Indian River Chloride Project

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Tip of the Mitt Watershed Council

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Acknowledgements

Tip of the Mitt Watershed Council (TOMWC, hereafter referred to as the Watershed Council) would like to offer our special thanks to the Mullett Area Preservation Society (MAPS) for their sincere interest in the protection of Northern Michigan's waters and for contracting with us to complete a chloride monitoring project in the Indian River and Mullett Creek. The following report is intended to be a comprehensive overview of the results from the contract made between TOMWC and MAPS. We would also like to offer our special thanks to Jim Leh and Graham Tillotson, the dedicated lake association volunteers who completed all chloride data collection, weather monitoring, and data reporting for this project. Their efforts and time are sincerely appreciated.

Introduction

The Mullett Lake Watershed is one of sixteen large watersheds within the Watershed Council's service area (Figure 1). These sixteen watersheds are considered sub-watersheds of the six primary watersheds that make up the Watershed Council's service area (the Carp River, Cheboygan River, Elk River Chain of Lakes, Lake Charlevoix, Little Traverse Bay, and Other/Coastal Watersheds). The Mullett Lake Watershed is situated within the Cheboygan River Watershed and encompasses 744 square miles. The primary tributaries of Mullett Lake include the Indian River, the Pigeon River, the Little Sturgeon River, the Little Pigeon River, and Mullett Creek. The outflow of Mullett Lake is the Cheboygan River, which empties into Lake Huron.

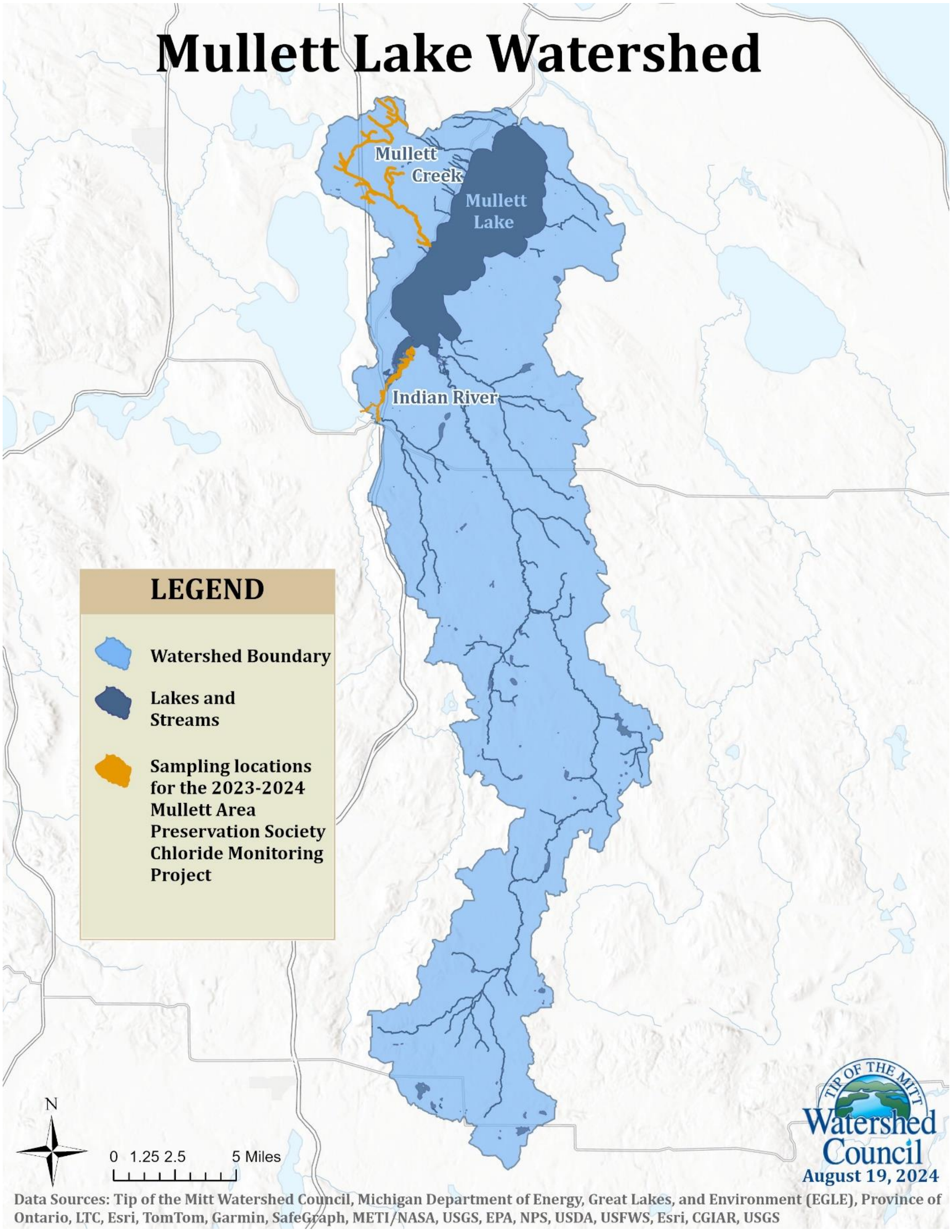


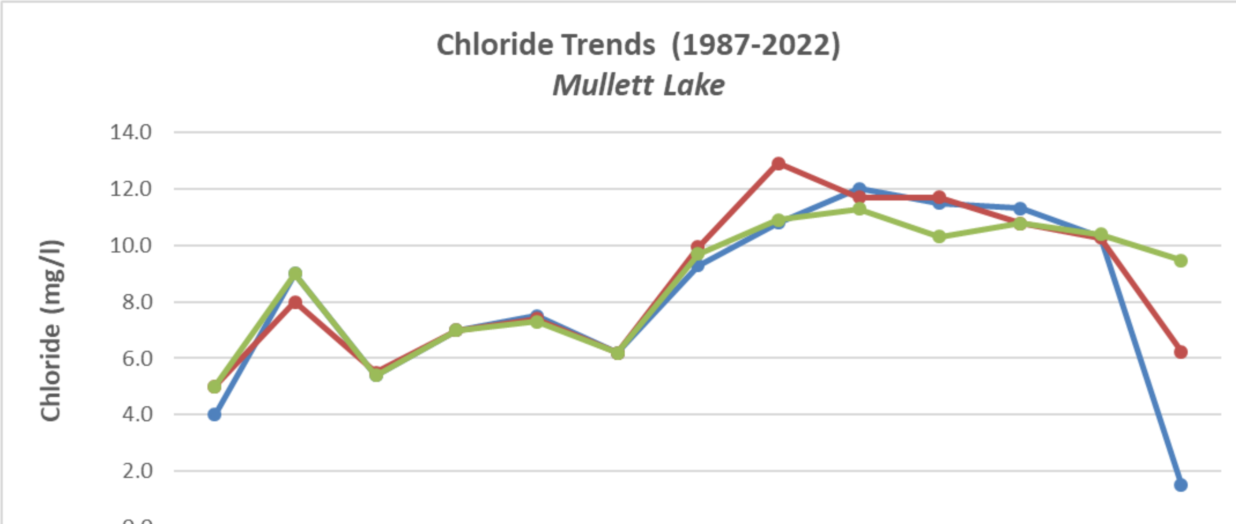
Figure 1. A map of the Mullett Lake Watershed with the Indian River and Mullett Creek highlighted in orange. These are the two waterbodies on which chloride sampling was conducted for the MAPS Chloride Project.

Mullett Lake itself has a surface area of 16,630 acres and a shoreline of 28 miles. Its deepest point reaches 145 feet. Mullett Lake is a notable part of Michigan's Inland Waterway – a chain of rivers and lakes spanning nearly 40 miles in length. It ranks as the state's fifth largest lake. The lake is a popular spot for recreational activities, including boating, fishing, kayaking, canoeing, and swimming. It is a major tourist attraction in Northern Michigan and visitation to the lake spikes during the summer months. Unfortunately, Mullett Lake does have a confirmed presence of invasive species – with Zebra and Quagga mussels posing problems with ecosystem health and nutrient imbalance. Despite the presence of invasive mussels, Mullett Lake is considered a high-quality natural resource supporting a wide diversity of habitat, wildlife, ecosystem services, and human uses.

For the MAPS chloride project, the monitoring was conducted in the Indian River and Mullett Creek (Figure 1). Both of these waterbodies are critical parts of the Mullett Lake Watershed, but only the Indian River has stormwater outfall pipes present at which to conduct monitoring. These stormwater outfall pipes were initially suspected to be some of the largest contributors of chloride to the river and the surrounding watershed. Mullett Creek was an additional site added by MAPS volunteers, and sampling was completed at the mouth of the creek. Indian River is a direct inflow to Mullett Lake, and is a highly urbanized residential area, meaning it can provide indication of excess chloride runoff into the lake itself. Mullett Creek extends from the west side of the lake and can also provide a general indicator of chloride contamination directly to Mullett Lake and within the watershed as a whole. Mullett Lake itself was not monitored for chloride pollution as it does not have any municipalities present, and thus, would not be an ideal waterbody in which to capture chloride contamination via wastewater or stormwater runoff.

The sampling sites for this project consisted of stormwater outfall pipes within the Indian River and Mullett Creek (Figure 7). The Indian River originates at the southeast end of Burt Lake and flows through residential areas before entering the urban environment of Indian River, then through a wetland area before it drains into Mullett Lake. The length of the Indian River is over 4 miles in total. Mullett Creek is the third largest tributary of Mullett Lake, behind the Pigeon River and the Indian River. It is fed by cold groundwater streams at its headwaters, making it a coldwater stream and an excellent spot for brook trout fishing. It is 11 miles in length and has confirmed presence of *Phragmites*, and invasive species of reed.

The issue of potential chloride contamination in Mullett Lake, and its surrounding watershed, was brought to the attention of the Watershed Council in early 2023 via MAPS. The lake association was interested in investigating chloride levels that may be entering the Mullett Lake Watershed via stormwater outfall pipes. Stormwater outfalls are pipes that convey stormwater runoff, or brine and road salt effluents to a receiving waterbody. MAPS pursued the development of the project with the Watershed Council due to the noticeably increasing chloride trends in Mullett Lake (Figure 2).



	4/24/1987	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Middle	4.00	9.00	5.40	7.00	7.50	6.20	9.28	10.80	12.00	11.50	11.30	10.32	1.53
Surface	5.00	8.00	5.50	7.00	7.40	6.20	9.95	12.90	11.70	11.70	10.78	10.27	6.23
Bottom	5.00	9.00	5.40	7.00	7.30	6.20	9.70	10.90	11.30	10.30	10.79	10.39	9.48

Figure 2. Chloride trends in Mullett Lake, from 1987 - 2022, collected through the Comprehensive Water Quality Monitoring Program. Note: Not noted by red line as levels are nowhere near the maximum (320 mg/L – see Table 1).

Water Quality in the Indian River

The Indian River has been monitored every three years (from 2007-2019) through the Watershed Council's Comprehensive Water Quality Monitoring (CWQM) Program for dissolved oxygen, specific conductivity, pH, total nitrogen, total phosphorus, and chloride levels. Physical data collection was completed for the Indian River in 2022, but no chemical data was collected/analyzed.

