. This amounted to 59% of the watersheds total N loading annually (Williams et al., 2015).

Inversely, P leaching through tile drainage has only become recognized in more recent publications (King et al., 2015; Kleinman et al., 2015; Saadat et al., 2018; Smith et al., 2015; Vidon and Cuadra, 2011; Woodley et al., 2018). Prior to this. P in drainage waters, particularly subsurface drains such as tile lines, were often mistakenly assumed to be a minor contributor of P losses from agricultural fields (Kleinman et al., 2015). Phosphorous, normally thought of as a surface runoff issue is able to access tile lines through preferential flow pathways from either fissures and cracking of the soil through desiccation (Peron et al., 2009), or biological activity in the form of earthworms and root channels (Nielsen et al., 2010); allowing P to move down the soil profile. During precipitation events, macropores act as a direct linkage from the tile lines to the soil surface, precipitation transports P from the surface down the these macropores to the tile system (Smith et al., 2015). Vidon and Cuadra (2011) found a correlation between high P fluxes and export rates were associated with high tile discharge events**.** A study by Enright and Madramootoo (2004) found that tile contributed 40% of the total P exported from agricultural fields located along the Pike River in Quebec. Likewise, Smith et al. (2015) concluded that as much as 50% of the P loads in the tributary of Indiana's St. Joe Watershed may be derived from tile drainage. King et al. (2016) found that Given that P is often the limiting factor in freshwater ecosystems, and is associated with harmful algal blooms throughout North America, understanding the dynamics between P and tile drainage is essential if we are to control P exports moving forward.

Much like N and P, tile drains have a profound effect on stream flow. Woodley et al. (2018) found that tile drainage was the dominant avenue for water flow in a test plot scenario. This added connectivity allows for changes in total water yields, timing, and shape of hydrographs in a given watershed (Blann et al., 2009). Several studies show significant contributions from tile in regards to total watershed discharge, 30-45%, 51%, 56% were found by Amado et al. (2017), King et al. (2015), and Williams et al. (2015) respectively. Tile drainage additions to total watershed discharge are linked to what percentage of precipitation is recovered via the tile lines. In a 2007 study, Algoazany et al. found that over a seven-year period in Illinois, tile drains were able to recover 13 to 19% of precipitation from four different fields.

Similarly, Logan et al. (1980) found that annual discharge from tile systems represented 13%, 17%, and 25% of the annual rainfall in Iowa, Minnesota, and Ohio respectively. King et al. (2016) observed similar relations for three sites in Ohio, accounting for 34% of the annual precipitation over an eight-year study. However, when broken down to individual tile systems they ranged from 11-86% in annual rainfall recovery (King et al., 2016). Understanding the correlation and effects of tile drain contribution to watershed discharge is essential to understanding the total hydrology of the watershed.

1.3. Literature Cited

Alexander, R.B., Boyer, E.W., Smith, R.A., Schwarz, G.E., & Moore, R.B. (2007). The Role of Headwater Streams in Downstream Water Quality. *Journal of the American Water Resources Association*, 43(1), 41-59. doi:10.1111/j.1752-1688.2007.00005.x.

Amado, A., Schilling, K.E., Jones, C.S., Thomas, N., & Weber, L.J. (2017). Estimation of tile drainage contribution to streamflow and nutrient loads at the watershed scale based on continuously monitored data. *Environmental Monitoring and Assessment*, *189*(426). doi:https://doi.org/10.1007/s10661-017-6139-4.

Andreasen, R.J. and Trede, T.A. (2000). Perceived Benefits of an Agricultural Capstone Course at Iowa State University. *North American College and Teachers of Agriculture.* 44(1), 51–56.

Arthur, M.A. and Thompson, J.A. (1999). Problem-Based Learning in a Natural Resources Conservation and Management Curriculum: A Capstone Course. *Journal of Natural Resources and Life Science Education*, 28, 97–103.

Algoazany, A.S., Kalita P.K., Czapar G.F., and Mitchell, J.K. (2007). Phosphorus transport subsurface drainage and surface runoff from a flat watershed in eastern Illinois, USA. *Journal of Environmental Quality*, 36, 681-693.

Aupperle, K.E. and Sarhan, M.H. (1995). Assessing Financial Performance in the Capstone,Strategic Management Course: A Proposed Templé. *Journal of Education for Business*, 71(2), 72-81.

Berkson, J. and Harrison, A.L. (2002) Refocusing Natural Resources Management a Multidisciplinary Road to Reality. *Journal of College Science Teaching*, 31(7), 464.

Blann, K.L., Anderson, J.L., Sands, G.R., & Vondracek, B. (2009) Effects of Agricultural Drainage on Aquatic Ecosystems: A Review. *Critical Reviews in Environmental Science and Technology*, *39*(11), 909-1001. doi:https://doi.org/10.1080/10643380801977966.

Casper, A.A., Fernandez-Gimenez, M.E., and Balgopal, M.M. (2016). Natural Resource Management Students' Perceptions of Conceptual Change in a Capstone Course. *Journal of Natural Resources and Life Science Education*, 45.

Christianson, L.E., Harmel, R.D., Smith, D., Williams, M. R., & King, K. (2016) September 16). Assessment and Synthesis of 50 Yeats of Published Drainage Phosphorus Losses. *Environmental Quality*, *45*(5), 1467-1477.

Crunkilton, J.R., Cepica, M.J., and Fluker, P.L. (1997). Portfolio of Capstone Courses in College of Agriculture. United States Department of Agriculture.

David, M.B., Gentry, L.E., Kovacic, D.A., & Smith, K.M. (1997). Nitrogen Balance in and Export from an Agricultural Watershed. *Journal of Environment Quality*, 26(4), 1038. doi:10.2134/jeq1997.00472425002600040015x.

Davis, T.W., Berry, D.L., Boyer, G.L., & Gobler, C.J. (2009). The effects of temperature and nutrients on the growth and dynamics of toxic and non-toxic strains of Microcystis during cyanobacteria blooms. *Harmful Algae*, 8(5), 715-725. doi:10.1016/j.hal.2009.02.004.

Downing, J.A., Watson, S.B., & Mccauley, E. (2001). Predicting Cyanobacteria dominance in lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, 58(10), 1905-1908. doi:10.1139/cjfas-58-10-1905.

Dunlap, J.C. (2005). Problem-based Learning and Self-efficacy: How a Capstone Course Prepares Students for a Profession. *Education technology research and development*, 53(1), 65-85.

Enright, P., and Madramootoo, C.A. (2004). Phosphorus losses in surface runoff and subsurface drainage waters on two agricultural fields in Quebec. p. 160–170. *In* R.A. Cooke (ed.) Drainage: Proceedings - International Symposium, 8th, Sacramento, CA. 21–24, Mar. 2004. American Society of Agricultural and Biological Engineers. St. Joseph, MI.

Goswami, D., Kalita, P., Cooke, R., & Mcisaac, G. (2009). Nitrate-N loadings through subsurface environment to agricultural drainage ditches in two flat Midwestern (USA) watersheds. *Agricultural Water Management*, 96(6), 1021-1030. doi:10.1016/j.agwat.2009.02.007.

Habron, G., Goralnik, L., and Thorp, L. (2012). Embracing the Learning Paradigm to Foster Systems Thinking. *International Journal of Sustainability in Higher Education*, 13(4), 378-393.

Hillel, D., Warrick, A.W., Baker, R.S., and Rosenzweig, C. (1998). Content and Composition of Soil Air. In: Hillel. D., Environmental Soil Physics. Academic Press, San Diego, CA. p.277-290.

Ikenberry, C.D., Soupir, M.L., Schilling, K.E., Jones, C.S., & Seeman, A. (2014). Nitrate-Nitrogen Export: Magnitude and Patterns from Drainage Districts to Downstream River Basins. *Journal of Environment Quality*, 43(6), 2024. doi:10.2134/jeq2014.05.0242.
King, K.W., Williams, M.R., Macrae, M.L., Fausey, N.R., Frankenberger, J., Smith, D.R., Smith, P.J., Kleinman, A., and Brown, L.C. (2015). Phosphorus Transport in Agricultural Subsurface Drainage: A Review. *J. Environ. Qual*. 44:467-485. doi:10.2134/jeq2014.04.0163

King, K.W., Williams, M.R, and Fausey, N.R. (2016). Effects of crop typeand season on nutrient leaching to tile drainage under a corn-soybean rotation. *Journal of Soil and Water Conservation,* 71(1), 56-68.

Kleinman, P.J., Smith, D.R., Bolster, C. H., & Easton, Z.M. (2015). Phosphorus Fate, Management, and Modeling in Artificially Drained Systems. *Journal of Environment Quality*, 44(2), 460. doi:10.2134/jeq2015.02.0090.

Knowles, J.G. and Hoefler, V.B. (1995). The Student Teaching Who Wouldn't Go Away: Learning from failure. In: R.J. Kraft and J. Kielsmeier (Eds). Experiential Learning in Schools and Higher Education. Boulder, CO: Kendall/Hall.

Logan, T.J., Randall, G.W., and Timmons, D.R. (1980). Nutrient content of tile drainage from cropland in the north-central region. North Central Regional Research Publication 268. Ohio Agricultural Research and Development Center, Research bulletin 1119.

Magner, J.A., Payne, G.A., & Steffen, L.J. (2004). Drainage Effects on Stream Nitrate-N and Hydrology in South-Central Minnesota (USA). *Environmental Monitoring and Assessment*, 91(1-3), 183-198. doi:10.1023/b:emas.0000009235.50413.42.

McCullough, G.K., Page, S., Hesslein, R.H., Stainton, M.P., Kling, H.J. Salki, A., Barber, D.G. (2012) Hydrological forcing of a recent trophic surge in Lake Winnipeg. *J. Great Lakes Res.* 38 (suppl. 3), 95-105.

Meffe, G.K. (1998). Conservation Scientists and the Policy Process. *Conservation Biology*, 12(4), 741-742.

Nash, P.R., Nelson, K.A., Motavalli, P.P., Nathan, M., & Dudenhoeffer, C. (2015). Reducing Phosphorus Loss in Tile Water with Managed Drainage in a Claypan Soil. *Journal of Environment Quality*, 44(2), 585. doi:10.2134/jeq2014.04.0146.

Nielsen, M.H., Styczen, M., Ernstsen, V., Peterson, C.T., and Hansen, S. (2010). Field study of preferential flow pathways in and between drain trenches. *Vadose Zone Journal* 9, 1073-1079.

Nilsson, K.H. and Fulton, J.R. (2002). The capstone experience course in agricultural curriculum. Agricultural and Applied Economics Association selected paper, Long Beach, California, July 28-31, 2002.

Noss, R.F., and Cooperrider, A.Y. (1994). Chapter 10: “The Task Ahead”. In “Saving Nature’s Legacy: Protecting and Restoring Biodiversity.” pg. 325-338.

Peron, H., Hueckel, R., laloui, L., and Hu, L.B. (2009). Fundamentals of desiccation cracking of fine grained soils: Experimental characterization of mechanisms identification. *Canadian Geotechnical Journal*, 46, 1177-1201.

Pile, L.S, Watts, C.M., and Straka, T.J. (2012) “Forest Resource Management Plans: A Sustainability Approach.” *Journal of Natural Resource and Life Science Education*, 41, 79-86.

Prokopy, L.S. (2009) “Looking at the Big Picture: Engaging Natural Resource Students in Landscape Level Planning Through a Capstone Course. *Journal of Forestry*, 90–94.

Sample, V.A., Ringgold, P.C., Block, N.E., and Giltmier, J.W. (1999). Forestry Education: Adapting to the Changing Demands. *Journal of Forestry*, 97(9), 4–10.

Sample, V.A., Bixler, R.P., McDonough, M.H., Bullard, S.H., and Snieckus, M.M. (2015). The Promise and Performance of Forestry Education in the United States: Results of a Survey of Forestry Employers, Graduates, and Educators. *Journal of Forestry*, 113(6), 528-537.

Sargent, S.D., Pennington, P., and Sitton, S. (2003). Developing leadership skills through capstone experiences. Educational resources information center, http://www.arex.uiuc.edu/-ALE/2003/sargent1.pdf.

Saadat, S., Bowling, L., Frankenberger, J., & Kladivko, E. (2018). Nitrate and phosphorus transport through subsurface drains under free and controlled dranage. *Water Research*, 142, 196-207. doi:10.1016/j.watres.2018.05.040.0043-1354.

Schilling, K.E., Wolter, C.F., T.M., Isenhart, T.M., and Schultz, R.C. (2015). Tile drainage density reduces groundwater travel times and compromises riparian buffer effectiveness. *Journal of Environmental Quality*, 44(6), 1754-1763.

Smith, D.R., King, K.W., Johnson, L., Francesconi, W., Richards, P., Baker, D., and Sharpley A.N. (2015) Suface Runoff and Tile Drainage Transport of Phosphorus in the Midwestern United States. *Journal of Environmental Quality,* 44, 495-502

Vidon, P., & Cuadra, P. (2011). Phosphorus dynamics in tile-drain flow during storms in the US Midwest. *Agricultural Water Management*, 98(4), 532-540. doi:10.1016/j.agwat.2010.09.010.

Williams, M., King, K., & Fausey, N. (2015). Drainage water management effects on tile discharge and water quality. *Agricultural Water Management*, 148, 43-51. doi:10.1016/j.agwat.2014.09.017

Woodley, A.L., Drury, C.F. Reynolds, W.D. Tan, C.S. Yang, X.M. And Oloya, T.O. (2018). Long-term Cropping Effects on Partitioning of Water Flow and Nitrate Loss between Surface Runoff and Tile Drainage. *Journal of Environment Quality*, 47(4), 820. doi:10.2134/jeq2017.07.0292.

Yeon-Su, K., S. Dwhurst, and Hospodarsky, D. (2007). “The 2005 Planning Rule as a Teaching Tool. *Journal of Forestry*, 105, 320-325.

Zucker, L.A., and Brown, L.C., (1998). Agricultural drainage: Water quality impacts and subsurface drainage studies in the Midwest. Bulletin, 871-898. St. Paul, Minnesota: University of Minnesota Extension.

CHAPTER 2. WATER QUALITY OBSERVATIONS OF A HEADWATER WATERSHED IN THE RED RIVER BASIN

2.1. Abstract

Subsurface drainage in areas with a high water table can greatly increase production, but also influence water quality within surrounding watershed. Subsurface drainage, commonly called tile drainage, implementation has grown in the Northern Great Plains, specifically the Red River Valley of the North. This study provides methodology to assess and baseline data on a relatively untiled sub-watershed of the Red River that contains four distinct drains and is likely to have tile implementation in the near future. Once tile is implemented, baseline data from this study can be used to evaluate any potential positive and negative effects at the sub-watershed scale. The site was analyzed for nutrients during runoff and storm events during the 2019 and 2020 growing seasons. Results indicate the study site is well suited for further evaluation, as the four different drainages often behave similarly to one another for both concentration and loading. Individual drains showed more significant differences between one another when constituents were weighted based on flow then results compared without flow or just concentration.

2.2. Introduction

Alterations in agricultural practices can greatly influence water quality within watersheds dominated by agricultural production. Tile drainage, a common land use practice in agricultural lands utilizes perforated pipes installed in parallel configurations to lower the water table in soils that are seasonally or perpetually wet across North America and Europe (Saadat et al., 2018). The implications of these land use changes have significantly impacted watershed hydrology, nutrient fate, and transport over the past 50 years (Blann et al., 2009; King et al., 2015; Christianson et al., 2016).

Prior research on tile drainage contributions to watersheds have primarily focused on comparing nutrient load exports at the field scale (Nash et al., 2014; De Schepper et al., 2015; Smith et al., 2015; Lavaire et al., 2017; Saadat et al., 2018). These studies primarily focus on utilizing best management practices for controlling nutrient exports of nitrogen and phosphorus in tiled fields, though few studies have provided baseline data. To the authors' knowledge, no study to date has assessed pre and post tile implementation on a watershed scale. This information is imperative to understanding what changes subsurface drainage brings to a watershed in areas where little to no land is currently tiled.

Tile drainage studies are primarily conducted in states such as Ohio (King et al., 2014; Smith et al., 2015; Williams et al., 2015), Illinois (David et al., 1997), Minnesota (Mager et al., 2004), Missouri (Nash et al., 2014), and Indiana (Saadat et al., 2018) with minimal research coming from far northern climates beyond the focus of improving crop production (Rijal et al., 2012; Acharya et al., 2019a; Acharya et al., 2019b and Niaghi et al., 2019). The utilization of tile drainage has rapidly expanded in the Red River Watershed, allowing earlier planting dates and higher crop yields (Pates, 2011). Areas within the Red River Watershed without tile drainage are becoming increasingly difficult to find. Schindler et al. (2012) found that the Red River Watershed supplied 70% of the phosphorus (P) load and 35% of the nitrogen (N) load entering Lake Winnipeg causing harmful algal blooms to double in size since the 1990s. As the global population continues to grow, and demand for food production increases it is likely tile drainage will be a management tool used by producers to bolster production through controlling drainage on cropped lands, which is necessary to optimize production (Wang et al., 2020). It is because of this, understanding the hydrologic and water quality effects of tile drainage has at a watershed level is crucial. Furthermore, collecting baseline information before tile drainage is implemented within a watershed would facilitate identifying any watershed changes due to the tile drainage. This pre/post treatment comparison not only exposes the changes tile drainage does and does not bring to a watershed, but will help guide best management practices.

This study evaluates current water quality conditions and flow in a headwater sub-watershed of the Red River Watershed that currently is not dominated by tile drainage. The study will provide accurate baseline data for further studies to determine changes in water quality and flow once tile is implemented, and determine how conservation measures may or may not have an impact on those changes. It will also provide a new approach to subsurface drainage studies, as to authors knowledge, no study has captured a before/after comparison at a watershed scale. The specific objectives of this study are as follows:

1.) Analyze Total Phosphorus (TP), Dissolved Phosphorus (DP), Total Nitrogen (TN), Nitrate + Nitrite (N+N), and Total Suspended Solids (TSS) contributions from the sub-watershed that contribute to the Red River during spring runoff and varying precipitation events.

2.) Assess velocity and flow of water coming from each drain and the entire sub-watershed during spring runoff and precipitation events to determine flow weighted contributions to the Red River.

2.3. Methods and Materials

2.3.1. Study Area

Study sites were located in eastern North Dakota, USA within the Red River Valley, an area that occupies the ancient Lake Agassiz basin. The sub-watershed used for this study was chosen due to lack of tile drainage within its boundaries. Though an unknown acreage within the basin is tile drained, it is thought to be a small percentage of the overall watershed. The primary land use within the watershed is agricultural production of row crops, with few other major land uses occurring within the watershed's boundaries. The primary soil types found throughout the sub-watershed are clay and silty clay loams with minimal slope found (NRCS Web Soil Survey 2020). Normal crop rotations found within the sub-watershed follow a corn-soybean-wheat cycle with minimal cover contributed to sugar beets. The total drainage area of the watershed is 6,967 ha (26.9 sq mi), within which four large open ditches drain a network of shallow surface drains (Figure 2.1). The four large open ditch drains are referred to as Drain 30, Drain 70-N, Little 13, and Drain 70-S; and they drain 2,072 ha (29.75%), 1,139.59 ha (16.34%), 3030.29 ha (43.49%), and 725.19 ha (10.43%) of the sub-watershed, respectively. All four ditch drains converge to form one large open drain referred to as Drain 13 before passing under Interstate 29 (Figure 1.2).

2.3.2. Sample Collection

Samples were collected at five sites (Figure 2.1) within the study area, four sites were located on 167th Ave SE at each crossing of the four smaller open ditches. These sites were named for the given ditch at which they sampled (Drain 30, Drain 70-N, Little 13, and Drain 70-S), explained above. A fifth sample site was placed along old highway 81 at the crossing of Drain 13, this site was referred to as 81 Cross.

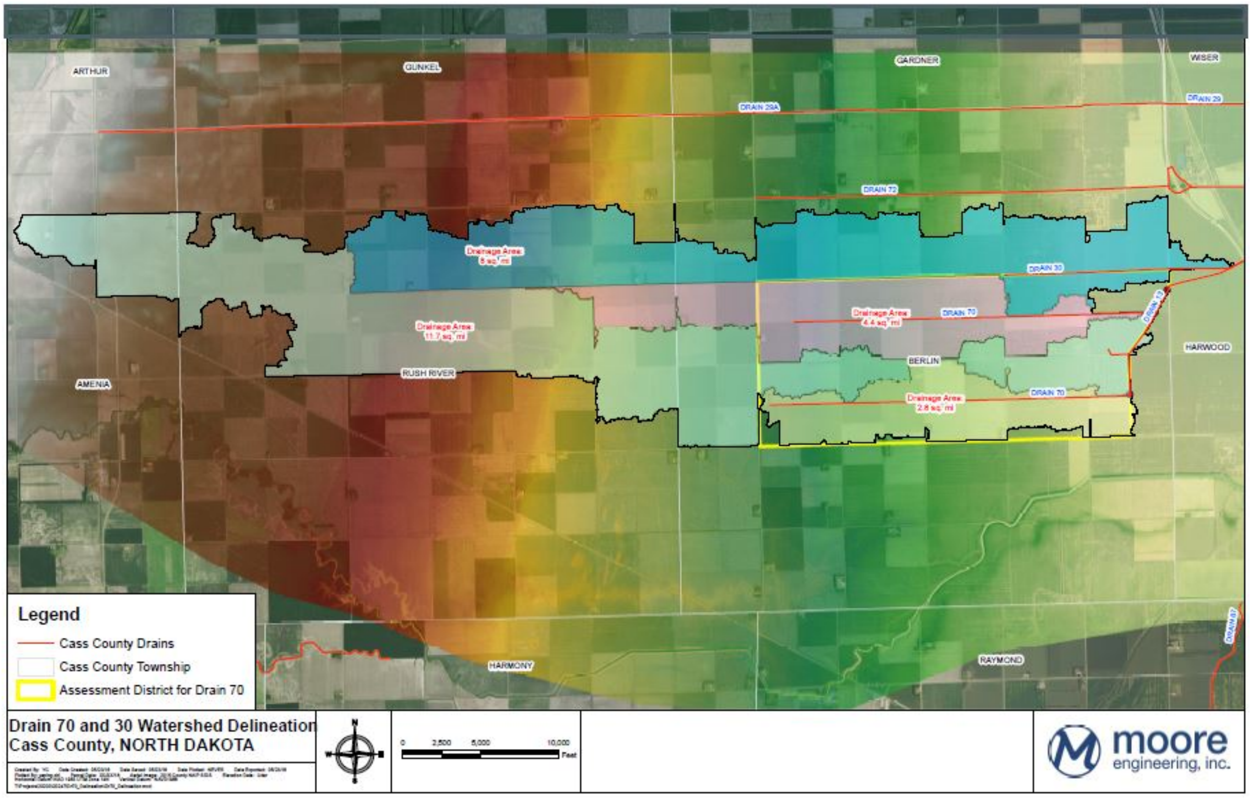

Figure 2.1 Watershed delineation completed by Moore Engineering Inc., West Fargo, ND, USA During spring runoff (April 6th – May 16th, 2019; April 2nd – April 29th, 2020).

Grab samples were taken at a depth of 0-0.5m and flow measurements were taken weekly at each of the five sites. Grab samples were taken via dip cup following North Dakota Department of Environmental Quality protocol (NDDEQ, 2013). Samples were preserved according to protocol, cooled on ice, and transported to the NDDEQ lab in Bismarck, North Dakota for analysis. Water quality parameters investigated included TSS, nutrients complete (TN, Total Kjeldahl Nitrogen, N+N, and TP), major cation and anions, and trace metals. Samples for dissolved phosphorus were during alternating weeks (two total samples) during spring runoff, the limitation of every other week was used to ensure we did not go over our contracted amount of dissolved phosphorus (DP) samples with the NDDEQ.

Figure 2.2. Study site location with sample sites indicated in blue with names in white.

These samples were filtered using a Masterflex easy load II model no. 77200-52 attached to a 12v drive motor model no. 07533-50 (Cole-Parmer, Vernon Hills, Illinois, USA) and a Geotech 0.45 micron dispos-a-filter model no. 73050011 (Geotech Environmental Equipment Denver, Colorado, USA). These samples were also preserved, cooled, and transported to the NDDEQ laboratory for analysis. Temperature, pH, conductivity, and dissolved oxygen were measured on site using a YSI Pro DDs sonde Model No. 626870-1 (YSI Inc., Yellow Springs, Ohio, USA). Flow measurements were taken using a CR-4.0 philly metric leveling/measuring rod model no. 92023 (Crain Enterprises Inc., Mound City, Illinois, USA) to measure the distance between the top of the culvert and the top of the water for later use in Manning's equation flow calculations (Hillel, 1980).

Teledyne Isco Avalanche portable refrigerated samplers (Model no. 682970003, Lincoln, Nebraska, USA) were used to sample storm events during the summer, being deployed around the 15th of May both in 2019 and 2020. These samplers were utilized until the end of September each year when temperatures fell below suggested operation temps. Height measurements were collected using a Teledyne Isco model 720-submergible height and velocity probe (Model no. 686700068, Teledyne Isco, Lincoln, Nebraska, USA). Intake lines were placed next to the pressure transducer approximately 4" off the bottom of the ditch within the primary current. Flow measurements were taken in 30-minute increments starting 24 hours before the forecasted precipitation event. Samplers were programed to enable sampling once height measurements rose 5cm above baseflow levels. Once samplers were enabled, water sample collection happened every hour, for a total of fourteen hours. Each hour a sample was placed into a 950 ml sample for each site, following each event. Once a sample was taken, the sampler would cool the collected samples to 4ºC (±1ºc) and purge the intake line before the next sample collection. Following the completion of the sampling program, the hydrograph and sample time data was retrieved from each sampler using Teledyne Isco Flowlink v 5.0 (Item no. 682540200) and a COMM CA USB communications cable (model no. 602004508, Teledyne Isco Lincoln, Nebraska, USA) was used to transfer data from the sampler to a laptop computer. The hydrograph was used to identify what time the rising limb, peak, and falling limb of the storm event occurred for that drain. These times were used to select the sample(s) that were taken during the rising limb, peak, or falling limb of the hydrograph. Samples that fell within the same area of the hydrograph were composited to have distinct water samples from the rise, peak, and falling limb of the hydrograph. Composite samples were bottled and preserved according to NDDEQ protocol and sent to the NDDEQ lab for analysis. Composite samples were analyzed for nutrients complete, major cations and anions, TSS, and trace metals.

All samples from auto samplers were also analyzed with a YSI DSS Pro sonde (626870-1, YSI Inc., Yellow Springs, Ohio, USA) for specific conductivity, dissolved oxygen, and pH; the temperature was not utilized as all samples had been cooled. During the second year (2020) of the study, HOBO Rx water level stations (RX2104, Onset Computer Corp., Bourne, Massachusetts, USA) were placed at each sample site (five total) to collect water level readings every 15 minutes over the growing season using a smart water level sensor (MX 2001-04-S, Onset Computer Corp. Bourne, Massachusetts, USA). These stations also were equipped with tipping buckets (S-RGA-M002, Onset Computer Corp. Bourne, Massachusetts, USA) to better monitor rainfall amounts across the sites. The station also recorded rainfall every 5 minutes to the hundredth of a centimeter. Each of the five sites was also equipped with submerged continuous data loggers (Model no. U24-001, Onset Computer Corp. Bourne, Massachusetts, USA) placed within each ditch to monitor electrical conductivity for each site through the growing season (May 15th to September 30th, 2020) during the second year of the study. This data was retrieved using a HOBO shuttle (BASE-U-4, Onset Computer Corp. Bourne, Massachusetts, USA) and HOBOware pro (version 3.7.16, Onset Computer Corp. Bourne, Massachusetts, USA) to import into digital format.

2.3.3. Data Analysis

Flow calculation will utilize stream height data gathered throughout the season, and Manning's equation to calculate streamflow within the culvert. An average of stream flow will be calculated for the given limb of the hydrograph and used with nutrient data to determine time step loading during the given hydrograph limb. Stream nutrients, dissolved nutrients, and suspended solids concentrations will be used to calculate budgets for each of the five sites by multiplying the concentration by the flow in gallons per minute. The data will then display the systems net change between the four ditches and the confluence at site 81 cross. Flow tables and manning's equation parameters for each site can be found in appendix E.

Constituent concentrations and time step loading were compared using one way ANOVA analysis of variance. Spring runoff samples were compared by site using dates as replicants and dates were compared using sites as replicants. Event sampling analysis for both concentration and time step loading were compared using one way ANOVA analysis of variance, and separate analysis was conducted for each of the three distinct portions of the hydrograph (rising limb, peak, and falling limb). Comparison of sites used storm events as replicants. Comparison of storm events used sites as replicants. Tukey's post hoc comparison of means was utilized for all comparisons to test for significant differences amongst sites, sample dates (spring runoff only), and storm events (event samples only).

2.4. Results and Discussion

2.4.1. Spring Runoff

A one-way ANOVA analysis was utilized to identify significant differences among the sampling dates and sampling sites for seven constituents (TN, TP, TSS, N+N and DP), DP was not taken during the 2019 runoff samples. Concentration (mg/L) and time step loading (TSL) (lb /min) were analyzed for both site and date. Time step loading was calculated through flow height measurements taken at the time of sampling, and converted to gal/min using Manning's equation. Site 81 was significantly different and had double the TN (Figure 2.3) concentration of that found at Drain 30, 70-N, and Little 13, while 70-S was not significantly different from any other site. For N+N (Figure 2.4) similar results were found with Site 81 Cross having magnitudes higher concentrations compared to Drain 30, 70-N, and Little 13, while 70-S did not differ. Mean concentration of TP (Figure 2.5) at Little 13 was significantly different from 81 Cross, 70-N, and 70-S, while Drain 30 was not significantly different than any of the four sampling sites.

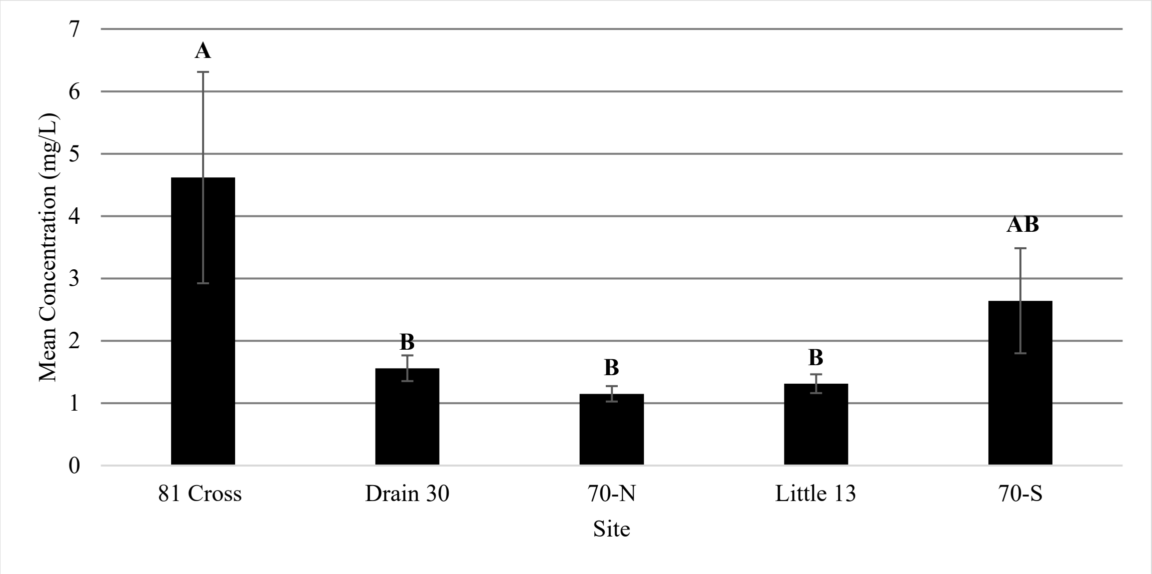

Figure 2.3. Mean Total Nitrogen concentration in 2019 spring runoff sampling by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

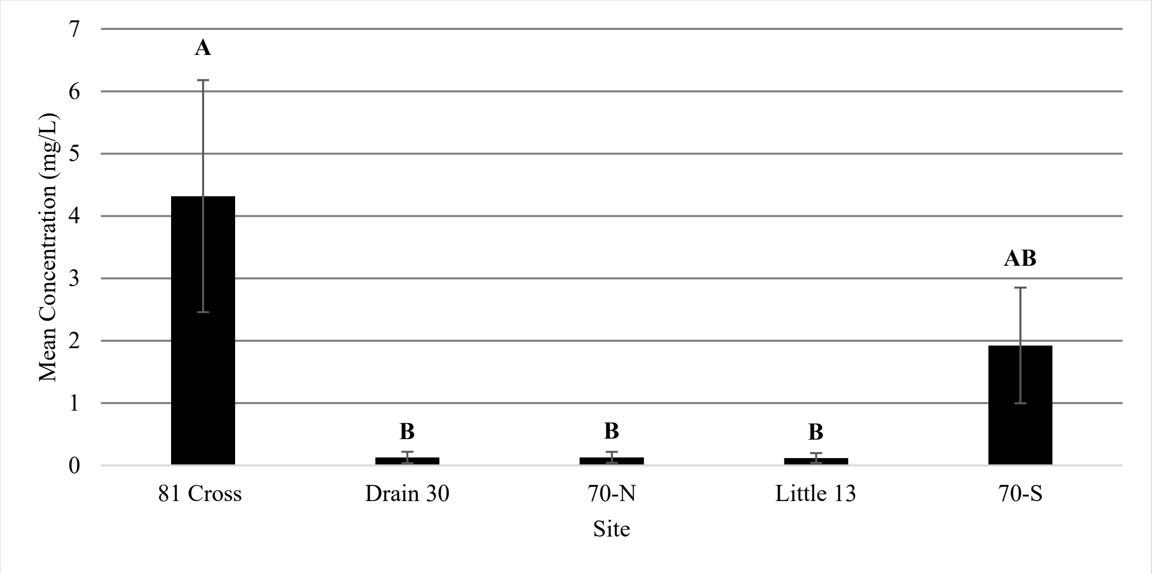

Figure 2.4. Mean Nitrate + Nitrite concentration in 2019 spring runoff sampling by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

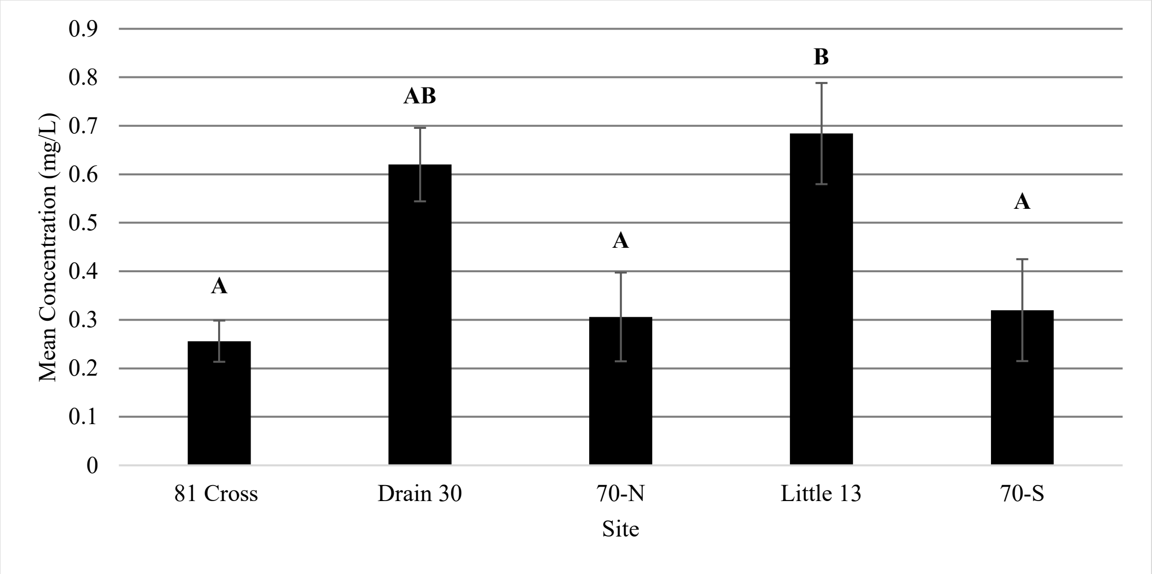

Figure 2.5. Mean Total Phosphorus concentration for 2019 spring runoff sampling by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

The TSL values for TN (Figure 2.6) across sites were different from just concentrations, with more differences among the sites than N+N (Figure 2.7), where Cross 81 had much higher values compared to the other four sites. Mean TSL values for TP (Figure 2.8) were greatest at site Little 13, 81 Cross and Drain 30 displayed lower mean TSL but were not significantly different then Little 13 while the two remaining sites showed mean TSL of TP at a far lower value in comparison.

Sampling dates were compared to identify possible temporal differences for both mean concentration (mg/L) and mean TSL (lb/min) for spring runoff dates. Mean concentration for TN (Figure 2.9) greatly increased in the later sampling dates compared to earlier sampling dates. Few significant differences were found between the April 8th and May 16th, 2019 sample dates, with only May 1 being significantly greater than April 24th and lower then May 7th, and April 15th being significantly different from April 24th and May 7th. Mean concentrations of N+N (Figure 2.9) followed a similar trend as TN with the highest means occurring during the later sampling dates with all dates other then April 24th and May 1st being significantly different.

Analysis of TSL over sampling dates did not yield significant differences for any of the analyzed constituents (Appendix A). Results for all additional 2019 spring runoff data did not show significant differences between sample site or date and concentration or TSL (results can be found in Appendix A).

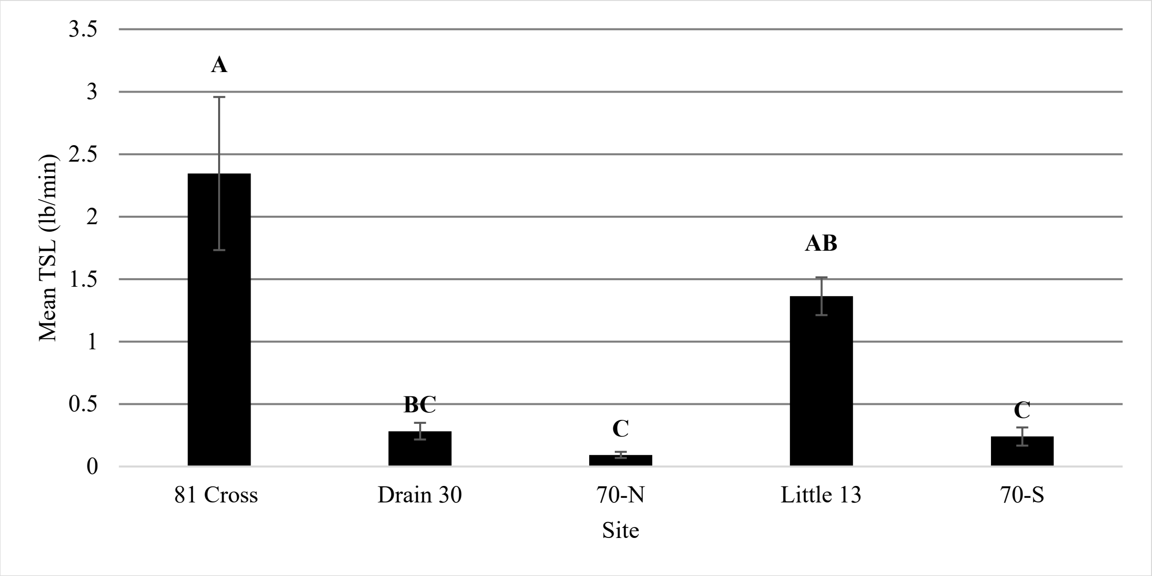

Figure 2.6. Mean Total Nitrogen time step loading for 2019 spring runoff sampling by site. Different letters indicate significant differences at $p \leq 0.05$. Bars represent standard error.

