Investigation of groundwater geochemistry and seepage rates to determine domestic nutrient input into eutrophic Lake Altoona, Wisconsin

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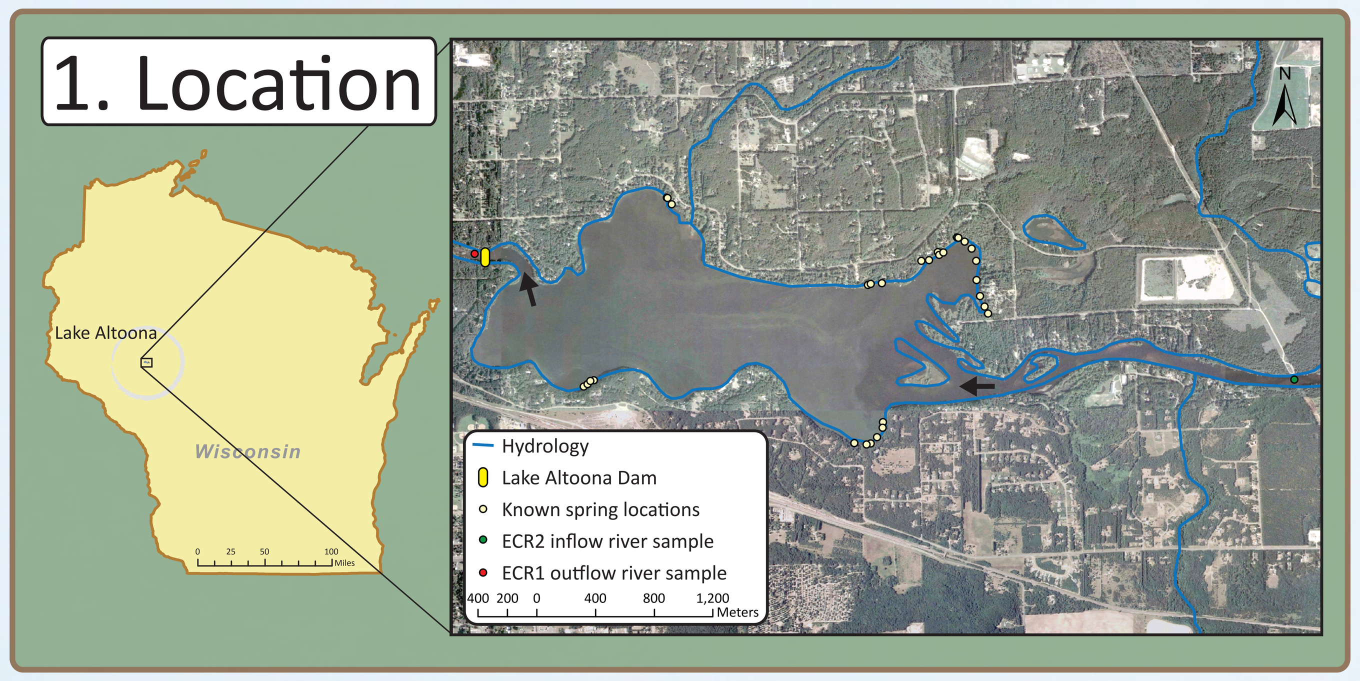
1. Location



2. Introduction

Lake Altoona, located in West Central Wisconsin, is an impounded lake created by the damming of the Eau Claire River in 1938 (see above). Lake Altoona has exhibited eutrophication and sedimentation problems largely attributed to agrochemicals transported via inflow from the Eau Claire River. Water flows quickly through the lake; residence times vary from 2 days during periods of high flow to 15 days during periods of low flow (James et. al, 2001). During low flow periods (summer months) algae growth is prominent in much of the lake. The lake is also surrounded by several hundred homes with private septic systems. Research conducted at Lake Altoona has revealed several areas of groundwater influx along the lakeshore that may serve as possible sites of domestic nutrient influence into Lake Altoona (Fairbairn et al. 2008). This study aims to determine the chemical composition of both ground and surface waters and the degree of groundwater influx into the lake. Chemical analyses were used to determine the significance of domestic derived nutrients on lake water chemistry and seepage rate measurements were performed to delineate possible regions of groundwater influx.