Aquatic nutrients, such as total phosphorus and total nitrogen, are important chemical parameters that form the foundation of all freshwater ecosystems. Total phosphorus is an essential aquatic nutrient required by algae and rooted aquatic plants to facilitate their growth and reproduction. Total phosphorus predicts both biological productivity and current trophic states of freshwater bodies. It can be used to determine whether nutrient pollution is occurring, and to what extent. Nutrient pollution can not only cause increased aquatic plant and algal growth, but can contribute to decreased water clarity, depleted levels of dissolved oxygen, mucky lake bottoms, unstable food chains, hypoxic zone formation, and death of benthic organisms.

Total nitrogen is another essential nutrient found in aquatic ecosystems. Nitrogen contributes to the growth of algae and plants, which provide wildlife habitat. Similar to total phosphorus, excess levels of nitrogen are indicative of a eutrophic ecosystem. Nitrogen-heavy waters may reflect environmental disturbances or anthropogenic activities, such as fertilizer use, stormwater runoff, or wastewater leakage from malfunctioning septic systems.

Chloride is the third and final nutrient measured through the CWQM program, and is the contaminant of focus for this project. Chloride occurs naturally in freshwater, and is needed by aquatic organisms to carry out basic life functions. However, excess levels of chloride (whether from road salting, brining, drilling of gas and oil wells, or runoff) can pollute freshwater in many ways. For example, chloride can contaminate drinking water, can destabilize aquatic plant community structure, and can be toxic to amphibians and fish. Furthermore, chloride may cause soil to be more sensitive to erosion by affecting its ability to retain water, can corrode infrastructure, and may even cause death if ingested by wildlife.

Below are the assessment criteria used for nutrient parameters sampled through the Watershed Council's CWQM program (Table 1). The assessment criteria are derived from the United States Environmental Protection Agency's (EPA) ambient water quality recommendations (Total Phosphorus, Total Nitrogen) and the State of Michigan (Department of Environment, Great Lakes, and Energy – chloride). Standard parameter values vary based on classification of waterbodies (i.e. lake or stream), type of parameter (i.e. type of nutrient, type of physical parameter, etc.), and EPA ecoregions and subecoregions. An ecoregion refers to specific areas where ecosystems are generally similar. A subecoregion refers to an ecoregion, but on a smaller geographic scale. The Indian River falls into subecoregion 50.

Table 1. Aquatic parameters measured as part of the Watershed Council's CWQM program.

Total Phosphorus (micrograms per liter, or ug/L)	**Subecoregion 50:** 12 ug/L streams, 9.7 ug/L lakes
Total Nitrogen (micrograms per liter, or ug/L)	**Subecoregion 50:** Streams: 440 ug/L streams, 400 ug/L lakes
Total Chloride (milligrams per liter, or mg/L)	Aquatic Maximum Value: 320 mg/L

Table 2. Results of Comprehensive Water Quality Monitoring on the Indian River, in descending order from most recent year (2022) to the first year of monitoring (2007).

CWQM Site Name	Date	Depth (m)	Class	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (uS/cm^2)	pH
Indian River	4/6/2022	-0.04	Surface	3.61	13.21	380.40	8.16
Indian River	5/18/2019	1.012	Middle	11.517	11.27	328.6	8.27
Indian River	4/14/2016	1.0	Middle	4.19	13.68	271.8	8.13
Indian River	4/10/2013	1.2	Middle	3.27	13.41	326.2	8.31
Indian River	4/21/2010	1.2	Middle	10.03	11.32	301.4	8.48
Indian River	5/22/2007	0.9	Middle	12.62	10.13	284.7	8.25

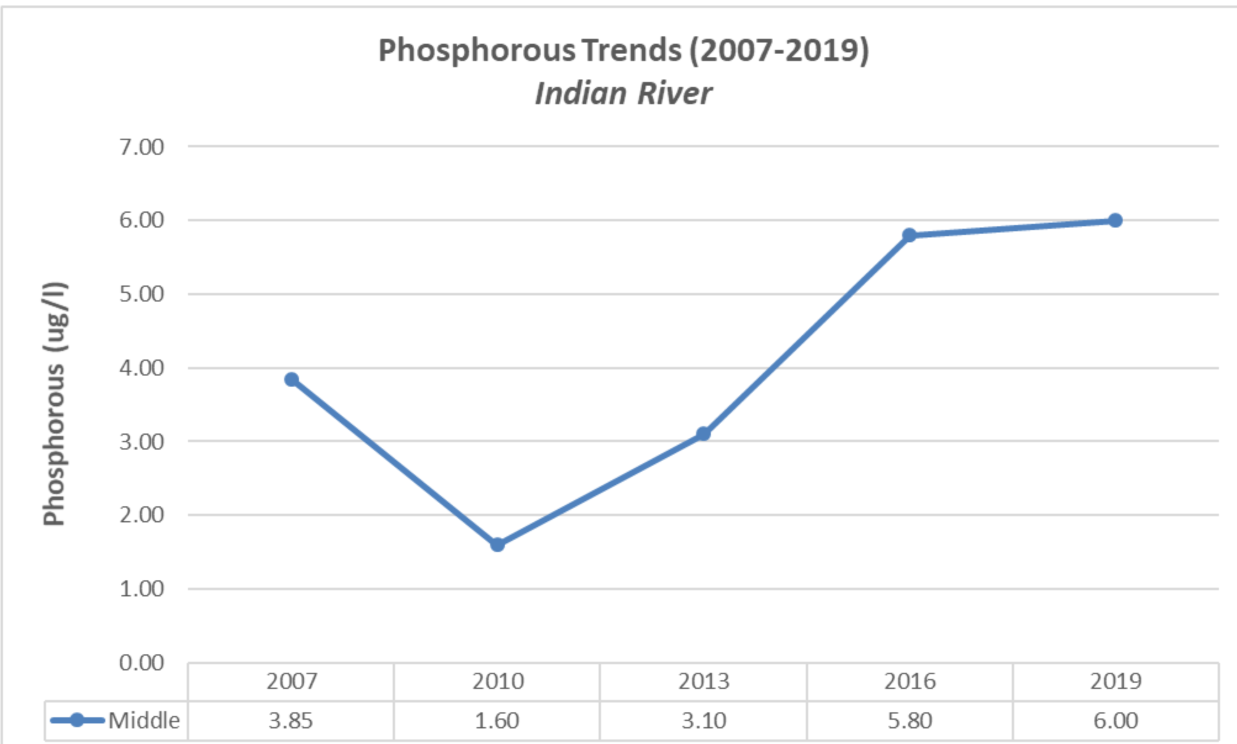


Figure 3. Phosphorus trends in the Indian River, from 2007 - 2019, collected through the Comprehensive Water Quality Monitoring Program. Note: Not noted by red line as levels are not near the maximum (12 ug/L).

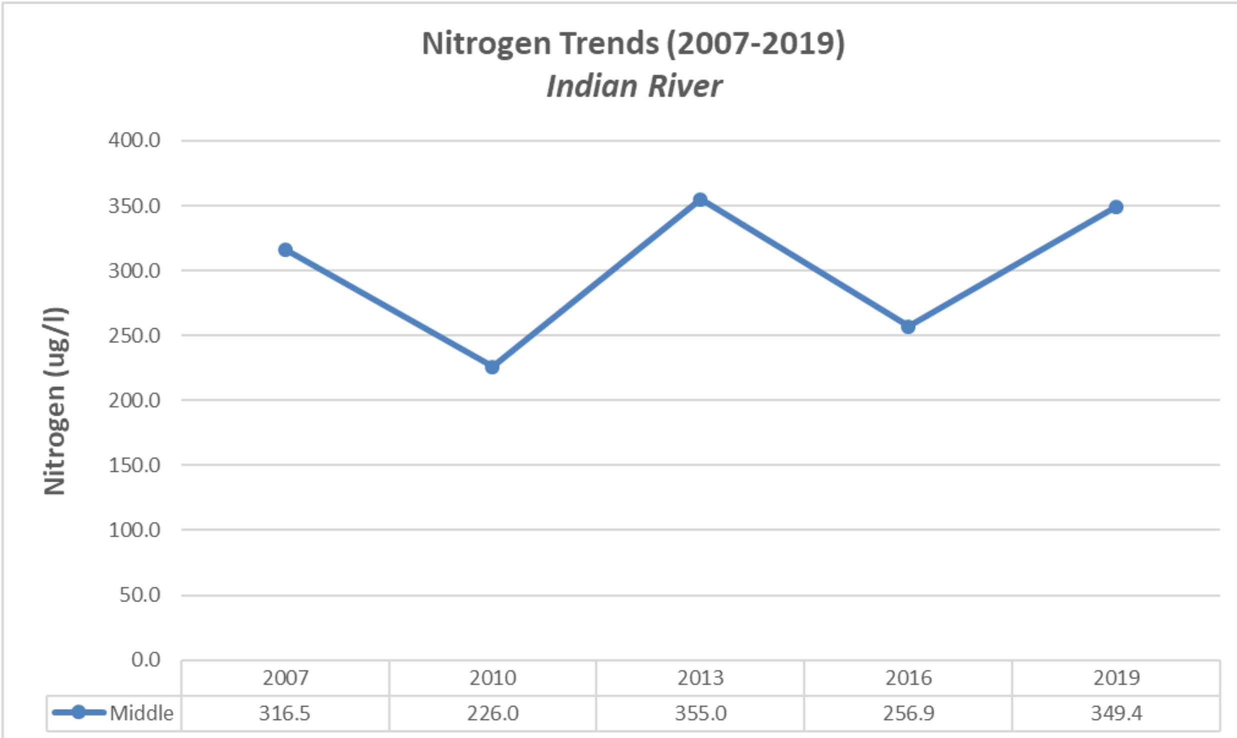


Figure 4. Nitrogen trends in the Indian River, from 2007 - 2019, collected through the Comprehensive Water Quality Monitoring Program. Note: Not noted by red line as levels are not near the maximum (440 ug/L).