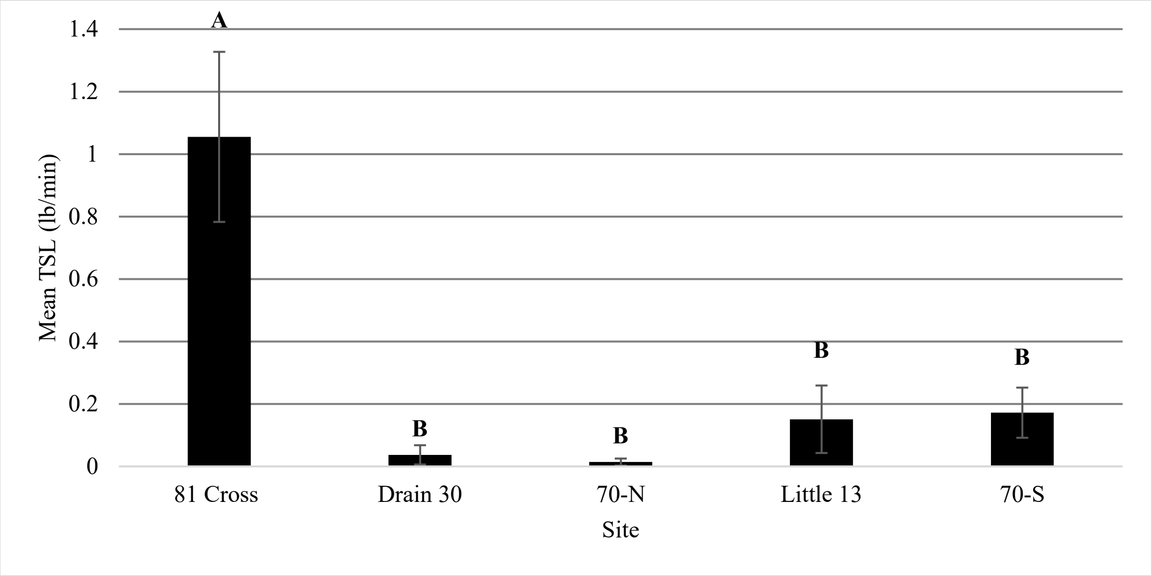

Figure 2.7. Mean Nitrate + Nitrite time step loading for 2019 spring runoff sampling by site. Different letters indicate significant differences at $p \leq 0.05$.

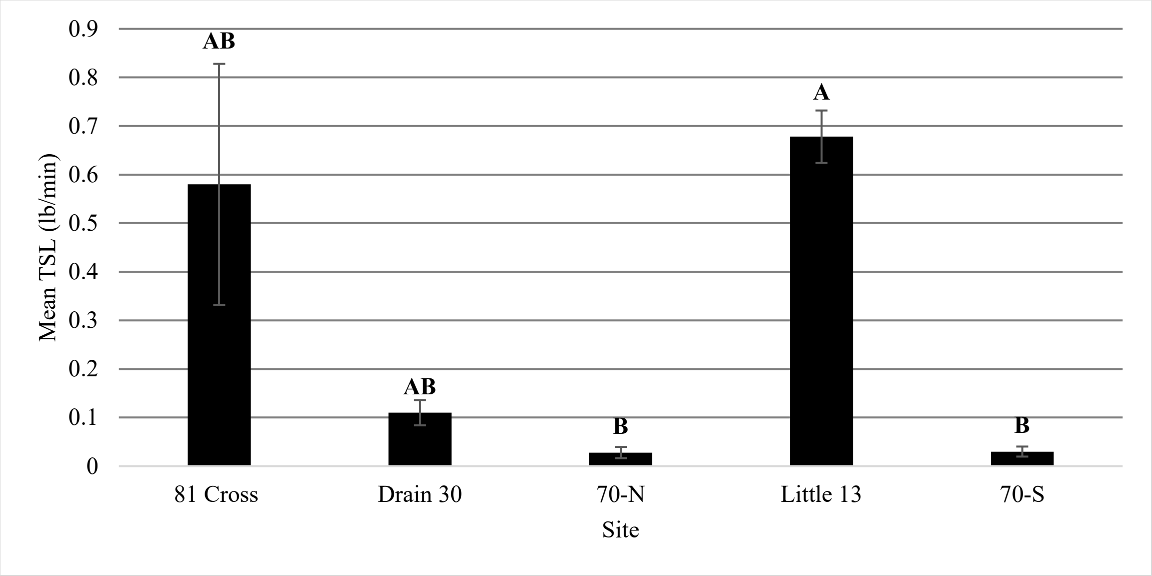

Figure 2.8. Mean Total Phosphorus time step loading for 2019 spring runoff sampling by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

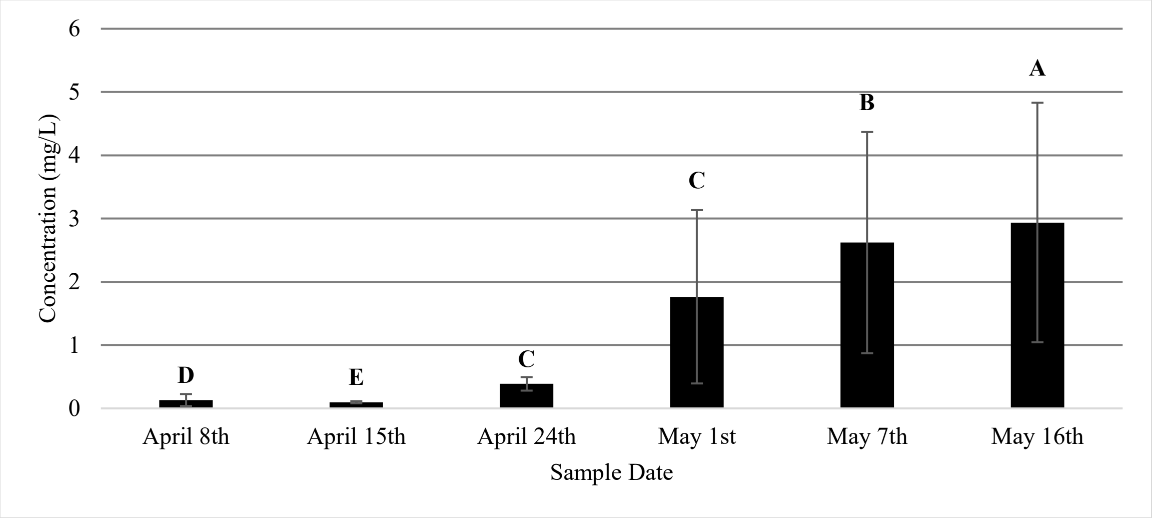

Figure 2.9. Mean Nitrate + Nitrite concentration for 2019 spring runoff sampling by sample date. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

Results from 2020 runoff sampling data found few significant differences, those constituents that displayed no significant differences by site or sample date can be found in Appendix A. Mean concentration of TSS (Figure 2.10) was significantly greater for April 2nd compared to April 15th sampling date, and April 7th and April 29th were not significantly different from all other sampling dates.

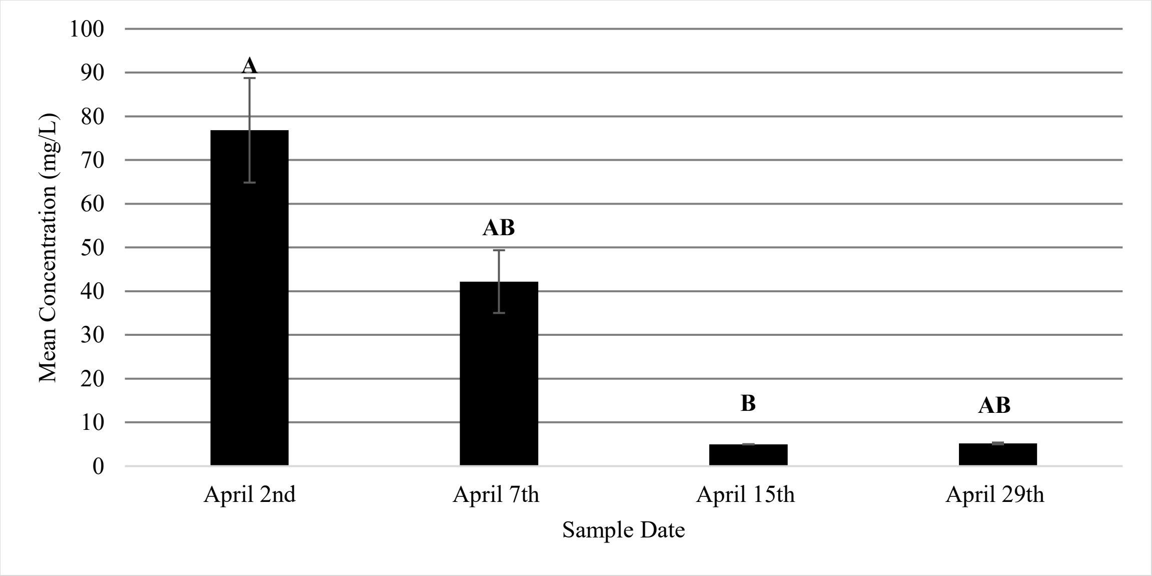

Figure 2.10. Mean Total Suspended Solids concentration in 2020 spring runoff sampling by sample date. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

Within the Red River Valley spring runoff is often a long process, as the topography of the land does not allow for quick drainage and soils with low Ksat values dominate the study area which allows for little infiltration. Runoff sampling during the two separate years were on extreme ends of the spectrum. The 2019 spring sampling was following a snowy winter and prolonged freeze thaw in the spring with large amounts of flooding occurring in the valley and significant overland flooding within the study area. Conversely, 2020 had a gradual melt which allowed the drainage systems in the study area to handle the flow within its banks. Overall, little flooding occurred within the study area and base flow was met two weeks sooner than in the 2019 runoff sampling. Frigid winter temperatures in the norther latitudes of our sample area allow the soil to freeze to depths of 2 feet plus, this essentially halts water movement in the upper reaches of the soil profile, locking nutrients left over from the growing season until it is released during the spring thaw. Some constituents such as N+N and TN, which are highly mobile in the soil surface (Goswami et al., 2009), showed trends in both 2019 and 2020 of increased concentrations later in sampling sets, likely due to frost depths in earlier sampling dates. Following the thaw of surface and subsurface soils, normal water/soil interactions can occur, such as infiltration, which would allow soluble constituents to move freely into groundwater or tile lines.

2.4.2. Storm Event Sampling

Following spring runoff, and above freezing low temperatures, automated refrigerated samplers were deployed to the five sample sites to capture storm event runoff. For each site three samples were analyzed, one for each distinct part of the hydrograph (rising limb, peak, and falling limb) for all constituents except DP which was only measured during the peak. A one-way ANOVA analysis of variance was completed to identify differences among concentration and TSL for both specific storms and sampling sites. Analyses that did not identify significant differences for concentration and TSL split by the three portions of the hydrograph can be found in their respective appendices, rising (Appendix B), peak (Appendix C), and falling (Appendix D).

2.4.2.1. Hydrograph Rising Limb

Mean concentration of TP (Figure 2.11) for the rising limb was found to be significantly higher at sites Little 13 and Drain 30 compared to the other three sites. Mean TSL for the rising limb was significantly different and greater at 81 Cross than all other sites for both TN (Figure 2.12) and N+N (Figure 2.13). The other four sites all have very low mean concentrations of TN and N+N, though Little 13 had slightly higher measures then the other three sites, but it was not significantly different. All other measures of mean concentration were not found to be significantly different between sites and can be found in Appendix B.

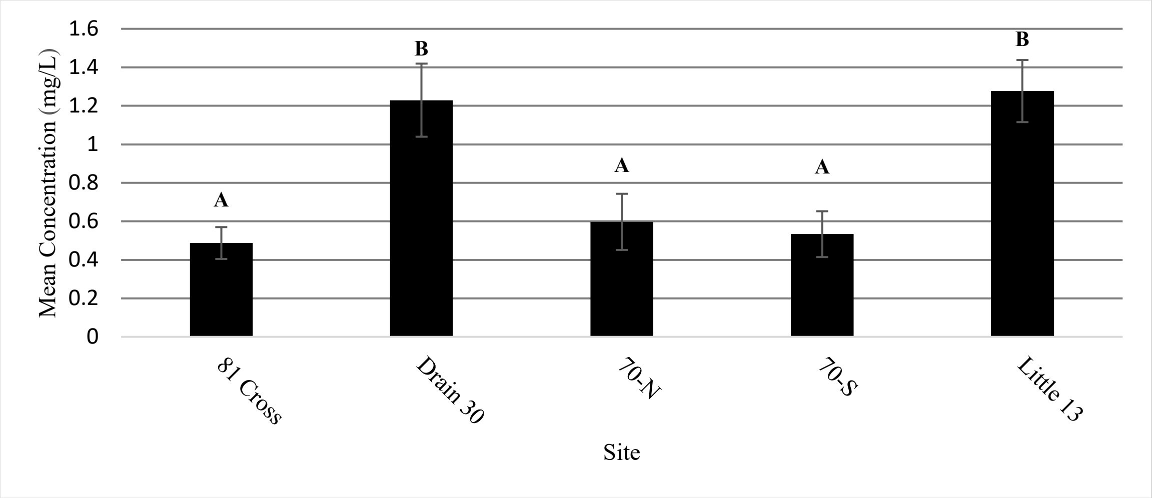

Figure 2.11. Mean Total Phosphorus concentration for the rising limb of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

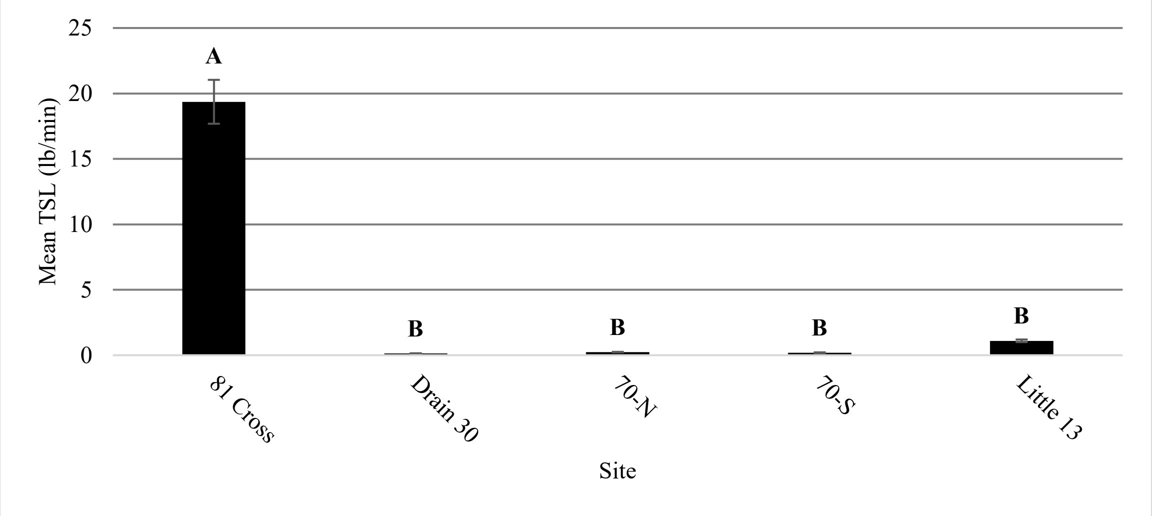

Figure 2.12. Mean Total Phosphorus time step loading for the rising limb of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

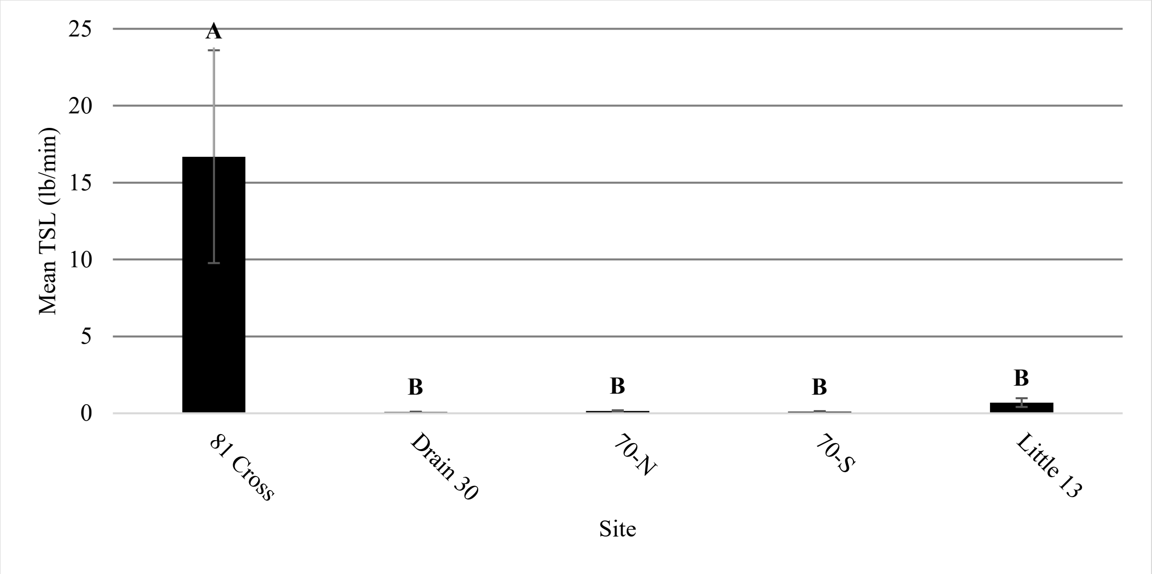

Figure 2.13. Mean Nitrate + Nitrite time step loading for the rising limb of the hydrograph by site. Different letters indicate significant differences at $p \leq 0.05$. Bars represent standard error.

Storm events were coded for statistical analysis, codes were utilized in a way that the first number reflects sample year and the second reflects the month sampled. The third and fourth number describes the sample count, third number being for the month and the fourth number being for the year. For explanation, storm event 19-6-1-1 reflects the first storm sampled for the 2019 sampling year, and the first storm sampled in the month of June. Storm codes and rising limb sample dates are displayed in Table 2.1, along with 24 hour storm rainfall totals starting 6 hours prior to the rising sample. This reflects our sample sites responsiveness to storm events as the rising limb typically was sampled 3 hours following intense rainfall, peak after 6 hours, and the falling limb was taken 14 hours following initial rising limb sampling.

Table 2.1. Storm code, date, and 24 hour rainfall totals for sampled events June, 2019 to August, 2020

Storm Code	Initial Sample Date	Rainfall Amount
19-6-1-1	June 20th, 2019	1.2”
19-7-1-3	July 4th, 2019	0.97”
19-7-2-4	July 9th, 2019	4.03”
19-8-1-5	August 26th, 2019	1.21”
19-9-1-6	September 21st, 2019	2.24”
20-6-1-1	June 8th, 2020	1.73”
20-7-1-2	July 8th, 2020	0.36”
20-7-2-3	July 17th, 2020	1.39”
20-7-3-4	July 21st, 2020	1.22”
20-7-4-5	July 24th, 2020	1.30”
20-8-1-6	August 9th, 2020	1.28”
20-8-2-7	August 14th, 2020	2.08

Storm event comparisons by date for the rising limb reveal significant differences in mean concentration for TN and TSS, along with significant differences in mean TSL for TP and TSS. Mean concentration of TN (Figure 2.14) was significantly greater for storm events 20-6-1-1 than storm event 20-7-4-5, all other storm events were not significantly different. Storm event 20-6-1-1 rising limb was also significantly different from all other storm codes for mean concentration of TSS (Figure 2.15). Storm event rising limb for 19-7-2-4, 20-8-1-6, and 20-8-2-7 were significantly greater than all other storm codes except 20-7-4-5, which was also not significantly different to all storm even rising limb indicated with a C (Figure 2.15). The mean TSL of TP (Figure 2.16) for rising limb during storm 19-7-2-4 was magnitudes greater than all other storm events other than 19-6-1-1 and 20-7-3-4, no other significant differences existed within the data. The mean TSL of TSS (Figure 2.17) for rising limb during storm 19-7-2-4 was magnitudes greater than all other storm events, but only 20-6-1-1 and 20-7-1-2 were significantly different from 19-6-1-6 and 20-8-2-7. All other storms did not show significant differences between one another (Appendix B). Storm event comparisons seemed to show that nitrogen moves similarly regardless of rainfall amount, but TSS and phosphorus contributions could be affected by rainfall amounts.

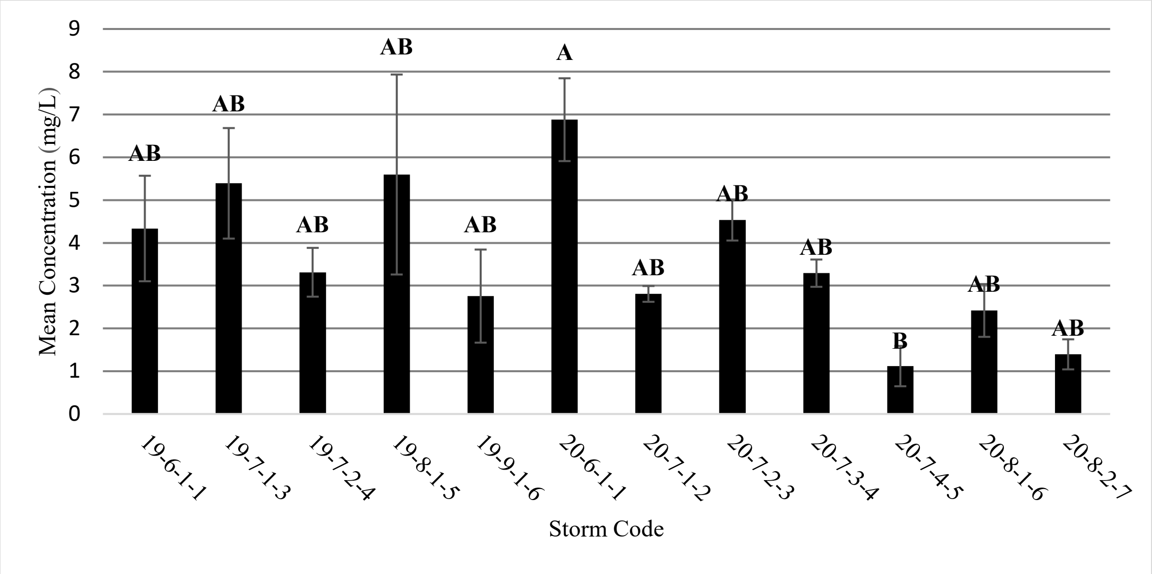

Figure 2.14. Mean Total Nitrogen concentration for the rising limb of the hydrograph by storm event. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

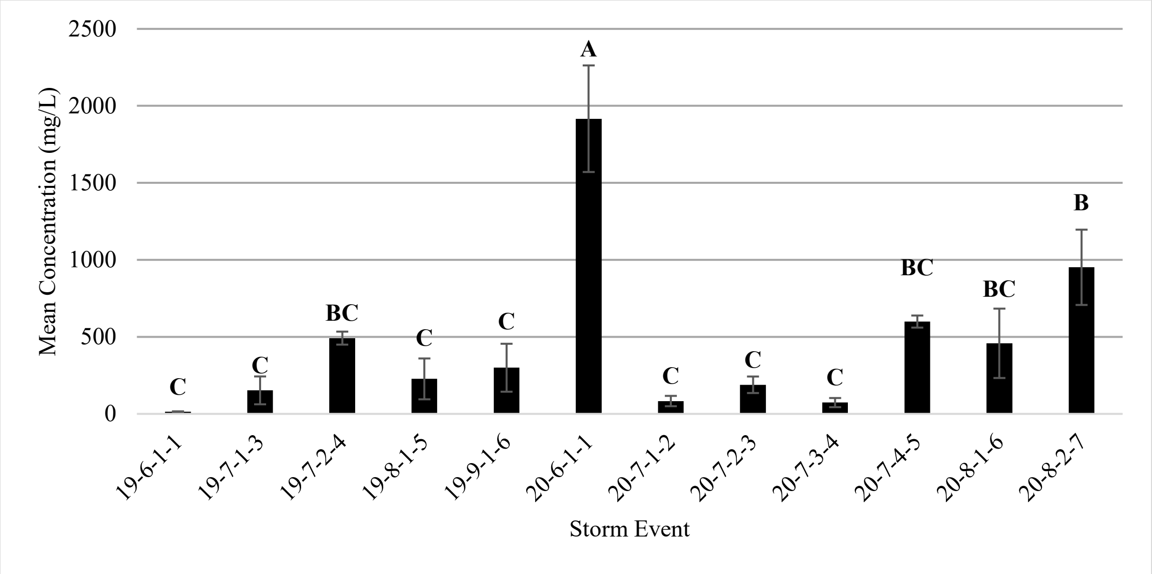

Figure 2.15. Mean Total Suspended Solids concentration for the rising limb of the hydrograph by storm event. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

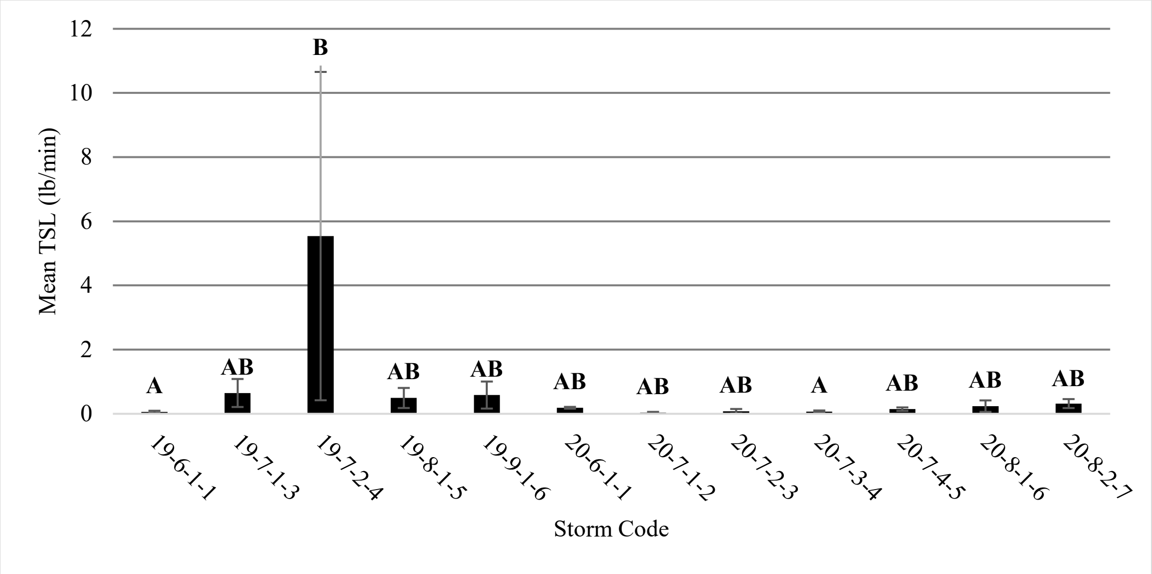

Figure 2.16. Mean Total Phosphorus time step loading for the rising limb of the hydrograph by storm event. Different letters indicate significant differences at $p \leq 0.05$. Bars represent standard error.

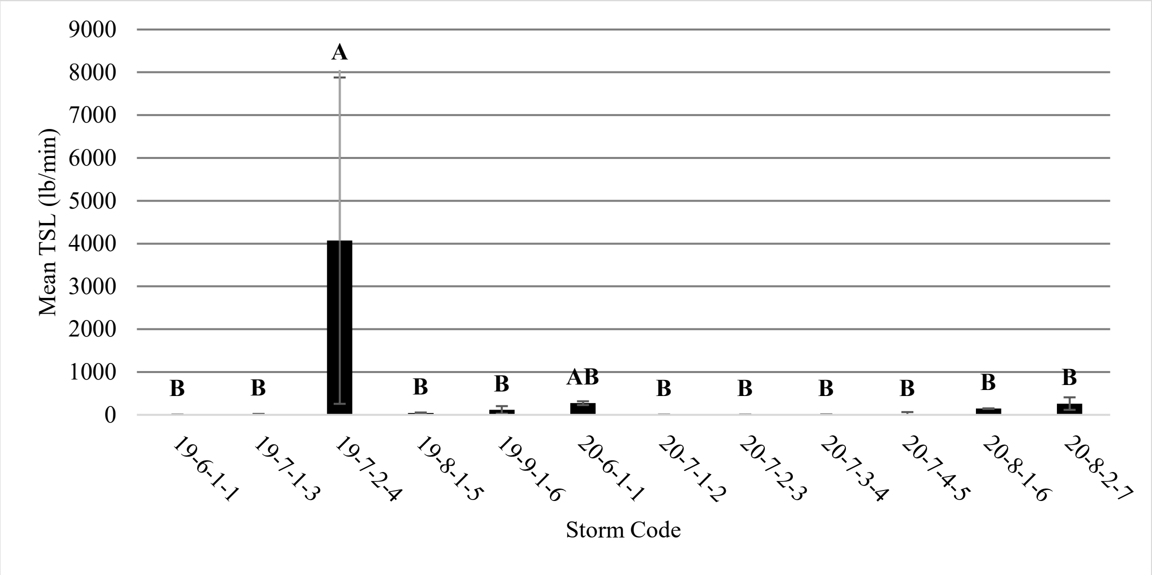

Figure 2.17. Mean Total Suspended Solids time step loading for the rising limb of the hydrograph by storm event. Different letters indicate significant differences at $p \leq 0.05$. Bars represent standard error.

2.4.2.2. Hydrograph Peak

Mean concentrations for TN, N+N, and TSS were not found to be significantly different between the five sample sites for the peak limb of the hydrograph. There were observed significant differences between sample sites for TP (Figure 2.18), where sites Little 13 was significantly greater than 81 Cross, 70-N, and 70-S. Drain 30 was not significantly different then Little 13 or the three other sites, but did have the second highest mean concentration of TP. Mean concentrations of DP (Figure 2.19) were greatest at Little 13, which was not significantly different to Drain 30, but was greater than all other sites, and these two sites were significantly different from 81 Cross, 70-N, and 70-S. All constituents (TN (Figure 2.20), N+N (Figure 2.21), TP (Figure 2.22), DP (Figure 2.23), and TSS (Figure 2.24)) displayed the same trend for mean TSL, with 81 Cross being significantly greater than the other four sample sites. This is likely due to the fact that 81 cross contains water from all of the other individual drains in one stream of water as it flows through the area, leading to higher TSL for all constituents at the peak of the hydrograph.

When analyses were conducted on peak samples comparing storm events, no significant differences were found for TSL and storm event (Appendix C). For TSS (Figure 2.25) mean concentration was significantly less for storm event 19-6-1-1 compared to all other storm events sampled during the study. Mean N+N (Figure 2.26) concentrations were also found to be significantly different between storm events. The 19-6-1-1, 19-8-1-5, 20-6-1-1 storm event was significantly greater than the 20-7-4-5, 20-8-1-6, and 20-8-2-7 events. All other storm events were not found to be significantly different to each other for mean N+N concentrations.

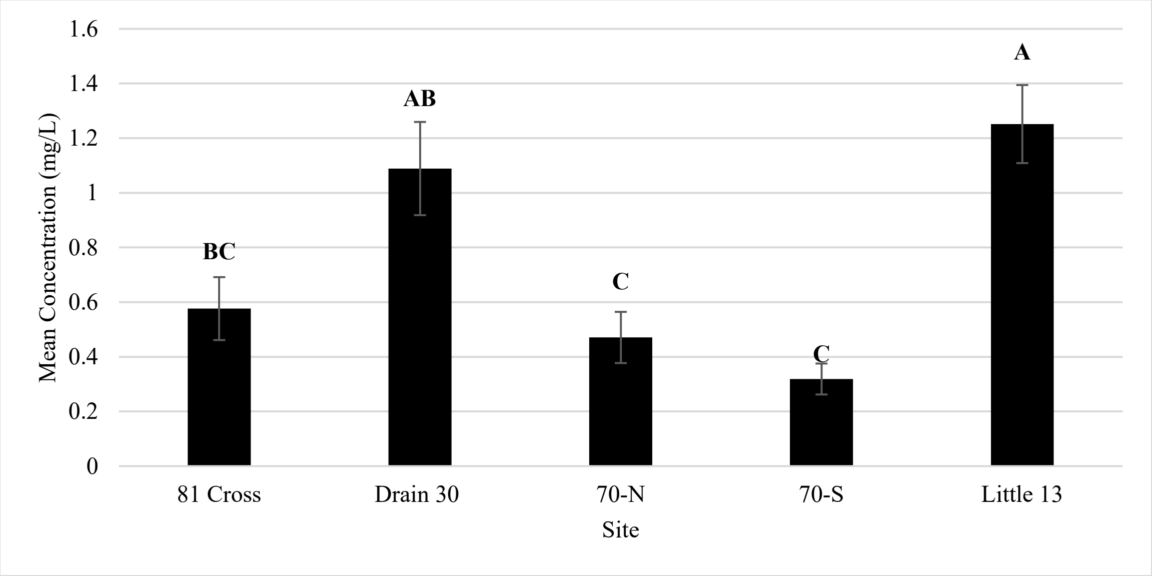

Figure 2.18. Mean Total Phosphorus concentration for the peak of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

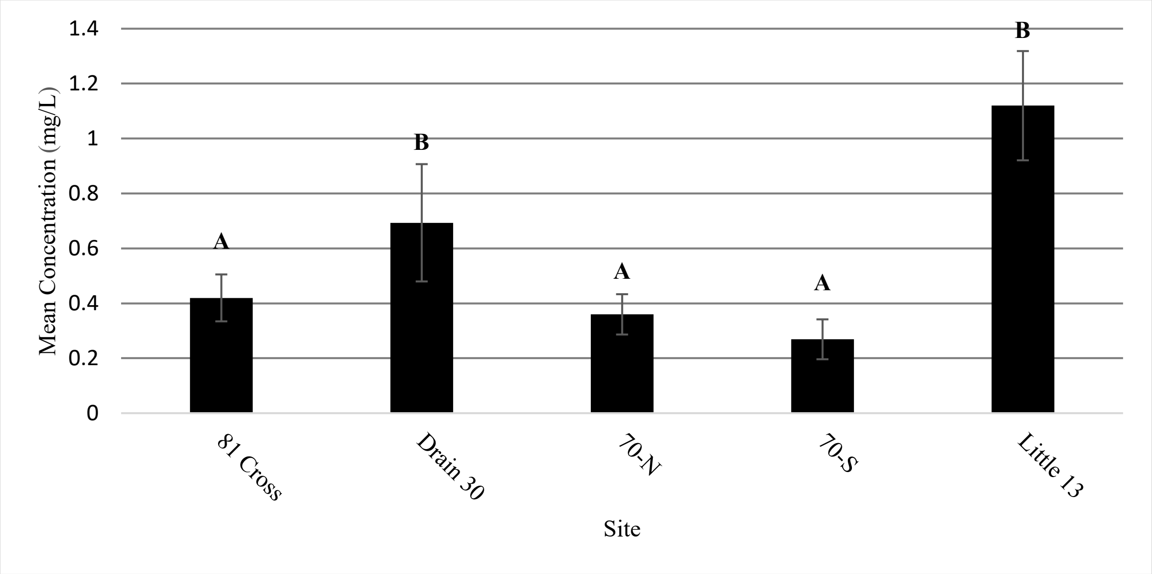

Figure 2.19. Mean Dissolved Phosphorus concentration for the peak portion of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

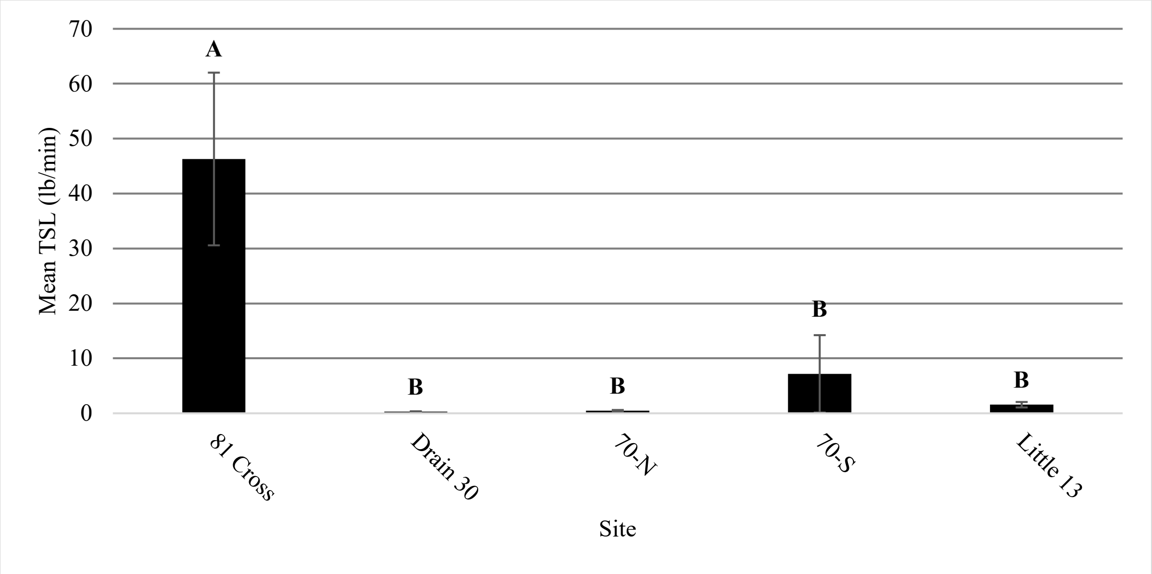

Figure 2.20. Mean Total Nitrogen time step loading for the peak of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

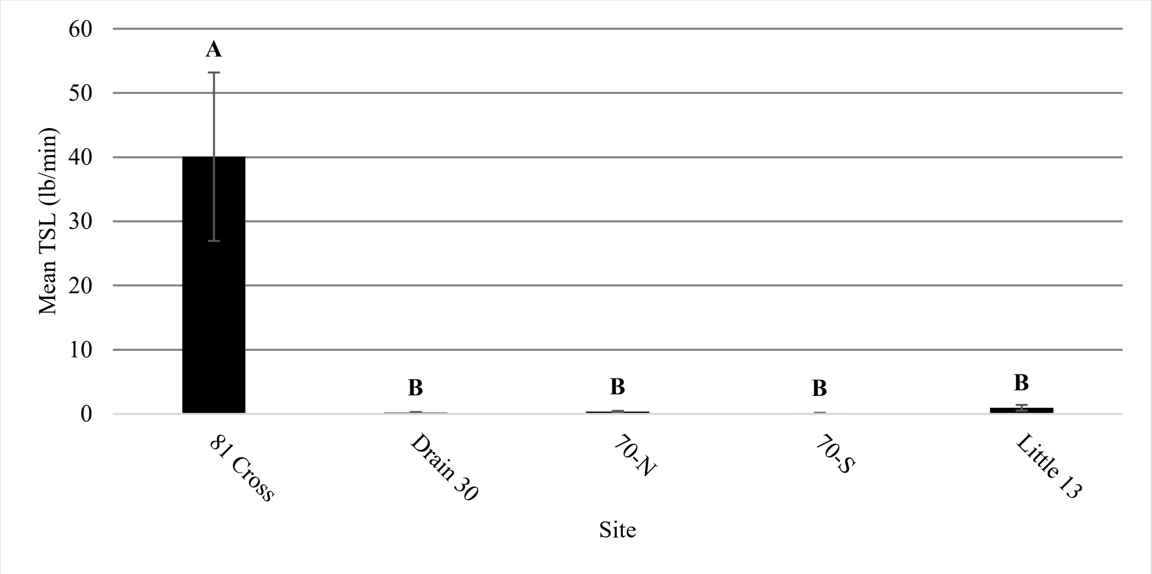

Figure 2.21. Mean Nitrate + Nitrite time step loading for the peak portion of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