3. Methods


photo 1: Anna and Bridget collecting water samples from a spring location in the winter


photo 2: HACH meter used to find pH, EC and DO in the field

Surface water, lake water, and groundwater samples have been collected seasonally at Lake Altoona since fall of 2007. Surface water samples were collected near the shore at spring locations (photo 1) and where the Eau Claire River flows in and out of the lake. Lake water samples were collected from the middle of the lake during fall and summer months and through the ice in the winter. Groundwater samples were collected at a number of spring locations along the lakeshore. Groundwater was extracted with minipiezometers constructed from 3/8 inch polyethylene tubing inserted 1-2 feet into lake sediment (photo 3). Measurements of electrical conductivity, dissolved oxygen, and pH where performed in the field with HACH meters (photo 2). Alkalinity concentrations were determined by Gran titration using a HACH digital titrator. NH_4^+ and NO_3^- concentrations were determined using colorimetric HACH kits, total and reactive PO_4^{3-}concentrations were determined using a DR2000 spectrometer, and major and minor ion concentrations were determined with an Inductively Coupled Plasma Mass Spectrometer (ICPMS). Groundwater influx was quantified with seepage meters constructed from 55 gallon drums that were placed in multiple locations along the lakeshore (photos 4 and 5). Sample locations were documented with GPS data collected with a Trimble ProXT GPS unit (photo 6).


photo 3: Anne and Bridget collect a groundwater sample next to a seepage meter near the lake shore

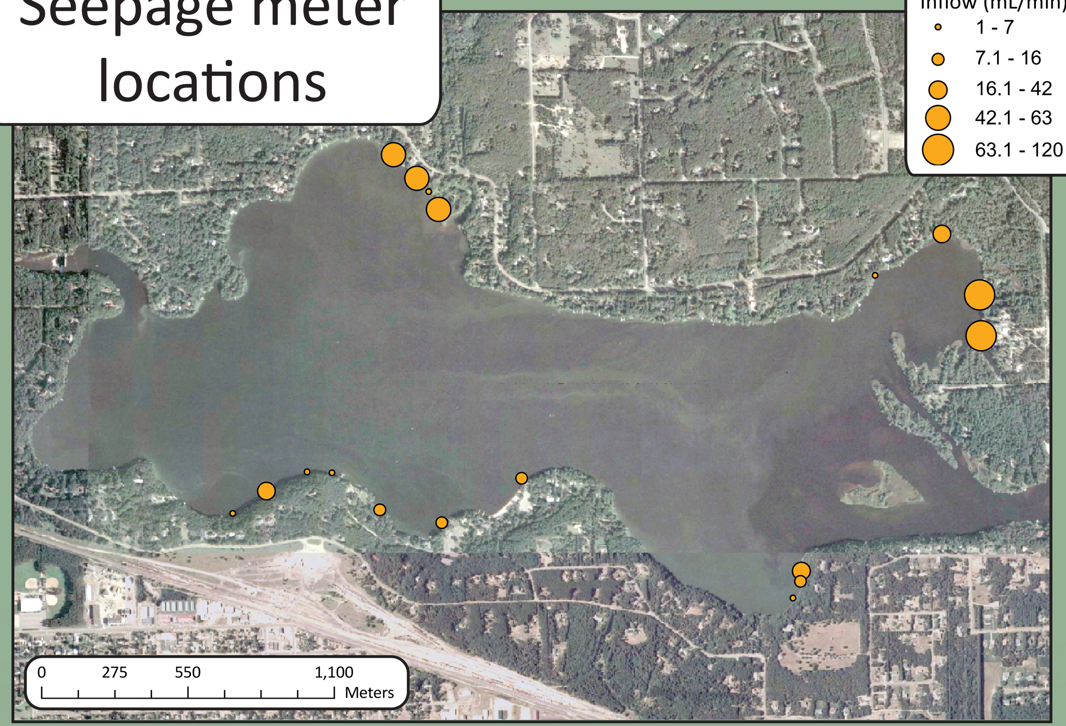

photo 4: Bianca measuring water from a seepage meter near the northwest shore


photo 5: Seepage meter "drums" used to measure groundwater influx. (boots for scale)