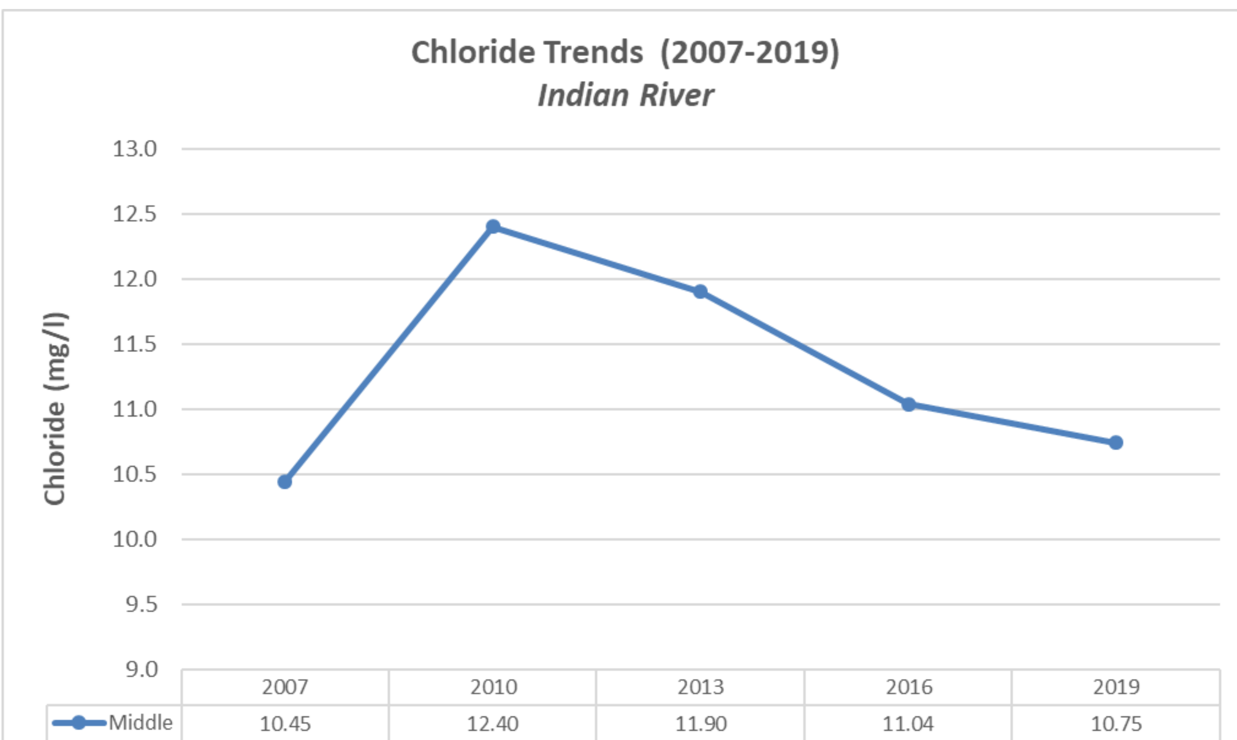
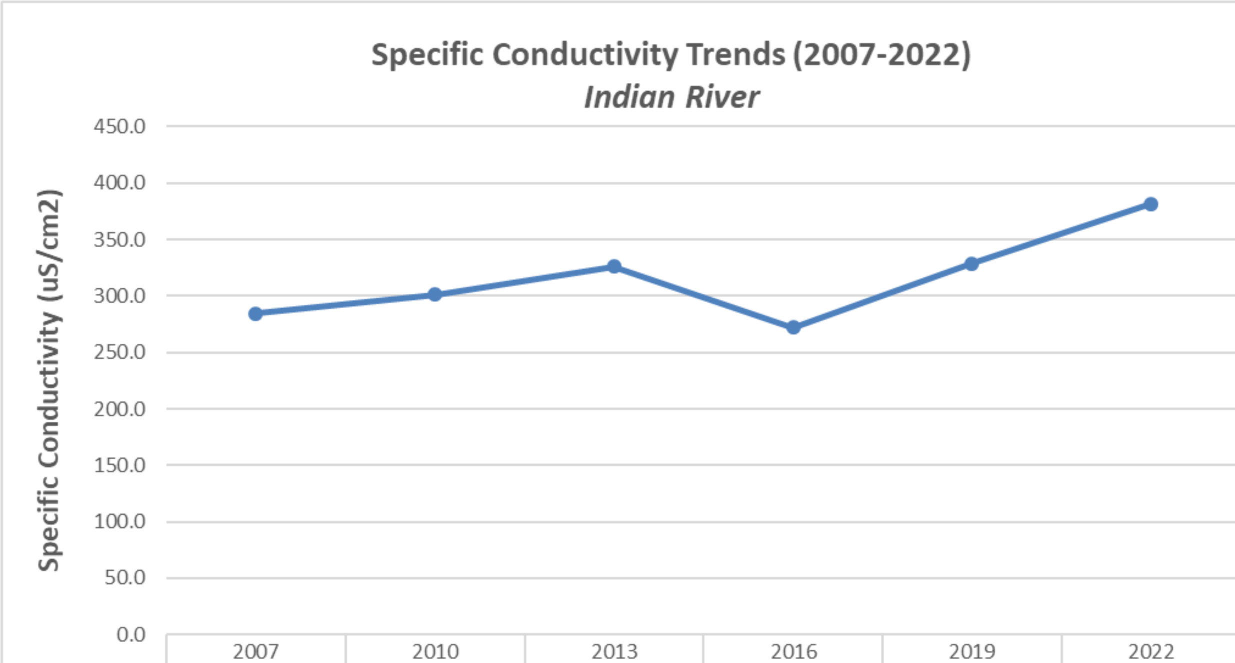


Figure 5. Chloride trends in the Indian River, from 2007 - 2019, collected through the Comprehensive Water Quality Monitoring Program. Note: Not noted by red line as levels are nowhere near the maximum (320 mg/L).



	2007	2010	2013	2016	2019	2022
Middle	284.7	301.4	326.2	271.8	328.6	381.8

Figure 6. Conductivity trends in the Indian River, from 2007 - 2022, collected through the Comprehensive Water Quality Monitoring Program. Note: A suitable conductivity range to support freshwater fish populations is 150 - 800 uS/cm^2.

Based on the above nutrient and conductivity data, we see that the Indian River has excellent water quality overall. There are no instances of total phosphorus or total nitrogen exceedances throughout the entire span of data collection for the river. Although total phosphorus levels have been increasing since 2010, levels have not yet exceeded the recommended maximum (12 ug/L). While total nitrogen levels show no exceedances of the recommended maximum (440 ug/L), levels did peak in 2013 and 2019 at around 350 ug/L. Chloride levels in the river demonstrated no concrete pattern, and did not come close to crossing the aquatic maximum value (320 mg/L). There was a peak in chloride levels in 2010, but levels have steadily declined since that year. Finally, specific conductivity levels were within a healthy range to support freshwater fish populations. There is no observable trend in the conductivity data from the years 2007 to 2022.

Water Quality in Mullett Creek

Mullett Creek is the third largest tributary of Mullett Lake, closely following the Pigeon River and the Indian River. It is a coldwater stream that extends for about 11 miles. While the creek has healthy brook trout populations, it does have invasive *Phragmites.* Mullett Creek is monitored annually through the Watershed Council's Volunteer Stream Monitoring (VSM) Program for temperature, conductivity, and macroinvertebrates. Stream health is determined via macroinvertebrate data (number of individual families, number of sensitive families, and number of Ephemeroptera, Plecoptera, and Trichoptera families). The creek is monitored at two sites, Crump Road and M-27, both of which are monitored once in the spring and once in the fall. The results from macroinvertebrate sampling at both sites in 2023 are shown below.

Table 3. Results of Volunteer Stream Monitoring on Mullett Creek, 2023.

VSM Stream Site Name	Date	Total Families	EPT Families	Sensitive Families	Average Yearly Score
Mullett Creek - Crump Road	5/20/2023	20	10	6	59
Mullett Creek - Crump Road	9/16/2023	11	4	1	
Mullett Creek - M-27	5/20/2023	22	4	1	32
Mullett Creek - M-27	9/16/2023	19	2	0	

Based on the above macroinvertebrate data, we see that Mullett Creek demonstrates different levels of macroinvertebrate diversity based on the site sampled. For example, the Crump Road site had an average yearly score of 59, which corresponds to a letter grade of 'B'. The number of total families, EPT families, and sensitive families was relatively high across all parameters. Interestingly, the site at M-27 had an average yearly score of only 32, which corresponds to a letter grade of 'C'. While the number of total families identified was high for the M-27 site, the number of EPT and sensitive families was relatively low. Since Mullett Creek sites had letter grades of 'B' and 'C', it is likely that the creek itself is experiencing impacts from non-point source pollution such as nutrient influx, chloride runoff (e.g. from brining or road salting), sedimentation, and more.

Interestingly, Mullett Creek (across all VSM monitoring locations – see link: Mullett Creek - Tip of the Mitt Watershed Council for publicly accessible data and list of monitoring sites) has displayed stream health grades of almost all 'A's, with a few monitoring events showing 'B's, and only from 2021 and a few recent years has data dipped into the 'C' category. Examining these long-term trends in VSM stream health grades, and their decline in recent years, further suggests that chloride pollution, among other water quality issues, may be contributing to diminishing stream health and overall health of the Mullett Lake watershed.

Furthermore, the results of the Mullett Lake Tributary Monitoring Study (2007) indicate that Mullett Creek (at multiple monitoring locations) had notable incidences of bacteriological exceedances (*E. coli*), nutrient concentration exceedances, and (at the time – the report was published in 2007) had chloride levels that exceeded typical CWQM values for Mullett Creek based on monitoring done prior to the report's publishing. While the tributary monitoring data is from 2007, and while only chloride is the parameter of focus for this study, it is important to identify previously existing water quality issues within critical tributaries of the Mullett Lake Watershed.

Methodology

All sampling for this project was completed by MAPS volunteers. Relevant Watershed Council staff reviewed proper sampling protocols with the volunteers before sampling was conducted. To complete the chloride monitoring, two volunteers sampled throughout four seasons at 10 different sites. 9 of these sites were on the Indian River, and the final site was at the mouth of Mullett Creek (Figure 7). Each site was sampled twice per season. At the majority of sites, water was collected directly from outfall pipes, with the following exceptions: 1) no water was running at the time/date of collection, 2) the site was under construction, or 3) the site did not have an outfall pipe to begin with (Mullett Creek, Sites 11 and 12).

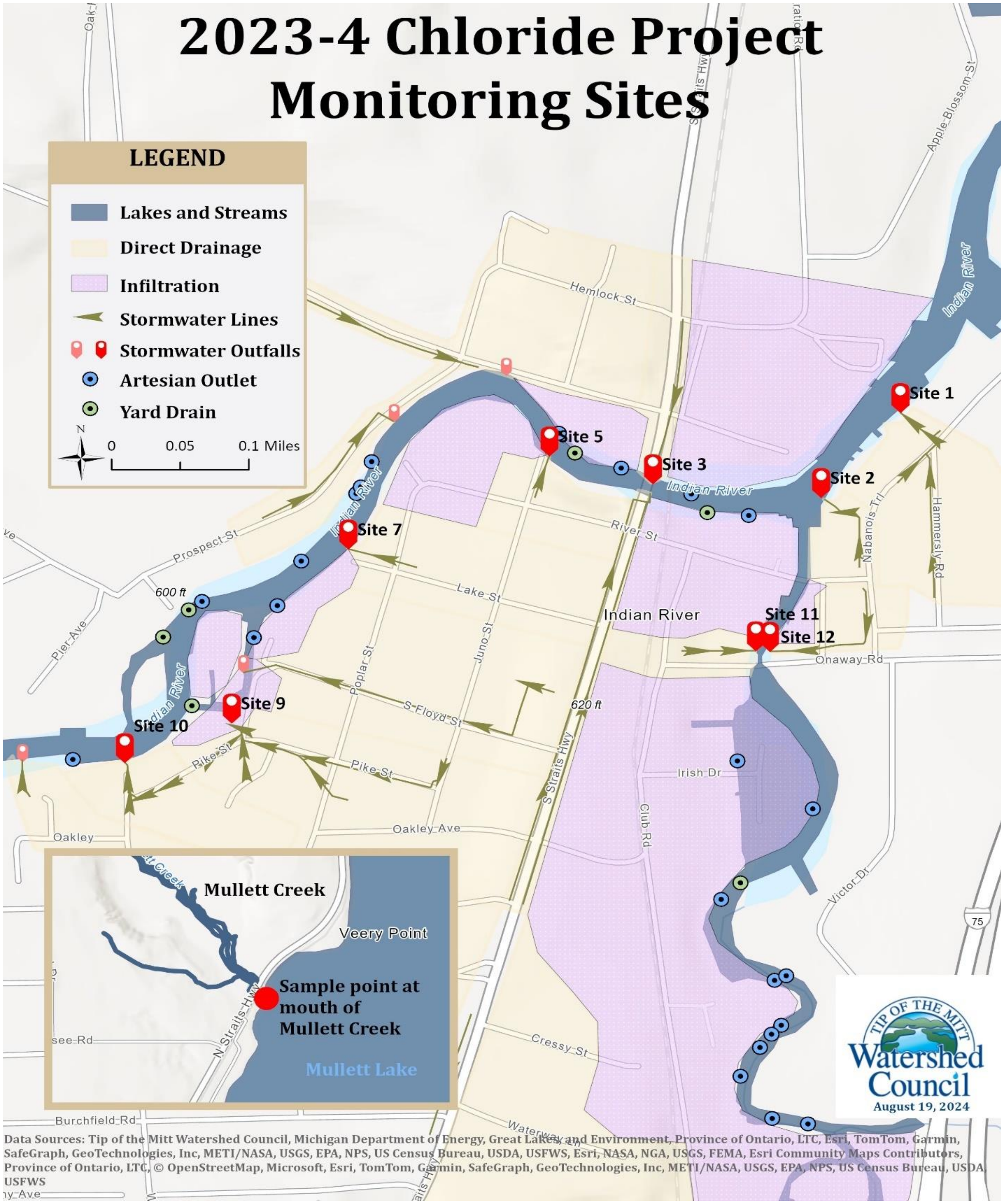


Figure 7. A map of the 10 sampling sites monitored for chloride levels (parts per million, or ppm) by MAPS volunteers from Fall 2023 – Summer 2024. Note that Site 9 includes two stormwater outfall pipes that were monitored, but is only marked as one site on the map above. The Mullett Creek (Mouth) site was added by MAPS volunteers and was sampled throughout all four seasons.