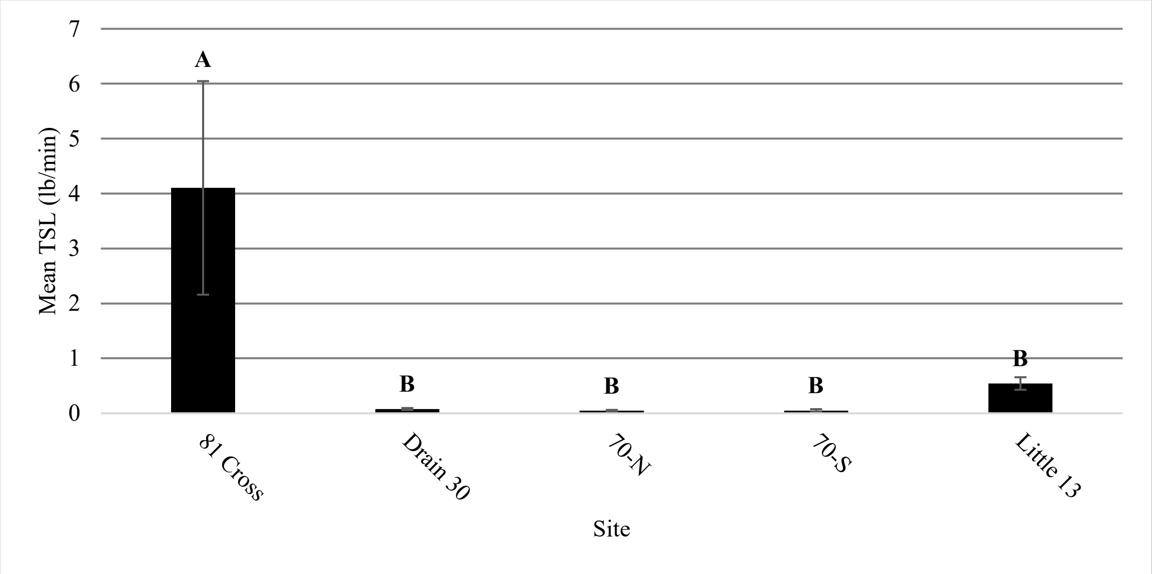

Figure 2.22. Mean Total Phosphorus time step loading or the peak of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

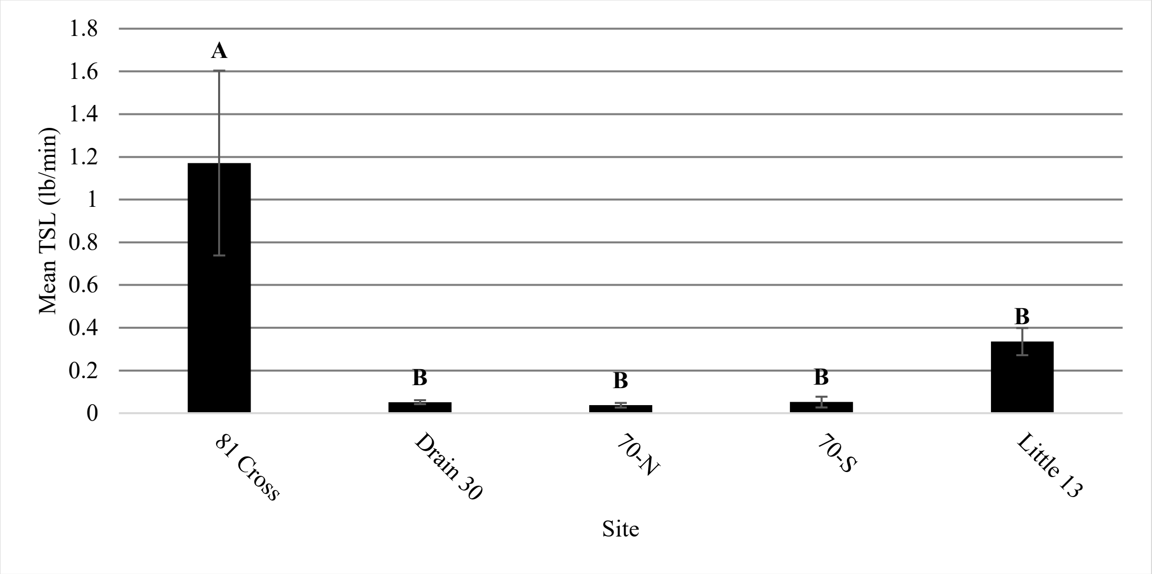

Figure 2.23. Mean Dissolved Phosphorus time step loading for the peak portion of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

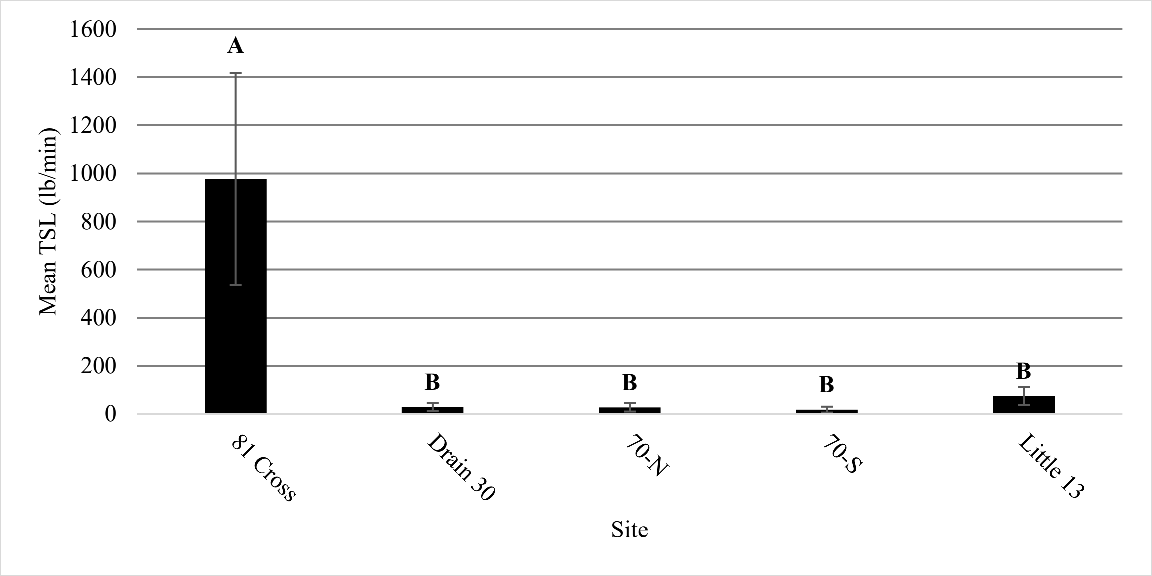

Figure 2.24. Mean Total Suspended Solids time step loading for the peak of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

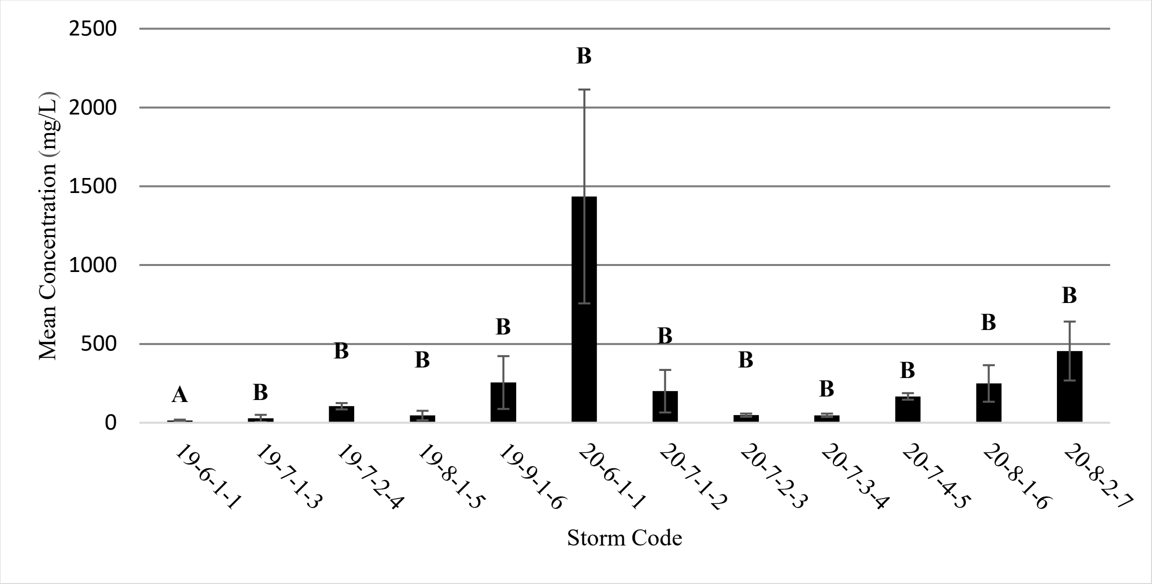

Figure 2.25. Mean Total Suspended Solids concentration for the peak of the hydrograph by storm event. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

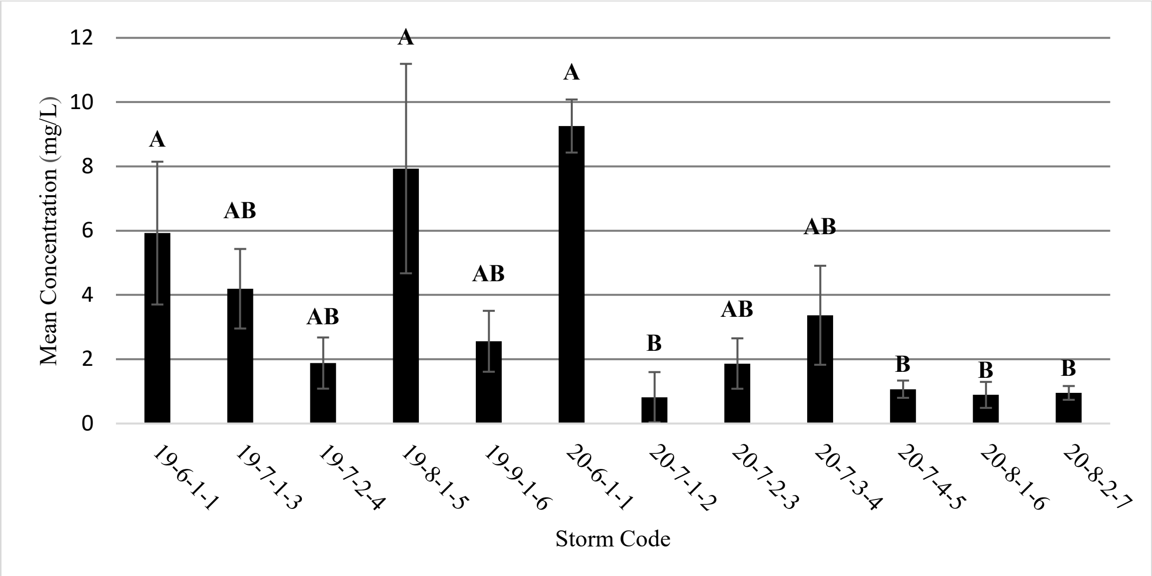

Figure 2.26. Mean Nitrate + Nitrite concentration for the peak portion of the hydrograph by storm event. Different letters indicate significant differences at $p \leq 0.05$. Bars represent standard error.

2.4.2.3. Hydrograph Falling Limb

Results for mean concentration during the falling portion of the hydrograph did not show any significant differences when comparing sites (Appendix D). Results for mean TSL were found to have significant differences between sites for all four of the constituents. Mean TSL for TN (Figure 2.27) and N+N (Figure 2.28) both displayed a trend of 81 Cross mean TSL being significantly higher than the four other sample sites. Mean TSL for TP (Figure 2.29) showed a significantly higher amount at 81 Cross compared to 70-N, 70-S, and Drain 30, while Little 13 was found to not be significantly different from any other site.

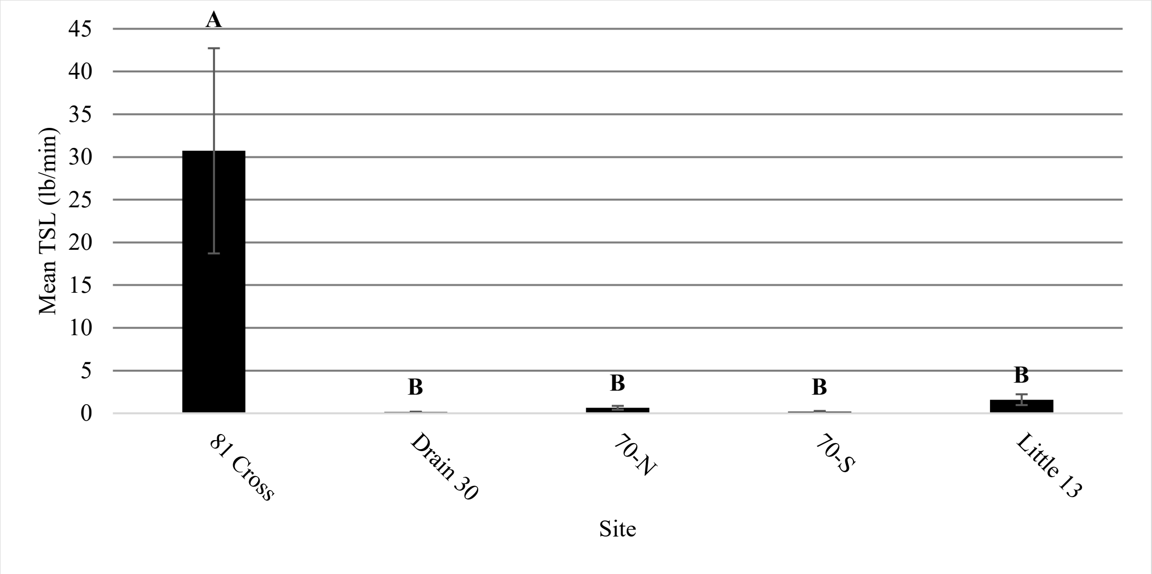

Figure 2.27. Mean Total Nitrogen time step loading for the falling limb of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

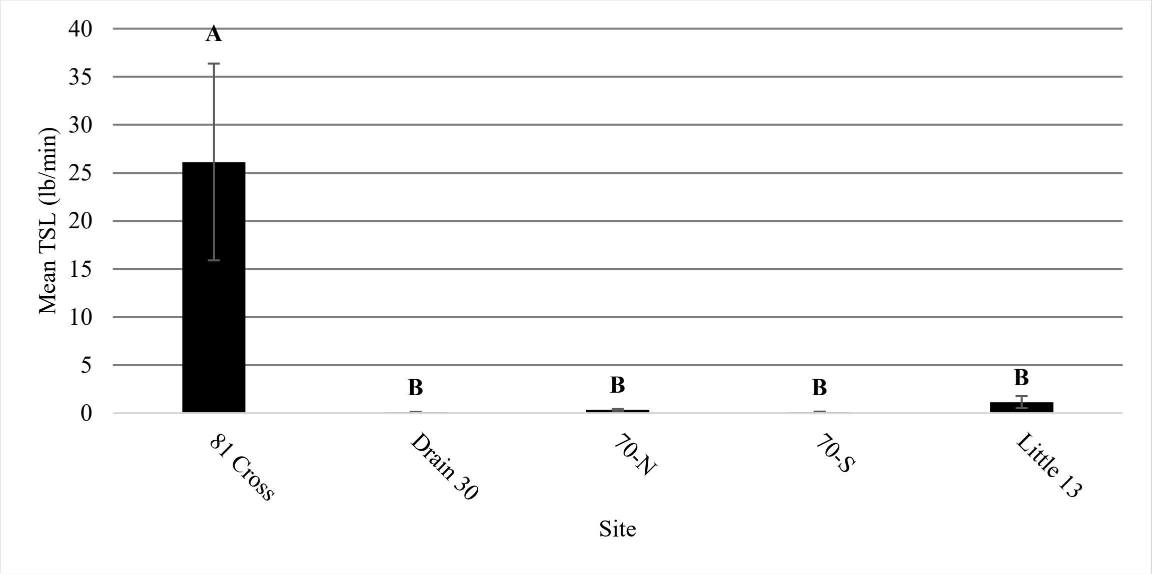

Figure 2.28. Mean Nitrate + Nitrite time step loading for the falling limb of the hydrograph by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

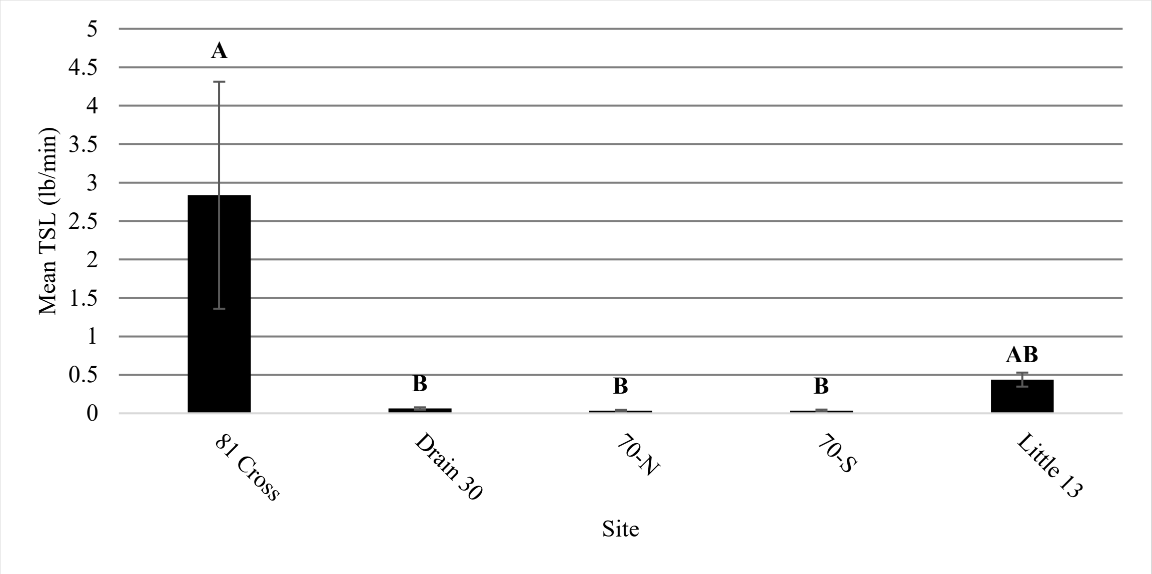

Figure 2.29. Mean Total Phosphorus time step loading for the falling limb of the hydrograph by site. Different letters indicate significant differences at $p \leq 0.05$. Bars represent standard error.

Mean concentration for samples taken during the falling limb of the hydrograph did not have significant differences for TN and TP when comparing storm events (Appendix D). Mean concentration of N+N (Figure 2.30) during event 19-6-1-1 was significantly greater than all storms except events 19-7-3-1, 19-8-1-5, 20-6-1-1, and 20-7-2-3. The four events which were not significantly different than the 19-6-1-1 storm were also not significantly different than all other events sampled. Significant differences between storm events were observed for falling limb samples of TSS (Figure 2.31). Mean concentration of TSS was found to be significantly greater between storm event 20-6-1-1 and all other storms except 20-8-1-6 and 20-8-2-7, which were not significantly different from any other storm events. Results for TSL of all four constituents during the falling limb of the hydrograph were not found to be significantly different among the sampled storm events (Appendix D).

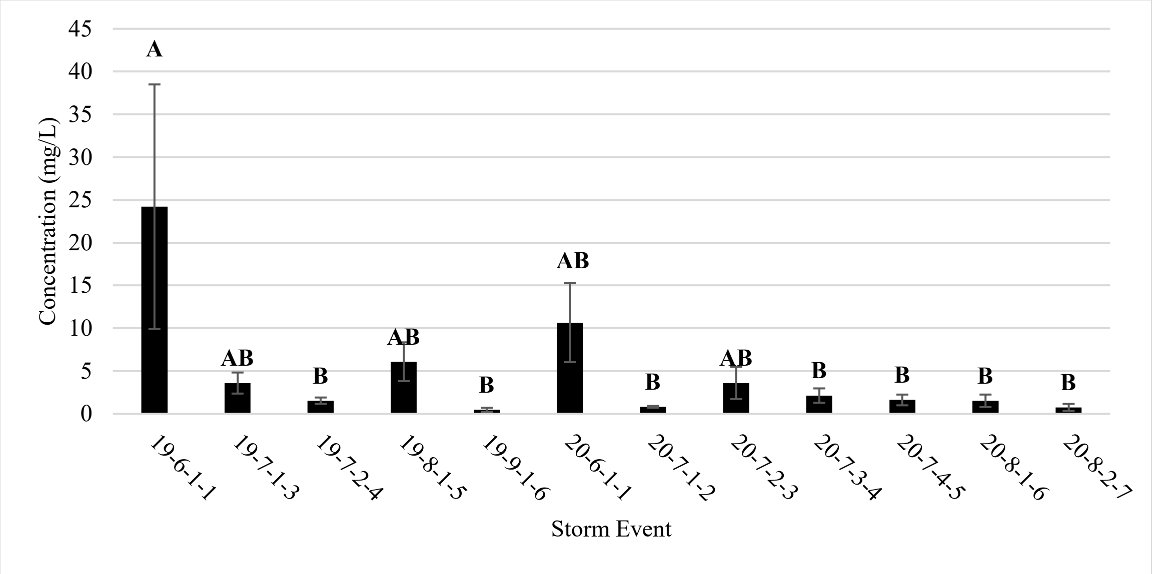

Figure 2.30. Mean Nitrate + Nitrite concentration for the falling limb of the hydrograph by storm event. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

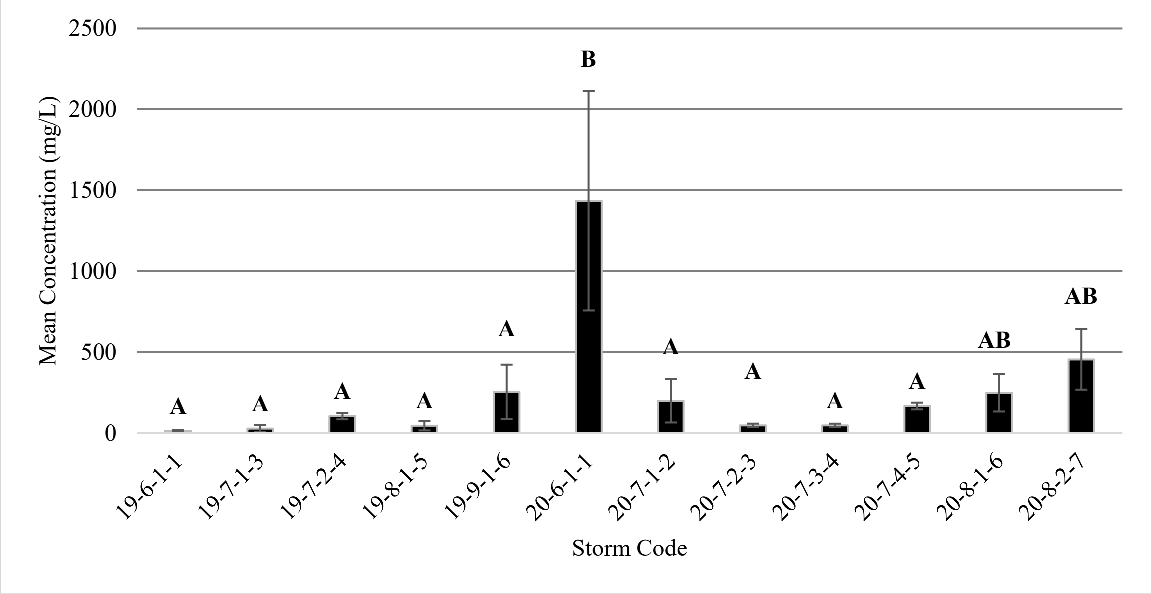

Figure 2.31. Mean Total Suspended Solids concentration for the falling limb of the hydrograph by storm event. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

2.4.3. Electrical Connectivity

During the second year of this study (2020), electrical conductivity loggers were placed at each sample site and logged EC every 15 minutes from June 1st to September 1st. Sites 81 Cross, 70-N, and 70-S showed highly variable EC measures (Figure 2.32) compared to those of

Drain 30 and Little 13. This is possibly due to 81 Cross, 70-N and 70-S nearly drying completely several times during the sampling season. Little 13 and Drain 30 tended to hold some water throughout the sampling season. EC is often used as a surrogate for TDS (Miguntanna et al., 2010), our study does follow this trend as significant differences ($p<0.05$) were found among all five sample sites for EC when a one-way analysis of variance was completed on the data set, though it is worth noting the sample size was very large. Over 8,000 observations were taken for each of the five sites, allowing for extremely accurate means to be calculated, the large number of observations could be the cause of all five being significantly different even though the means of some drains are strikingly near the means of other drains.

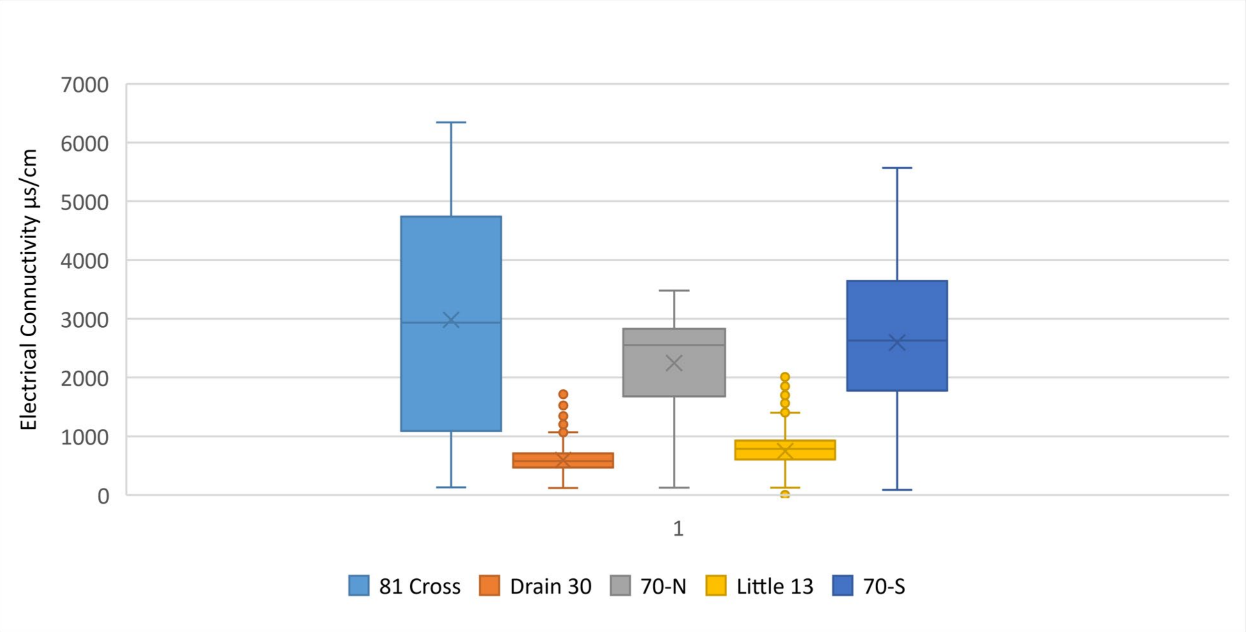

Figure 2.32. Continuous Electrical Conductivity results taken from June 1st to September 1st, 2020.Significant differences were found between all five sample sites ($P>0.05$).

2.4.4. Implications for Study Area

Results show few differences between study sites within the three sampled limbs of the hydrograph in respect to mean concentrations of the examined constituents. For TP, mean concentration was highest during peak samples at the five sample sites, and mean loading was also greatest at this sampling point. This observation agrees with observations of Correll et al. (1999) who observed the greatest flux just prior to the hydrograph peak. Larger storm events and early season events were shown to contribute higher mean TP to the system. Phosphorous is normally thought of as a surface runoff issue (Peron et al., 2009), so it was not surprising that early season events and large storm events caused high fluxes in TP. Early in the growing season plant canopy does not intercept as much water, and general plant water uptake is much lower than in the later growing stages. This could allow for increased surface runoff. It is worth mentioning that the silty clay soils that dominate the study area have low Ksat values, due to this infiltration is extremely slow, causing ponding and eventual surface runoff to occur very quickly. If subsurface drainage is introduced on a mass scale within the watershed some surface runoff could be reduced, potentially altering TP fluxes within the watershed. Interestingly, Peron et al. (2009) observed interactions between tile lines and P to increase P movement within the watershed.

Preferential pathways such as earthworm or root channels allow P to move quickly into tile systems rather than being tied up in the soil profile (Nielsen et al., 2010). The shrink/swell behavior of shmectitic clays in the Red River Valley could also behave as direct lines for P to access tile drains. During the growing season these soils tend to crack when dry periods persist, allowing large pathways to form deep in the soil profile. Following a rain event these pathways can close, but only after the soil begins to near saturation, allowing for would be surface runoff to enter the fissures and potentially interact with tile systems below the soil surface. In the literature high P export rates have been associated with high tile discharge rates due to precipitation events (Enright, 2004; Vidon and Cuadra, 2011; Smith et al., 2015). Overall, DP made up <10% of average TP at every site other than Little 13, where DP made up 31% of the average TP concentration. Often DP is a concern because it is more bioavailable compared to other forms of P in an aquatic system. If subsurface drainage is implemented the ratio between DP and TP can be altered, one possible cause of this can be explained by the decrease in surface runoff often observed in efficient tile systems.

The movement of N has long been associated with tile drainage, particularly N+N movement (Goswami et al., 2009; Amado et al., 2017). Our study found that there were no significant differences between sites and timing in the hydrograph for TN and N+N measures. There does appear to be trends between event timing and sample years. Later events tended to be similar to each other within their respected years, possibly due to mid-season dry periods that hamper denitrification processes (Goswami et al., 2009). Trends between years could be linked to cropping systems as normal practice in the Red River Valley would be to alter crop types on a given field annually (King et al., 2016). The transport of N via tile drainage has been shown to correlate with precipitation events (David et al., 1997; Mager et al., 2004; Goswami et al., 2009). If tile drainage is introduced to this watershed, we expect N fluxes to increase, with the increased connectivity between the stream and the soil profile via tile lines.

Overall, TSS observations showed a trend of initial flux early in the hydrograph prior to stream peak. Subsurface drainage research tends to focus on nutrient transport while TSS is not a primary factor of any tile study to date. In the Red River Valley high TSS is a common impairment (NDdEQ, 2019; MPCA, 2020). It is commonly thought that subsurface drainage reduced surface runoff by allowing the soil profile to accept more water then what might naturally be available. Due to this, there is a possibility that TSS could be reduced through tile installation. It is more likely that because of the small particle size of Red River Valley soil types that other best management practices would be needed to alleviate TSS contributions within the study site.

2.5. Conclusion

Agricultural drainage has moved to the forefront of water quality concerns due to high profile cases such as the Gulf of Mexico's hypoxic zone, and Lake Erie and Lake Winnipeg harmful algae bloom problems. Subsurface drainage, a commonly used practice to lower water tables within agricultural fields, can act as a route for nutrients to move into surface waters. No study to our knowledge has been able to look at the pre and post installation effects of tile on a watershed scale. Globally, subsurface drainage will likely become more and more utilized to increase agricultural productivity. Understanding the relationship between a watershed, nutrients, and tile instillation is pivotal in making meaningful planning recommendations to landowners.

This study identified and evaluated four distinct watersheds that share the same pour point, allowing for simultaneous evaluation of tiles effects on water quality and impact of installed best management practices. This project provides baseline data and lays the ground work for continued research within the study area to better answer if tile drainage effects warrant concern on water quality issues at a watershed level. Once understood, these effects can be studied and tested for control measures through known BMPs such as saturated buffers, controlled drainage, and bioreactors. It is because of this, comparing pre and post water quality parameters during subsurface drainage installation is so important to water quality issues moving into the future.

2.6. Literature Cited

Acharya, U., Chatterjee, A., and Daigh, A.L.M. (2019a). Effect of subsurface drainage spacing and depth on crop yield. *Agronomy Journal*. 111(4), 1675-1681.

Acharya, U., Chatterjee, A., and Daigh, A.L.M. (2019b). Effects of subsurface drainage, crop rotation, and tillage on crop yield in Fargo clay soil. *Journal of Soil and water conservation*. 74(5), 456-465.

Blann, K.L., Anderson, J.L., Sands, G.R., and Vondracek, B. (2009). Effects of Agricultural Drainage on Aquatic Ecosystems: A Review. *Critical Reviews in Environmental Science and Technology*, *39*(11), 909-1001. doi:https://doi.org/10.1080/10643380801977966.

Christianson, L.E., Harmel, R.D., Smith, D., Williams, M. R., and King, K. (2016). Assessment and Synthesis of 50 Yeats of Published Drainage Phosphorus Losses. *Environmental Quality*, *45*(5), 1467-1477.

David, M.B., Gentry, L.E., Kovacic, D.A., and Smith, K.M. (1997). Nitrogen Balance in and Export from an Agricultural Watershed. *Journal of Environment Quality*, 26(4), 1038. doi:10.2134/jeq1997.00472425002600040015x.

De Schepper, G., Therrien, R., Refsgaard, J.C., and Hansen, A.L. (2015). Simulating coupled surface and subsurface water flow in a tile-drained agriculture catchment. *Journal of Hydrology*, 521, 374-388.

Enright, P., and Madramootoo, C.A. (2004). Phosphorus losses in surface runoff and subsurface drainage waters on two agricultural fields in Quebec. p. 160–170. *In* R.A. Cooke (ed.) Drainage: Proceedings - International Symposium, 8th, Sacramento, CA. 21–24, Mar. 2004. American Society of Agricultural and Biological Engineers. St. Joseph, MI.

Goswami, D., Kalita, P., Cooke, R., and Mcisaac, G. (2009). Nitrate-N loadings through subsurface environment to agricultural drainage ditches in two flat Midwestern (USA) watersheds. *Agricultural Water Management*, 96(6), 1021-1030. doi:10.1016/j.agwat.2009.02.007.

Hillel, D., Warrick, A.W., Baker, R.S., and Rosenzweig, C. (1998). Content and Composition of Soil Air. In: Hillel. D., Environmental Soil Physics. Academic Press, San Diego, CA. p.277-290.

Hillel, D., Warrick, A.W., Baker, R.S., and Rosenzweig, C. (1980). Suface runoff and water erosion. In: Hillel. D., Environmental Soil Physics. Academic Press, San Diego CA. p. 427-448
King, K.W., Fausey, N.R., and Williams, M.R. (2014). Effects of subsurface drainage on streamflow in an agricultural headwater watershed. *Journal of Hydrology*, 519, 438-445.

King, K.W., Williams, M.R., Macrae, M.L., Fausey, N.R., Frankenberger, J., Smith, D.R., Smith, P.J., Kleinman, A., and Brown, L.C. (2015). Phosphorus Transport in Agricultural Subsurface Drainage: A Review. *J. Environ. Qual*. 44:467-485. doi:10.2134/jeq2014.04.0163

Lavaire, T., Gentry, L.E., David, M.E., and Cooke, R.A. (2017). Fate of water and nitrate using drainage water management on tile systems in east-central Illinois. *Agricultural Water Management*, 191, 218-228.

Minnesota Environmental Protection Agency (MPCA. (2020), Proposed 2020 Impaired Waters List, Accessed 3/14/21, https://www.pca.state.mn.us/water/minnesotas-impaired-waters-list
Miguntanna NS, Egodawatta P, Kokot S, and Goonetilleke A. (2010) Determination of a set of surrogate parameters to assess urban stormwater quality. *Science of the Total Environment*. 408(24):6251-9. doi: 10.1016/j.scitotenv.2010.09.015. PMID: 20888615.

Niaghi, A.R., Jia., X., Steele, D.D., and Scherer, T.F. (2019). Drainage water management effects on energy flux partitioning, evapotranspiration, and crop coefficients of corn. *Agricultural Water Management*. 225(20), 1-11.

North Dakota Department of Environmental Quality. (2019). North Dakota 2018 Integrated Section 305(b) Water Quality Assessment Report and Section 303(d) List of Waters Needing Total Maximum Daily Loads. Accessed: 17 March 2021.

https://deq.nd.gov/publications/WQ/3_WM/TDML/1_IntegratedReports/2018_Final_ND_Integrated_Report_20190426.pdf

North Dakota Department of Environmental Quality. (2013). Water quality assessment methodology for North Dakota’s surface waters. Accessed 3/14/21. Water Quality Assessment Methodology for North Dakota’s Surface Waters (nd.gov).

Pates, M. 2011. Handling Wet Soils a Farm Show Focus. Agweek. Available online at http://www.agweek.com/event/article/id/19116/publisher_ID/80/. Date Accessed:17 March 2021

Schindler, D.W., Hecky, R.E, and McCullough, G.K. (2012). The rapid eutrophication of Lake Winnipeg: Greening under global change. *Journal of Great Lakes Research*, 38, 6-13.

Smith, D.R., King, K.W., Johnson, L., Francesconi, W., Richards, P., Baker, D., and Sharpley A.N. (2015) Suface Runoff and Tile Drainage Transport of Phosphorus in the Midwestern United States. *Journal of Environmental Quality,* 44, 495-502

Calijuri, M.L., Castro, J.D., Costa, L.S., Assemany, P.P., and Alves Mattos. J.E. (2015). Impact of land use/land cover changes on water quality and hydrological behavior of agricultural subwatershed. *Environmental Earth Science*, 74, 5373- 5382.

Rijal, I., Jia, X., Zhang, X., and Steele, D.D. (2012) Effects of subsurface drainage on evapotranspiration for corn and soybean crops in southeastern North Dakota. *Irrigation and Drainage*. 138(12), 1060-1067.

Wang, Z., Shao, G., Lu, J., Zhang, K., Gao, Y., and Ding, J. (2020) Effects of controlled drainage on crop yield, drainage water quantity and quality: A meta-analysis. *Agricultural Water Management,* 239, 1-14.