photo 6: Bridget collects GPS data points to mark our sample locations

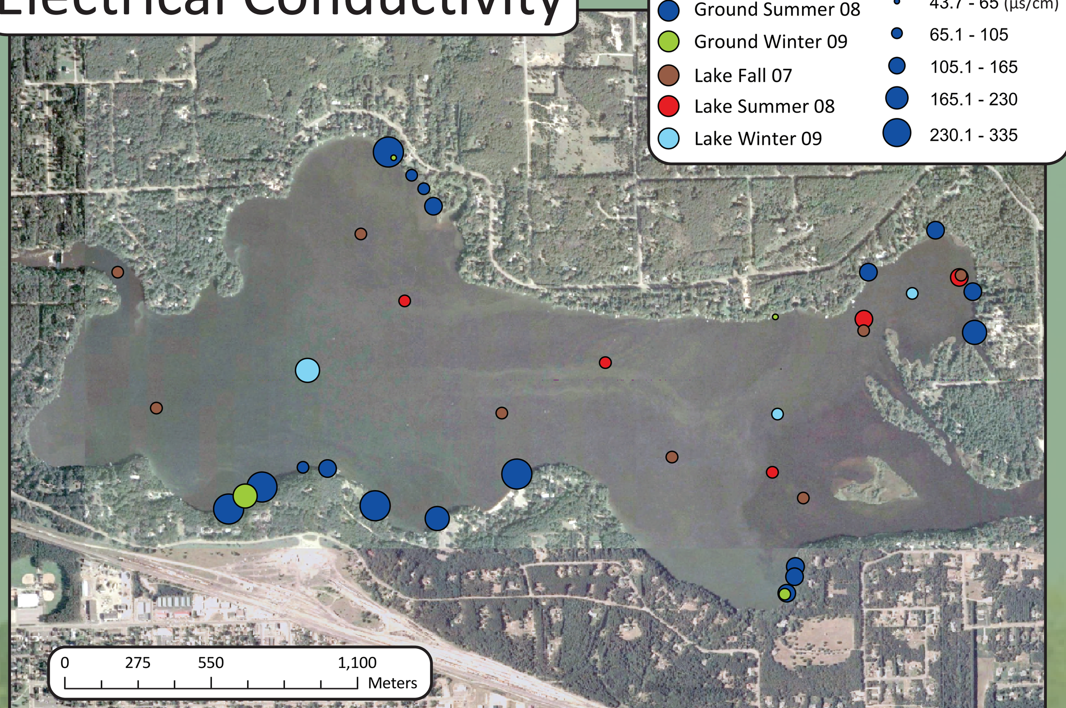
4. Results

Seepage meter locations



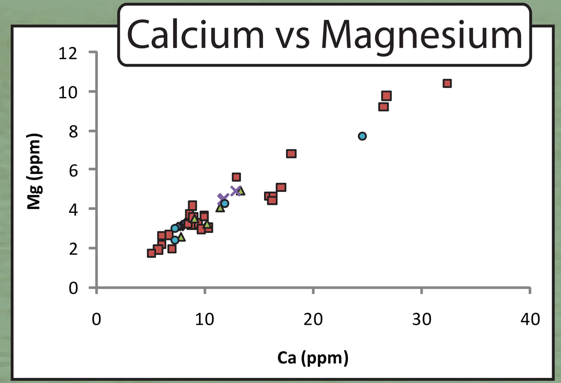
4.1 Seepage rates along the shore range from 1-120 mL/min. The highest seepage rates are found along the north shore, the lowest along the south shore. Along the north shore houses are built close to the shoreline and subsequently have leachate fields that are close to the lake. Many of the septic systems along the north shore are also older and are more likely to operate ineffectively than those along the south shore.