Data collection was completed using Hach® Chloride Test Strips. Hach® Chloride Test Strips are easy-to-use paper strips that can be dipped in sample water and used to quantify the amount of chloride within that sample. The test strip provides a Quantab unit, which can then be directly converted to chloride levels in parts per million, or ppm (or mg/L, which are equivalent in value, Figure 8). The strips utilized for data collected were low range, meaning the test strips could detect chloride levels ranging from 30 ppm to 620 ppm. These low-range strips were suitable for conducting the chloride monitoring, as the state-recommended aquatic maximum value is 320 mg/L, and given the high-quality, typically oligotrophic (clear, nutrient-poor) waters within the Watershed Council's service area, we did not expect to see chloride values above 620 ppm.

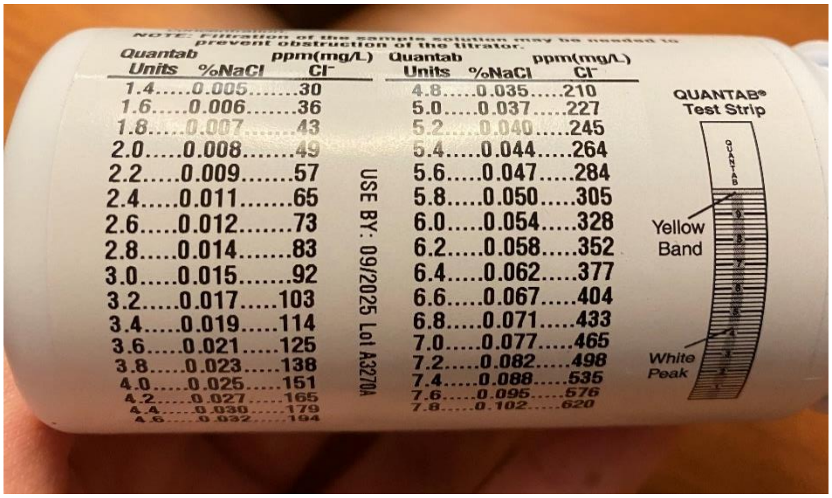
Data collection occurred within 24 hours after a rain event occurred. A rain event is defined as either 1) 0.5 inches over a 24-hour timeframe, or 2) 0.25 inches over a 12 hour timeframe. The Watershed Council recommended sampling as soon as possible after the rain event had occurred. Volunteers also documented how much rain was received prior to each sampling event.

Two chloride readings were collected per site, per season. Separate test strips were used after separate rain events. Volunteers adhered to the following protocol when collecting chloride data: First, MAPS volunteers filled out a provided datasheet from the Watershed Council with their names, the date, time, and site number. Collection bottles, used to hold water to dip the chloride strip into, were triple-rinsed with river water (or water from Mullett Creek). Sample bottles were filled directly from the outfall pipes, with the exception of sites that did not have an outfall pipe, in which case water samples were collected by dipping the sample bottle below the water's surface and filling (Mullett Creek, Sites 11 and 12).

Once a water sample was collected, the chloride test strip was submerged in the sample until fully saturated. The test strip was the interpreted using the chart on the back of the Hach® bottle, which provided a way to convert the test strip reading into a chloride value (ppm). For example, if volunteers recorded a value of 1.4 on the test strip itself, this value correlates to 30 ppm on the back of the Hach® bottle (Figure 8). Data was collected at all sites twice per season from fall 2023 until summer 2024. Copies of data sheets were delivered to the Watershed Council office as sampling events were completed.

Results

Below are the results for five of the 10 total sites monitored for chloride levels via MAPS volunteers (Figure 9). It is important to note that **only sites with chloride readings greater than 30 ppm were included in this figure (i.e. Sites 1, 3, 5, 11, and 12).** This is due to 1) the fact that chloride readings



below 30 ppm are deemed very low and are not a cause for water quality concern (State of Michigan aquatic maximum value recommends chloride levels stay at or below 320 mg/L, see Table 1 and 'References'), and 2) a large portion of the collected chloride data readings were less than 30 ppm across multiple project sites, suggesting that ambient chloride levels within the

Figure 8. A photo of the back of the Hach® Chloride Test Strip Bottle. Quantab units are on the left, and the chloride result in ppm(mg/L) is on the right. The range for chloride (ppm) goes from 30 ppm to 620 ppm.

Mullett Lake Watershed are consistently low (<30 ppm), and 3) the conversion chart on the back of the Hach® Chloride Test Strip bottle (Figure 8) does not provide conversion of Quantab Units to ppm below 30 ppm. The conversion factor is non-linear, so with test strip readings below 1.4 (Figure 8), we can only definitively say that levels are below 30 ppm. We cannot assign a value without the direct conversion.

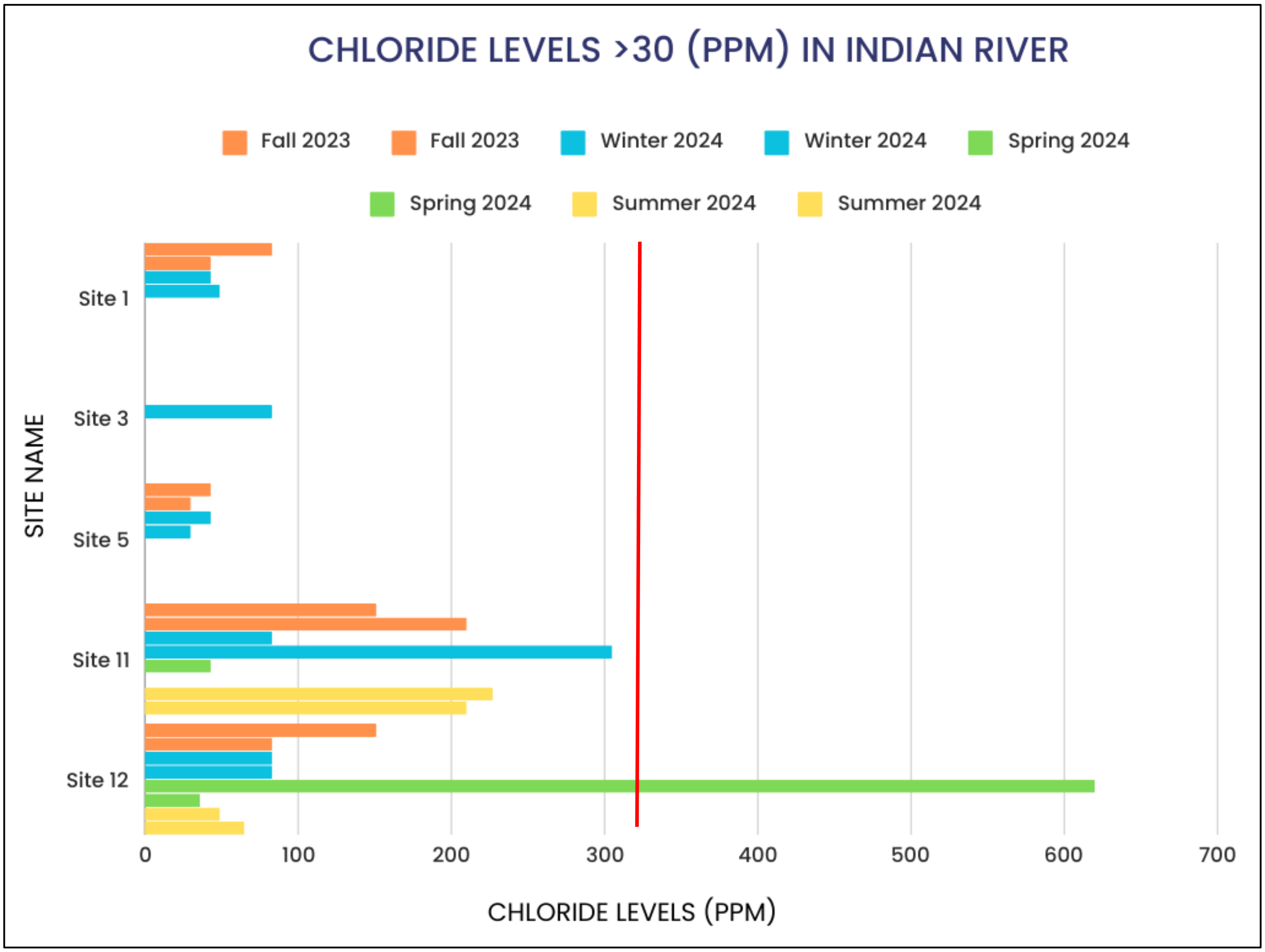


Figure 9. Results of four-seasons monitoring of chloride levels in Indian River (Mullett Creek site not included, see explanation above) for the 5 sites that had chloride levels ≥ 30 ppm. Two chloride readings were collected per season, with fall sampling taking place in 2023, and winter, spring, and summer sampling taking place in 2024. Red dashed line indicates the State of Michigan threshold for the aquatic maximum value of chloride (320 mg/L (or ppm)) in aquatic environments.

**Note:* parts per million (ppm) is equivalent in value to milligrams per liter (mg/L). Both units are used in this report.*

Discussion

Of the 10 sites that were monitored, half of them (Sites 1, 3, 5, 11, and 12) had chloride levels ≥ 30 ppm (Figure 9). Sites 2, 7, 9, 10, and the Mullett Creek site had data readings that were all under 1.4 Quantab units, indicating that the chloride levels were below 30. It should be noted that for Sites 2, 3, and 11, there was one instance of missing data per site. This is due to 1) the site being closed for construction or 2) no water was running on the selected sampling day, and thus, a water sample could not be tested for chloride levels.