CHAPTER 3. VALUE OF AN INTERDISCIPLINARY MAJORS CAPSTONE COURSE IN THE NATURAL RESOURCE SCIENCES

3.1. Abstract

Post-secondary curriculum is designed to prepare students for their careers following graduation, which traditionally revolves around technical aspects of their respected career field. Capstone courses were introduced to help ease students' transition from the university into their career following graduation. However, little research has been done on the effectiveness of capstone courses. This study evaluated six years of course graduates from an interdisciplinary capstone course, seeking to understand the skills gained during the course and pieces of the course that were most useful in transitioning students to their future career. Results showed that the course was able to enhance students writing, communication, job preparation, and teamwork skills. Interestingly, students valued learned information on soft skills such as communication and teamwork over technical skills specific to their major. Overall, the students valued the interdisciplinary nature of the course as most natural resource issues are interdisciplinary. Areas that could be improved in this capstone model were focused on improving individual student's verbal communication and presentation skills. Information from this study is useful to colleges and universities across the globe utilizing capstone courses to determine skills that can be taught and to determine if utilizing interdisciplinary work in their course would be beneficial.

3.2. Introduction

Natural resources issues are, by definition, multidimensional, and multidisciplinary (Arthur and Thompson, 1999). This forces professionals to utilize cross discipline thinking and team work to solve management problems. In order to prepare future natural resource professionals, higher education institutions need to implement classes that teach students teamwork, problem-solving skills, and the ability to integrate a broad spectrum of disciplinary-based knowledge in the natural and social sciences (Leefers et al., 1996; Nielsen and Decker, 1995). However, in additional to knowledge, soft skills are also required. Sample et al. (1999) found that employers feel that early career natural resource professionals lack in ability to work as a team and address public concerns. Similarly, Prokopy (2009) found that employers from private firms and public agencies rank ethics, working effectively with others, oral and written communication skills, and being able to define a problem as top skills needed for professionals in natural resources. One way education institutions are answering the need for these skills is by implementing a capstone course in the final semester(s) of a student's curriculum. These courses often implement a professional expectation, including knowledge and soft skills, to simulate what a student might encounter once graduated.

Trends in the literature regarding capstone courses within the natural resource sciences tend to fall into one of two categories. The first, utilizing classic pre and/or post course evaluations to gauge student perceptions of course goals (Berkson and Harrison 2002; Sargent et al. 2003). This structure of study provides good insight into how students gain skills from completing the course, though they provide little insight into the effectiveness of the courses main goal, preparedness for professional careers. The second trend involves surveying individuals within a professional setting, whether that be potential employers or past students (Proposky 2009; Sample et al. 1999; Sample et al. 2015).

The studies surveying potential employers and past students have brought to light the need for specific skills when entering a natural resources field, though they do not evaluate if their students possess these skills. A study by Proposky (2009) showed the top six skills needed for employees (from an employer's perspective), five were soft skills including ethics, working effectively with others, managing time effectively, oral and written communication skills, and being able to define a problem. Similarly, in Sample et al. (1999) employers once again ranked soft skills such as ethics, written communication, oral communication, collaborative problem-solving, and managerial leadership higher than many technical skills. The Sample et al. (1999) study was improved upon in Sample et al. (2015), and in 2015 they again showed soft skills like communication and teamwork outranked many technical skills. Sample et al. (1999) and Sample et al. (2015) also gauged past graduates perceptions of their preparedness on the same skills ranked by employers. A trend was identified in that skills employers felt were most important, were often the same skills in which the past graduates had the least confidence (Sample et al., 1999; Sample et al., 2015). These studies exemplify the importance of capstone courses preparing students for the professional world and soft skills following graduation. However, to authors knowledge, only one study to date has evaluated if a capstone class is improving on those skills needed professionally. A 2000 study by Andreasen and Trede evaluated capstone course effectiveness by surveying past graduates on their perceptions of the course as it prepared them for their first career following graduation. The survey questions asked primarily evaluated the course structure and did not go in depth on how the course prepared the student for their career. This is useful for course alteration, but does not inform on the goal of capstone courses in preparing students for their future career. In general, more evaluations of capstone courses in the literature are needed to assist higher education institutions in preparing their students for careers post-graduation.

The current study focuses on how a capstone course helps ease the transition from a student's academic career to their professional career. Understanding what part(s) of a capstone course provide benefits post-graduation, identify skills that were enhanced, and what skills could have been enhanced during the student's time enrolled in the course to better prepare them for careers following graduation. The specific objectives of the study are to:

1.) Gauge the value students put on the interdisciplinary structure of the capstone course.
2.) Gauge the skills learners felt were enhanced and/or learned in the course that can be transferred to other capstone experiences.

3.3. Materials and Methods

3.3.1. Study Site

Located in Fargo, North Dakota, USA North Dakota State University (NDSU) is a land grant university that has a student population of 13,173 total students (NDSU, 2019), population trends are not available for the School of Natural Resources (SNRS), but the College of Agriculture, Food Systems, and Natural Resources which hosts SNRS has a student population of approximately 1,330 students (NDSU, 2019). North Dakota, as a state, exhibits little diversity, the U.S. Census estimates that 87% of North Dakotans identify as Caucasian, the next largest ethnic group being American Indian/Alaska Native making up 5.6% of the population (U.S. Census QuickFacts, 2019). Similarly, North Dakota State University's student population is 82% Caucasian (NDSU, 2019). The study population for this project was past graduates of the SNRS capstone course at NDSU. This course consists of both undergraduate and graduate students, who majored in one of four areas rangeland management, natural resources management, entomology (Graduate only), and soil science. Following graduation, these students if working in the field will either work for a government agency or a private company with job titles such as environmental consultant, biologist, soil technician, etc. It is the goal of the capstone course to prepare students to apply their school knowledge to situations they might encounter in their future career.

3.3.2. Course Overview

The capstone course is primarily taken by fourth-year students in one of the last two semesters of their college career, graduate students are able to take it, though much fewer enroll as it is not a requirement to graduate for masters or doctoral students. At the beginning of the semester, students are placed in small groups and presented with projects brought in by an outside group. These groups have included United States Fish and Wildlife Service, The Nature Conservancy, Audubon, private businesses and consulting firms, and more. Student groups work throughout the semester to draft a management plan aimed at solving the presented problem, finally presenting the finished product to the organization with both a verbal presentation and a written final report/management plan. Throughout the project, students are encouraged to reach out to professionals and collect expert advice on their management ideas, while also drawing information from credible sources such as academic and extension publications. The students, are given a few ideas for potential management options, but really requiring them to think critically of other viable options to solve the presented problem.

Students are required to attend and interact during every class period. In order to create an atmosphere that is reflective conditions following graduation, students are required to act professionally when in class and dress accordingly during final presentations. Throughout the semester, instruction on other real-life situations are presented to the class. Including ethics, where students are handed a situation that has been provided by past graduates or professionals to evaluate how they might handle it. Students are also exposed to potential future jobs, pro's and con's of the types of jobs, benefits package terminology, insurance, and retirement. A major focus of these non-project based class times is centered on resume and cover letter writing, job searching and interview skills. Students are required to choose a job from a job board and create a resume and cover letter for the position. The student's resume and cover letter are evaluated by the instructor, who provides constructive criticism on how the student might better their approach and improve their job search potential.

3.3.3. Survey Creation and Distribution

A survey instrument was created to assess students' perceptions of the effectiveness of an interdisciplinary capstone course post-graduation. The creation of the survey instrument utilized two separate focus groups to hone in questions that would produce the best evaluation of the course and ensure clarity for the user. The first focus group consisted of five graduate students, who had not taken the capstone course, and evaluated the original 31 survey questions for clarity, flow, and content. This group's suggestions led to the addition of two fill in the blank questions used to collect demographic information regarding gender and degree obtained during enrollment, in addition to changes to improve clarity in multiple questions. The second focus group consisted of four different department leaders and one administrator within SNRS and evaluated the survey after it was updated based on student focus group feedback. An additional two questions, one multiple selection and another fill in the blank where added with the goal to identify possible strengths and weaknesses of the school’s curriculum. Additionally, questions utilizing the Likert scale were split to alter the scale used, so that 6 of the questions would have a 6 point scale to include an “I do not remember” option, as these questions were focused on topics only touched on during a single class meeting and there could have been student absences during the topic discussion. The final survey consisted of 35 questions, with 17 questions utilizing a five-point Likert scale, 6 questions using a six-point Likert scale, and twelve questions being primarily open-ended, fill in the black, used to collect information such as current job title, employer, etc. Examples of survey questions can be found in Figure 3.1, and the complete survey instrument can be found in Appendix F.

Please answer the following question using the scale below, selecting the number that best fits your opinion of the question.

Answer Scale

1-Strongly Disagree | 2-Disagree | 3-Neutral | 4-Agree | 5-Strongly Agree

Question: The capstone course provided an opportunity to work in a professional group environment similar to teamwork experiences I have had following graduation/during employment.

Figure 3.1 Example of survey instrument questions and layout.

The survey instrument was distributed through email using Qualtrics (Qualtrics XM, Provo, Utah). Student emails were obtained from the university's alumni association for all individuals who had graduated from SNRS between 2014 (first year of capstone course) and 2020. Those students who graduated in 2019 and 2020 were asked to provide post-graduation contact information at the completion of the capstone course if they were willing to consider taking the survey. When emails were missing or obsolete, attempts to find contact information were conducted via other avenues (ie. Google search, Facebook, etc.). Following approval from the Institutional Review Board (IRB), the instrument was distributed to 151 out of a possible 160 past students. The survey instrument took approximately 10-20 minutes to complete. All survey information received was anonymous. The survey was distributed in June 2020, and was left open for 30 days closing in July. Three reminders were sent out during this time, at 10 days, 16 days, and 20 days after the survey was deployed. Following distribution, a total of 11 emails failed, meaning 140 emails reached their respected mailbox and were able to be completed.

3.4. Results and Discussion

3.4.1. Demographic Information

A total of 79 past capstone students completed the survey out of a possible 140 surveys deployed. This high response rate, 56.4%, is greater than the 50% response rate considered adequate for scholarly work (Baruch and Holtom, 2008), and allowed for the assumption of responses to be reflective of the entire population. Since the responses are reflective of the whole population, no statistical analysis was done on the data set and responses are reported as percentages of the total answers for each question. Survey participants predominantly identified as male (68.3%, n=54) compared to female (31.6%, n=25), no other gender distinction was identified by participants. This demographic breakdown is similar to what is typical in enrollment within the majors that take the capstone course as recorded by the university. As of 2021, the undergraduate student population (freshman through senior combined) for the majors taking the course was 92 students, with 62% identifying as male (n=57) and 38% identifying as female (n=35). In general, participants were predominantly pursuing an undergraduate degree (n=70, 88.6%) at the time of enrollment in the course, compared to graduate students (n=9, 11.4%).

The capstone course was first implemented in 2014 and this survey was launched in 2020, therefore there were seven possible graduation years for participants. Out of the seven possible years, the portion of total responses were highest for 2020 (25.32%, n=20), and percent of participants decreased the longer time since students took the course: 2019 (21.52%, n=17); 2018 (17.72%, n=14); 2017 (11.39%, n=9); 2016 (15.19%, n=12); 2015 (6.33%, n=5); and 2014 (2.53%, n=2). A possible explanation for the unequal response rate is due to collection of emails, for the 2019 and 2020 population, emails were collected during the time those students were enrolled in the course. While the 2014-2018 participants were contacted via emails that were collected via alternative methods, and could have resulted in the survey being sent to an email address that is no longer used by the individual.

When asked to identify their current position title, the largest portion of participants did not identify with a provided option, but rather opted to fill in the blank (Figure 2.2). Participants who were unable to align with a provided option showed a wide spectrum of job titles including First Responder, Wildland Firefighter, Industrial Worker, Military, Invasive Species Manager, Groundskeeper, Easement and Land Acquisition Specialist, Farmer, and Paraprofessional. Of the options provided, Graduate Student was the most represented field (n=12, 15%). Other well-represented job fields included Environmental Scientist and Soil Conservation Manager/Technician representing 13% (n=10) and 10% (n=8) respectfully. There was a significant drop off in representation in any other job title provided, only Biologist (n=3, 4%), Rangeland Manager/Technician (n=3, 4%), Consultant (n=3, 4%), and Soil Scientist (n=2, 3%) had representation over 2% (Figure 3.2).

One possible reason for the high number of participants that identified as graduate students, is that a majority of the individuals surveyed did not leave the university for their graduate work, allowing for easier tracking of correct contact information. The wide variety of job titles was not surprising to authors as the capstone course is interdisciplinary, and therefore students who enroll will enter a wide variety of career paths. Interestingly, some respondents did not identify as working within a natural resources related field, such as one respondent who identified as a paraprofessional. Similar findings were found by Solmon (1981), in which they found approximately 25% of people surveyed indicated that they worked in a field completely unrelated to their college major. It is assumed that this percent would fluctuate over time and based on major. In the current study, participants who identified not working in a natural resources related field was much lower, near 7%. This indicates that graduates of the capstone course are generally finding positions related to their major following graduation.

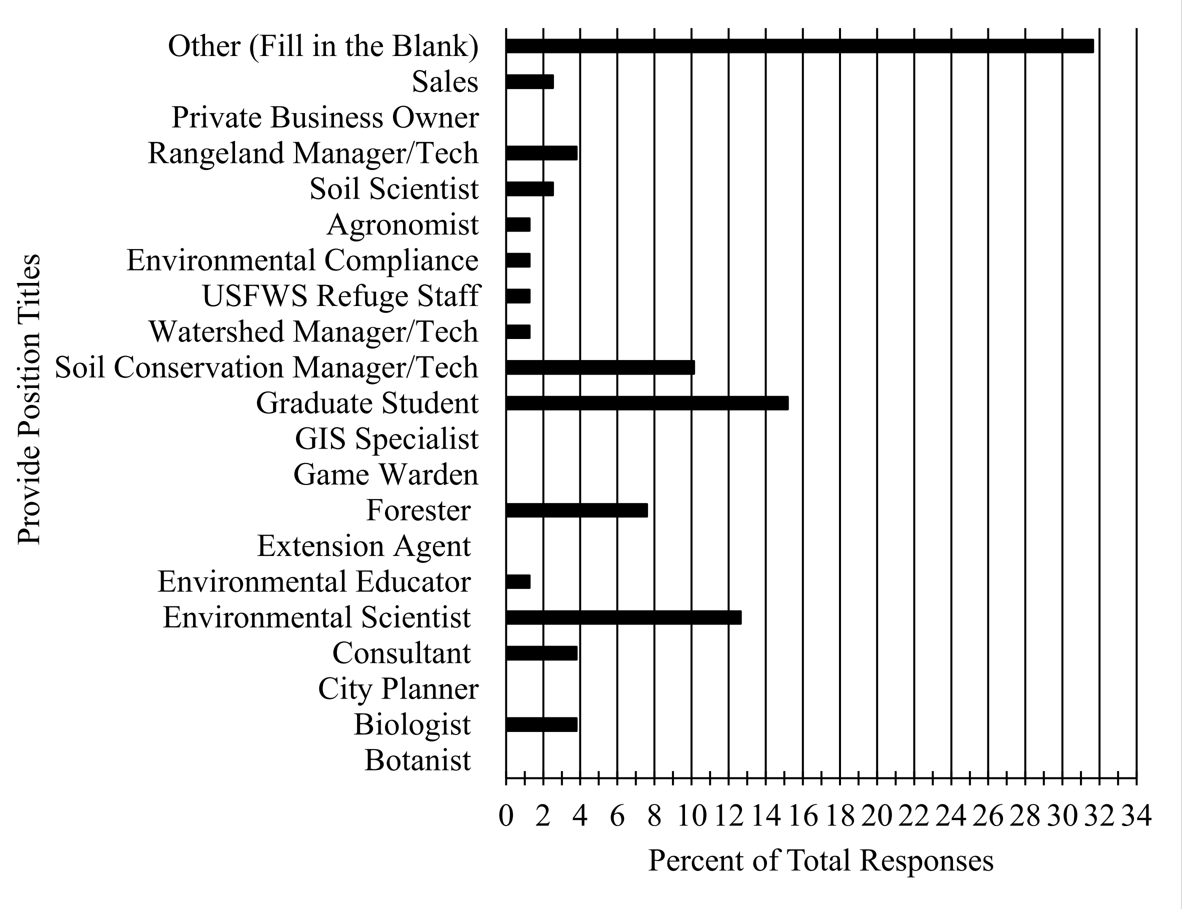

Figure 3.2. Percent of participants who identified with a provided position title, participants whom identified as other were asked to specify.

3.4.2. Professional Skills

3.4.2.1. Teamwork

Teamwork is an important aspect of careers in natural resources, and a skill utilized in the capstone course. Survey participants were asked if the capstone course provided an opportunity to work in a professional group environment similar to teamwork experiences that were needed following their graduation/during employment (Figure 3.3). On average, participants agreed, with an average Likert score of 4.10. For this question there were no responses recorded for strongly disagree, and only 1% (n=1) of responses disagreed. The primary response to this statement was agree (n= 40, 51%) followed by strongly agree (n= 24, 30%), and neutral (n=14, 18%). Participants were then asked if the capstone course increased their ability to work as a team to solve a specific problem and/or question (Figure 3.3). Again, there were no responses strongly disagreeing with the statement, most participants agreed (n=44, 55%), with less participants strongly agreeing (n=21, 27%), neutral (n= 11, 14%), and only 4% (n=3) of participants disagreed, the average Likert score was 4.05.

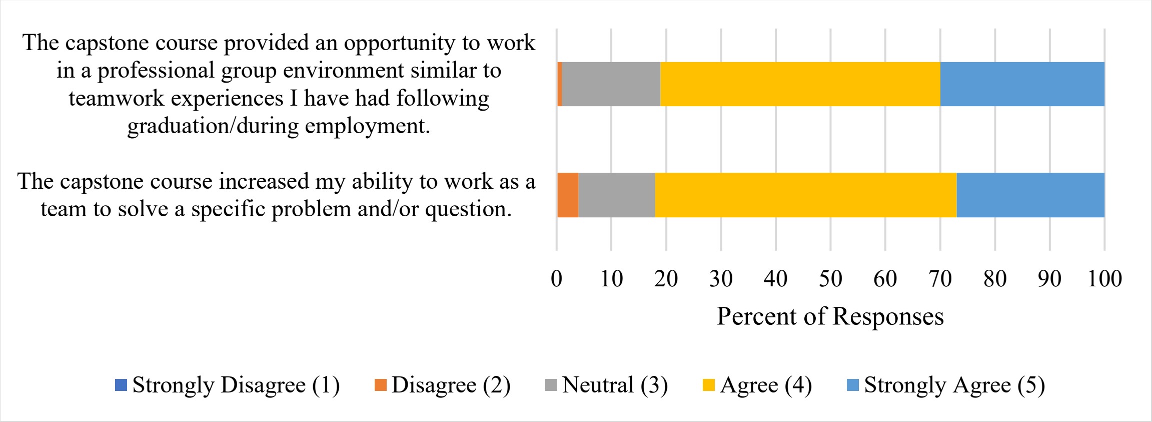

Figure 3.3. Frequency of Likert responses gauging teamwork and problem solving.

Andreasen and Trede (2000) evaluated past students' opinions of their capstone course and found a majority of participants (Likert average = 3.91) felt the course helped prepare them for professional experiences. Conversely, a study by Sargent et al. (2003) evaluated students' opinions of teamwork skills gained during their capstone course with pre and post capstone course surveys. Results showed no difference between surveys, meaning the students did not feel the class helped them gain teamwork skills (Sargent et al., 2003). Often capstone courses operate with a goal of preparing students for work following graduation. The current study's results indicate the course prepared students for teamwork in their professional careers, but based on results of the Sargent et al. (2003) students do not always gain these skills in a capstone course and must gain them somewhere else. Interestingly, Bastarriea et al. (2017) found that students were more aware of the difficulties presented by teamwork following the completion of a capstone course.

3.4.2.2. Writing

In the capstone course, students were expected to write at a technical and scientific level similar to that of general professionals in the field of natural resources. Participants were asked if management plan writing in the capstone course increased their competency in professional/technical writing. The average Likert score for responses was 4.08 (Figure 3.4). Again, there were no recorded responses for strongly disagree, 4% (n=3) disagreed, 14% (n=11) were neutral, 53% (n=42) agreed, and 29% (n=23) strongly agreed with the statement.

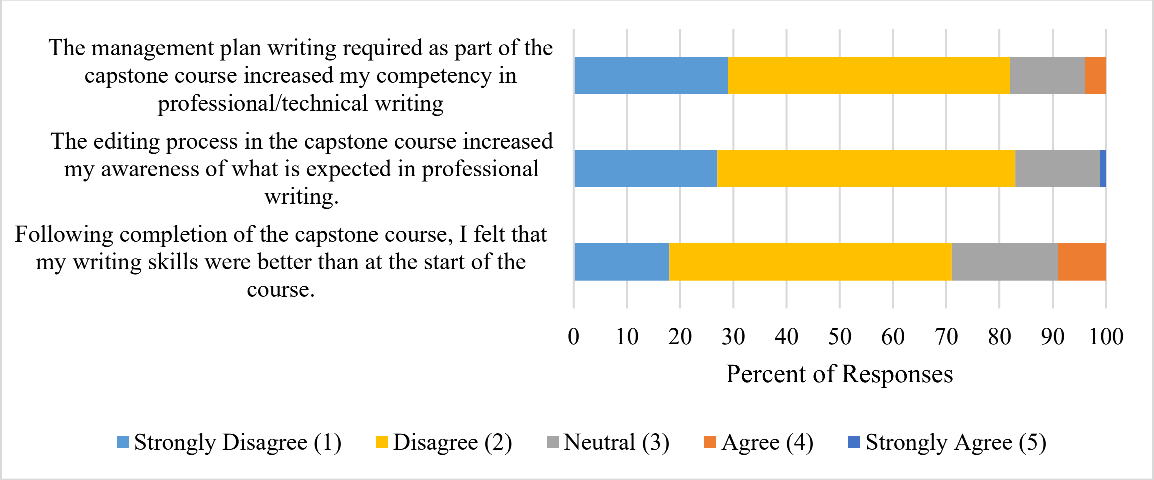

Figure 3.4. Frequency of responses for questions gauging writing skills.

These responses were similar to Andreasen and Trede (2000), where participants were asked if they felt the capstone course increased their competency in report writing, and responses showed an average score of 4.02 on the Likert scale. The results of the current study and those reported by Andreasen and Trede (2000) indicate there is value in including a major writing assignment in capstone courses to improve writing skills and make students career ready.

Students in the capstone course were asked to submit their management plan twice within the semester for commenting by the instructor. Therefore, survey participants were asked if the editing process in the capstone course increased their awareness of what is expected in professional writing in natural resources (Figure 3.4). Likert scores averaged 4.06 for this question, with no responses disagreeing. The majority of participants agreed (n=44, 56%), followed by strongly agree (n=21, 27%), neutral (n=13, 16%), and one participant strongly disagreed with the statement (n=1, 1%). When asked if following the completion of the capstone course participants felt that their writing skills were better than when they started the course, participants average Likert score was 3.80 (Figure 3.4). Most participants agreed (n=42, 53%) followed by neutral (n=16, 20%), strongly agree (n=14, 18%), and disagree (n=7, 9%), no participant strongly disagreed with the statement. The high overall Likert scores to questions focused on writing shows that a strong focus on editing and multiple versions of documents helps to demonstrate what is expected in professional writing, but they may not fully feel their writing improves. Finegold and Notabartolo (2008) and Stillman et al. (2020) explain that employers are willing to spend time teaching skills that pertain to specific job tasks, but skills such as writing and communication are expected to meet their standard at hiring. Therefore, it is imperative that capstone and other college courses provide opportunities for students to be evaluated on and improve their professional writing skills so they are job ready when leaving the university.

3.4.2.3. Communication

Communication skills are pivotal abilities that employers expect new hires to possess (Sample et al., 2015). The following questions focused on learned skills for communication in the capstone course. Students who took the capstone course in the spring of 2020 were not asked questions about the final presentation, as their final presentation was not the same due to the Covid-19 pandemic. Participants that were asked this question felt the capstone course increased their ability to communicate effectively through written word (Figure 3.5). Only one participant strongly disagreed (1%), four disagreed (5%), thirteen were neutral (16%), and 18 strongly agreed (23%), and the agreed (n=43, 54%) with the statement, giving an average Likert score of 3.92.

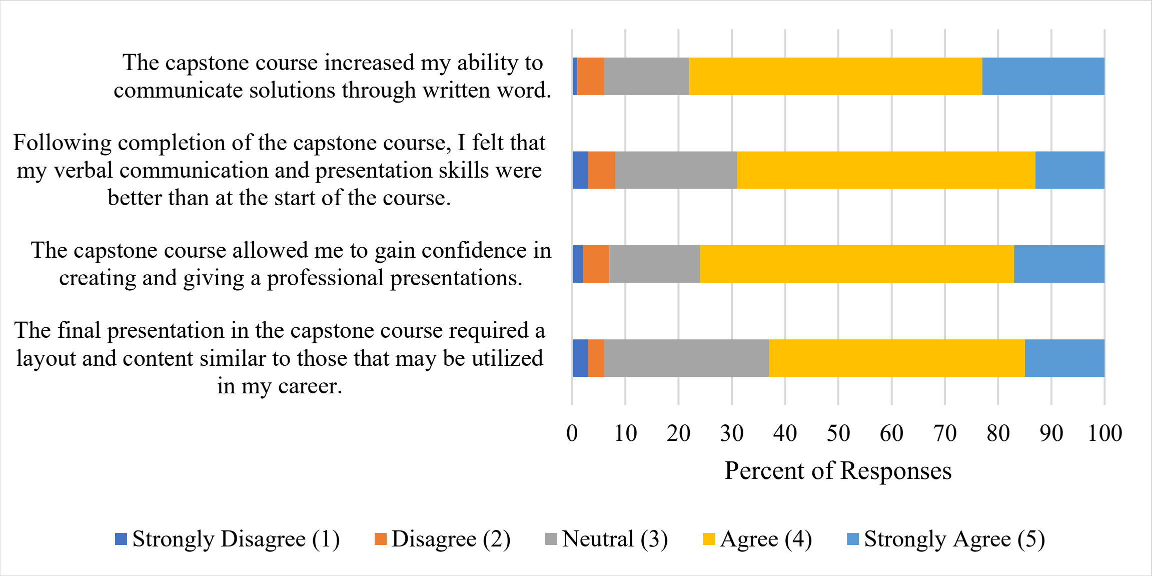

Figure 3.5. Frequency of Likert responses for questions gauging communication skills.

When participants were asked if their verbal communication and presentation skills were better following completion of the course, the average Likert score was 3.71 (Figure 3.5). Most participants agreed (n= 21, 56%), followed by neutral (n= 9, 23%), strongly agree (n= 5, 13%), disagree (n=2, 5%), and strongly disagree (n= 1, 3%). Andreasen and Trede (2000) found a similar average Likert score of 4.02, which was higher than in the current study (3.71). One possible explanation for the lower average score could be due to the structure of the required presentation. The presentation in the capstone course for this study was at the end of the semester and explained the details contained in the written management report. Only one student was required to give the presentation and was chosen by their group. Meaning that one student in a group of four to six gives the presentation, and the others help plan it, but do not need to physically present. Authors recommend that providing more opportunity for verbal expression/presentation of information throughout an entire capstone course may help improve students' verbal communication skills. Additionally, each individual, no matter comfort level with verbal communication, should be encouraged to present so all students are able to improve skills and not just focus on those who are strong presenters already.

Researchers wanted to be assured that the required presentation was bolstering students comfort levels in the preparation/execution of professional presentations, which responses indicate is occurring (Figure 3.5). The average Likert score for this question was 3.84 showing a majority of participants felt that it did help them, with the highest number of participants agreeing (n=34, 58%), followed by strongly agree (n=10, 17%), neutral (n=10, 17%), disagree (n = 3, 5%), and strongly disagree (n= 1, 2%). Layout requirements for the presentation were also evaluated to see if those used in the capstone course were similar to those participants had experienced in their careers. Average Likert score for this question was 3.71, with responses much more variable than other questions in the survey. The highest number of responses fell in the agree category (n= 18, 49%), 31% were neutral (n= 12), 15% strongly agreed (n= 6), and both disagree (n= 1) and strongly disagree (n= 1) each had 3% of responses.

Participants in the study agreed that their confidence preparing for professional presentations was increased by taking the capstone course. There was less agreement on if the course requirements for the presentation met the expectations found in careers post-graduation. A possible explanation for this is the wide variety of positions and disciplines students are currently working in. Further research would need to be conducted to determine if the difference in responses was due to the career participants pursued post-graduation (within discipline or not), not meeting presentation needs for professionals early in their career, or if presentations expectations are different than those taught in class. In general, employers place heavy emphasis on soft skills like communication for recent graduates (Sample et al., 1999; Finegold and Notabartolo, 2008; Sample et al., 2015; Stillman, 2020). Prior research shows students realize the necessity of soft skills over technical skills following the completion of capstone course (Keller et al., 2015; Bastarrica et al., 2017) Each major serviced by a capstone course should evaluate needs for communication post-graduation and incorporate those needs into the class. This will bolster the ability of the capstone course to provide a real world career experience.

3.4.2.4. Source Evaluation

In natural resources, as with most every scientific field, it is important for professionals to provide accurate and sound scientific information. Sharing of information on the internet and social media makes it ever more challenging to distinguish quality information. During a student's time in college it is important to learn how to find quality information and how to differentiate from other less reliable sources. This concept is emphasized in the study's capstone course, and therefore participants were asked if they felt the course increased their knowledge on how to compile quality information to support their ideas, with most agreeing ($\bar{x}$ = 4.17) (Figure 3.6). Most participants agreed (n= 43, 55%), followed by 32% (n=25) strongly agreed, 11% (n=8) neutral, and 3% (n=2) disagree. No participant strongly disagreed.

Another goal of the class is to teach students to navigate the overwhelming amount of information from different sources and apply quality information to support management questions and report findings. Participants on averaged agreed ($\bar{x}$ = 4.09 Likert score) that the management plan writing in the capstone course increased their ability to evaluate and utilize relevant sources/literature for professional use (Figure 3.6). The majority of participants agreed with the statement (n=40, 50%), followed by strongly agree (n=25, 32%), neutral (n= 10, 13%) and disagree (n=4, 5%).

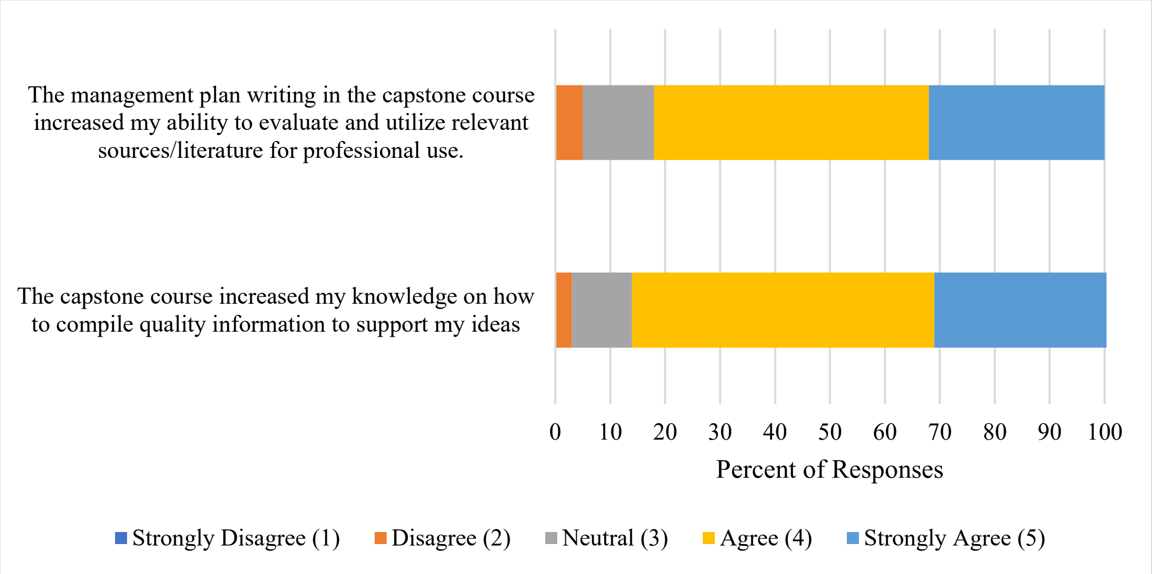

Figure 3.6. Frequency of Likert responses for questions gauging participants' ability to evaluate quality source information.

These results show similar trends to Andreasen and Trede (2000), who had an average Likert score of 3.59 for student improvement in use of quality information and being able to analyze information/literature to distinguish quality. Within the natural resource sciences, utilizing quality information is necessary, and the current study and Andreasen and Trede (2000) demonstrate that capstone courses can provide opportunities for students to improve on these important skills.

3.4.2.5. Critical Interdisciplinary Thinking and Problem Solving

Critical thinking has been outlined as a skill employers find important for employees (Sample et al., 1999; Berkson and Harrison, 2002; Finegold and Notabartolo, 2008). The capstone survey participants felt that the course provided an opportunity to gain critical thinking skills when evaluating management solutions for a parcel of land ($\bar{x}$=4.13) (Figure 3.7). The highest number of responses agreed (55%, n=43) with the statement, followed by strongly agree (31%, n=24), neutral (10%, n=8), and disagree (4%, n=3). Additionally, problem solving has also been identified as an important job skill (Sample et al., 1999; Finegold and Notabartolo, 2008; Sample et al., 2015). Results from the survey indicate that a capstone experience can enhance problem solving skills, as most respondents agreed that the course helped them identifying problems affecting management of land and natural resources (x̄=4.14) (Figure 3.7). The majority agreed (59%, n=47) followed by strongly agree (28%, n=22), neutral (9%, n=7), and disagree (3%, n=2).

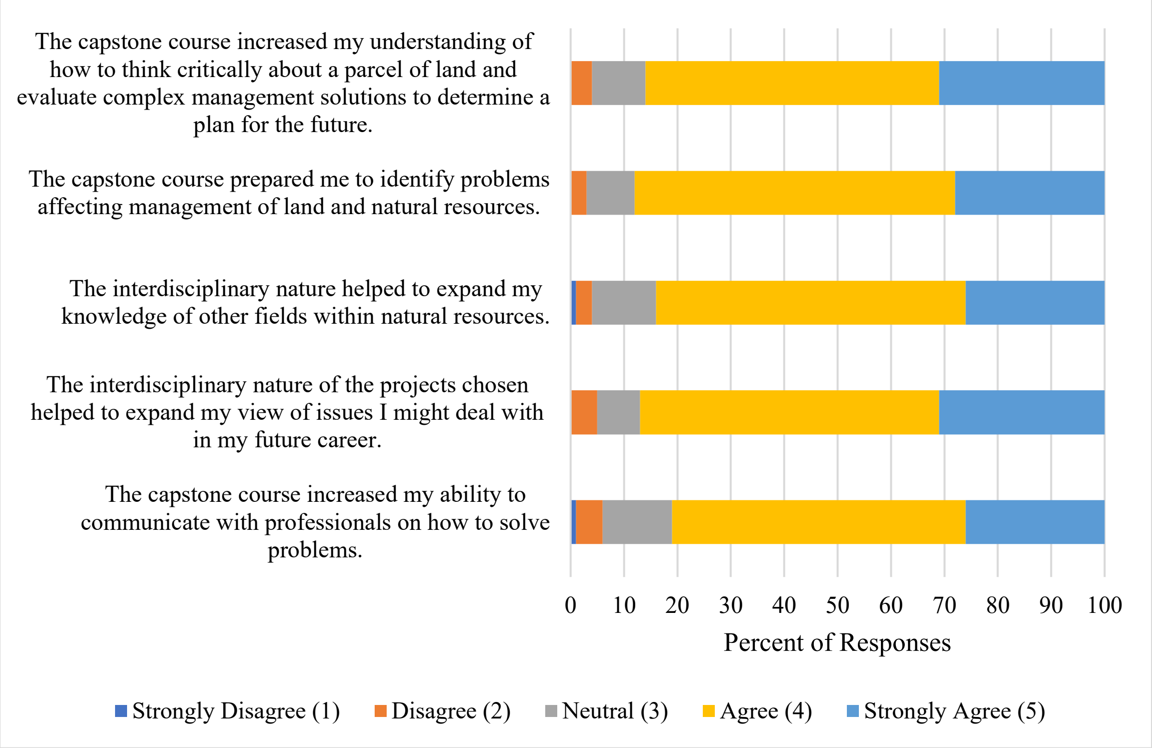

Figure 3.7. Frequency of Likert Scores for questions gauging impact of interdisciplinary natural resource work within the course.

Critical thinking and problem solving within natural resource professions are critical skills. If the capstone course was not preparing students entering their career in problem solving and critical thinking, we would not see the high Likert scores found in responses, with well over 75% agreeing or strongly agreeing. Finegold and Notabartolo (2008) note in their study that analytical skills, such as critical thinking, need to be integrated into education as it is a pivotal skill needed for 21st century businesses. Therefore, authors feel it is important to incorporate these skills into any capstone class no matter the major(s) it is serving.

The capstone course studied for this project allows students from four distinct academic majors to enroll, and students from multiple majors are purposely put in groups together. This allows students to work on diverse projects and utilize interdisciplinary thinking in their work. When respondents were asked if this helped students gain knowledge from different fields in natural resources, most respondents agreed with an average Likert score of 4.06 (Figure 3.7). Within each category, there were 21 agree responses (58%), followed by strongly agree, neutral, and disagree receiving 26% (n=21), 12% (n=9), and 3% (n=2) respectively. A single participant (1%) strongly disagreed. Participants also felt that the inclusion of interdisciplinary structure within the course helped them expand their views on issues they might face in their career, (average Likert 4.14) (Figure 3.7). The majority of participants agreed (57%, n=25), followed by strongly agree (31%, n=25), neutral (8%, n=6), and disagree (5%, n=4). Traditional curriculum in natural resource related majors tends to be primarily focused on scientific content for that particular field, and it often lacks the other disciplines that are involved in natural resources planning and processes (Berkson and Harrison, 2002). The capstone course in this study aims to bridge the gap between those traditional skills necessary for a given field, and intertwine other disciplines, providing students valuable learning experience and increased exposure to other fields of study. Working as part of an interdisciplinary team, even if infrequent, is necessary in most natural resource professions. When this experience is learned in college, it provides a baseline expectation for situations they will incur with interdisciplinary teams in the future.

An important part of working as part of an interdisciplinary team is being able to communicate with colleagues. During the course, groups are encouraged to reach out to area professionals to obtain information related to their management plan/question and discuss solutions. Participants felt the course helped them become more comfortable communicating with professionals to solve a problem (Figure 3.7). The most common response was agree (n=43, 54%), then strongly agree (n= 20, 26%), neutral (n= 10, 13%), disagree (n=4, 5%), and strongly disagree (n=1, 1%), and the average Likert score for this question was 3.99. The majority of participants (80%) agreed or strongly agreed the class helped them work with other professionals, a skill that is valued by employers (Finegold and Notabartolo, 2008). Researchers were unable to find a capstone course outlined in the literature that explicitly encouraged students to reach out to area professionals. Khakurel and Porras (2020) found that the client relations and professionals utilized for the capstone course added a layer of intensity that pushed students to work harder on their final project, while exposing them to real world expectations. If this practice is not commonly associated with capstone courses in other universities, authors would encourage instructors to consider utilizing this technique to teach students to utilize all resources and diversify their knowledge, all while improving their communication and problem solving skills.