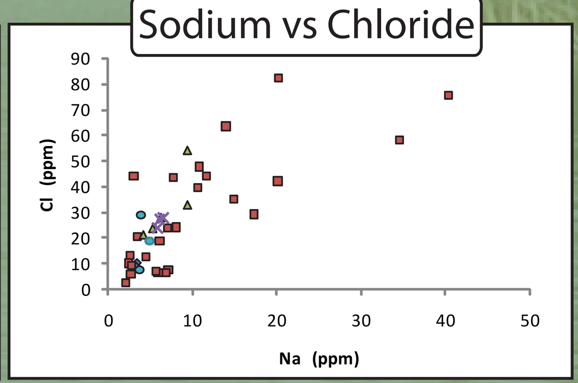
Electrical Conductivity



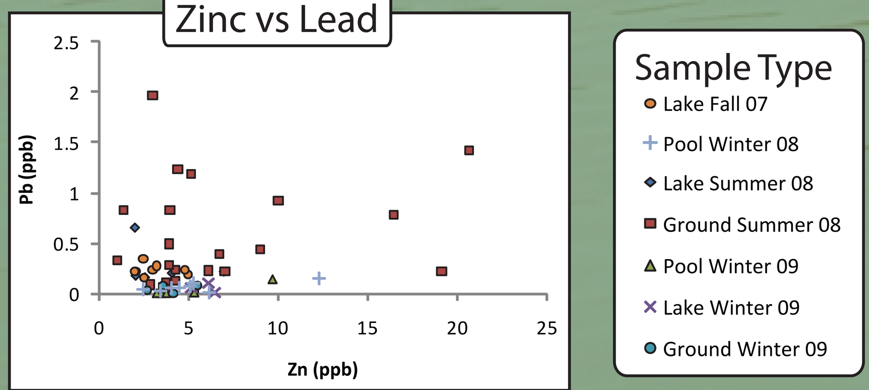
4.2 Comparisons of electrical conductivity (EC) measurements from the lake and the groundwater show that the groundwater in many locations has higher EC values than the lake water. This suggests that the discharging groundwater in these locations is influenced by domestic input and is most likely from septic system effluent.

Trace and Major Ion Analysis

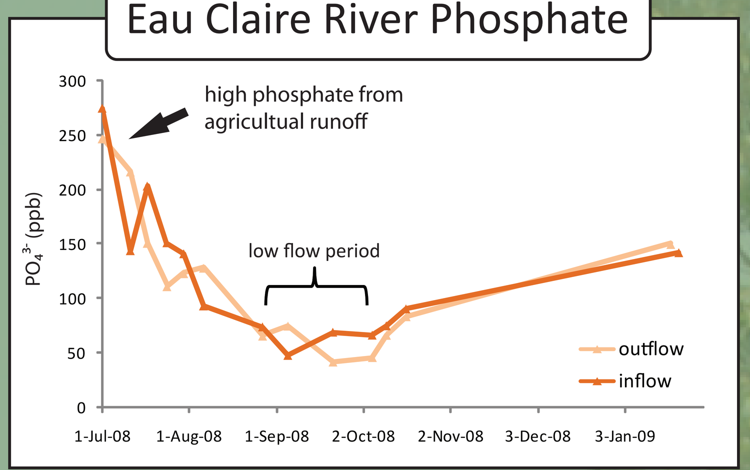




4.3 Major ion analyses show a positive corelation between Ca, Mg, Na and Cl for both lake water and groundwater indicating that the source of these ions is the same for both water types. Tracemetal analyses for groundwater show very high variability in concentrations (e.g. Zinc and Lead) while the lake water tends to show consistent values on the low end of the observed range. This indicates that the tracemetals in the groundwater are from an anthropogenic source other than agrochemicals. The high variability in tracemetal concentrations suggests that domestically derived ions reflect the variability of each property including the age of building structures (i.e houses and septic systems) and individual household's product use.