Ambient Chloride Levels

Of the 5 sites with chloride levels ≥ 30 ppm, Site 1 had levels of 83 ppm, 43 ppm, 43 ppm, and 49 ppm, from the first fall sampling event to the second winter sampling event, respectively. While these levels are not in exceedance of the State of Michigan aquatic maximum value of 320 mg/L, they are higher in comparison to what we may refer to as 'ambient' freshwater chloride levels within the Mullett Lake Watershed. For example, chloride data (mg/L) collected through the Watershed Council's CWQM program from 2007-2019 in the Indian River never exceeds 12.5 mg/L, indicating that historically, levels have remained under 30 mg/L (ppm). Extremely similar values are seen in Mullett and Burt Lakes, which are directly connected to the Indian River via the Inland Waterway. These chloride trends may indicate that low chloride values are typical for the Mullett Lake (and the larger Cheboygan River) Watersheds, and support the continued existence of mesotrophic to oligotrophic freshwater ecosystems found in this region. Sites 3 and 5 followed the same pattern as Site 1, displaying values above 30 ppm, but in a relatively low range (the highest value being 83 ppm across all sites).

Excess Chloride Levels

While chloride levels at Sites 1, 3, and 5 were in exceedance of ambient levels for the Mullet Lake/Cheboygan River Watersheds, levels at Sites 11 and 12 were much more concerning. Site 11 displayed chloride levels above 100 mg/L for 3 out of 8 total readings, with one of the readings being 305 mg/L. This value, while still not exceeding the State of Michigan aquatic maximum value, is well above other chloride values collected throughout the course of this project, and far surpasses historical chloride levels in the Indian River and Mullett Lake. While Site 12 had fewer concerning readings in comparison to Site 11, it also had the highest chloride level recorded during the entire course of this project, with a reading of 620 mg/L. This data value directly exceeds the aquatic maximum value of 320 mg/L. It should also be noted that all 8 data points collected at Site 12 surpassed 30 ppm, indicating that this Site may be susceptible to chloride influx, whether from road salting, brining, or urban runoff.

Rainfall and Stormwater Discharge

Throughout the course of monitoring, MAPS volunteers recorded the level of precipitation (in inches) that the Indian River and Mullett Creek received prior to testing for chloride. For Sites 1, 3, and 5, which demonstrated chloride levels greater than the seemingly 'ambient' values, but not approaching or exceeding the aquatic maximum value of 320 mg/L, rainfall prior to data collection ranged from 0.38" to 2.0". Interestingly, Site 1 had a reading of 83 ppm in the Fall, immediately after a 2.0" rainfall was recorded. With 2.0" of precipitation being the highest recorded for these three sites, we see that this high level of rain may be directly correlated with the highest chloride (between Sites 1, 3, and 5) reading of 83 ppm.

Sites 11 and 12 had levels far exceeding the suggested ambient levels for the region. In terms of rainfall, the two highest readings (305 ppm and 620 ppm at Sites 11 and 12, respectively) occurred after 0.50" and 0.52” of precipitation. While these high levels did not directly correlate with the highest levels of rainfall, we can see readings of 210 ppm and 227 ppm after 0.92” and 0.90” of rainfall, respectively. These levels of precipitation are some of the highest recorded during the project, and may be a critical source of the flushing of chloride into the Indian River after a storm event.

Chloride enters aquatic ecosystems in a number of ways, with stormwater runoff (particularly from stormwater outfall pipes, which were directly monitored via this project) being a major source of chloride and nutrient influx to streams, rivers, and lakes in developed areas/designated municipalities. With higher levels of precipitation occurring before data collection, it is likely that discharge of stormwater runoff contributed to these high chloride readings. Furthermore, stormwater runoff flowing through outfall pipes may collect and carry with it brine and road salt effluents, increasing the eventual concentration of chloride that enters the waterbody.

Site Location

The Site Map shows that Sites 11 and 12 are situated directly on a site of direct drainage and a confluence of stormwater lines (Figure 7). The location of these sites may make them considerably more susceptible to stormwater overflows and elevated chloride concentrations. In addition to this, both Sites 11 and 12 are located directly across from one another underneath a bridge (Onaway Road) (Images 1, 2).

Image 1. A photo taken at Site 11 by Watershed Council Staff. This site is adjacent to a bridge (Onaway Road) that may be a potential reason for high chloride levels in the Indian River.

The close proximity to the more urbanized landscape of Indian River, combined with storm events that may wash excess road salts/brine into the river, are highly probable causes for elevated chloride levels at these particular sites.

Image 2. A photo taken at Site 12 by Watershed Council Staff. This site is adjacent to a bridge (Onaway Road) that may be a potential reason for high chloride levels in the Indian River.

Seasonal Influence

Seasonal monitoring was purposefully incorporated into this project to understand if the time of year had any influence on chloride levels. For the two highest chloride readings collected during this project (305 ppm at Site 11 and 620 ppm at Site 12), the reading of 305 ppm was from the second winter sampling event, and the reading of 620 ppm was from the first spring sampling event. Winter is the season of heaviest road salt and chloride usage in Michigan, used to protect the safety of both pedestrians and drivers when inclement weather conditions strike. Thus, a winter sampling event aligning with a high chloride reading is not surprising. In terms of the spring event yielding the value of 620 ppm, this sample was collected on June 5th, 2024. Interestingly, upon corresponding with Tuscarora Township, Watershed Council staff received information that the Township applies brining solution in late May, early June, and again in late July. The chloride level of 620 ppm may be the direct result of brining solution washing into the Indian River and subsequently creating toxic levels for plant life, amphibians, freshwater fish, and threatening the stability of the riverine ecosystem and the lakes to which it is connected.

Other noticeably high levels of chloride across the 5 sites that had levels ≥ 30 ppm were the three readings above 200 ppm at Site 11 (210, 210, and 227). These readings occurred at the second fall sampling event (which occurred December 10th, 2023) and the two summer sampling events (July 24th, 2024 and August 18th, 2024). The winter reading may be high due to road salting, while the summer readings may be the result of residual brining solution entering the Indian River. While not as concerning as levels extremely close to or exceeding 320 mg/L, these readings are still higher than historical trends, and are indicative of a larger problem concerning chloride application and stormwater runoff.

Mullett Lake Watershed Management Plan

The Mullet Lake, Cheboygan/Black Rivers Watershed Management Plan, approved in 2023, identified critical and priority areas within the watershed(s) throughout water quality monitoring and resource inventories ([Mullett Lake, Cheboygan/Lower Black Rivers (watershedcouncil.org)](watershedcouncil.org)). A critical area is one that is in need of restoration actions, whereas a priority area is one that needs protective actions. Based on critical areas identified by the aforementioned plan, the Indian River falls within the following critical area categories: stormwater, streambank alterations, and wetland loss. These categories indicate that the geographic area surrounding Indian River is in crucial need of restorative action and policies that will prevent further damage and rectify existing environmental and ecological issues within the watershed.

Stormwater may be the most relevant of these critical area categories for the MAPS Chloride Project, as stormwater outfall pipes were monitored directly. The fact that the Indian River geographic area falls within a critical stormwater area further supports the idea that excess chloride is entering water resources in the Mullett Lake Watershed via stormwater runoff. This runoff is likely exacerbated by the issues of streambank alteration and functional wetland loss. When streambanks are altered and/or developed, vegetation is typically cleared, creating the space for erosion and reduction of nutrient filtration before runoff enters the nearest waterbody. Development of streambanks, combined with loss of wetlands (known as 'nature's kidneys'), only increases the possibility of high concentrations of chloride, alongside other problematic nutrients, to enter the watershed.

Sources of Excess Chloride

Chloride pollution is not only caused by stormwater runoff, road salting, and brining. Sources also include erosion of shorelines and streambanks, presence of road-stream crossings, agriculture, and even failing septic systems. While high chloride levels can be directly connected to the stormwater outfall pipes monitored (point-source pollution), chloride can also be much more difficult to pinpoint and address when it comes from numerous, widespread sources (non-point source pollution). Implementation tasks developed in the Mullett Lake Watershed Management Plan are an excellent place to start to properly address chloride pollution in Northern Michigan (see 'Recommendations').

Recommendations

(1) **Conduct additional chloride sampling at Sites 1, 3, 5, 11, and 12.** Re-testing these locations will provide greater insight into whether or not a persistent chloride pollution problem exists. Re-visiting these particular sites will also give further context as to whether any other factors besides rainfall, season, proximity to an urban landscape, and confluence of stormwater lines are contributing to chloride exceedances.

(2) Conduct additional sampling at lakes, rivers, and streams in the Mullett Lake/Cheboygan River Watershed to properly establish 'ambient chloride levels' for the geographic region. While the majority of waterbodies in Northern Michigan have low nutrient levels and low chloride concentrations, reference conditions for chloride levels in this particular watershed are uncertain. Understanding typical levels of chloride may help to understand the extent of the issue, and when or why levels are most subject to change.

(3) **Continue to monitor the Indian River, Mullett Creek, Mullett Lake, and other critical waterbodies in the Mullet Lake/Cheboygan River Watershed through Volunteer Stream Monitoring (VSM), Volunteer Lake Monitoring (VLM), and Comprehensive Water Quality Monitoring (CWQM) Programs.** Long-term trend data is extremely useful when it comes to interpreting environmental changes.

(4) Share the results/associated report for the MAPS Chloride Project with members of MAPS and with landowners who are directly connected to the Indian River or to the watershed as a whole. Education will be a key component in future chloride reduction efforts.

(5) **Implement Best Management Practices (BMPs) when it comes to chloride usage.** Many Road Commissioner/Public Works professionals promote and adopt chloride reduction efforts.

(6) **Install stormwater BMPs.** These include rain gardens, oil/grit separators, and more.

(7) **Incorporation of green infrastructure in highly developed areas to reduce chloride runoff.** Increased presence of vegetation in the form of rain gardens or greenbelts can protect vulnerable freshwater resources from potent nutrient influx. Green infrastructure installation can be completed via contractual service through the Watershed Council.

(8) Host educational workshops to highlight the effects of improper road salting and the detrimental effects it can have on wildlife, infrastructure, and plant communities.

(9) **Utilize bioengineering to prevent erosion from occurring or stabilize potentially vulnerable riparian zones.** Bioengineering installation can be completed via contractual service through the Watershed Council.