3.4.2.6. Ethics

During the semester, students are asked to evaluate how they might handle real life examples of ethical dilemmas submitted by previous students. Most participants felt that they were more prepared for ethical situations within the workplace following the course ($\bar{x}$=3.84) (Figure 3.8). The highest number of responses agreed (n=34, 45%) followed by strongly agree (n=21, 28%), neutral (n=14, 18%), strongly disagree (n=5, 7%), and disagree (n=2, 3%). Survey results indicated most participants felt the examples used in the class reflected those that they had encountered/may encounter in their career ($\bar{x}$= 3.84), with 41% (n=32) agreeing, 27% (n=20) strongly agreeing, 22% (n=16) neutral, 7% (n= 5) disagreeing, 3% (n=2) strongly disagreeing (Figure 3.8). Employers have been shown to value ethics in their employees in the natural resource sciences (Sample et al., 1999; Sample et al., 2015). Additionally, skills such as ethics often are not brought into traditional curriculums, but are expected by employers, reaffirming the need to provide students an opportunity to become exposed ethical situations and appropriate ways to deal with them.

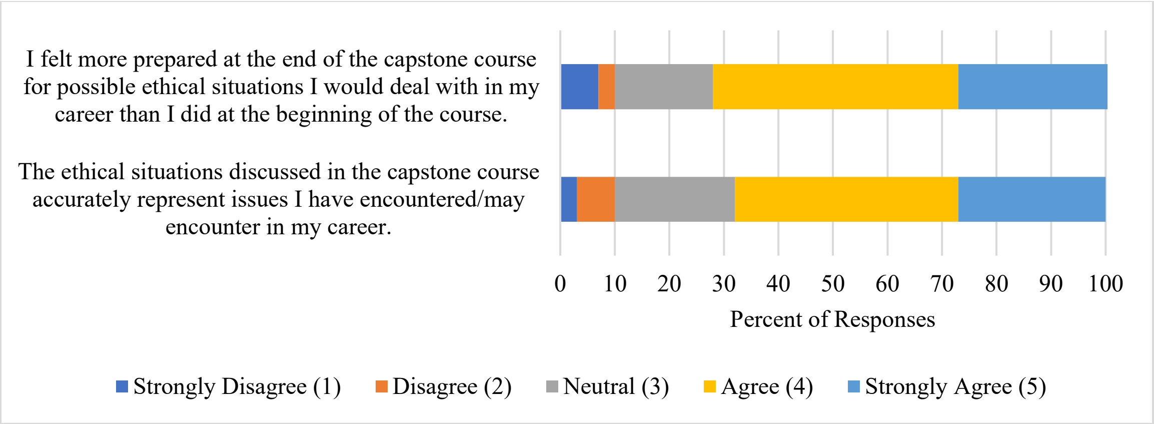

Figure 3.8. Frequency of Likert responses for questions gauging courses ability to prepare students for ethical situations.

3.4.2.7. Job Searching

The capstone course assessed in this study attempts to provide opportunities for students to enhance their job searching and interview skills, as well explaining the nuances related to the NRM field. Most participants felt the course provided useful information for applying for jobs ($\bar{x}$=4.10) (Figure 3.9). The majority of respondents agreed (n=37, 48%), followed by strongly agree (n=27, 33%), neural (n=9, 12%), and disagree (n=5, 7%). There were no recorded responses for strongly disagree. When asked if they felt the course familiarized them with professional resume styles, including traditional business and federal resume styles participants strongly agreed with an average Likert score of 4.36. The majority of respondents strongly agreed with the statement (51%, n=40), followed by 36% (n=28) agreed, 11% (n=8) neutral, and 3% (n=2) disagree.

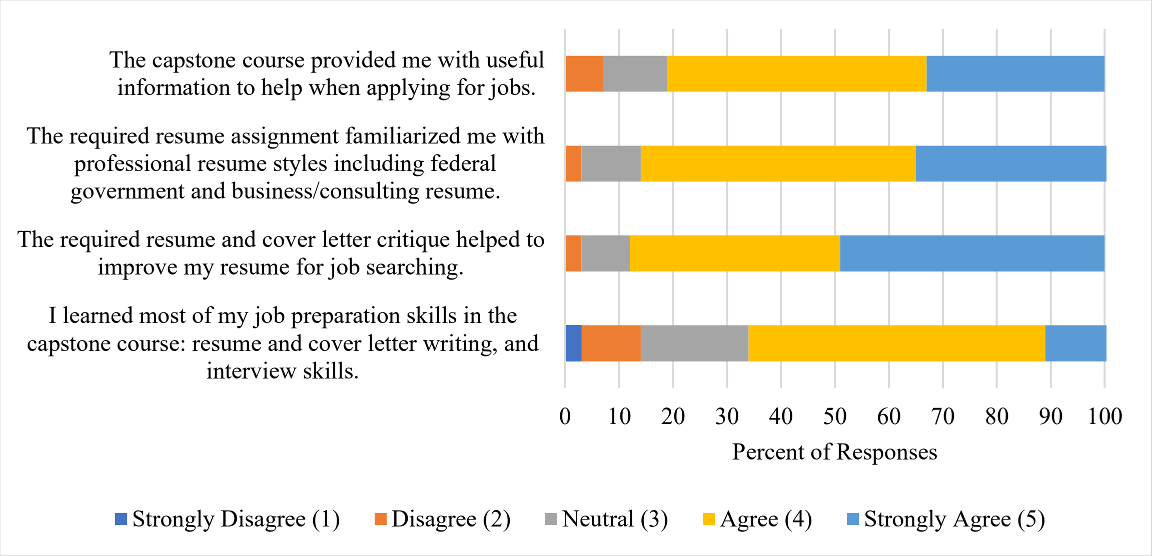

Figure 3.9. Frequency of Likert scores for questions gauging job search, resume and interview skills.

Each student in the course is required to submit a resume and cover letter for a job posting of their choosing. This activity was well received, as students felt the critique they received helped to improve their documents for job searches (average Likert score 4.36). A majority of responses strongly agreed (n=39, 49%), followed by 39% (n=30) agree, 9% (n=7) neutral, and 3% (n=2) disagree. The purpose of these activities in the course is to familiarize students with the workings of natural resource job search boards, application websites for private and federal jobs, and what to expect in an interview. Given the varied nature of natural resource careers, students who apply for jobs following graduation often do not get the support they need from university career centers. In the experience researchers for this study, this is especially true of federal government resumes and searches, as the other topics are fairly well covered by career centers.

When participants were asked if the capstone course was the place where participants felt they learned most of their job preparation skills, many agreed, but not all, with an average Likert of 3.64 (Figure 3.9). Overall, most agreed (n=43, 55%), followed by neutral (n=15, 20%), strongly agree (n=9, 12%), disagree (n=8, 11%), and strongly disagree (n=2, 3%). Researchers would hope that the capstone class is not the main place students learn about job search skills, as it is their last class before graduation and students would be better served learning those skills earlier in their college career. Results show that some students are learning the information elsewhere, but many are not. Authors feel it would be beneficial both at this university and other universities to include this information earlier in a student's college career, such as the third year in to a four year degree, to allow students time to improve the skills and perfect them before graduating.

The final four questions of the survey were open ended questions. The first was asked to determine what students felt was the most beneficial part of the course based on their career experiences. Students most commonly mentioned the teamwork aspect of the course as the most beneficial, followed by job searching, resume, and cover letter building skills. This is interesting as the teamwork aspect of the course is also typically the most disliked portion for students while in the course. Students also mentioned the use of real-world problem solving, communication and presentation skills, the writing/editing process, and interdisciplinary aspects as beneficial portions of the class. Students were then asked to provide possible improvements they felt could be made to the capstone course. Common responses included having all team members partake in the oral presentation, including feasibility evaluations in the management writing, increased ethical discussions, fieldwork, networking with clients, and more complexity to the presented management issue.

Participants were also asked to identify what topics studied during their schooling were most beneficial in their future careers. Students were able to select any and all that applied to them, results from this question are shown in Figure 3.10. Participants also mentioned areas where additional information or classes would have been helpful to graduates, the responses included project management, budgeting, forestry, environmental engineering, permitting and procedure, sociology and human dimensions, and plant identification.

It is interesting that in both the open-ended question, focused on the most beneficial portions of the class, and in Figure 3.10 participants identified soft skills such as writing, editing, and teamwork as the most beneficial to their career. In both the Sample et al. (1999) and Sample et al. (2015) surveys soft skills such as written and oral communication, teamwork, and thinking strategically were rated as important by recent graduates. Often in academia these skills are not valued as highly as technical skills; however, these studies indicate that professionals value these soft skills with equal or more importance than technical skills specific to the field of study (Sample et al., 1999; Sample et al., 2015).

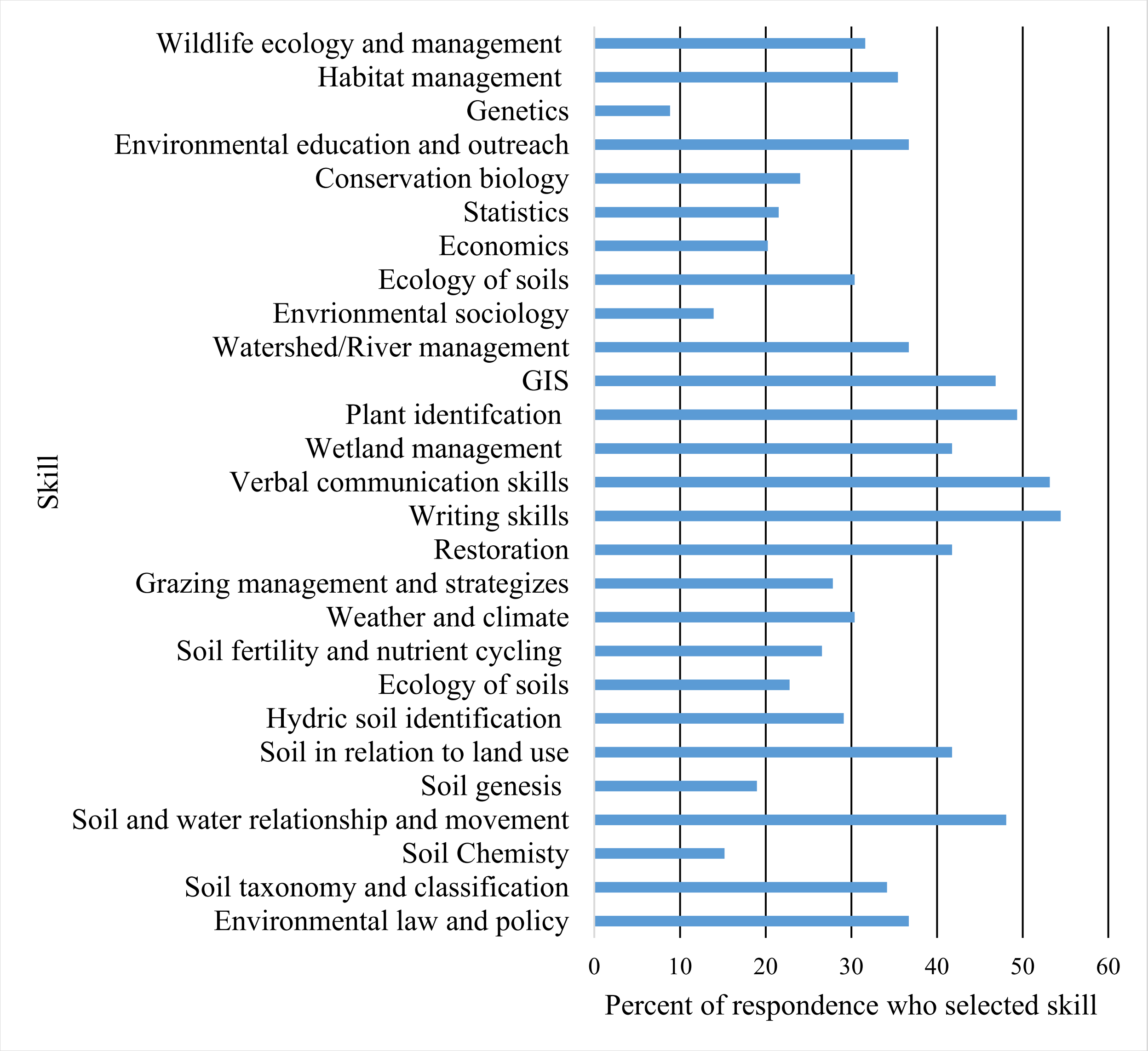

Figure 3.10. Breakdown of participants selected topics that were most important to their future careers.

3.5. Conclusion

This project evaluated an interdisciplinary capstone course to determine the value of the interdisciplinary nature of the course and the skills that were taught or enhanced in the class including communication, both written and verbal, evaluation of source material, teamwork, critical thinking, and problem solving. Overall, results show that the course provided numerous opportunities for teaching and enhancing skills students need in their careers and was successful in improving these skills. Interestingly, participants appeared to put as much or more emphasis on soft and basic professional skills such as communication and teamwork, as they did on technical skills that are typically the focus of the majority of natural resource college curricula. Due to this, researchers recommend that capstone courses across universities should include both writing and speaking opportunities for each student, lessons on ethics, team working opportunities, and job hunting skills such as outlined in this study. Researchers recommend that if job search assistance is not taught elsewhere within the curriculum, it should be included in the capstone course. However, if there are opportunities earlier in college, that may be more beneficial to students in the long term. The interdisciplinary nature of the course also appeared to be beneficial to enhancing students' abilities to think about an overall piece of land or ecosystem rather than focusing on one particular aspect such as plants, water or soils.

Further research on capstone courses and/or students' post-graduation should pay special attention to students who pursue careers outside of their field, as course goals should provide skills that transcend disciplines. Additionally, information on why this group doesn't pursue a career in the field would be helpful in understanding if it is a personal choice, problems obtaining employment, or if there are problems that could be remedied at the university level. As the world changes, the natural resources field is constantly changing, and efforts to evaluate curriculum and career field expectations should be continuous.

3.6. Literature Cited

Andreasen, R.J. and Trede, T.D. (2000). Perceived Benefits of an Agricultural Capstone Course at Iowa State University. *North American Colleges and Teachers of Agriculture*, 44(1), 51–56.

Arthur, M.A. and Thompson, J.A. (1999). Problem-Based Learning in a Natural Resources Conservation and Management Curriculum: A Capstone Course. *Journal of Natural Resources and Life Science Education*, 28, 97–103.

Baruch, Y. and Holtom, B.C. (2008). Survey response rate levels and trends in organizational research. *Human Relations*, 61(8), 1139-1160.

Bastarrica, M.C., Perovich, D., and Samary, M.M. (2017). What can students get from a software engineering capstone course. 2017 IEEE/ACM 39th Internation Conference on Software Engineering: Software Engineering Education and Training Track. DOI 10.1109/ICSE-SEET.2017.15

Berkson, J. and Harrison, A.L. (2002) Refocusing Natural Resources Management a Multidisciplinary Road to Reality. *Journal of College Science Teaching*, 31(7), 464.

Burrus, J., Jackson, T., Xi, N. and Steinberg, J. (2014). Identifying the most important 21st centuray workforce competencies: an analysis of the occupational information network (O*NET). Educational Testing Services research report series volume 2013 issue 2 1-55. Accessed: 17 March 2021 https://doi.org/10.1002/j.2333-8504.2013.tb02328.x

Census Bureau QuickFacts. (2019). U.S. Census Bureau QuickFacts: North Dakota. Accessed: 17 March 2021. www.census.gov/quickfacts/ND.

Finegold, D., and Notabartolo, A.S. (2008). 21st-Century competencies and their impact: an interdisciplinary literature review. William and Flora Hewlett Foundation. Accessed 3/17/21.

https://hewlett.org/library/21st-century-competencies-impact-interdisciplinary-literature-review/
Keller, S., Parker, C.M., and Chan, C. (2015). Employability skills: student perceptions of an IS final year capstone subject. *Innovation in Teaching and Learning in Information and Computer Sciences*. 10:2, 4-15

Khakurel, J. and Porras, J. (2020). The effect of real-world capstone project in an acquisition of soft skills among software engineering students. 32nd IEE Int. Conference on Software Engineering Education and Training.

Leefers, L.A., Campa III, H., and Karasek, G.L.B. (1996). Using interdisciplinary team assignments in a capstone course in natural resources planning and policy. Proceedings 1st biennial Conf. on University Education in Natural Resources, University Park, PA. 3-5 Mar. 1996. Pennsylvania State Univ., University Park, PA.

Nielsen, L.A., and Decker, D.J. (1995). Education of natural resources professionals for ecosystem management. *Renewable Resources Journal*, 7, 12-17

North Dakota State University. (2019). Enrollment Demographics Reports. https://www.ndsu.edu/data/enrollment/demographics/ Date Accessed: 3/17/2021

Prokopy, L. S. (2009). “Looking at the Big Picture: Engaging Natural Resource Students in Landscape Level Planning Through a Capstone Course. *Journal of Forestry*, 107(2), 90–94

Qualtrics XM. (2005). Copyright Year 2020. Version 7.2020. Qualtrics, Provo, UT, USA.
Sample, V.A., Ringgold, P.C., Block, N.E., and Giltmier, J.W. (1999). Forestry Education: Adapting to the Changing Demands. *Journal of Forestry*, 97(9), 4–10.

Sample, V.A., Bixler, R.P., McDonough, M.H., Bullard, S.H., and Snieckus, M.M. (2015). The Promise and Performance of Forestry Education in the United States: Results of a Survey of Forestry Employers, Graduates, and Educators. *Journal of Forestry*, 113(6), 528-537.

Sargent, S.D., Pennington, P., and Sitton, S. (2003). Developing leadership skills through capstone experiences. Educational resources information center, Accessed: 17 March 2021 http://www.arex.uiuc.edu/-ALE/2003/sargent1.pdf.

Silliman, B., H.C., Edwards, and J. C., Johnson. (2020). Long term effects of youth work internships: the project youth extension service approach. *Children and youth review.* 119, 1-5
Solomon, L.C. (1981). New findings on the link between college education and work. *Higher Education*, 10(6), 615-648.

APPENDX A. SPRING RUNOFF DATA 2019-2020

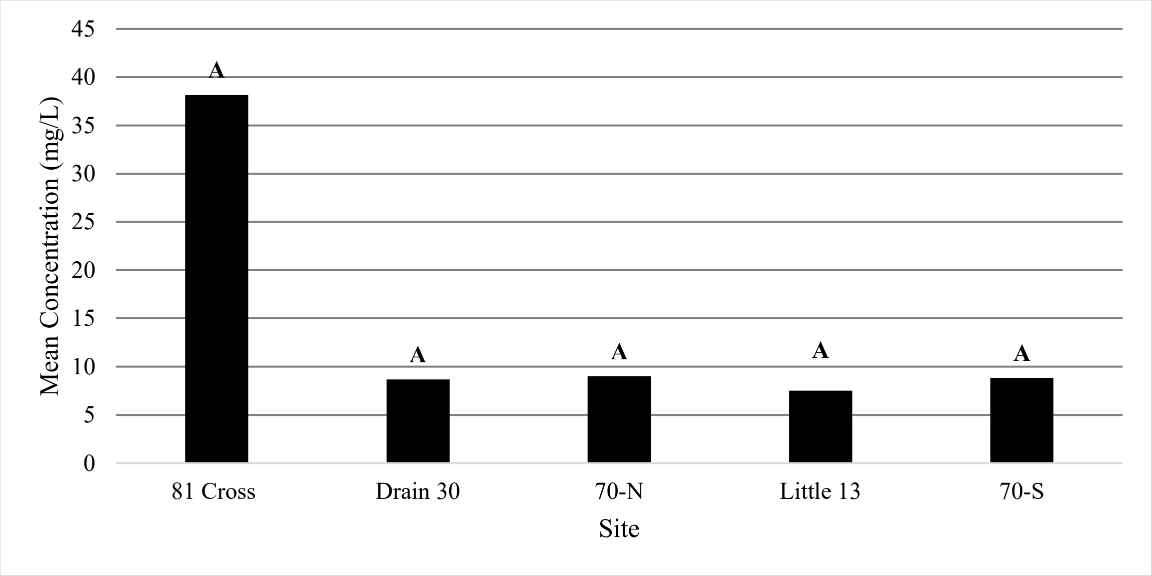

Figure A.1. 2019 spring runoff mean Total Suspended Solids concentrations by site. Different letters indicate significant differences at p≤0.05.

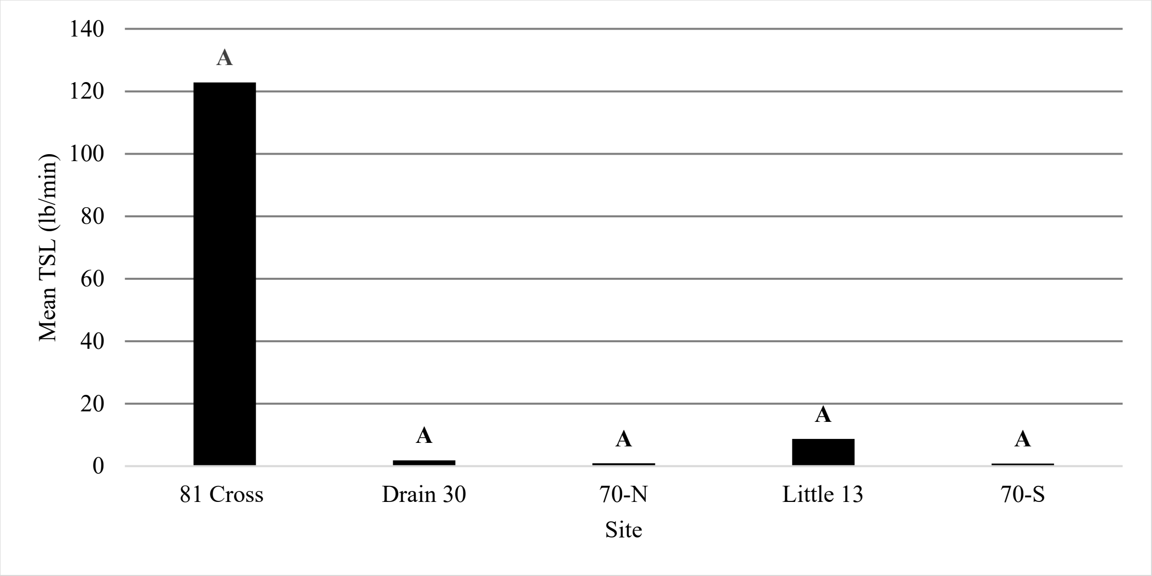

Figure A.2. 2019 spring runoff mean Total Suspended Solids time step loading by site. Different letters indicate significant differences at p≤0.05.

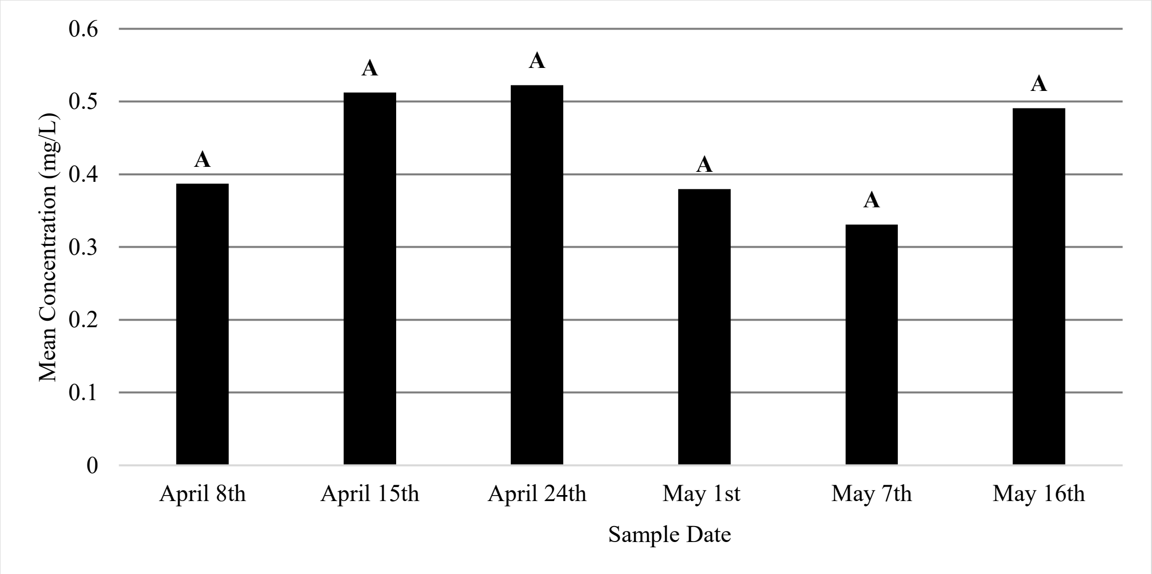

Figure A.3. 2019 spring runoff mean Total Phosphorus concentration by sample date. Different letters indicate significant differences at p≤0.05.

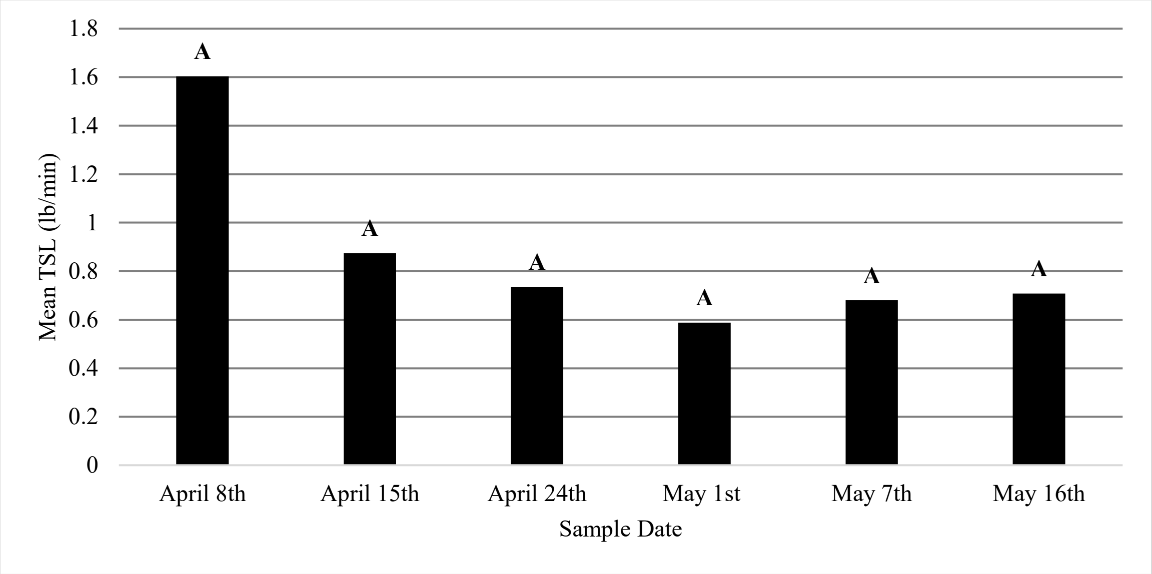

Figure A.4. 2019 spring runoff mean Total Nitrogen time step loading by sample date. Different letters indicate significant differences at p≤0.05.

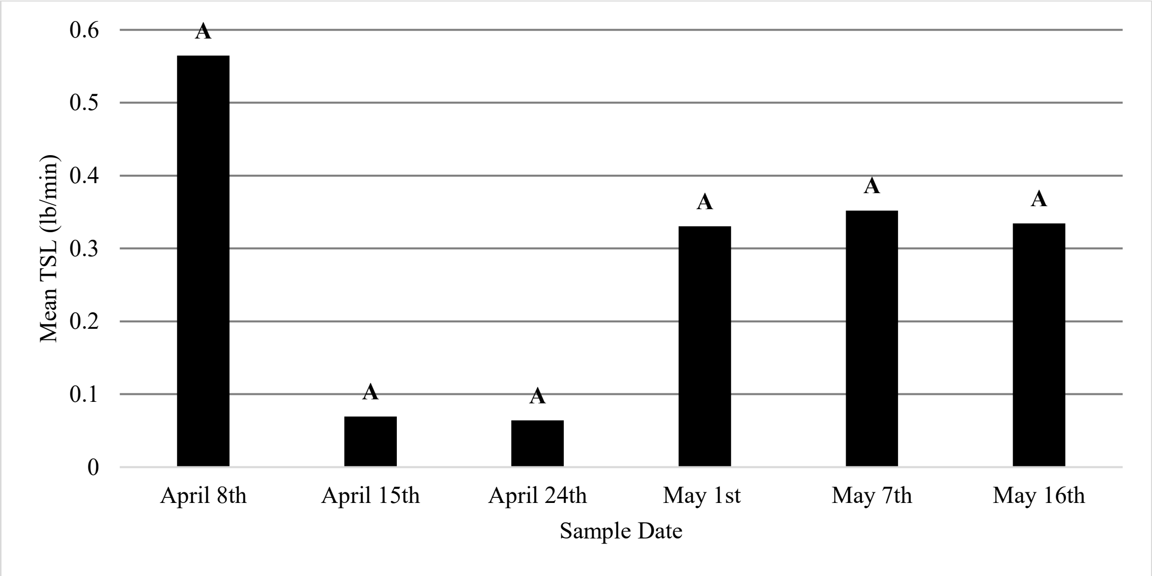

Figure A.5. 2019 spring runoff mean Nitrate + Nitrite time step loading by sample date. Different letters indicate significant differences at p≤0.05.

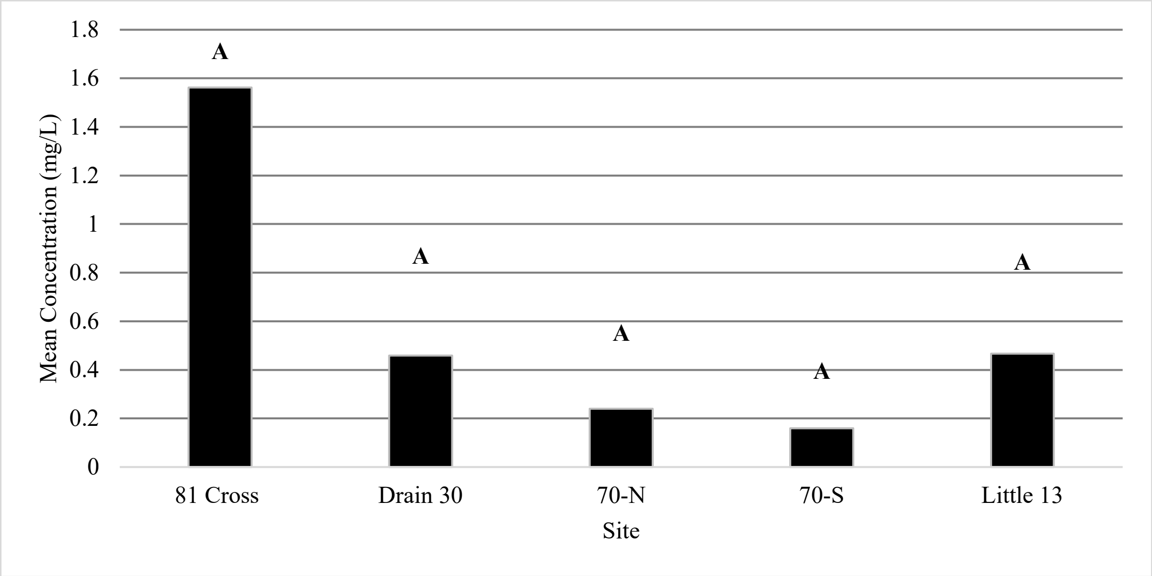

Figure A.6. Mean Total Phosphorus concentration in 2020 spring runoff sampling by site. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

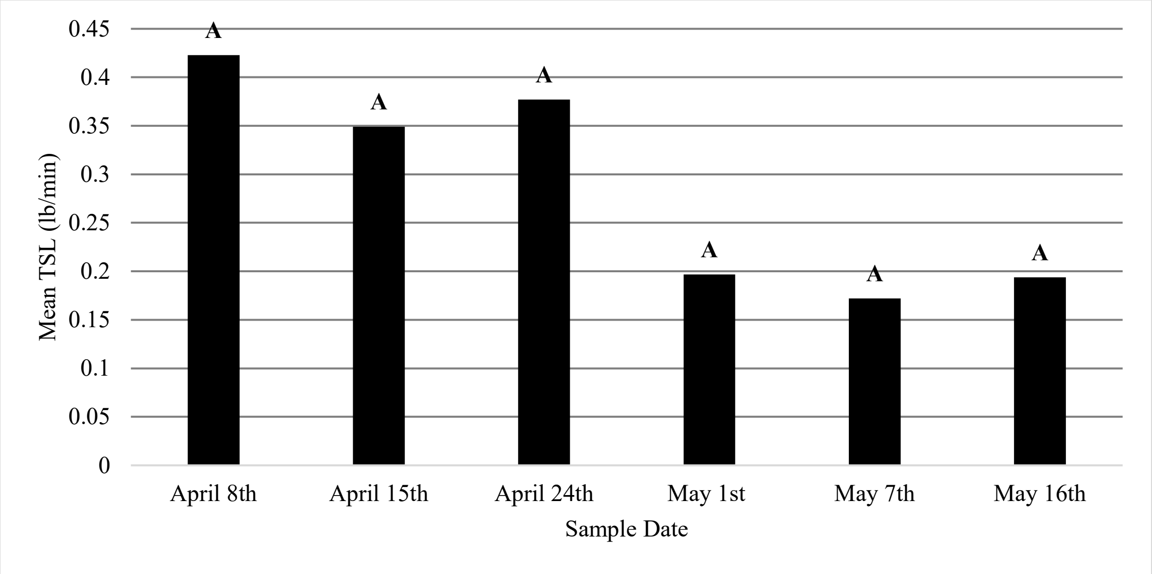

Figure A.7. 2019 spring runoff mean Total Phosphorus time step loading by sample date. Different letters indicate significant differences at $p \leq 0.05$.

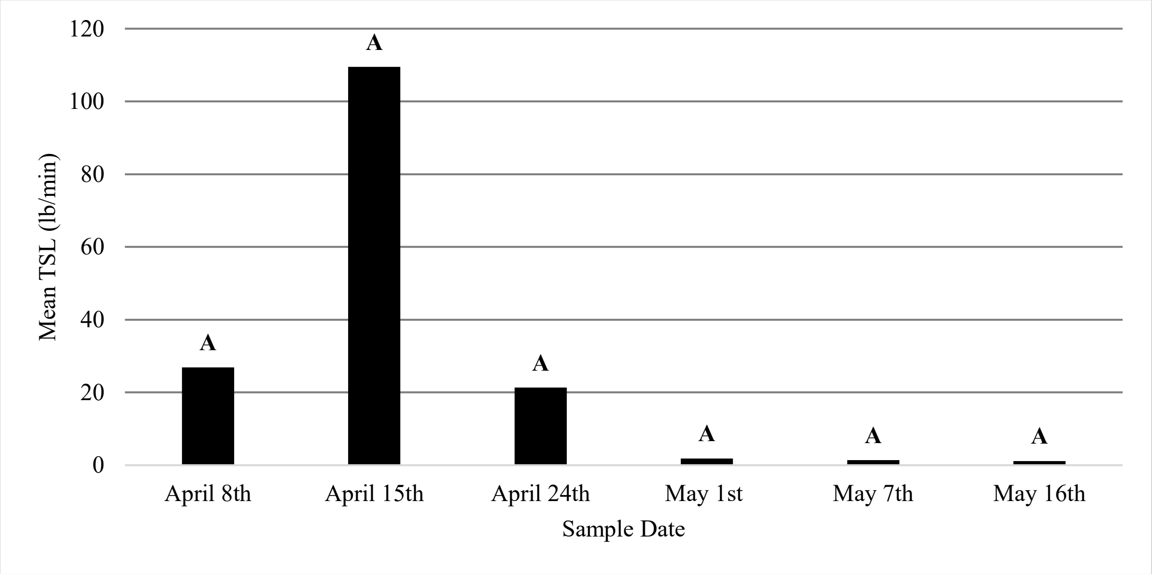

Figure A.8. 2019 spring runoff mean Total Suspended Solids time step loading by sample date. Different letters indicate significant differences at $p \leq 0.05$.

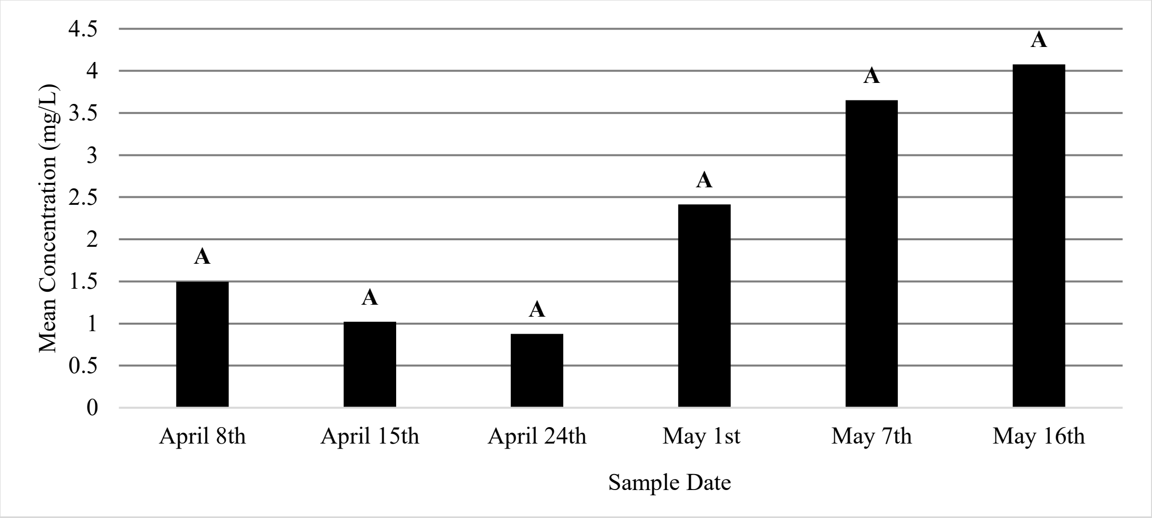

Figure A.9. Mean Total Nitrogen concentration for 2019 spring runoff sampling by sample date. Different letters indicate significant differences at p≤0.05.

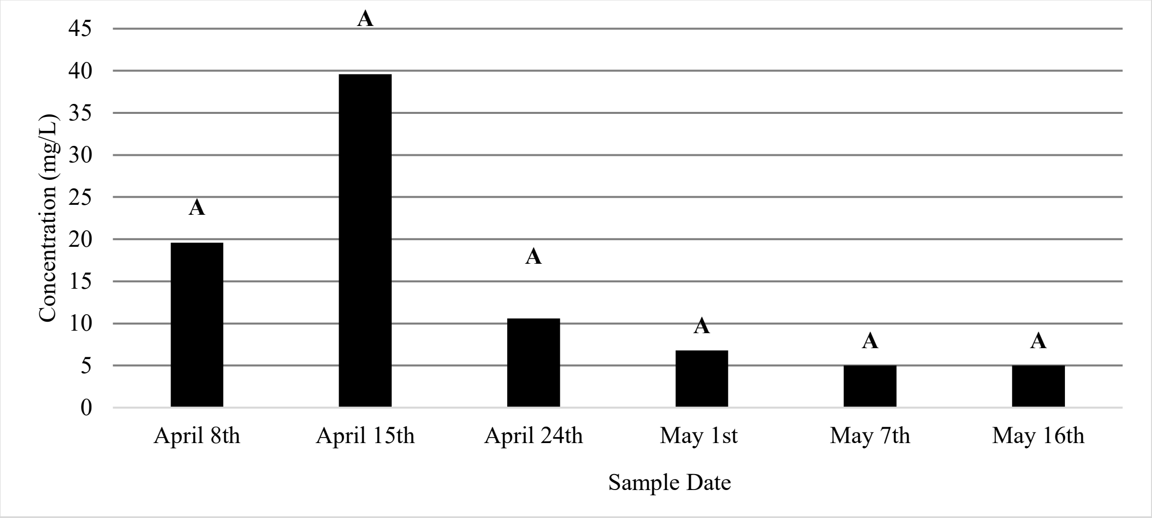

Figure A.10. Mean Total Suspended Solids concentration for 2019 spring runoff sampling by sample date. Different letters indicate significant differences at p≤0.05. Bars represent standard error.