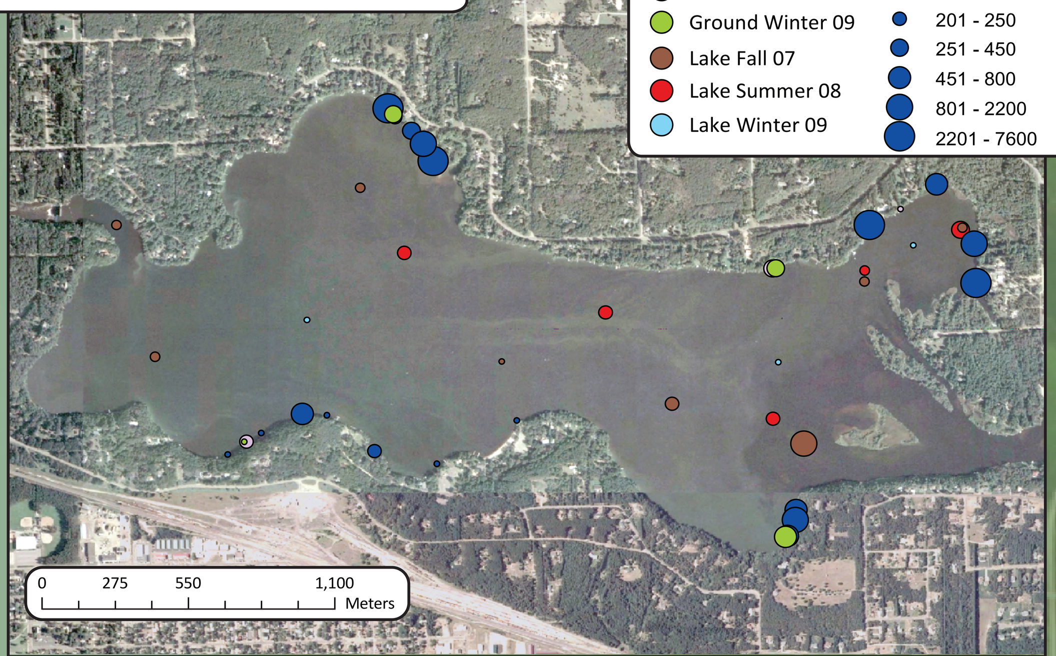


Eau Claire River Phosphate



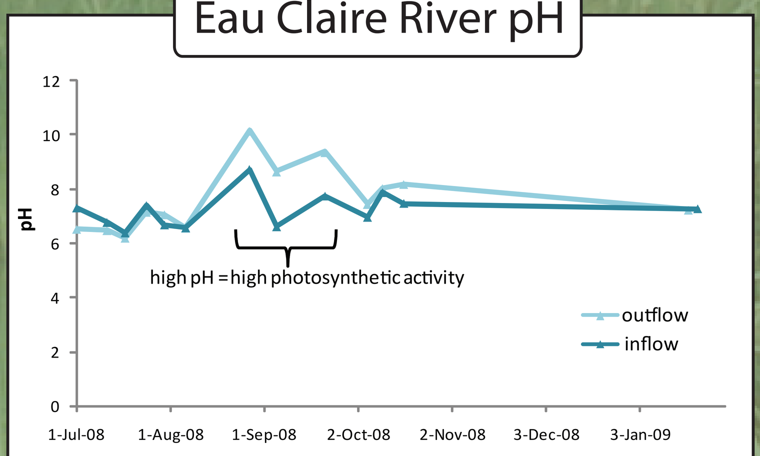
4.4 The highest concentrations of phosphate in the water entering and exiting the lake were observed in early July. From July to the end of September the concentration decreased from 275 ppb to 40 ppb. The low concentrations during the early fall indicate a decrease in agricultural phosphate input to the lake. During low flow periods, prominent algae growth is observed suggesting phosphate is added to the lake by non-agricultural sources.

Phosphate Levels



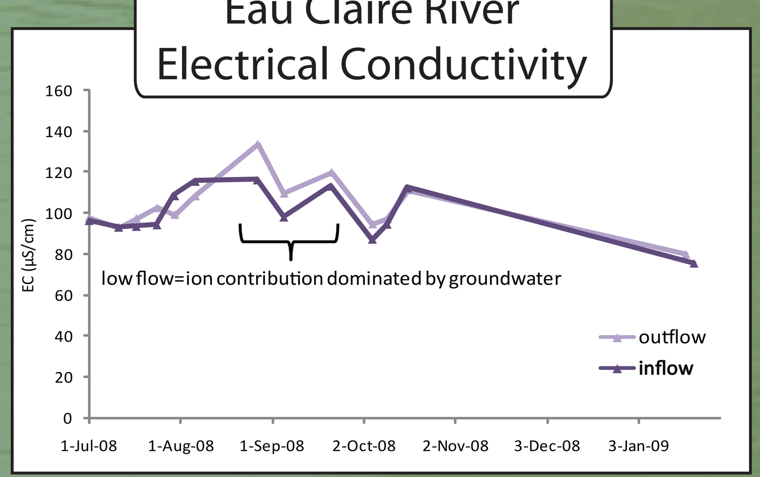
4.5 Phosphate concentration in the lake water is higher in the summer than in the winter. This is expected as baseflow is the main source of water in the lake during the winter months. Higher phosphate concnetrations ovserved during the summer are due to runoff carrying trace amounts of fertilizer contributes (see graph). The phosphate concentration in the groundwater discharging along the north shore, where discharge is greatest, generally have higher phosphate concentrations than what was observed in the lake water. This suggests that domestically influenced groundwater is a potentially significant contributor to lake phosphate concentrations, but only if the volume of groundwater discharging into the lake is relatively high compared to the river input.