(10) Continue to promote and adopt implementation tasks from the Mullett Lake, Cheboygan/Lower Black Rivers Watershed Management Plan. For full details on the implementation tasks, and the Watershed Plan in general, visit the following link: Mullett Lake, Cheboygan/Lower Black Rivers (watershedcouncil.org)

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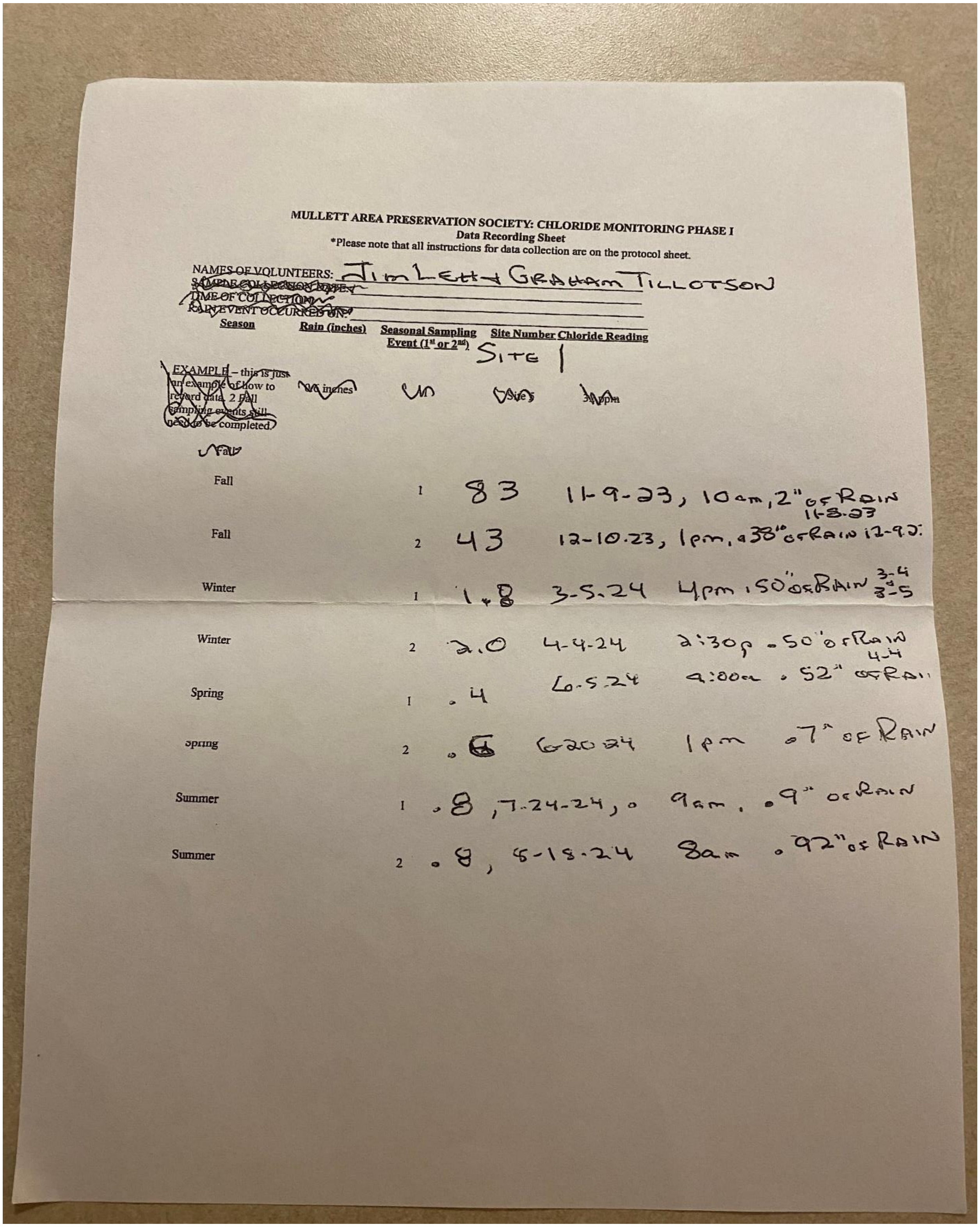
Appendix

See below all data from all 10 sites:



MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I
Data Recording Sheet
*Please note that all instructions for data collection are on the protocol sheet.

NAMES OF VOLUNTEERS: Jim Leh + Graham Tillotson
~~SAMPLE COLLECTION DATE:~~
~~TIME OF COLLECTION:~~
~~RAIN EVENT OCCURRED ON:~~

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number	Chloride Reading
			Site 1	
~~EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.~~	~~.06 inches~~	~~1~~	~~Site 5~~	~~3 ppm~~
~~Fall~~				
Fall		1		83 11-9-23, 10am, 2" of Rain 11-8-23
Fall		2		43 12-10-23, 1pm, .38" of Rain 12-9-23
Winter		1		1.8 3-5-24 4pm .50" of Rain 3-4 3-5
Winter		2		2.0 4-4-24 2:30p .50" of Rain 4-4
Spring		1		.4 6-5-24 9:00am .52" of Rain
Spring		2		.6 6-20-24 1pm .7" of Rain
Summer		1		.8, 7-24-24, 9am, .9" of Rain
Summer		2		.8, 8-15-24 8am .92" of Rain

MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I
Data Recording Sheet
*Please note that all instructions for data collection are on the protocol sheet.

NAMES OF VOLUNTEERS: Jim Lett + Graham Tillotson
~~SAMPLE COLLECTION DATE:~~
~~TIME OF COLLECTION:~~
~~RAIN EVENT OCCURRED ON:~~

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number	Chloride Reading
			Site 2	
~~EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.~~	~~.06 inches~~	~~1st~~	~~Site 5~~	~~30 ppm~~
~~Fall~~				
Fall		1	No Water Running	
Fall		2	(.02) 12-10.23, 1pm, .38" of Rain 12-9-23	
Winter		1	.2 3-5.25, 4pm, .50" of Rain 3-4 + 3-5	
Winter		2	.4 4-4-24 2:30p .50" of Rain 4-4-24	
Spring		1	.2 6-5-24 9:00a .52" of Rain 6-6.2	
Spring		2	.2 6-20-24 1pm .7" of Rain 6-20-24	
Summer		1	No Water Running 7-24-24	
Summer		2	.4, 8-18-24, 8am, .92" of Rain	

MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I

Data Recording Sheet

*Please note that all instructions for data collection are on the protocol sheet.

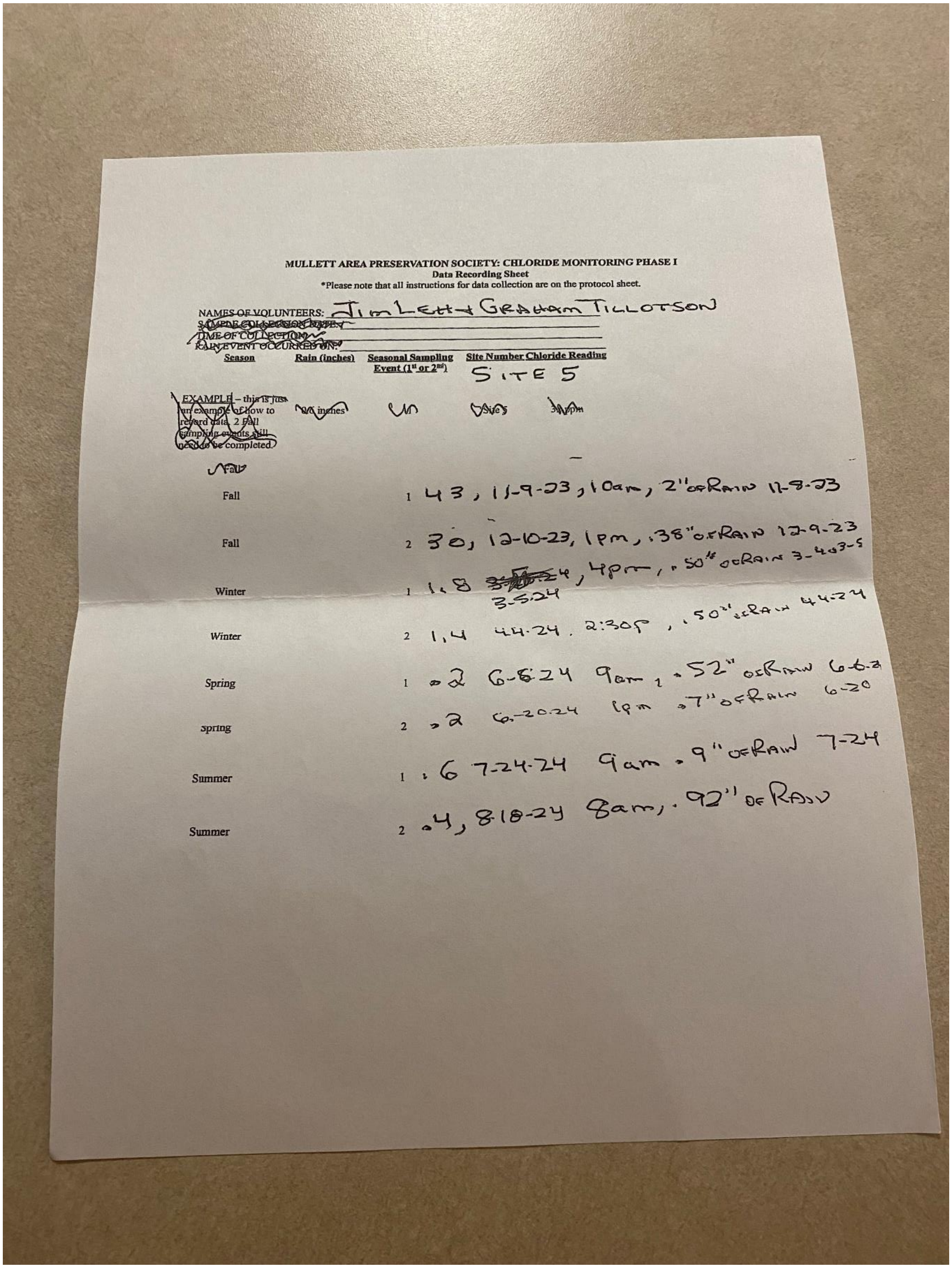
NAMES OF VOLUNTEERS: Jim Lett + Graham Tillotson

~~SAMPLE COLLECTION DATE:~~

~~TIME OF COLLECTION:~~

~~RAIN EVENT OCCURRED ON:~~

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number	Chloride Reading
			SITE 3	
~~EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.~~	~~0.6 inches~~	~~1st~~	~~Site 5~~	~~30 ppm~~
~~Fall~~				
Fall		1 (.2) 11-9-23, 10am, .2" of Rain 11-8-23		
Fall		2 (.4) 12-10-23, 1pm, .38" of Rain 12-9-23		
Winter		1 3-5-24 Site Closed for Construction		
Winter		2 4-4-24, 2.8, 2:30p, .50" Rain 4-4		
Spring		1 6-4-24 .4, 9am, .52" of Rain 6-5		
Spring		2 .2 6-20-24 1pm .7" of Rain 6-20		
Summer		1 .2 7-24-24 9am .9" of Rain 7-24		
Summer		2 .2, 8-18-24, 8am .92" of Rain		



MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I
Data Recording Sheet
*Please note that all instructions for data collection are on the protocol sheet.