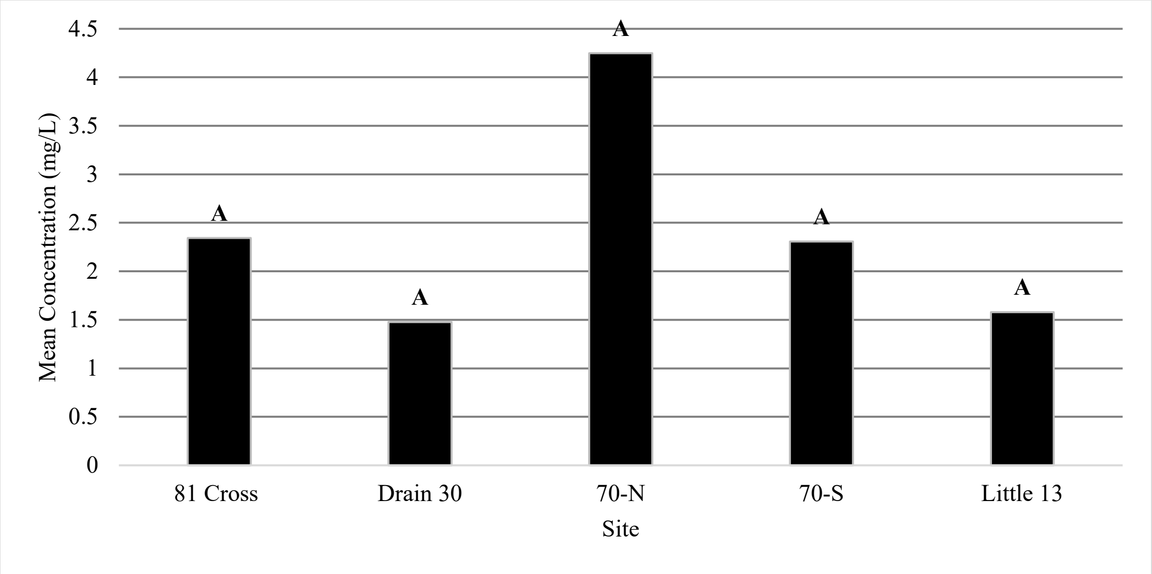

Figure A.11. 2020 spring runoff mean Total Nitrogen concentrations by site. Different letters indicate significant differences at p≤0.05.

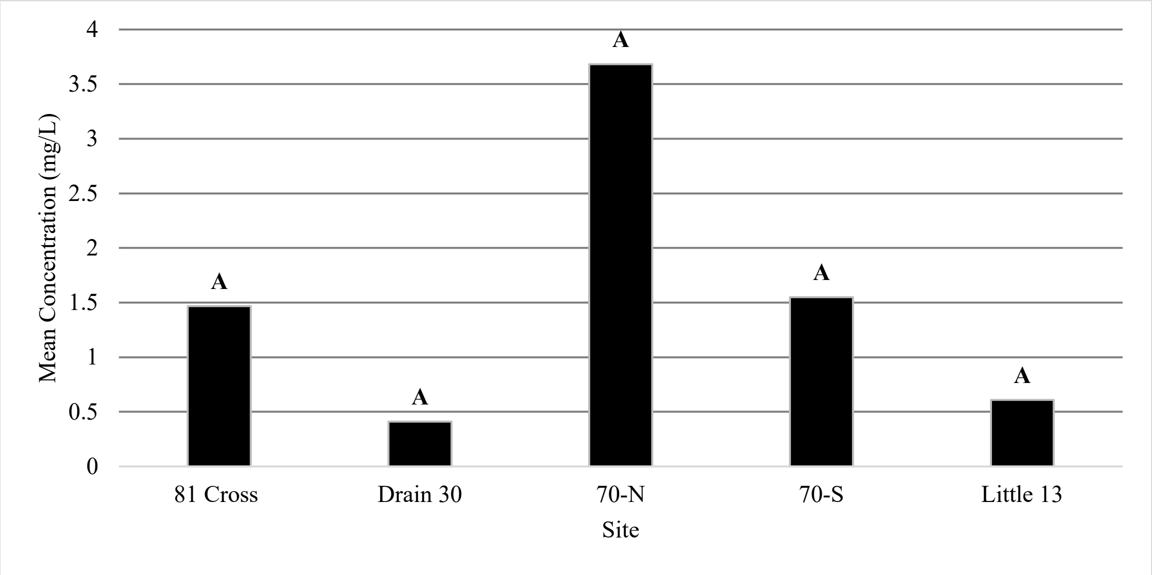

Figure A.12. 2020 spring runoff mean Nitrate + Nitrite concentrations by site. Different letters indicate significant differences at p≤0.05.

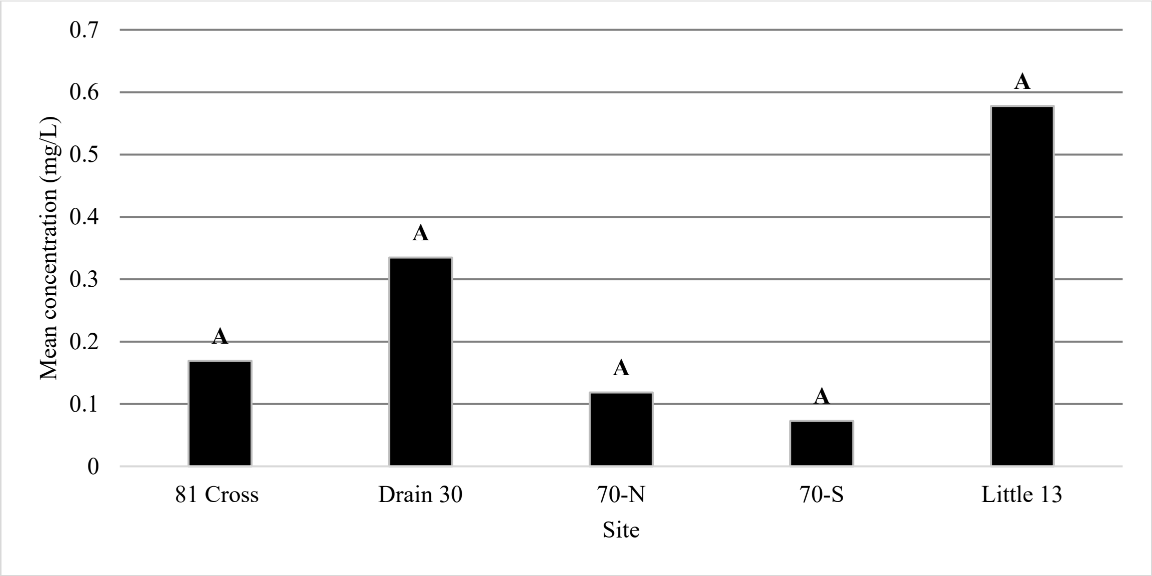

Figure A.13. 2020 spring runoff mean Dissolved Phosphorus concentrations by site. Different letters indicate significant differences at p≤0.05.

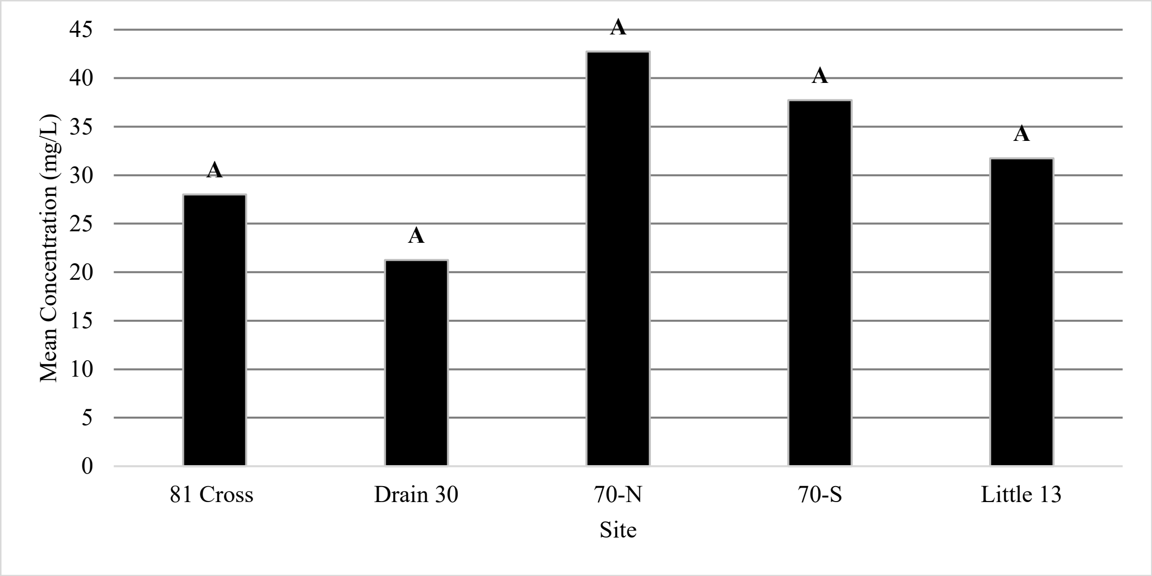

Figure A.14. 2020 spring runoff mean Total Suspended Solids concentrations by site. Different letters indicate significant differences at p≤0.05.

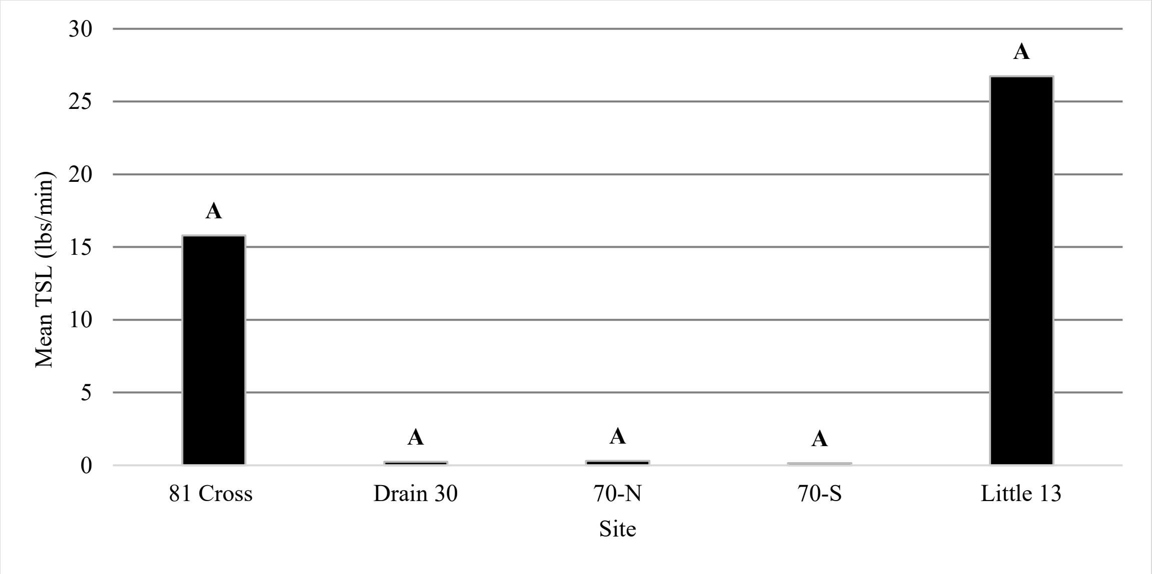

Figure A.15. 2020 spring runoff mean Total Nitrogen time step loading by site. Different letters indicate significant differences at p≤0.05.

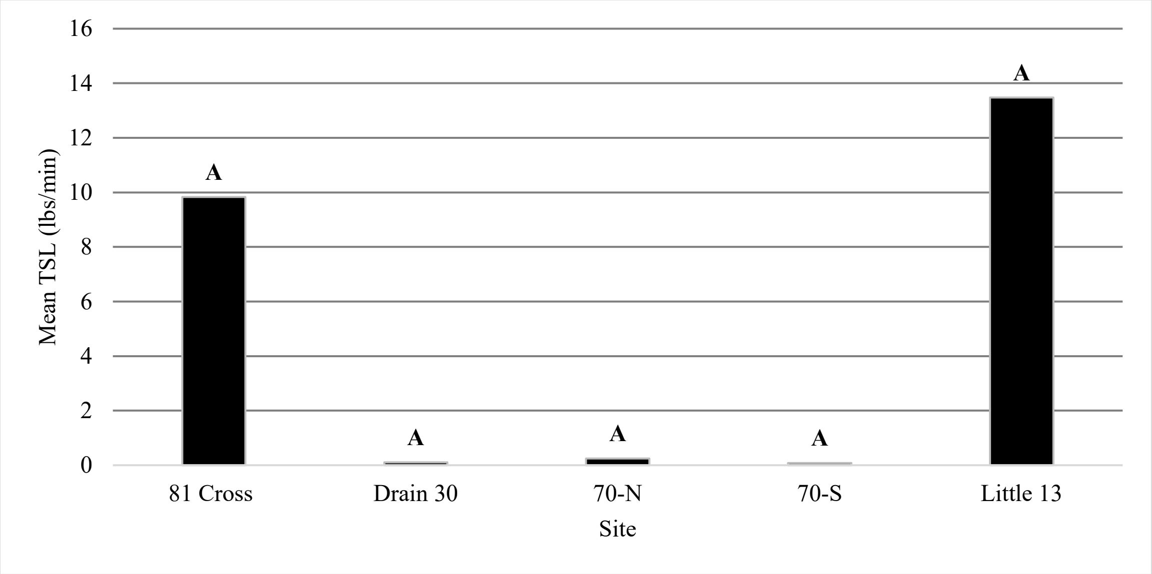

Figure A.16. 2020 spring runoff mean Nitrate + Nitrite time step loading by site. Different letters indicate significant differences at p≤0.05.

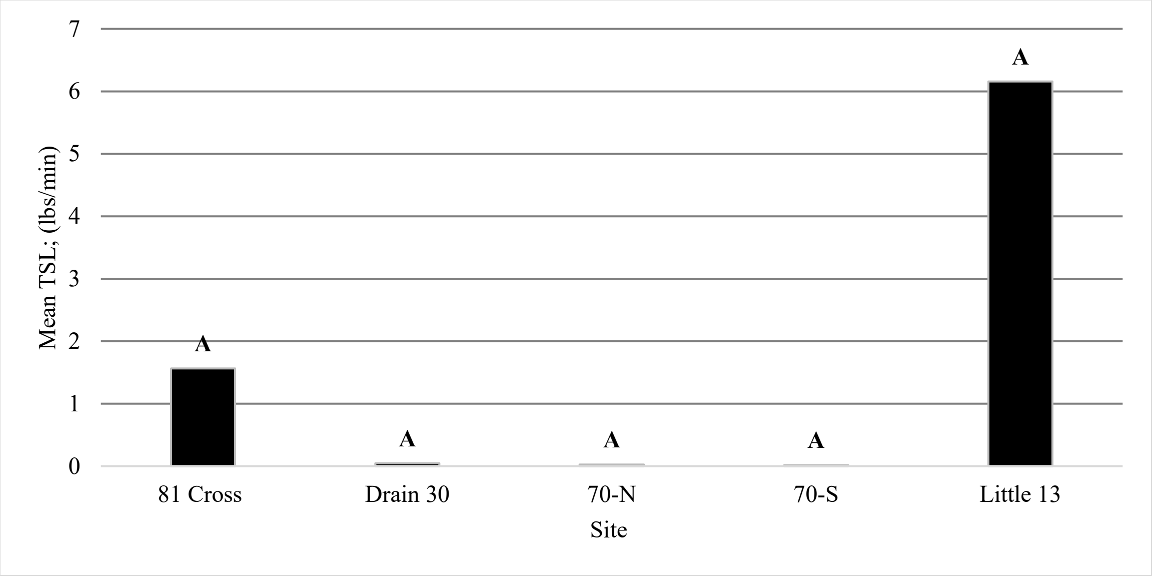

Figure A.17. 2020 spring runoff mean Total Phosphorus time step loading by site. Different letters indicate significant differences at p≤0.05.

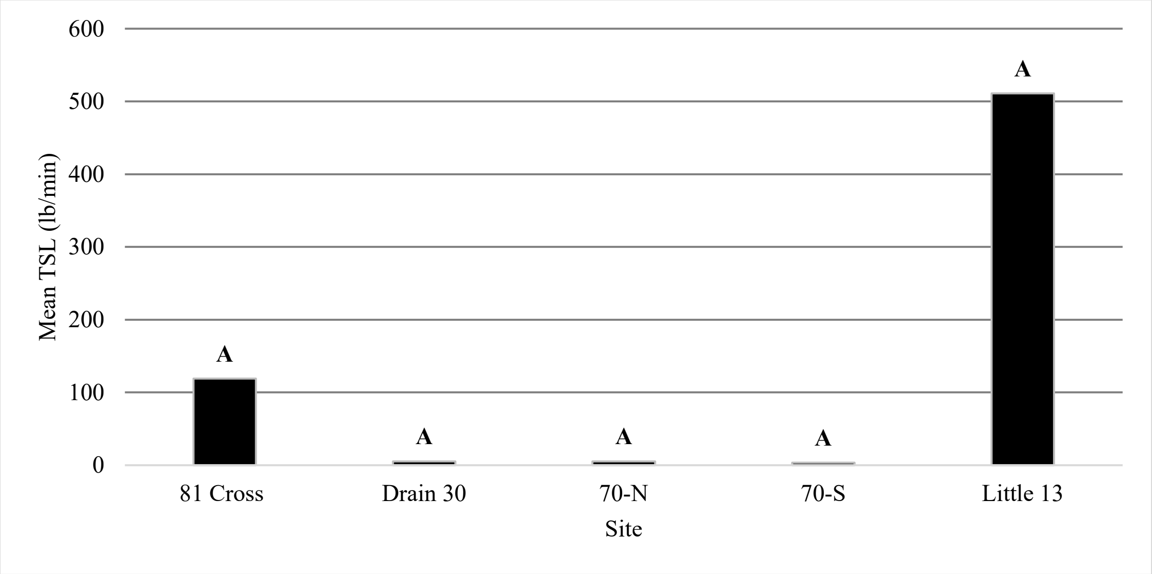

Figure A.18. 2020 spring runoff mean Total Suspended Solids time step loading by site. Different letters indicate significant differences at p≤0.05.

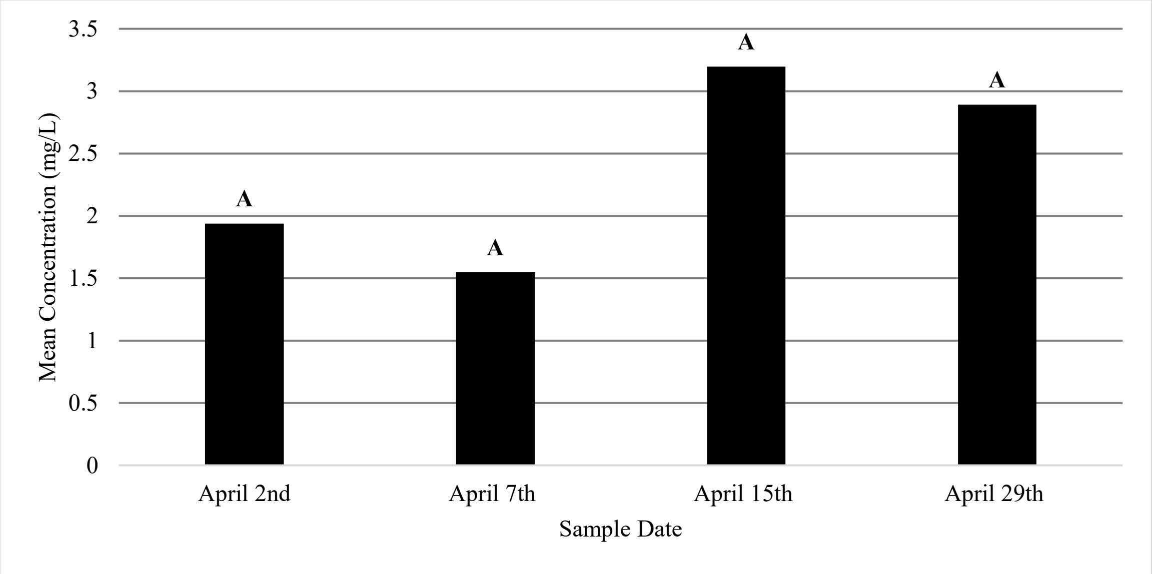

Figure A.19. 2020 spring runoff mean Total Nitrogen concentration by sample date. Different letters indicate significant differences at p≤0.05.

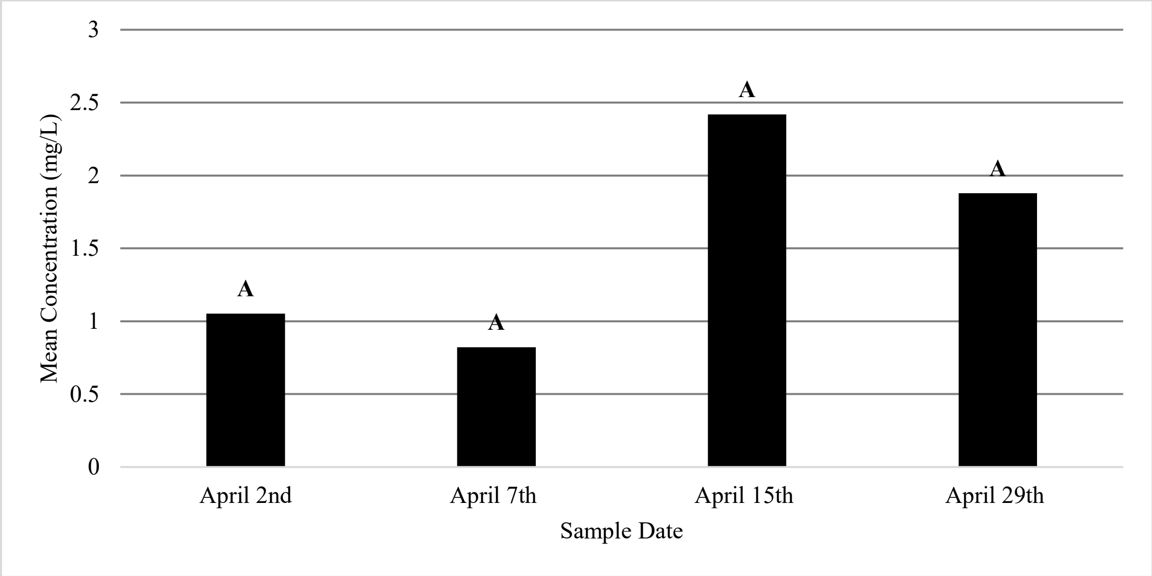

Figure A.20. 2020 spring runoff mean Nitrate + Nitrite time step loading by sample date. Different letters indicate significant differences at p≤0.05.

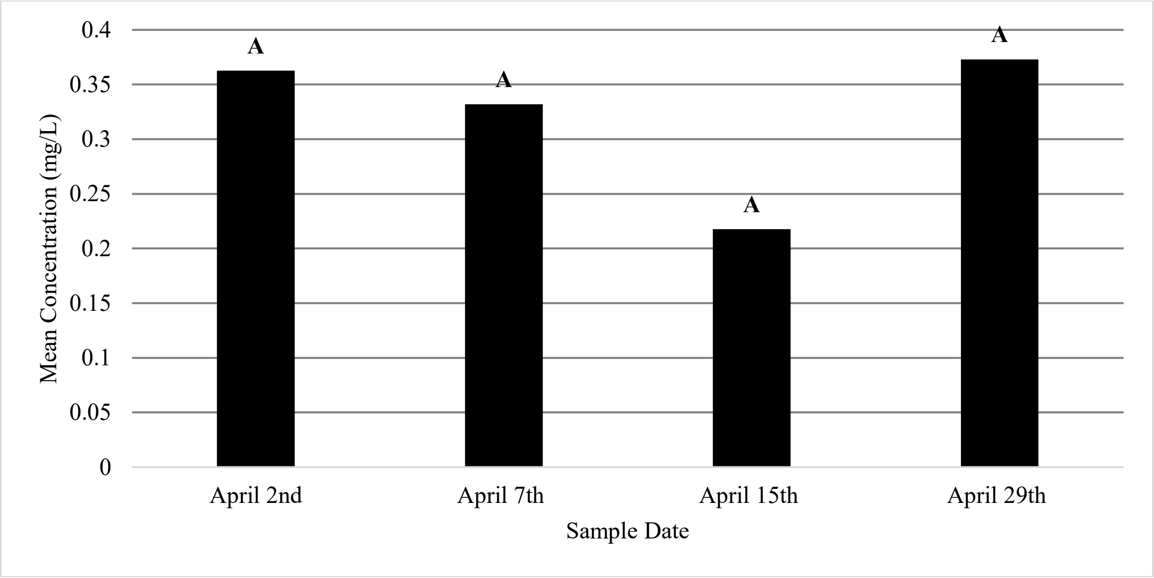

Figure A.21. 2020 spring runoff mean Total Phosphorus concentration by sample date. Different letters indicate significant differences at $p \leq 0.05$.

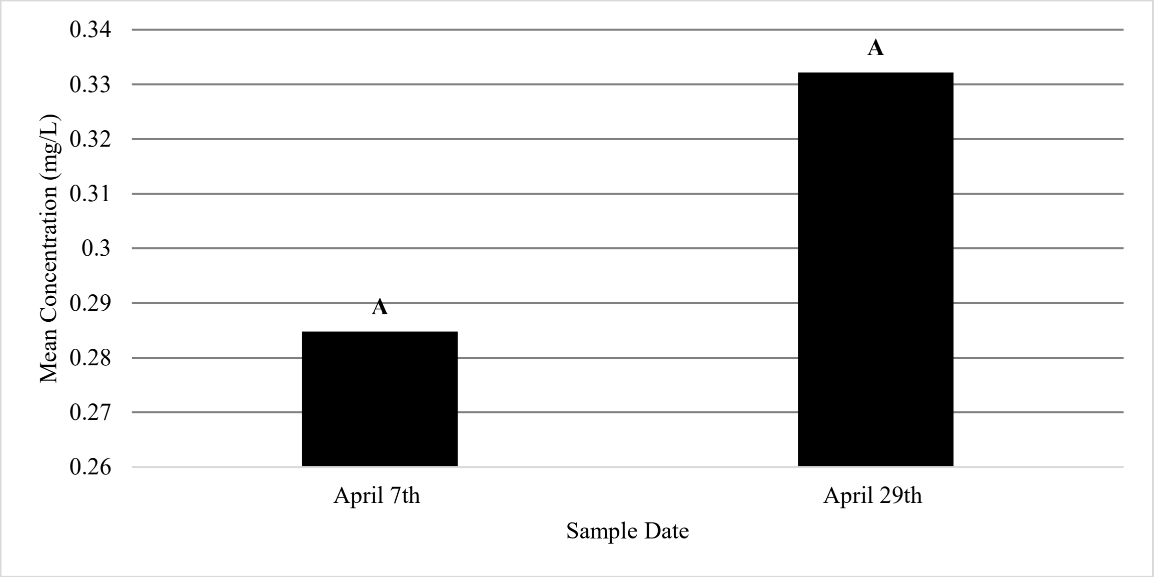

Figure A.22. 2020 spring runoff mean Dissolved Phosphorus concentration by sample date. Different letters indicate significant differences at $p \leq 0.05$.

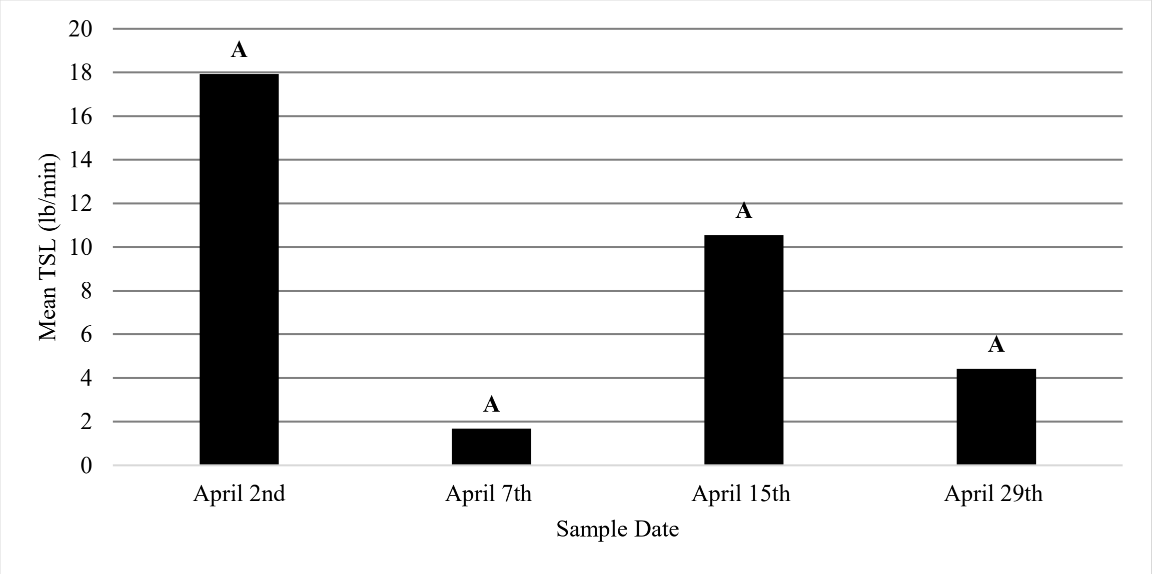

Figure A.23. 2020 spring runoff mean Total Nitrogen time step loading by sample date. Different letters indicate significant differences at p≤0.05.

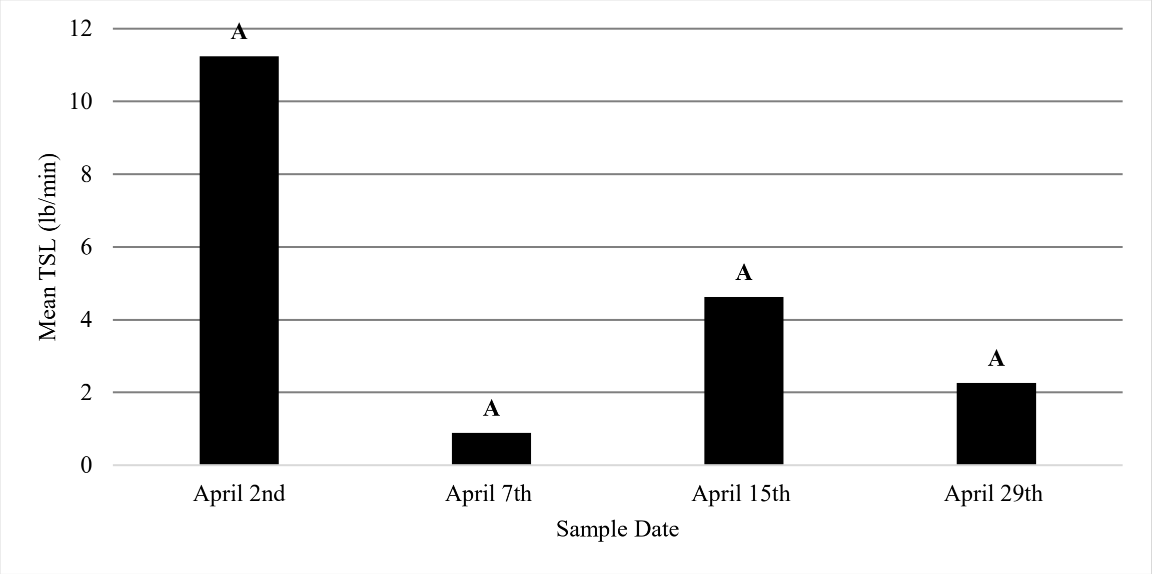

Figure A.24. 2020 spring runoff mean Nitrate + Nitrite time step loading by sample date. Different letters indicate significant differences at p≤0.05.

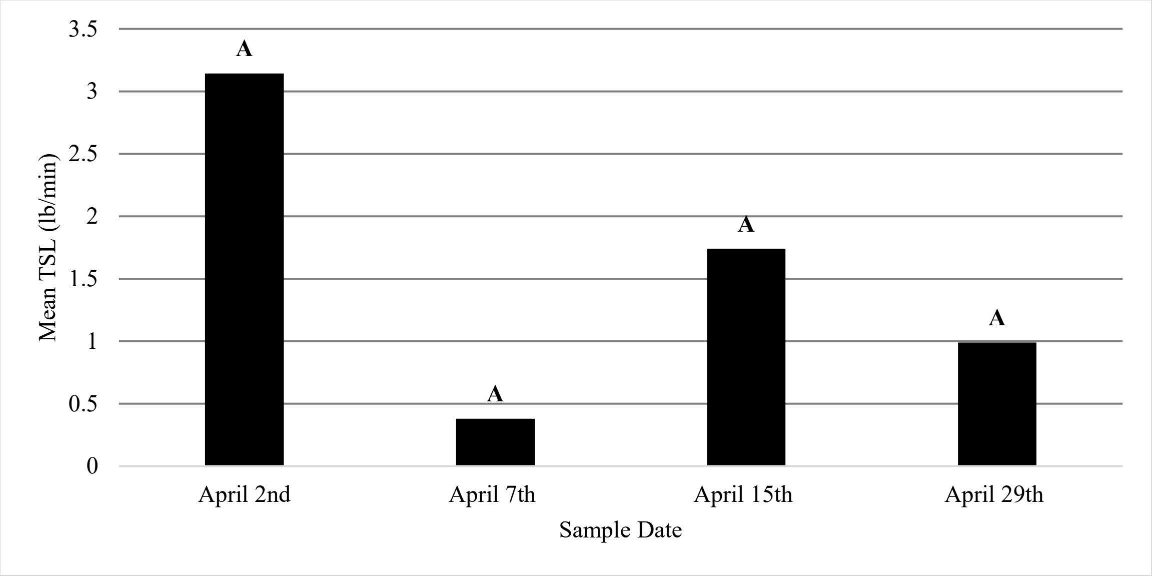

Figure A.25. 2020 spring runoff mean Total Phosphorus time step loading by sample date. Different letters indicate significant differences at p≤0.05.

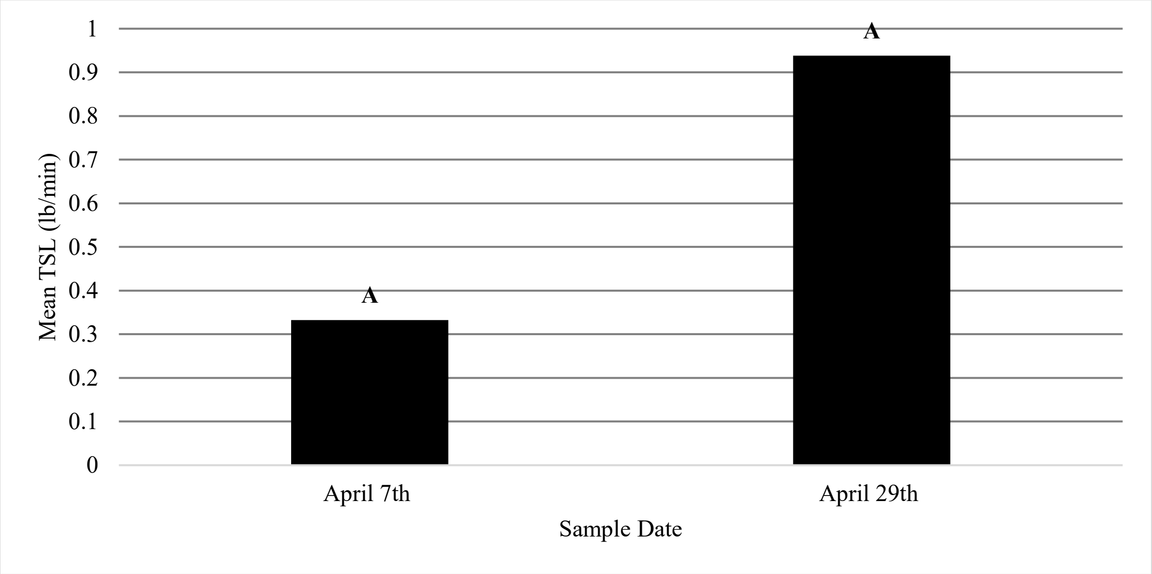

Figure A.26. 2020 spring runoff mean Dissolved Phosphorus time step loading by sample date. Different letters indicate significant differences at p≤0.05.

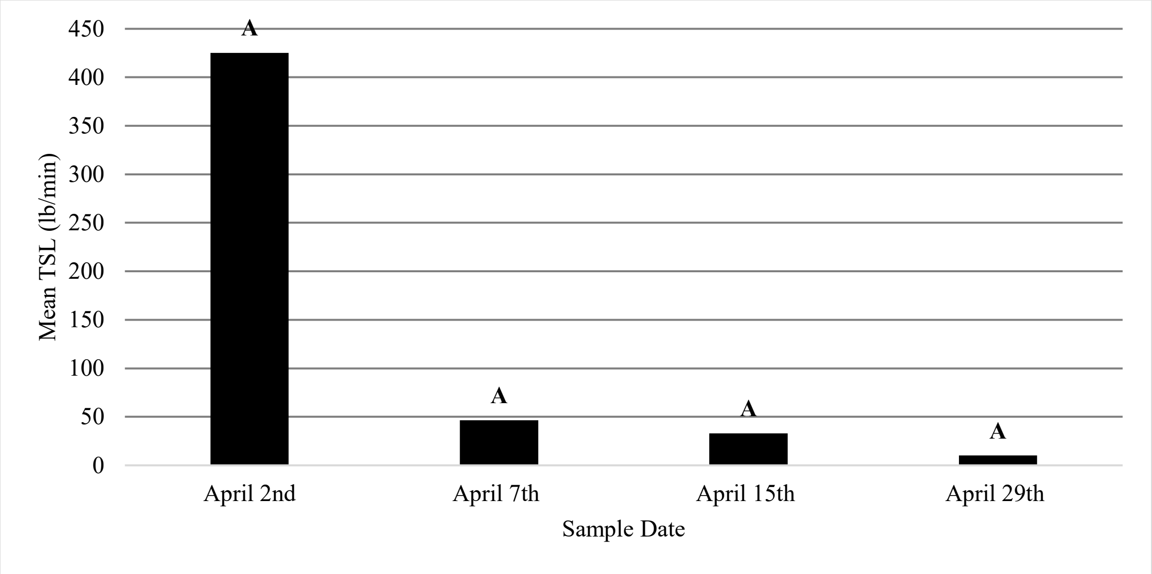

Figure A.27. 2020 spring runoff mean Total Suspended Solids time step loading by sample date. Different letters indicate significant differences at p≤0.05.