Eau Claire River pH



4.6 The high pH of water exiting the lake from the end of July to early October confirms that extensive photosynthetic growth of algae occurred in the lake during this period. This high growth occurs at a time when the river input of phosphate is the lowest (see Eau Claire River phosphate plot, results 4.4), which suggests that groundwater derived phosphate may indeed be an important nutrient source for the algae in the lake.

Eau Claire River Electrical Conductivity

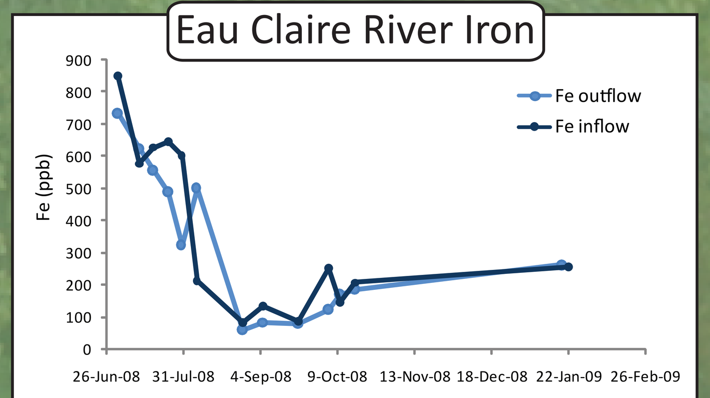


4.7a The plot of the electrical conductivity (EC) for water entering and exiting the lake shows that between the end of July and late September EC is higher for the outflow water than for the inflow water. (continued on next column)


Prominant algae growth during low flow periods causes lake water to become vibrant green.

4.7b (continued from previous column) High EC during low flow periods indicates that groundwater seepage is contributing significantly to lake water chemistry and/or that evaporation is occurring. Groundwater seepage contribution is only expected to be significant during low flow events during late summer and early fall. It is during these low flow events that the residence time in the lake is long enough to allow extensive algae growth. Prominant algae growth is evident throughout the lake and can be observed as vibrant green water in the lake.

Eau Claire River Iron



4.8 The plot of iron concentration for riverwater inflow and outflow shows that iron is lost from the water as it passes through the lake. Preliminary PHREEQC speciation of the lake water shows that the water is supersaturated with respect to most Fe-minerals in the database. This indicates that precipitation of Fe-minerals is an active removal process for iron in the lake environment. As Fe-minerals are rapidly precipitating in the lake, trace metals can co-precipitate with the iron, causing high trace metal concentrations to be added to the lake. Discharging groundwater may be contribute to high trace metal content in the lake sediment.

5. Conclusions

The electrical conductivity of water flowing in and out of the lake indicates that high EC groundwater is only of significant influence on the lake water quality during late summer/early fall. This corresponds to low flow conditions in the lake, which also promotes algae blooms. As a result it can be concluded that the high phosphate concentrations observed in the discharging groundwater maybe not be significant for the lake water quality during most of the year due to the low volume relative to the river water. However, during the low flow conditions of the late summer/early fall the relative contribution of groundwater to the lake water as evidenced by the high EC in outflow water. This suggests that groundwater derived phosphate may be significant in fueling the extensive algae blooms observed in the lake during this time period.

The high concentrations of trace metals in many of the groundwater samples, along with evidence of rapid Fe-mineral precipitation, suggests that co-precipitation of trace metals can occur at all times of the year. Increased trace metal concentration in the sediment may be of concern in relation to the periodic dredging in the lake.

References

Fairbairn, D, Pedersen, B, Teige, E, 2008, Using trace metal analysis to determine pollution sources impacting Lake Altoona, West-Central Wisconsin: Geological Society of America Abstracts with Programs, v. 40, no. 5, p 29.

James, W.F., J.W. Barko, and H.L. Eakin. (2001). "Limnological analysis of Lake Altoona, Wisconsin," Final Report prepared for the USACE, St. Paul and State of Wisconsin under Section 22

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