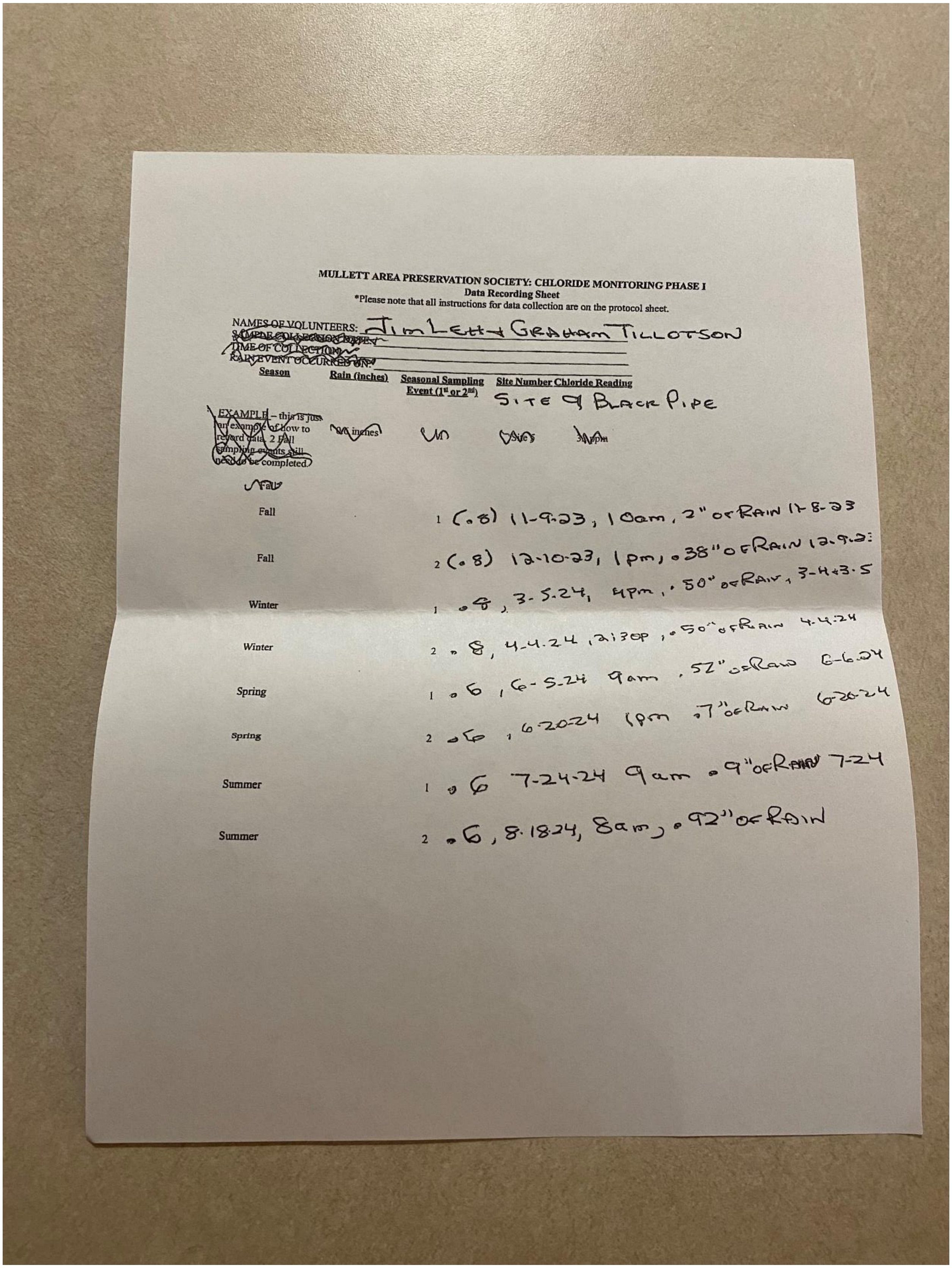
NAMES OF VOLUNTEERS: Jim Lett + Graham Tillotson
~~SAMPLE COLLECTION DATE:~~
~~TIME OF COLLECTION:~~
~~RAIN EVENT OCCURRED ON:~~

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number Chloride Reading
			SITE 5
~~EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.~~	~~0.0 inches~~	~~1st~~	~~Site 5~~ ~~3 ppm~~
~~Fall~~			
Fall		1	43, 11-9-23, 10am, 2" of Rain 11-8-23
Fall		2	30, 12-10-23, 1pm, .38" of Rain 12-9-23
Winter		1	1.8 ~~3-4-24~~ 3-5-24, 4pm, .50" of Rain 3-4 & 3-5
Winter		2	1.4 4-4-24. 2:30p, .50" of Rain 4-4-24
Spring		1	.2 6-8-24 9am, .52" of Rain 6-6-24
Spring		2	.2 6-20-24 1pm .7" of Rain 6-20
Summer		1	.6 7-24-24 9am .9" of Rain 7-24
Summer		2	.4, 8-18-24 8am, .92" of Rain

MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I
Data Recording Sheet
*Please note that all instructions for data collection are on the protocol sheet.

NAMES OF VOLUNTEERS: Jim Lett + Graham Tillotson
~~SAMPLE COLLECTION DATE:~~
~~TIME OF COLLECTION:~~
~~RAIN EVENT OCCURRED ON:~~

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number Chloride Reading
			Site 7
~~EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.~~	~~.06 inches~~	~~1st~~	~~Site 5~~ ~~30 ppm~~
~~Fall~~			
Fall		1	(.6) 11-9-23, 10am, 2" of Rain 11-8-23
Fall		2	(.6) 12-10-23, 1pm, .38" of Rain 12-9-23
Winter		1	.6, 3-5-24, 4pm, .50" of Rain, 3-4 & 3-5
Winter		2	.6, 4-4-24, 2:30p, .50" of Raw 4-4-24
Spring		1	.4 6-5-24 9am .52" of Rain 6-6-24
Spring		2	.4 6-20-24 1pm .7" of Rain 6-20-24
Summer		1	.4 7-24-24 9am .9" of Rain 7-24
Summer		2	.2 8-18-24, 8am, .92" of Rain



MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I
Data Recording Sheet
*Please note that all instructions for data collection are on the protocol sheet.

NAMES OF VOLUNTEERS: JIM LEH + GRAHAM TILLOTSON
SAMPLE COLLECTION DATE:
TIME OF COLLECTION:
RAIN EVENT OCCURRED ON:

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number Chloride Reading
			SITE 9 BLACK PIPE
EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.	inches		Site 3 ppm
Fall			
Fall		1	(.8) 11-9-23, 10am, 2" OF RAIN 11-8-23
Fall		2	(.8) 12-10-23, 1pm, .38" OF RAIN 12-9-23
Winter		1	.8, 3-5-24, 4pm, .50" OF RAIN, 3-4 + 3-5
Winter		2	.8, 4-4-24, 2:30P, .50" OF RAIN 4-4-24
Spring		1	.6, 6-5-24 9am, .52" OF RAIN 6-6-24
Spring		2	.6, 6-20-24 1pm .7" OF RAIN 6-20-24
Summer		1	.6 7-24-24 9am .9" OF RAIN 7-24
Summer		2	.6, 8-18-24, 8am, .92" OF RAIN

MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I

Data Recording Sheet

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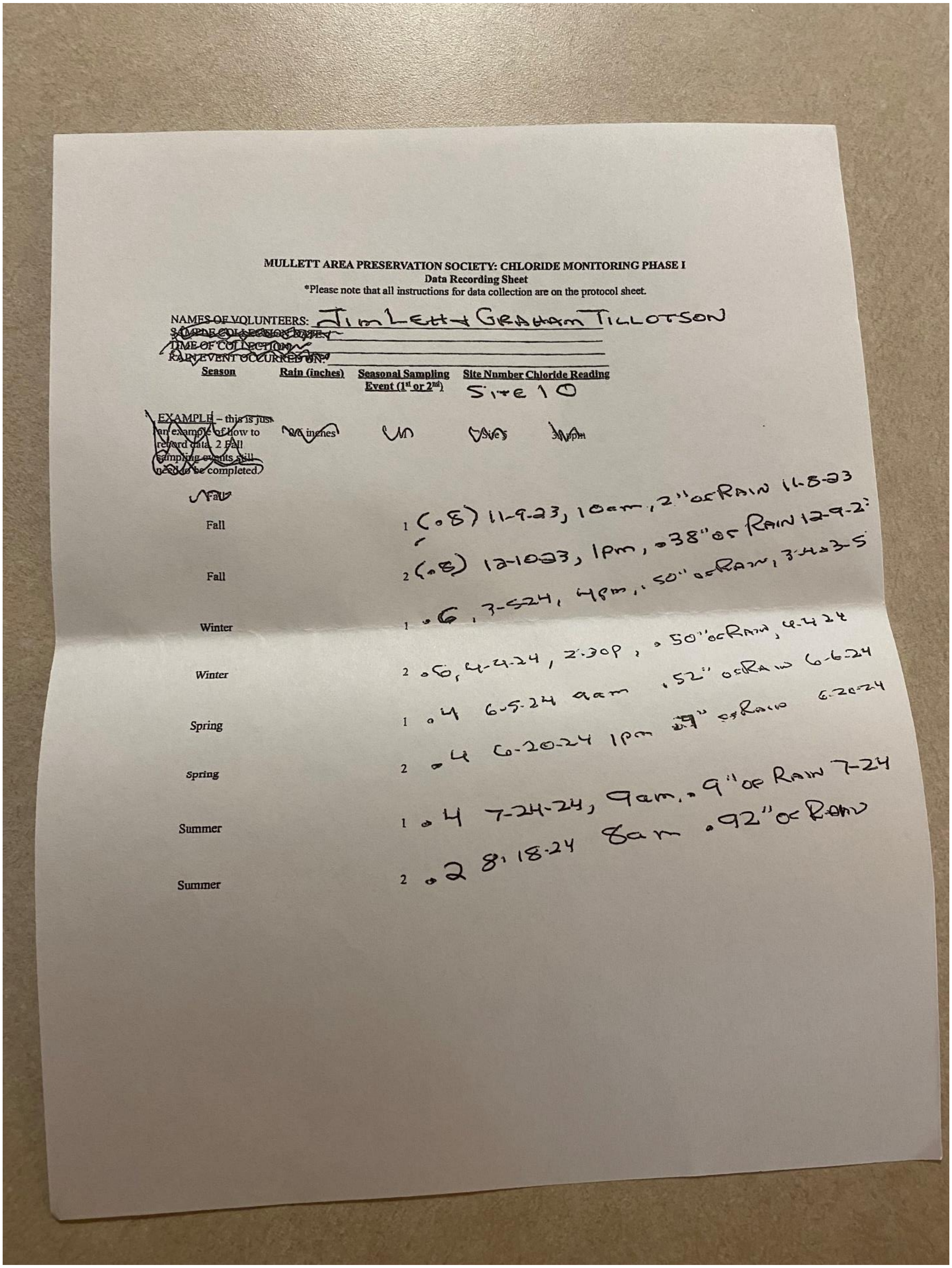
NAMES OF VOLUNTEERS: JIM LETT + GRAHAM TILLOTSON
~~SAMPLE COLLECTION DATE:~~
~~TIME OF COLLECTION:~~
~~RAIN EVENT OCCURRED ON:~~

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number	Chloride Reading
			SITE 9 METAL PIPE	
~~EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.~~	~~.6 inches~~	~~1~~	~~Site 5~~	~~34 ppm~~
~~Fall~~				
Fall		1 (.8) 11-9-23, 10am, 2" OF RAIN 11-8-23		
Fall		2 (.8) 12-10-23, 1pm, .38" OF RAIN 12-9-23		
Winter		1 1.0, 3-5-24, 4pm, 1.50" OF RAIN, 3-4 + 3-5		
Winter		2 .8, 4-4-24, 2:30p, 1.50" OF RAIN, 4-4-24		
Spring		1 .4, 6-5-24 9am .52" OF RAIN 6-6-24		
Spring		2 .4 6-20-24 1pm 1.7" OF RAIN 6-20		
Summer		1 .2 7-24-24 9am .9" OF RAIN 7-24		
Summer		2 .4, 8-18-24, 8am, .92" OF RAIN		


MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I
Data Recording Sheet
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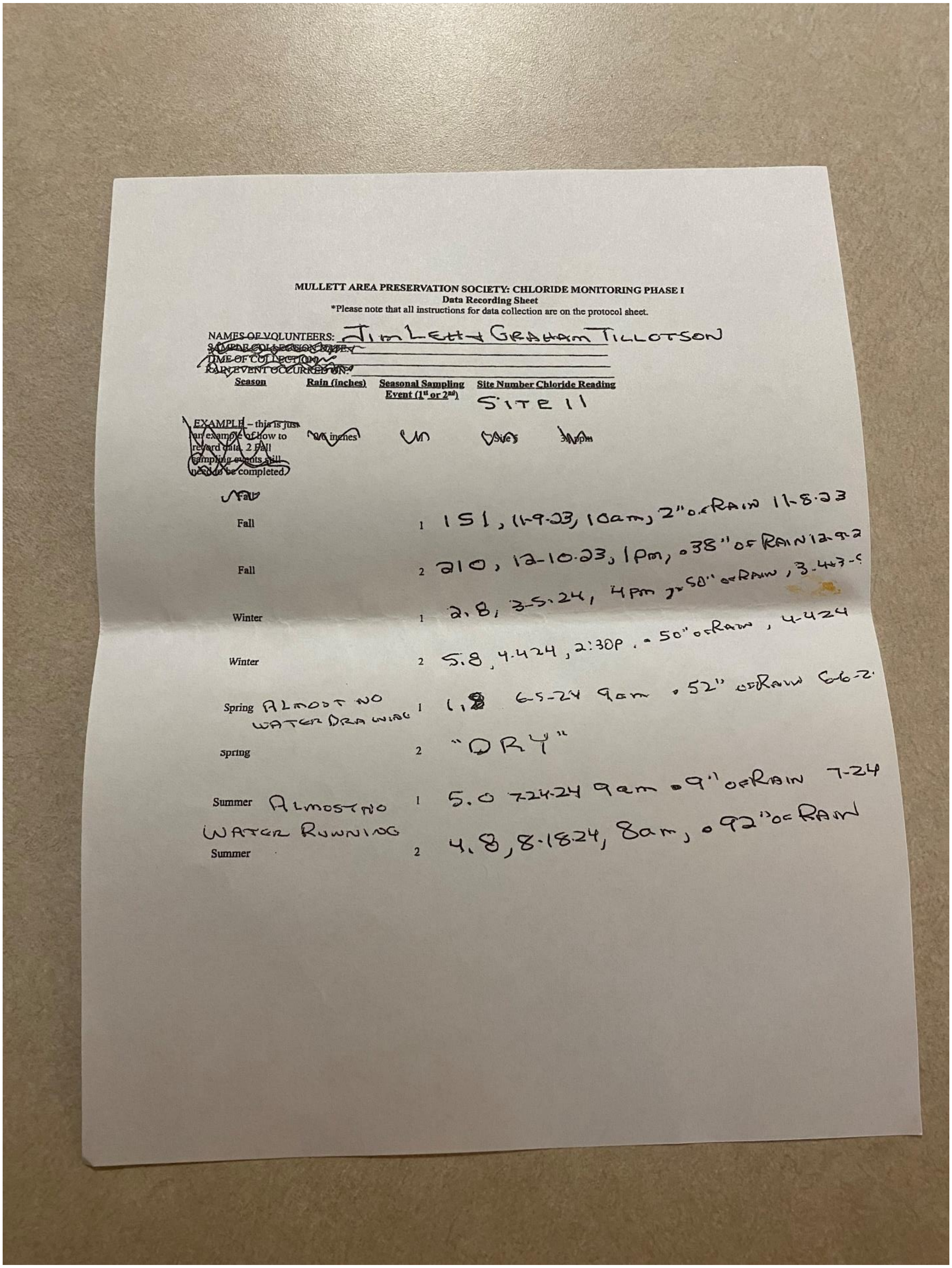
NAMES OF VOLUNTEERS: JIM LETT + GRAHAM TILLOTSON
~~SAMPLE COLLECTION DATE:~~
~~TIME OF COLLECTION:~~
~~RAIN EVENT OCCURRED ON:~~

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number	Chloride Reading
			SITE 10	
~~EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.~~	~~0.6 inches~~	~~1st~~	~~Site 5~~	~~30 ppm~~
~~Fall~~				
Fall		1 (.8) 11-9-23, 10am, 2" of RAIN 11-8-23		
Fall		2 (.8) 12-10-23, 1pm, .38" of RAIN 12-9-23		
Winter		1 .6, 3-5-24, 4pm, .50" of RAIN, 3-4 & 3-5		
Winter		2 .6, 4-4-24, 2:30P, .50" of RAIN, 4-4-24		
Spring		1 .4 6-5-24 9am .52" of RAIN 6-6-24		
Spring		2 .4 6-20-24 1pm .9" of RAIN 6-20-24		
Summer		1 .4 7-24-24, 9am, .9" of RAIN 7-24		
Summer		2 .2 8-18-24 8am .92" of RAIN		



MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I
Data Recording Sheet
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NAMES OF VOLUNTEERS: JIM LETT + GRAHAM TILLOTSON
SAMPLE COLLECTION DATE:
TIME OF COLLECTION:
RAIN EVENT OCCURRED ON:

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number	Chloride Reading
			SITE 11	
EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.	0.6 inches	1	Site 5	38 ppm
Fall				
Fall		1	151, 11-9-23, 10am, 2" of RAIN 11-8-23	
Fall		2	210, 12-10-23, 1pm, .38" of RAIN 12-9-2	
Winter		1	2.8, 3-5-24, 4pm, .50" of RAIN, 3-4+3-5	
Winter		2	5.8, 4-4-24, 2:30P. .50" of RAIN, 4-4-24	
Spring ALMOST NO WATER DRAINING		1	1.8 6-5-24 9am .52" of RAIN 6-6-2	
Spring		2	"DRY"	
Summer ALMOST NO WATER RUNNING		1	5.0 7-24-24 9am .9" of RAIN 7-24	
Summer		2	4.8, 8-18-24, 8am, .92" of RAIN	

MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I
Data Recording Sheet
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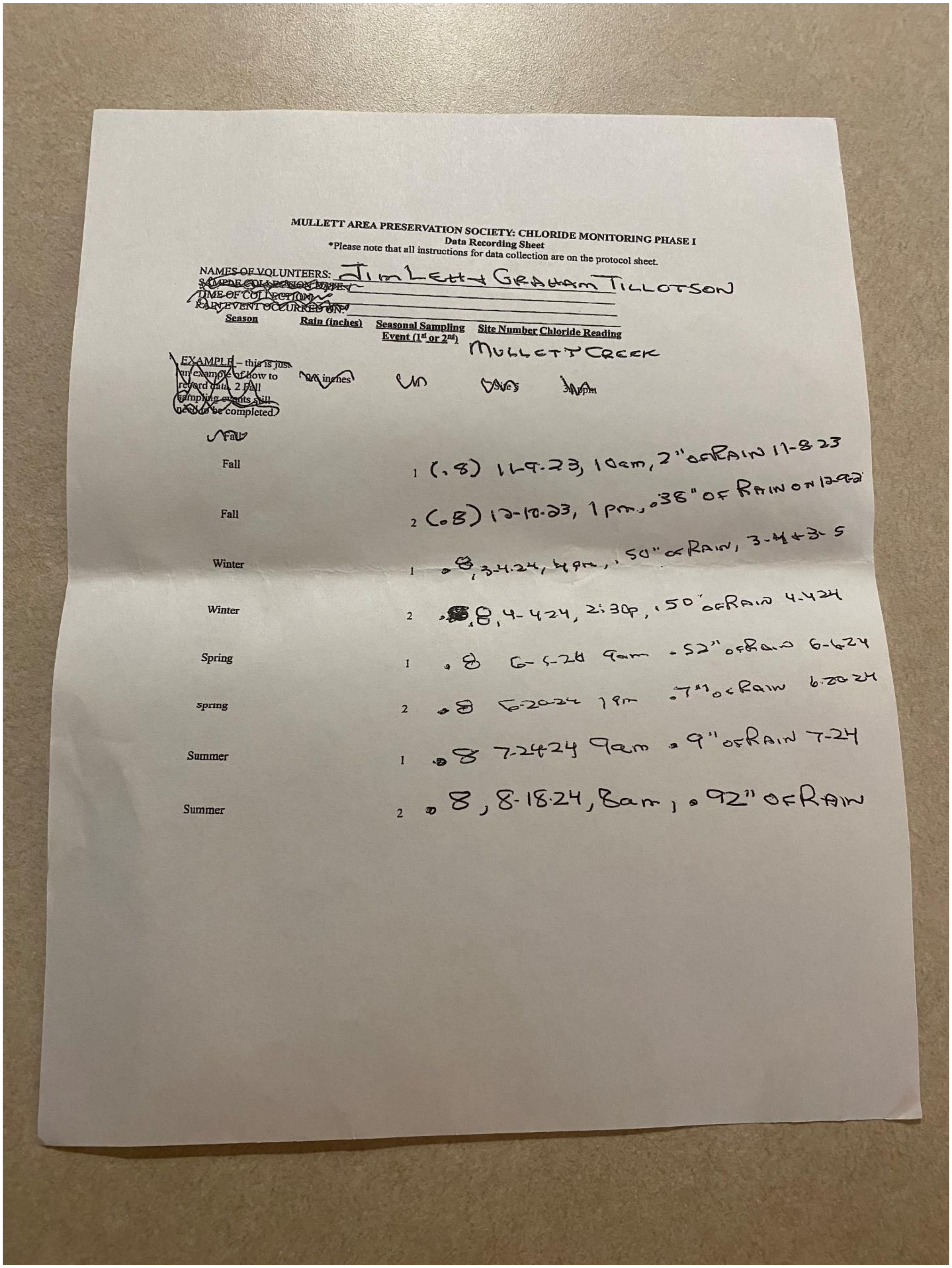
NAMES OF VOLUNTEERS: Jim Lett + Graham Tillotson
~~SAMPLE COLLECTION DATE:~~
~~TIME OF COLLECTION:~~
~~RAIN EVENT OCCURRED ON:~~

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number	Chloride Reading
			SITE 12	
~~EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.~~	~~.25 inches~~	~~1st~~	~~Site 5~~	~~30 ppm~~
~~Fall~~				
Fall		1	151, 11-9-23, 10am, 2" of RAIN 11-8-23	
Fall		2	83 12-10-23, 1pm, .38" of RAIN, 12-9-23	
Winter		1	2.8, 3-5-24, 4pm, .50" of RAIN, 3-4+3-5	
Winter		2	2.8, 4-4-24, 2:30p, .50" of RAIN, 4-4-24	
Spring WATER WAS MOVING		1	7.8 6-5-24 9am .52" of RAIN 6-6-24	
Spring		2	1.6 6-20-24 1pm .7" of RAIN 6-20-24	
Summer		1	2.0 7-24-24 9am .9" of RAIN 7-24	
Summer		2	2.4 8-18-24, 8am, .92" of RAIN	



MULLETT AREA PRESERVATION SOCIETY: CHLORIDE MONITORING PHASE I
Data Recording Sheet
*Please note that all instructions for data collection are on the protocol sheet.

NAMES OF VOLUNTEERS: JIM LETT + GRAHAM TILLOTSON
SAMPLE COLLECTION DATE:
TIME OF COLLECTION:
RAIN EVENT OCCURRED ON:

Season	Rain (inches)	Seasonal Sampling Event (1st or 2nd)	Site Number	Chloride Reading
			MULLETT CREEK	
EXAMPLE – this is just an example of how to record data. 2 Fall sampling events still need to be completed.	.06 inches	1st	Site 5	30 ppm
Fall				
Fall		1	(.8) 11-9-23, 10am, 2" of RAIN 11-8-23	
Fall		2	(.8) 12-10-23, 1pm, .38" OF RAIN ON 12-9-23	
Winter		1	.8, 3-4-24, 4pm, .50" of RAIN, 3-4 + 3-5	
Winter		2	.8, 4-4-24, 2:30p, .50" of RAIN 4-4-24	
Spring		1	.8 6-5-24 9am .52" of RAIN 6-6-24	
Spring		2	.8 6-20-24 1pm .7" of RAIN 6-20-24	
Summer		1	.8 7-24-24 9am .9" of RAIN 7-24	
Summer		2	.8, 8-18-24, 8am, .92" OF RAIN	