APPENDIX B. STORM EVENT RISING LIMB SAMPLE DATA

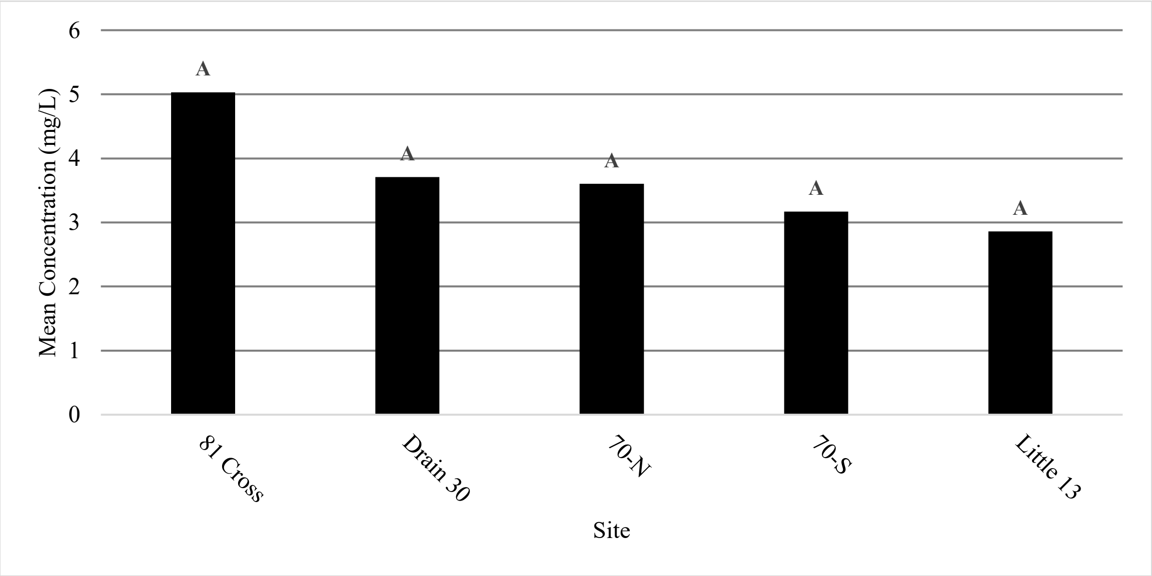

Figure B.1. Rising limb mean Total Nitrogen concentration by site. Different letters indicate significant differences at p≤0.05.

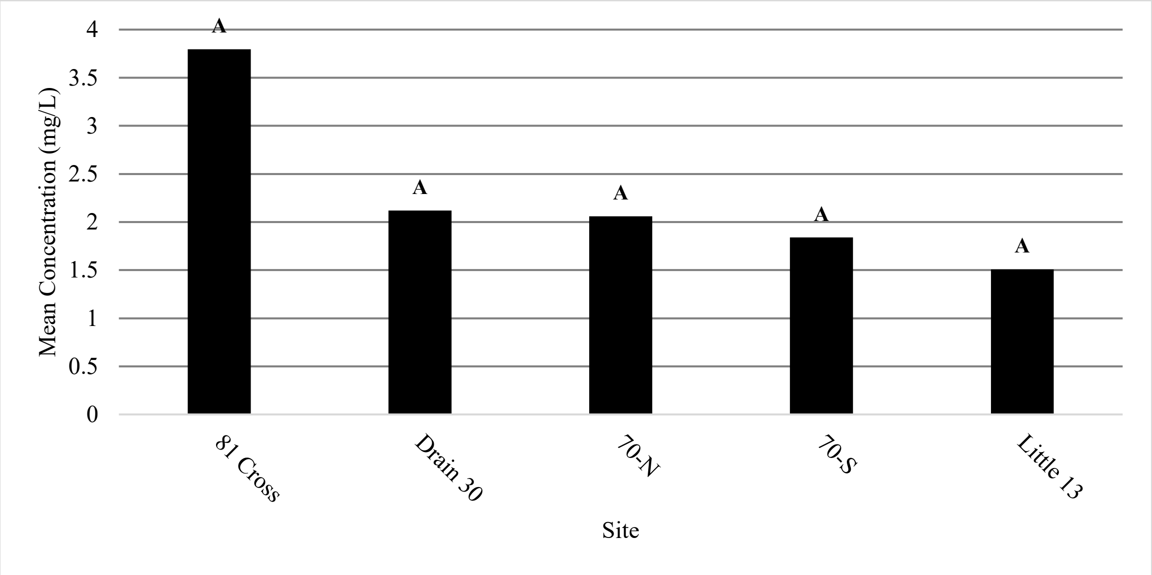

Figure B.2. Rising limb mean Nitrate + Nitrite concentration by site. Different letters indicate significant differences at p≤0.05.

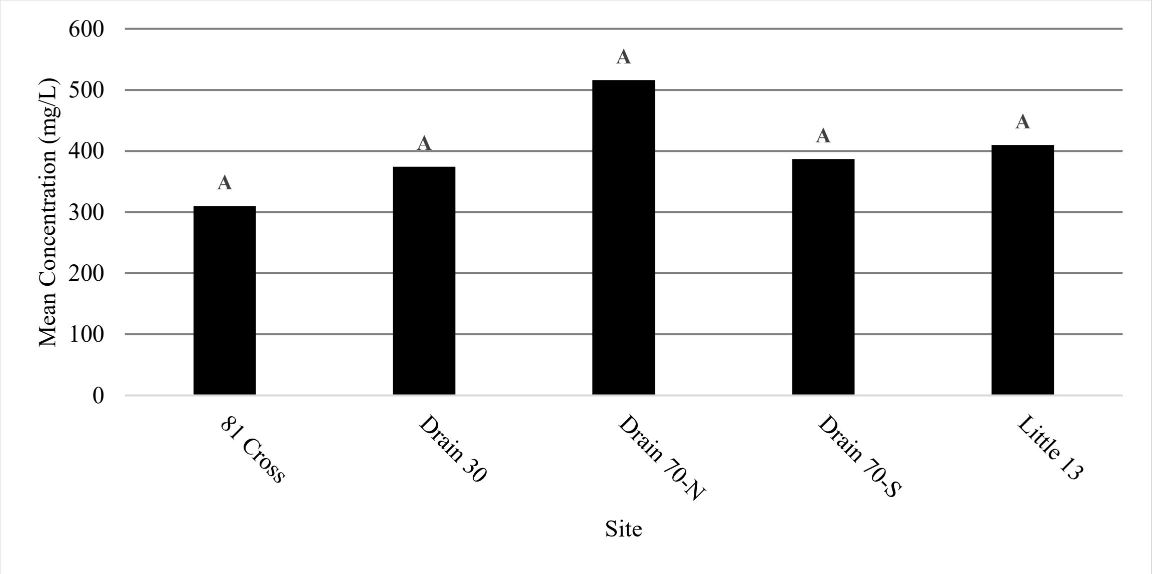

Figure B.3. Rising limb mean Total Suspended Solids concentation by site. Different letters indicate significant differences at p≤0.05.

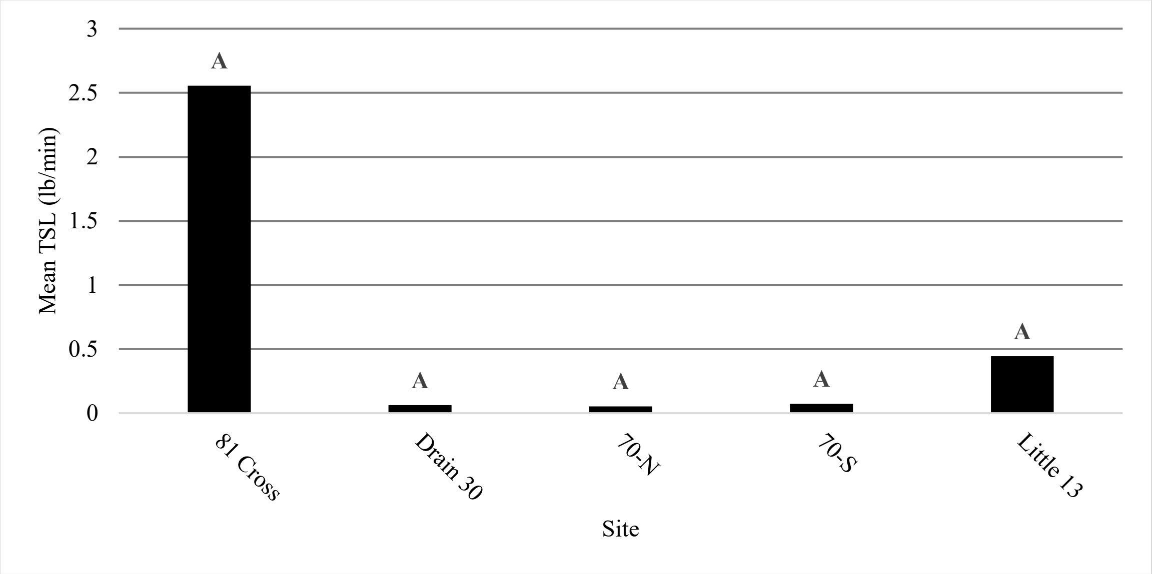

Figure B.4. Rising limb mean Total Phosphorus time step loading by site. Different letters indicate significant differences at p≤0.05.

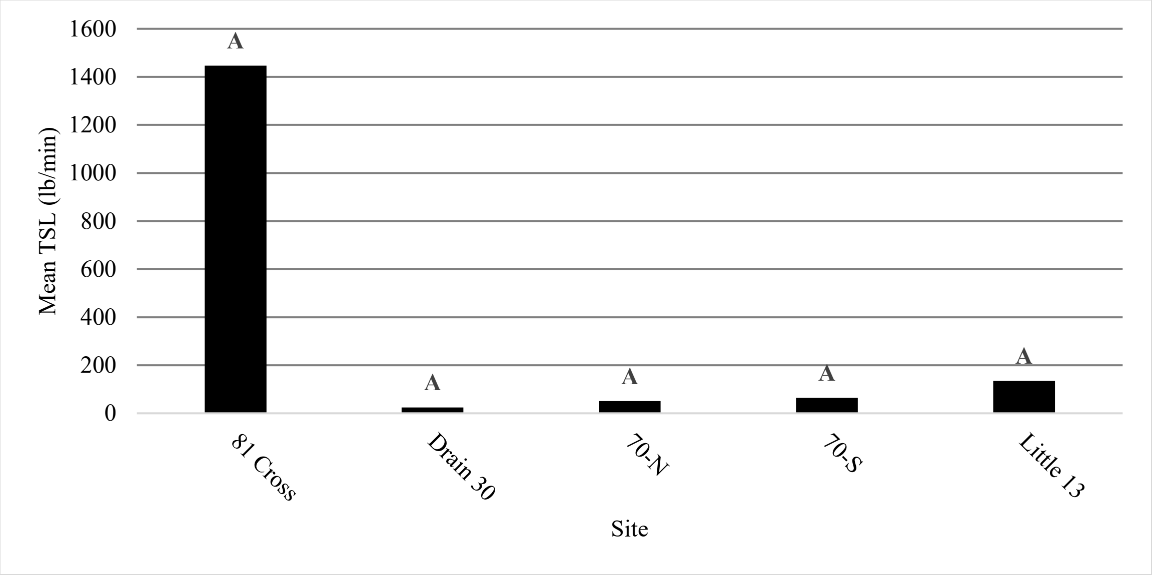

Figure B.5. Rising limb mean Total Suspended Solids time step loading by site. Different letters indicate significant differences at p≤0.05.

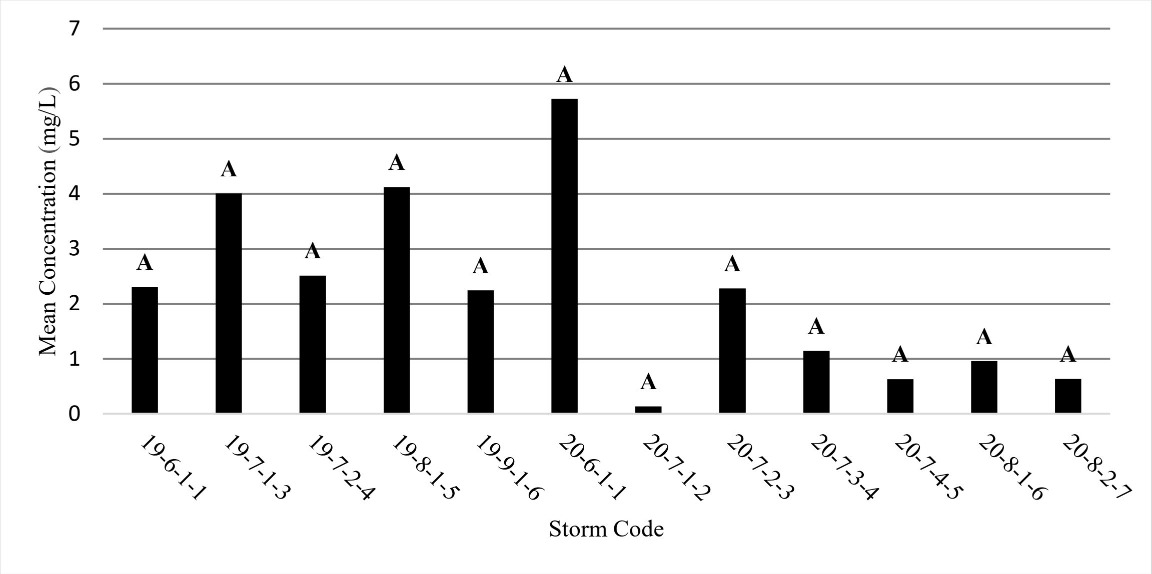

Figure B.6. Rising limb mean Nitrate + Nitrite concentation by storm event. Different letters indicate significant differences at p≤0.05.

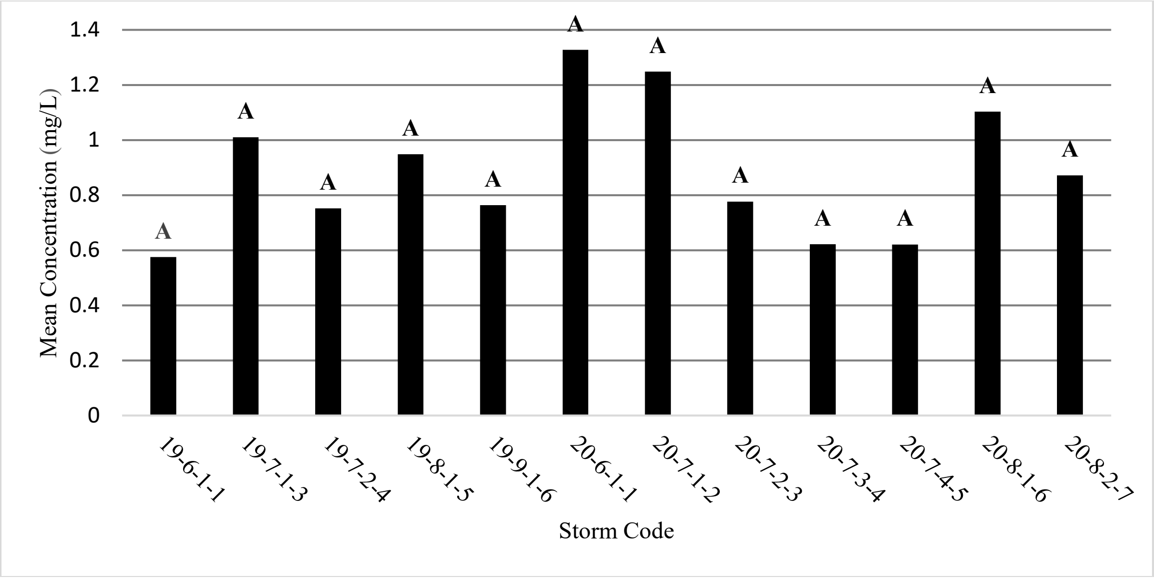

Figure B.7. Rising limb mean Total Phosphorus concentration by storm event. Different letters indicate significant differences at p≤0.05.

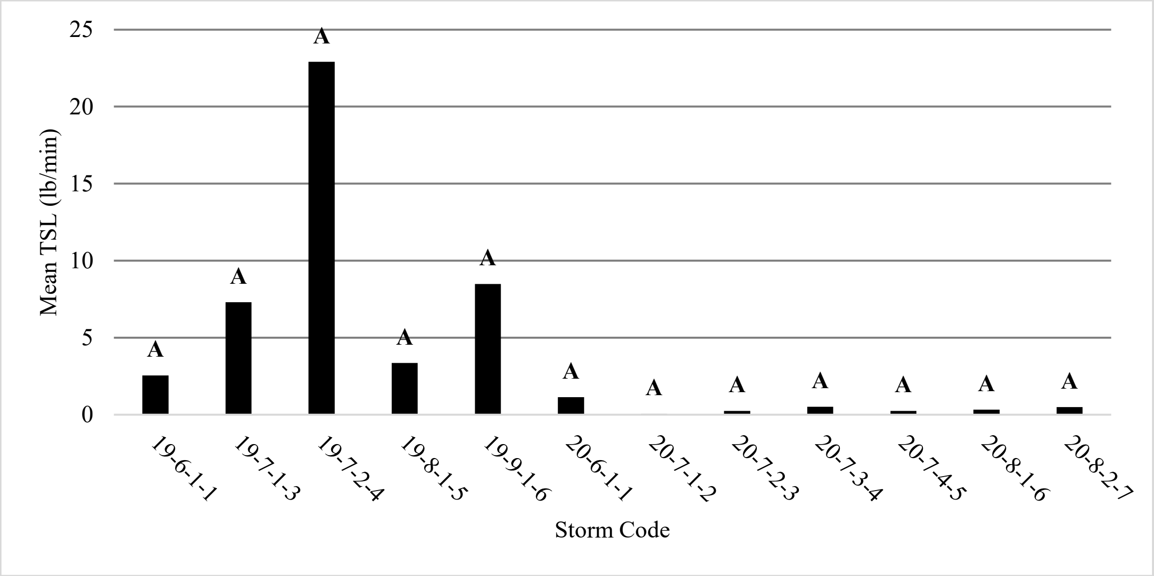

Figure B.8. Rising limb mean Total Nitrogen time step loading by storm event. Different letters indicate significant differences at p≤0.05.

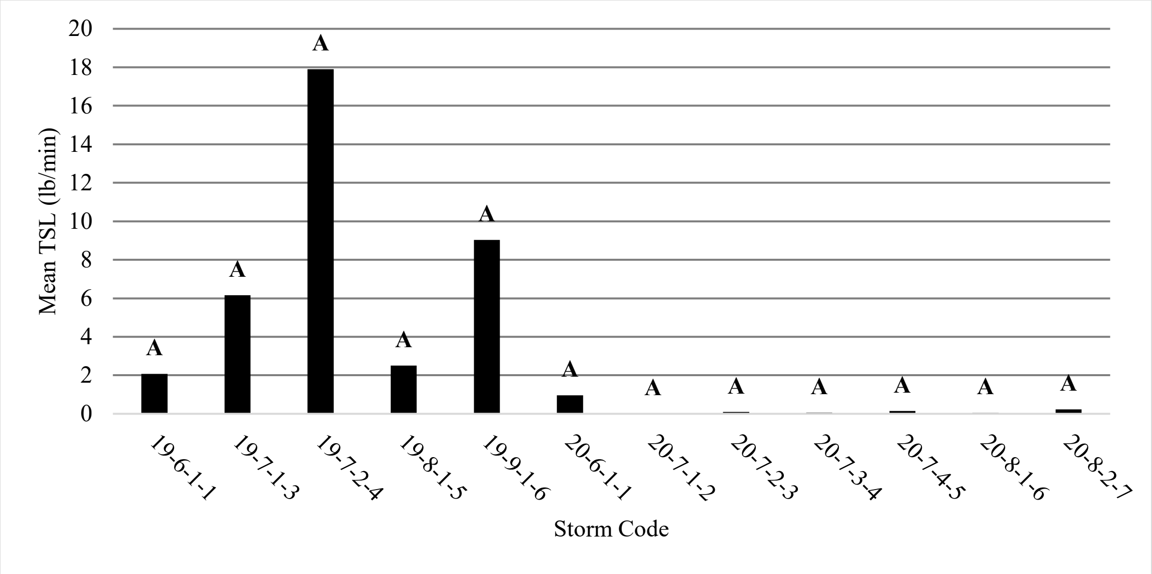

Figure B.9. Rising limb mean Nitrate + Nitrite time step loading by storm event. Different letters indicate significant differences at p≤0.05.

APPENDIX C. STORM EVENT PEAK SAMPLE DATA

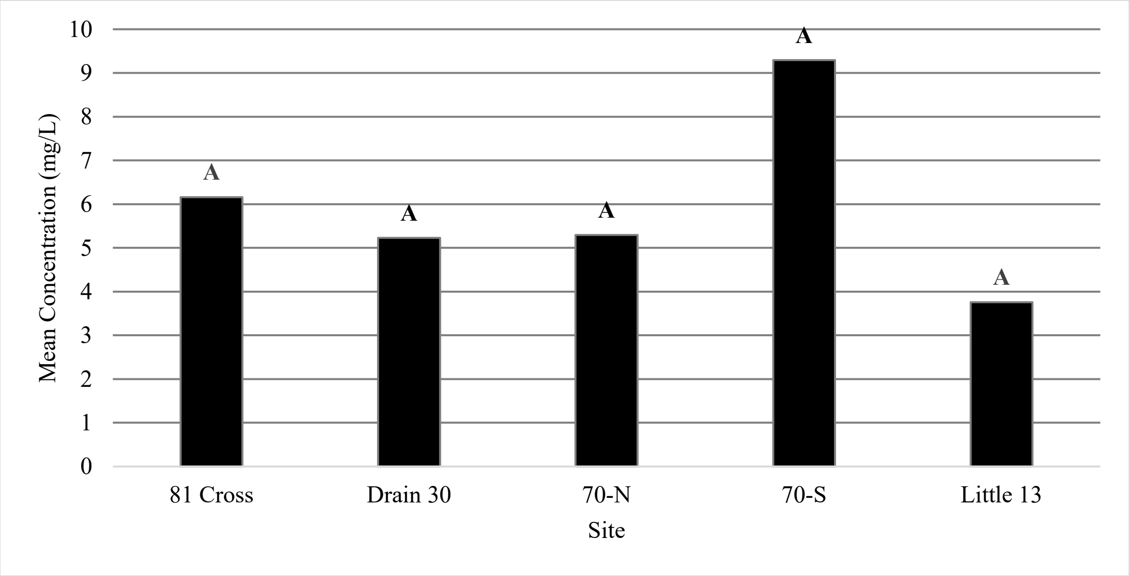

Figure C.1. Peak mean Total Nitrogen concentation by site. Different letters indicate significant differences at p≤0.05.

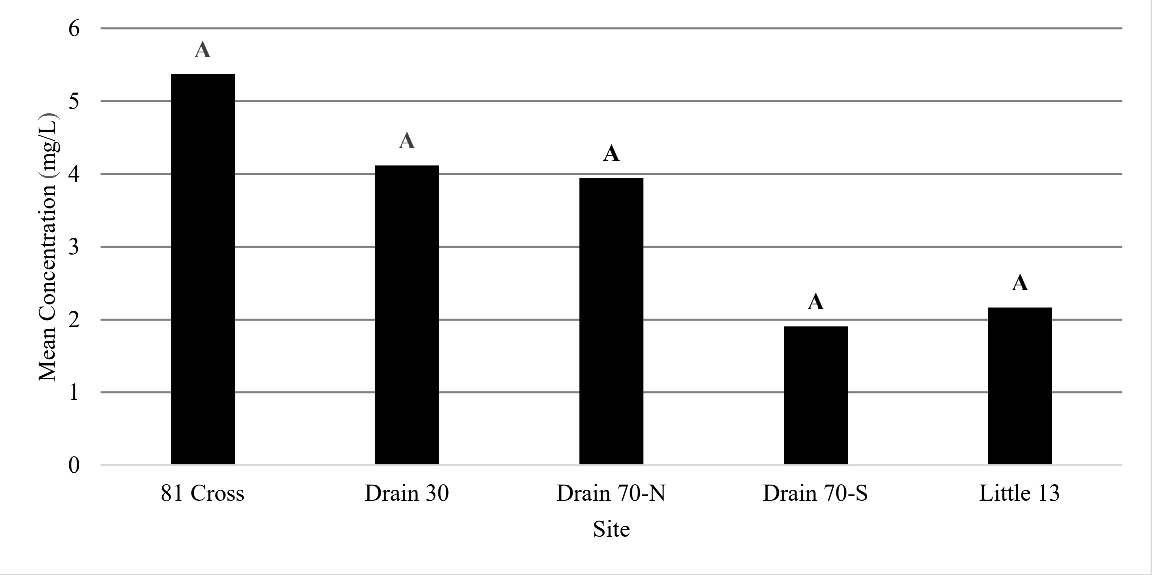

Figure C.2. Peak mean Nitrate + Nitrite concentration by site. Different letters indicate significant differences at p≤0.05.

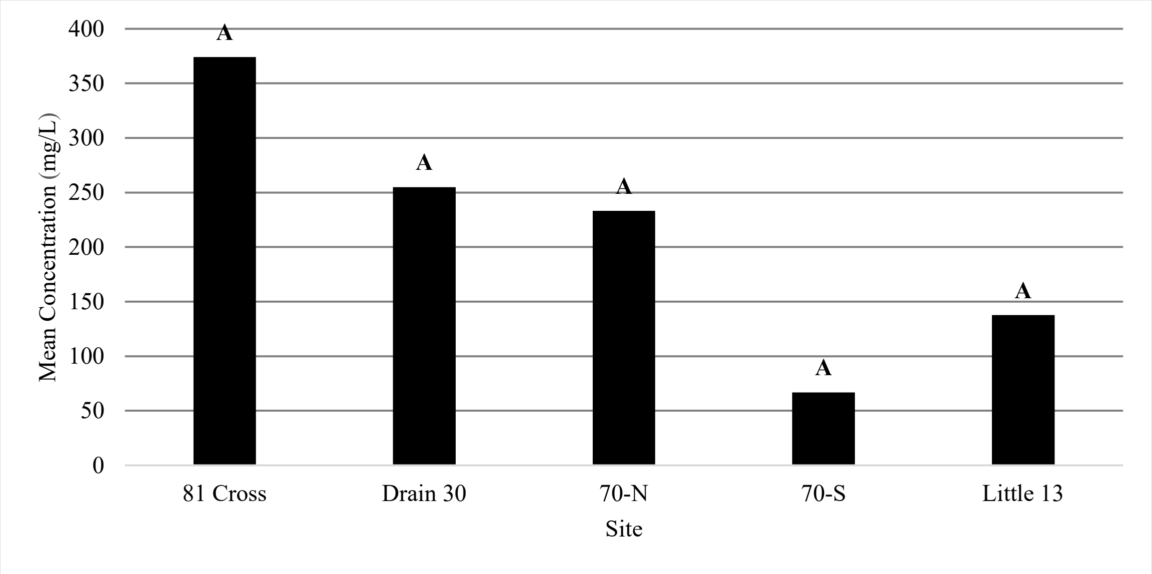

Figure C.3. Peak mean Total Suspended Solids concentation by site. Different letters indicate significant differences at p≤0.05.

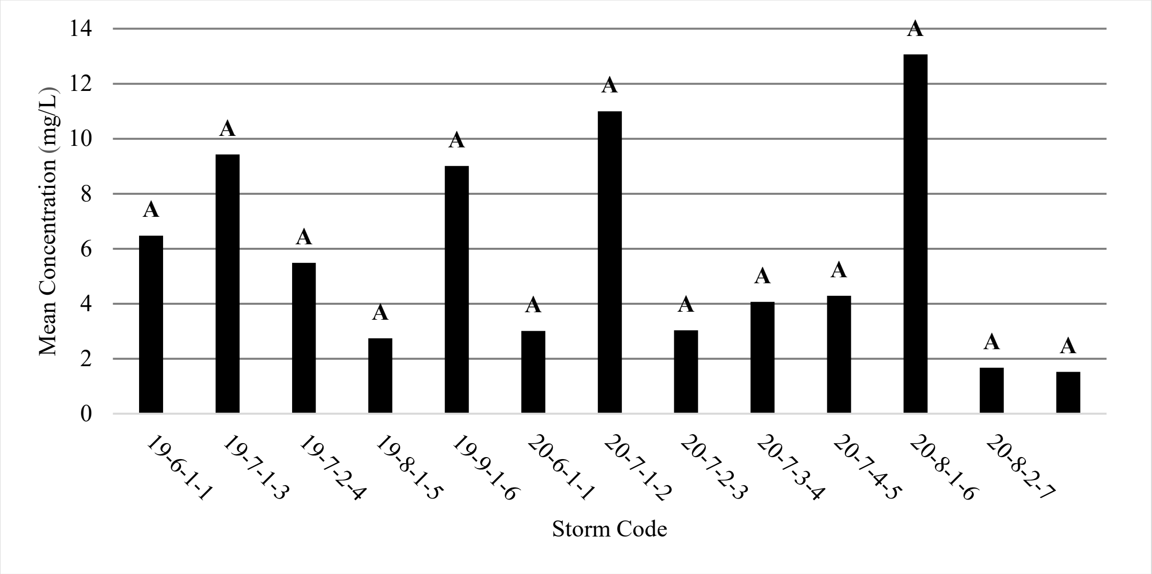

Figure C.4. Peak mean Total Nitrogen concentation by storm event. Different letters indicate significant differences at p≤0.05.

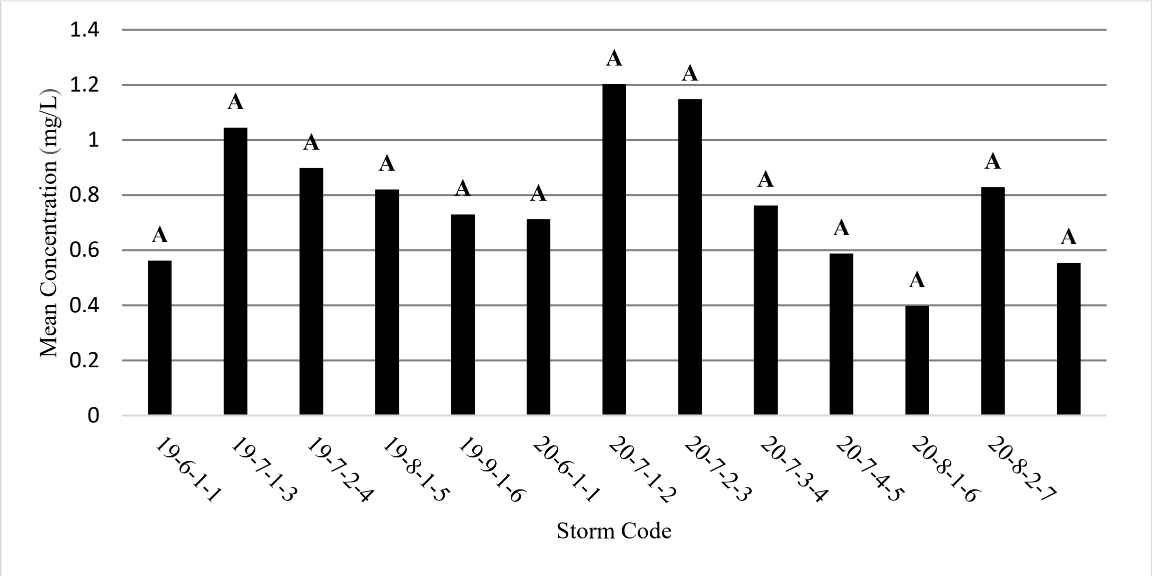

Figure C.5. Peak mean Total Phosphorus concnetation by storm event. Different letters indicate significant differences at p≤0.05.

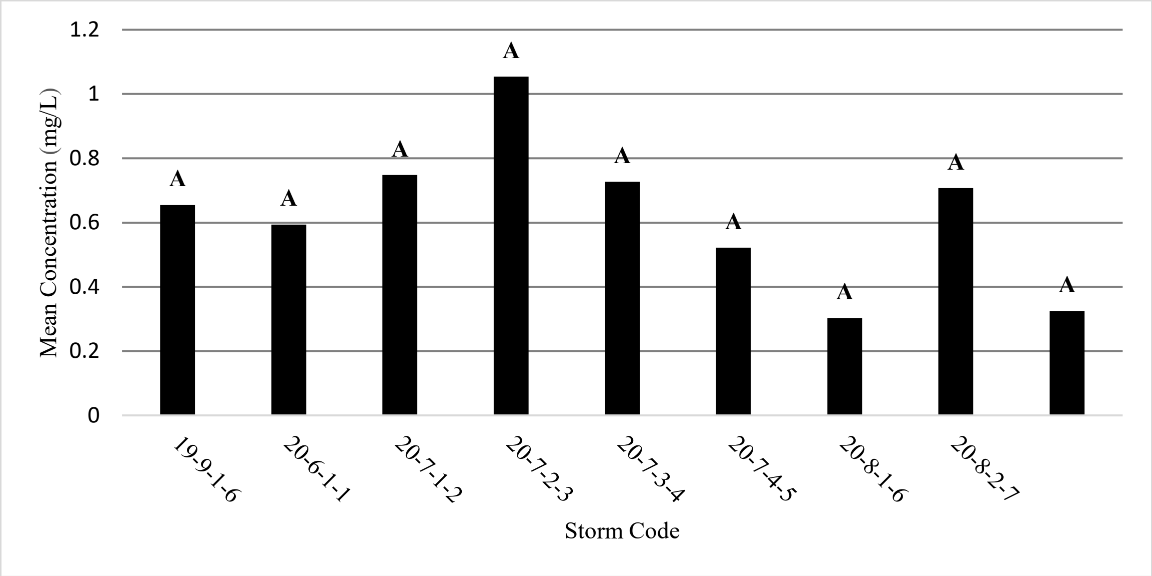

Figure C.6. Peak mean Dissolved Phosphorus concentation by storm event. Different letters indicate significant differences at p≤0.05.

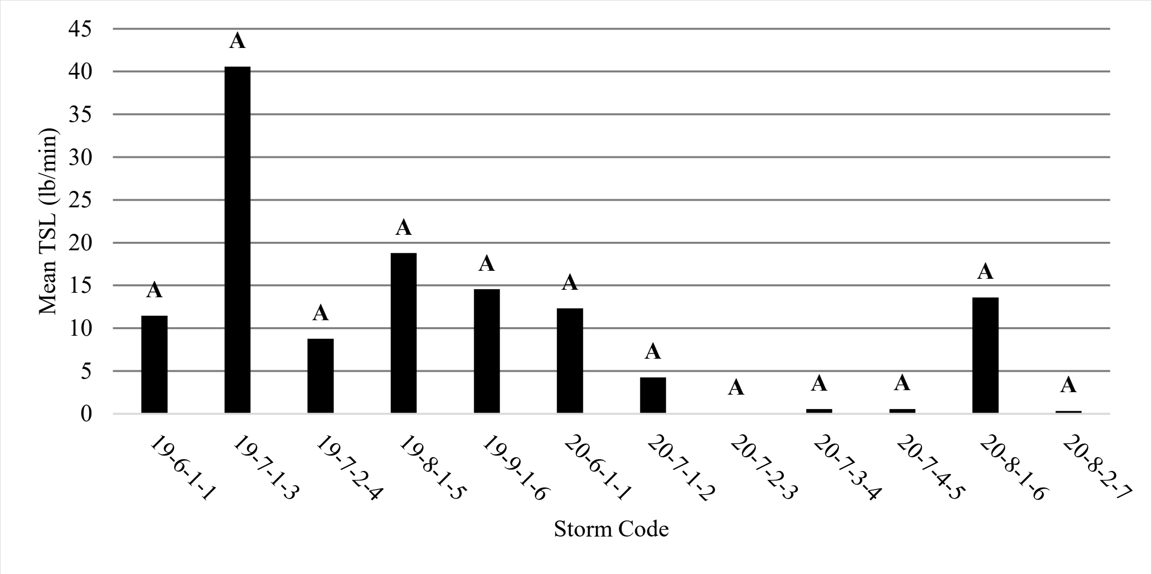

Figure C.7. Peak mean Total Nitrogen time step loading by storm event. Different letters indicate significant differences at $p \leq 0.05$.

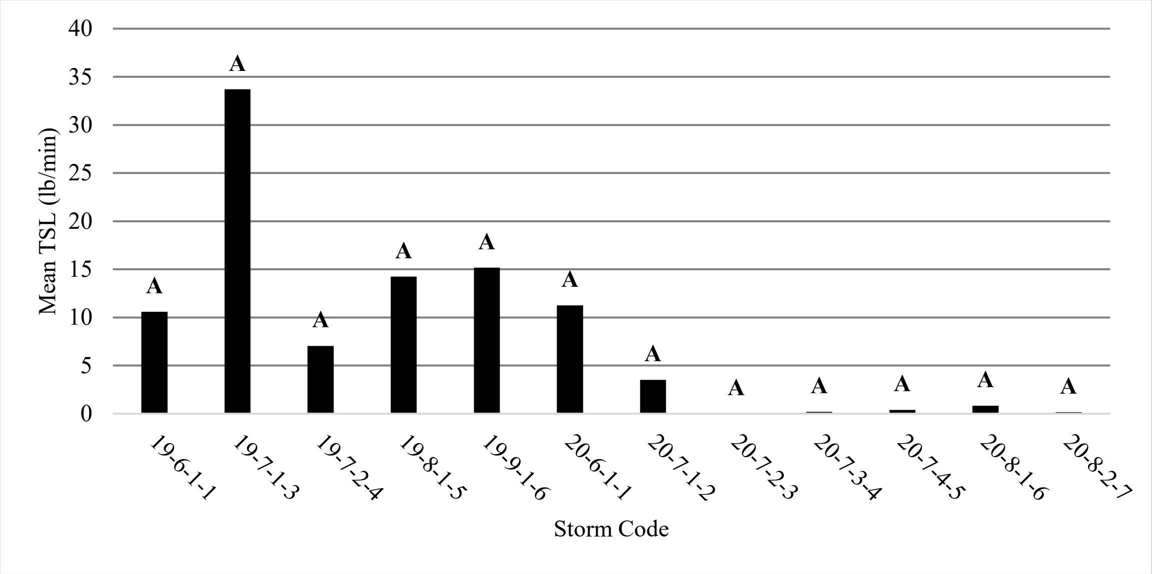

Figure C.8. Peak mean Nitrate + Nitrite time step loading by storm event. Different letters indicate significant differences at $p \leq 0.05$.

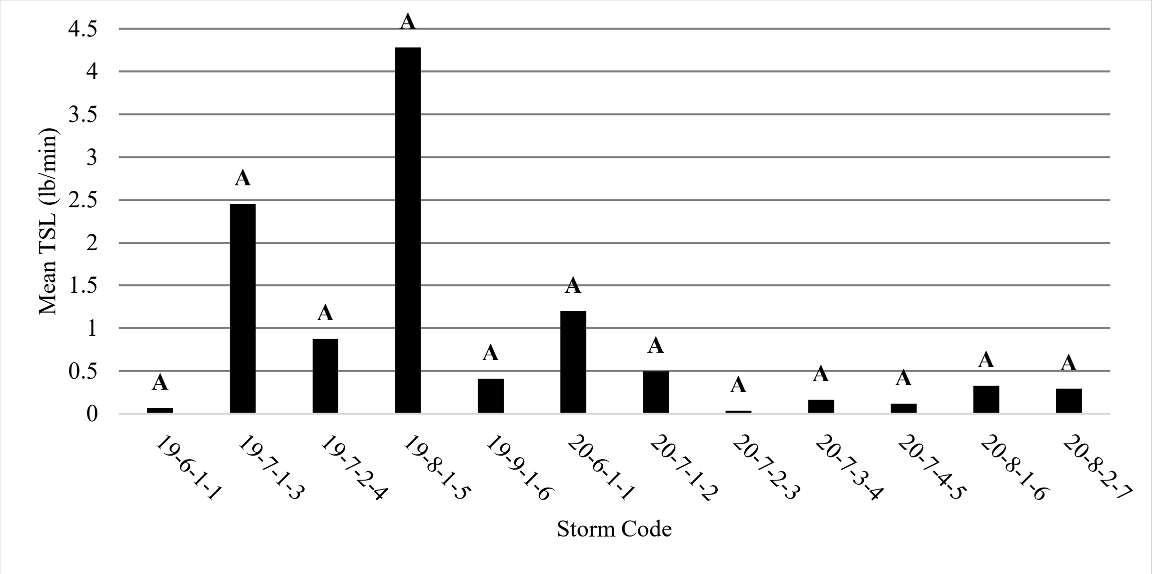

Figure C.9. Peak mean Total Phosphorus time step loading by storm event. Different letters indicate significant differences at p≤0.05.

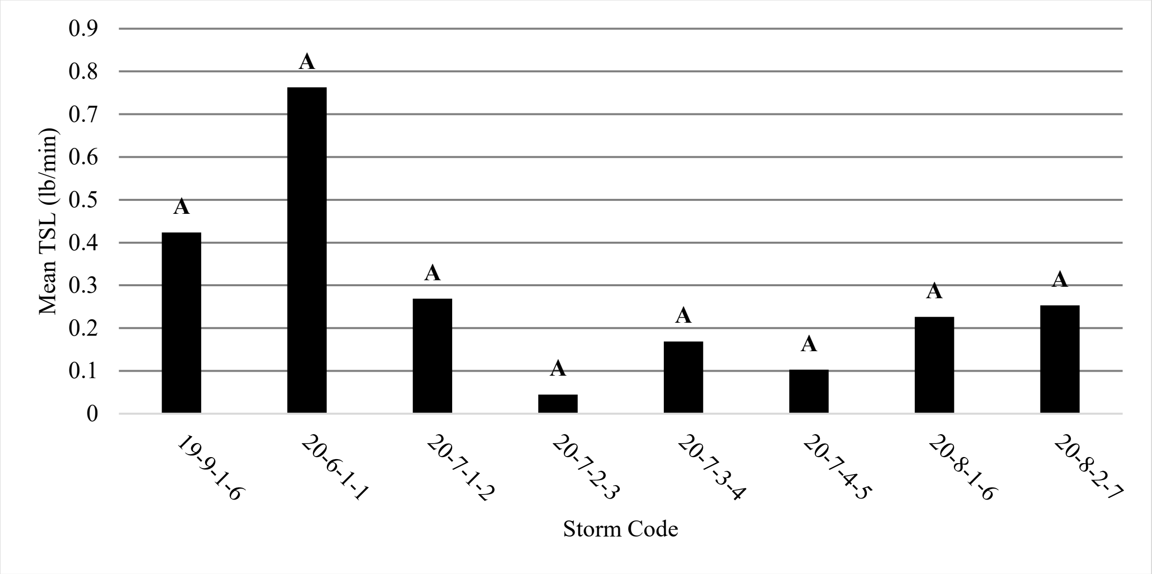

Figure C.10. Peak mean Dissolved Phosphorus time step loading by storm event. Different letters indicate significant differences at p≤0.05.

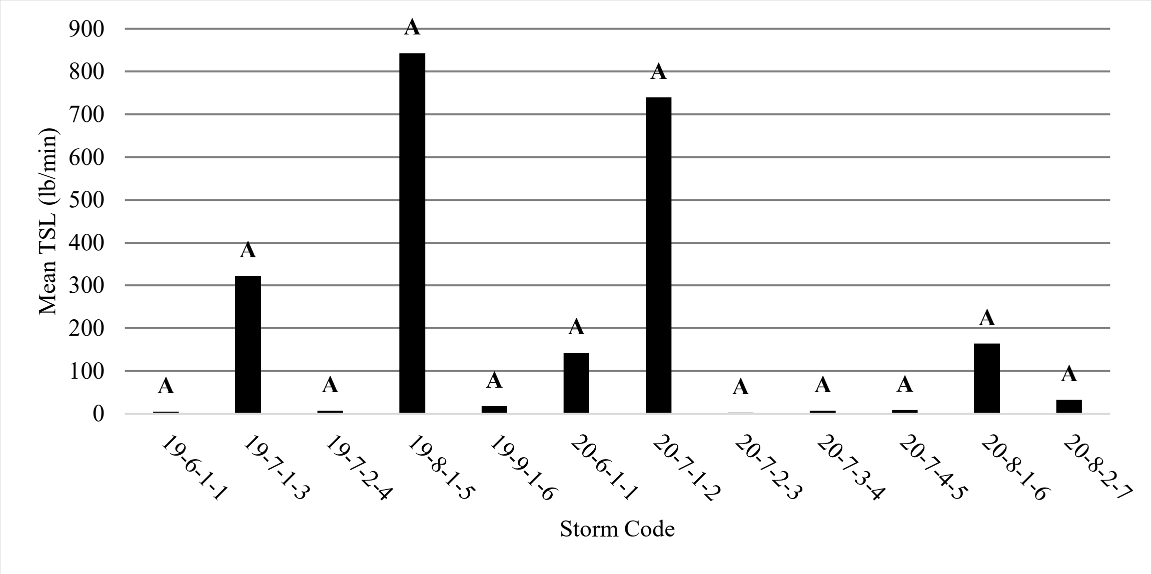

Figure C.11. Peak mean Total Suspended Solids time step loading by storm event. Different letters indicate significant differences at $p \leq 0.05$.

APPENDIX D. STORM EVENT FALLING LIMB SAMPLE DATA

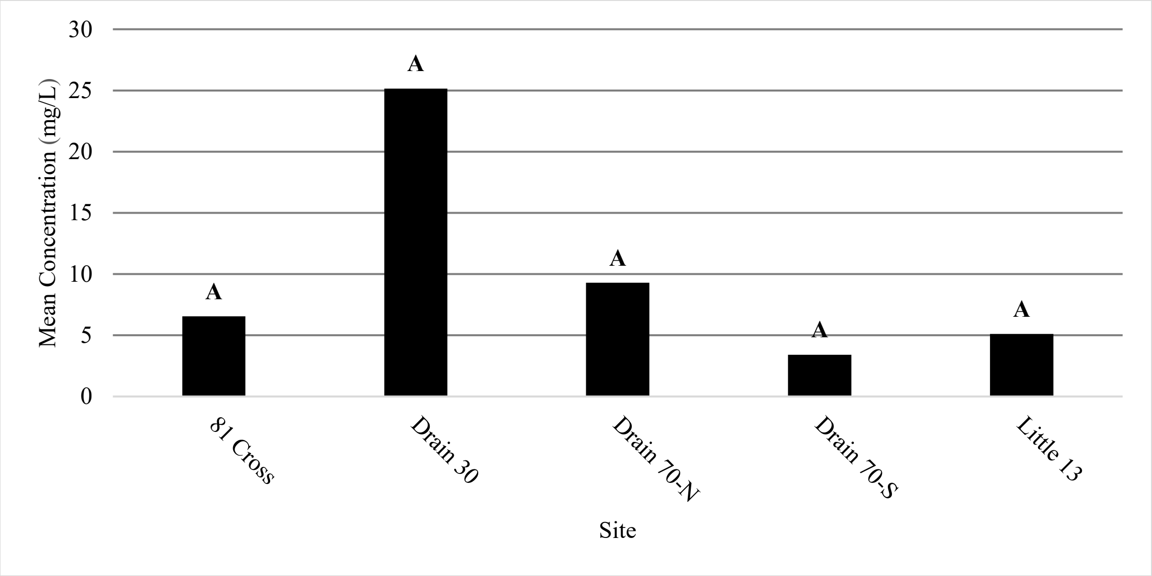

Figure D.1. Falling limb mean Total Nitrogen concentation by site. Different letters indicate significant differences at p≤0.05.

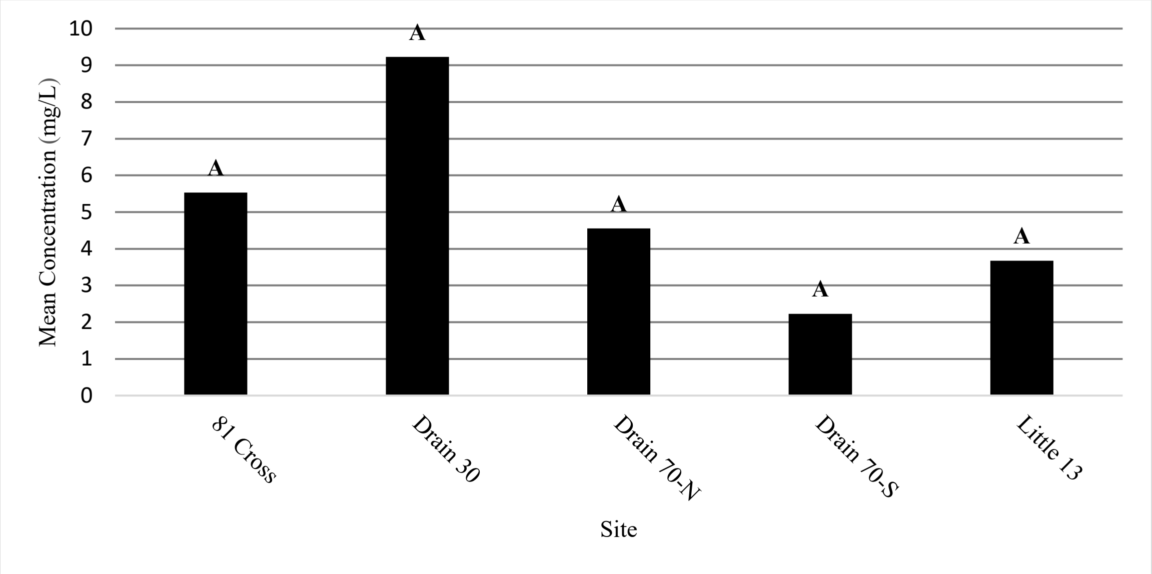

Figure D.2. Falling limb mean Nitrate + Nitrite concentation by site. Different letters indicate significant differences at p≤0.05.

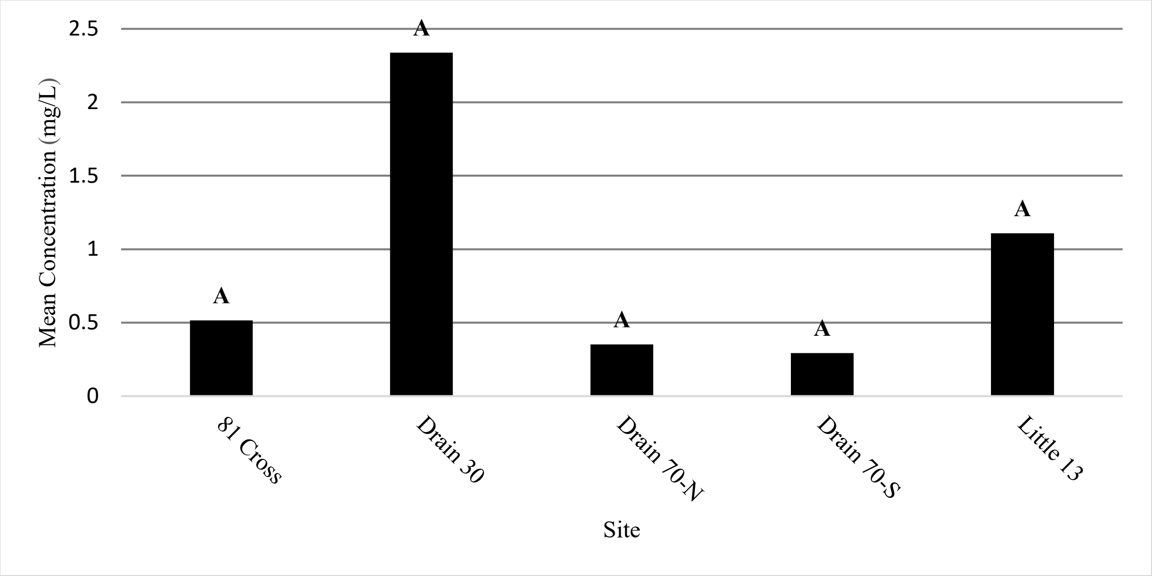

Figure D.3. Falling limb mean Total Phosphorus concnetation by site. Different letters indicate significant differences at p≤0.05.

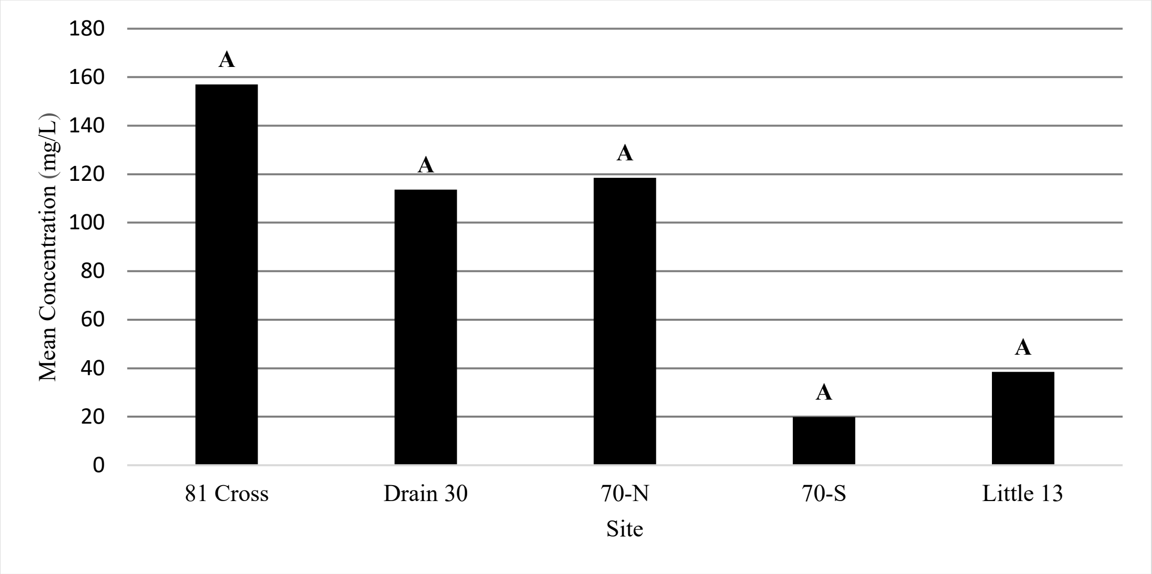

Figure D.4. Falling limb mean Total Suspended Solids concentation by site. Different letters indicate significant differences at p≤0.05.

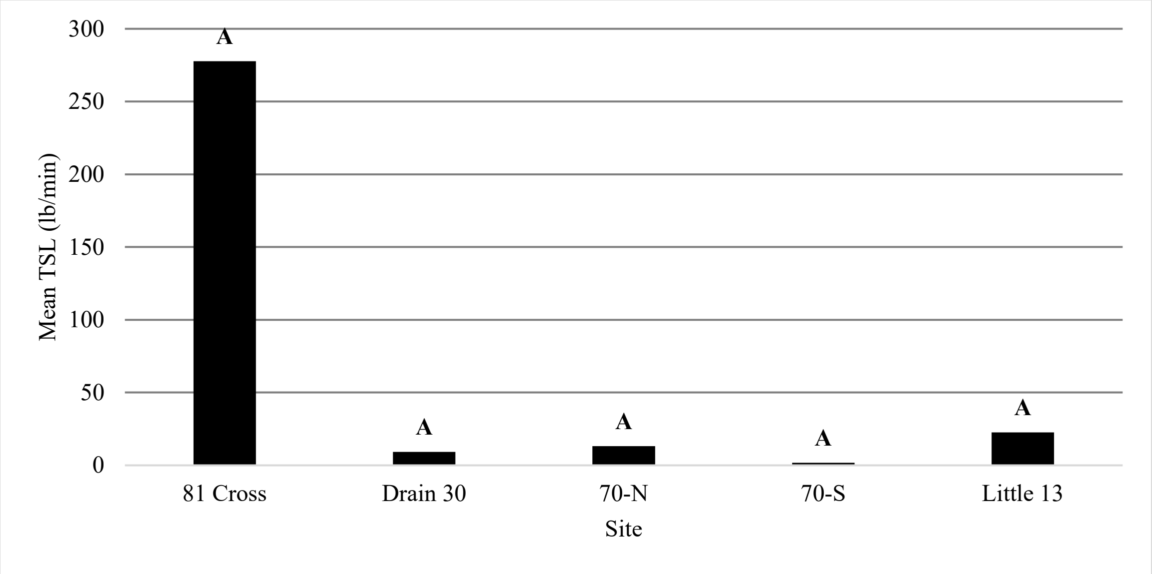

Figure D.5. Falling limb mean Total Suspended Solids time step loading by site. Different letters indicate significant differences at p≤0.05.

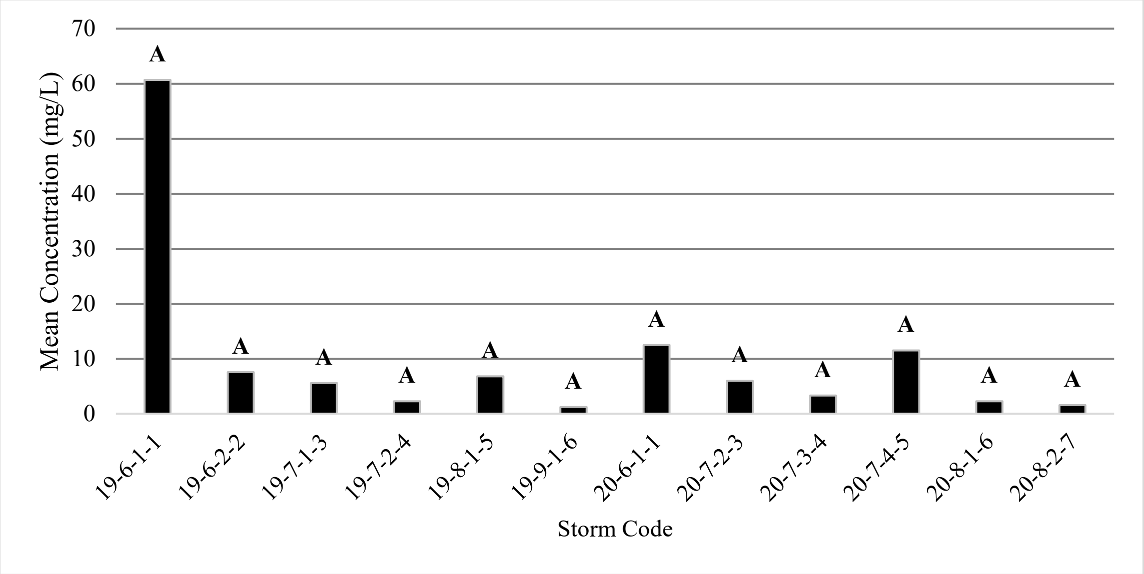

Figure D.6. Falling limb mean Total Nitrogen concentation by storm event. Different letters indicate significant differences at p≤0.05.

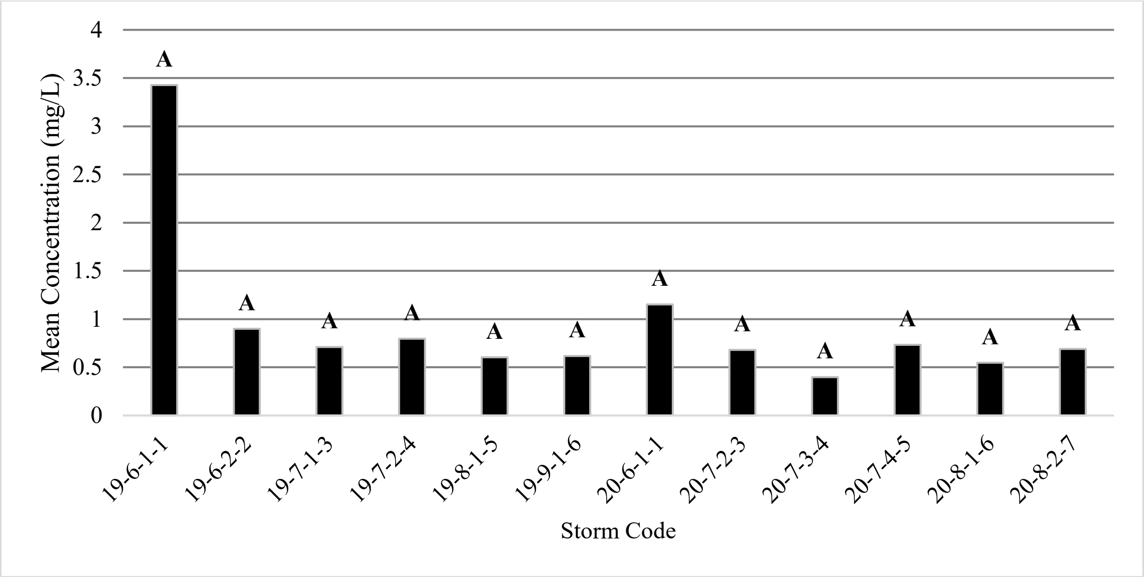

Figure D.7. Falling limb mean Total Phosphorus concentration by storm event. Different letters indicate significant differences at p≤0.05.

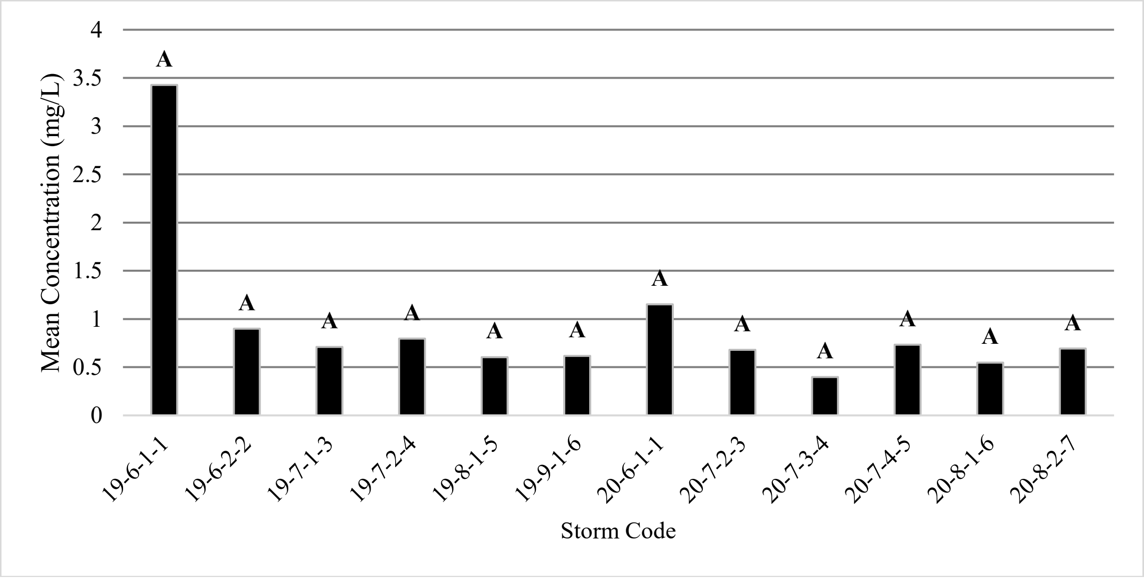

Figure D.8. Falling limb mean Total Suspended Solids concentation by storm event. Different letters indicate significant differences at p≤0.05.

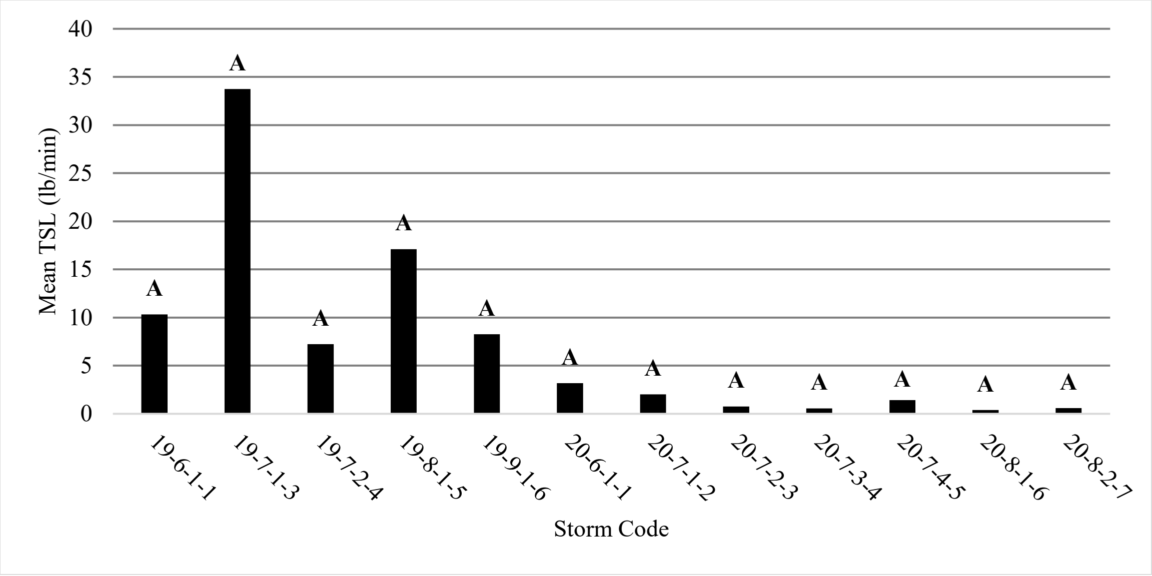

Figure D.9. Falling limb mean Total Nitrogen time step loading by storm event. Different letters indicate significant differences at p≤0.05.

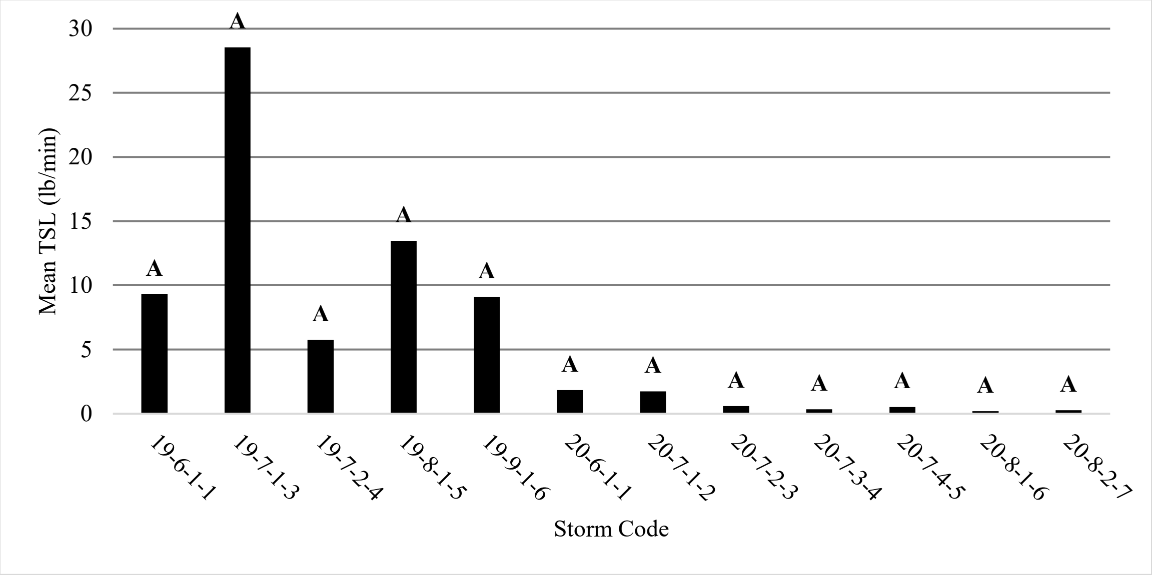

Figure D.10. Falling limb mean Nitrate + Nitrite time step loading by storm event. Different letters indicate significant differences at p≤0.05.

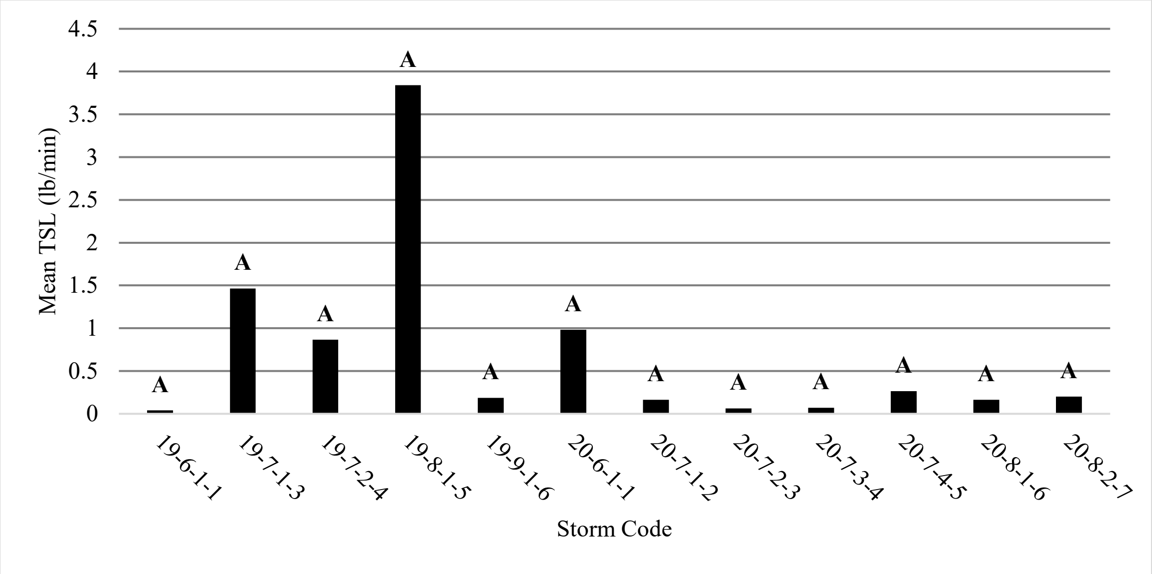

Figure D.11. Falling limb mean Total Phosphorus time step loading by storm event. Different letters indicate significant differences at p≤0.05.

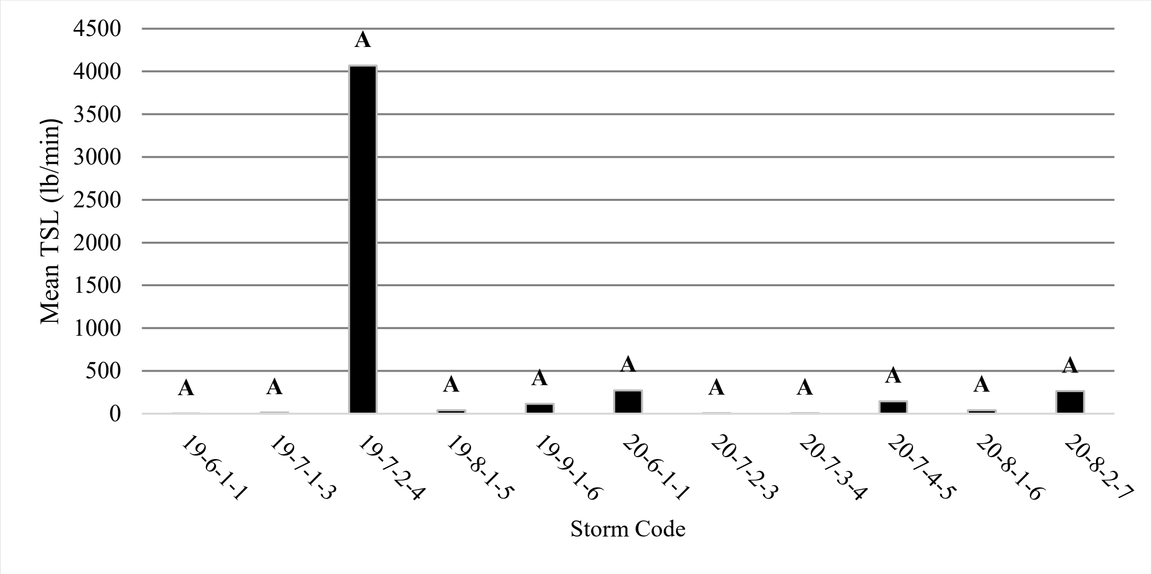

Figure D.12. Falling limb mean Total Suspended Solids time step loading by storm event. Different letters indicate significant differences at p≤0.05.

APPENDIX E. MANNING’S EQUATION PARAMETERS OF SAMPLE SITES.

Table E.1. Manning’s parameters of samples sites used for this study.

Site	Width (ft)	Height (ft)	Diameter (ft)	Slope	Roughness Coefficient
81 Cross	8.0	7.0	n/a	0.0058	0.012
Drain 30	n/a	n/a	6.6	0.001	0.022
70-N	n/a	n/a	2.6	0.0015	0.022
Little 13	10.0	5.0	n/a	0.001	0.012
70-S	n/a	n/a	2.6	0.0094	0.022

Table E.2. Example hydrologic readings of spring runoff at site 81 Cross.

81 Cross		
Sample Date	Wetted Height (ft)	Discharge (cfs)
April 8th, 2019	7	987.2275
April 15th, 2019	7	987.2275
April 24th, 2019	6.015748	816.3495
May 1st, 2019	0.897638	55.21112
May 7th, 2019	0.133596	40.34748
May 16th, 2019	0.667979	34.83649
April 2nd, 2020	7	987.2275
April 7th, 2020	7	987.2275
April 15th, 2020	3.74	4390.09
April 29th, 2020	1.35	1027.628

Table E.3. Example hydrologic readings during storm events at site 81 Cross.

Event	Rising Limb		Peak		Falling Limb	
	Wetted Height (ft)	Discharge (cfs)	Wetted Height (ft)	Discharge (cfs)	Wetted Height (ft)	Discharge (cfs)
20-7-2-3	0.703	377.4486	1.593	1314.554	1.205	898.25
20-7-3-4	1.60761	1332.39	1.73885	1495.326	1.614	1375.32
20-7-4-5	3.20	5672.847	5.3	7300.71	3.10	5472.95
20-8-1-6	1.24672	911.7419	2.06693	1921.967	.585	180.84
20-8-2-7	1.8377	1620.556	2.3622	2326.154	.425	148.41

APPENDIX F. CAPSTONE COURSE SURVEY

School of Natural Resources Sciences Capstone Course Evaluation – Deployed electronically using Qualtrics
By answering the questions below, you understand and agree to the terms listed above.
Questions:

1. Your major while taking the capstone course:

2. You took the capstone course as part of your: Undergraduate or Graduate degree?

3. Graduation Year for this Degree:

4. Gender:

5. Current Employer:

6. Current Position Title:

7. From the list below please select the job description that best fits your current position.

Botanist
Biologist
City Planner
Consultant
Environmental Scientist
Environmental Educator
Extension Agent
Forester
Game Warden
GIS Specialist
Graduate Student
Soil Conservation Manager/Tech
Watershed Manager/Tech
USFWS Refuge Staff
Environmental Compliance
Agronomist
Soil Scientist
Rangeland Manager/Tech
Private Business Owner
Sales
Other (Please fill in the blank)_________________

Throughout this survey NRM/SOIL/RNG 462/662 will be referred to as the capstone course. Please answer the following questions using the scale below, selecting the number that best fits your opinion of the question.

Answer Scale

1-Strongly Disagree | 2-Disagree | 3-Neutral | 4-Agree | 5-Strongly Agree

8. The capstone course provided an opportunity to work in a professional group environment similar to teamwork experiences I have had following graduation/during employment.

9. The capstone course increased my ability to work as a team to solve a specific problem and/or question.

10. The management plan writing required as part of the capstone course increased my competency in professional/technical writing.

11. The management plan writing in the capstone course increased my ability to evaluate and utilize relevant sources/literature for professional use.
12. The editing process in the capstone course increased my awareness of what is expected in professional writing in natural resources?

13. Following completion of the capstone course, I felt that my writing skills were better than they were at the start of the course.

14. The capstone course increased my ability to communicate solutions through written word.

15. Following completion of the capstone course, I felt that my verbal communication and presentation skills were better than they were at the start of the course.

16. The capstone course increased my ability to communicate with professionals on how to solve problems.

17. The capstone course allowed me to gain confidence in creating and giving a professional presentation.

18. The final presentation in the capstone course required a layout and content similar to those that may be utilized in my career.

19. The capstone course increased my knowledge on how to compile quality information to support my ideas.

20. The capstone course prepared me to identify problems affecting management of land and natural resources.

21. The capstone course increased my understanding of how to think critically about a parcel of land and evaluate complex management solutions to determine a plan for the future.

22. The interdisciplinary nature (multiple majors in the course, variety of disciplines needed to solve the capstone problems) helped to expand my knowledge of other fields within natural resources.

23. The interdisciplinary nature of the projects chosen helped to expand my view of issues I might deal with in my future career.

<u>Answer Scale</u>

1-Strongly Disagree | 2-Disagree | 3-Neutral | 4-Agree | 5-Strongly Agree| 6-I don't remember learning about this in capstone

24. I felt more prepared at the end of the capstone course for possible ethical situations I would deal with in my career than I did at the beginning of the course.

25. The ethical situations discussed in the capstone course accurately represent issues I have encountered/may encounter in my career.
26. The capstone course provided me with useful information to help when applying for jobs.

27. The required resume assignment familiarized me with professional resume styles including federal government and business/consulting resumes.

28. The required resume and cover letter critique helped to improve my resume for job searching.

29. I learned most of my job preparation skills in the capstone course: resume and cover letter writing, and interview skills. *If you answer 3 or less, please indicate in the provided space below where you feel you learned these skills (i.e. family, advisor, career center, a different class, etc.)

30. Please fill in your answer in the comment box provided below.

31. Based on your experiences, what was the most beneficial part of the capstone course?

32. Based on your experiences, what could be improved in the capstone course to better serve future students?

33. What topics studied while in the School of Natural Resource Sciences (RNG, SOIL, or NRM major) at NDSU were useful to you in your future career?

Environmental Law and Policy
Soil taxonomy and classification
Soil Chemistry
Soil water relationship and movement
Soil Genesis
Soils in relation to land use
Hydric soil identification
Ecology of soils
Soil fertility and nutrient cycling
Weather and Climate
Grazing Management and strategizes
Restoration
Writing skills
Verbal Communication Skills
Wetland Management
Plant Identification
Geographic Information Systems (GIS)
Watershed/River Management
Environmental Sociology
Ecology
Economics
Statistics
Conservation Biology
Environmental Education and Outreach
Genetics
Habitat Management
Wildlife ecology and management
Fisheries Management
Fire ecology and management
Rangeland sampling methods
Stocking rates
Rangeland contributions to ecosystem services and functions

34. What subjects/topics did you not learn while at NDSU, that you feel you should have learned or that would have been helpful to you in your future career?

35. Are there any subjects/topics/Skills that you feel were touched on, but should have been covered in more detail based on your professional work experiences?