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SEWRPC Technical Report No. 64

REGRESSION ANALYSIS OF SPECIFIC CONDUCTANCE AND CHLORIDE CONCENTRATIONS

Chapter 1

INTRODUCTION

1.1 PURPOSE OF THIS REPORT

This report documents the development of regression models that can be used to estimate the concentration of chloride in surface water from measurements of the water's specific conductance.

Conductivity measures the ability of water to conduct an electric current. Because this ability is affected by water temperature, conductivity values are corrected to a standard temperature of 25 degrees Celsius (ºC)[1] or 77 degrees Fahrenheit (°F). This corrected value is referred to as specific conductance. Pure water is a poor conductor of electrical currents and exhibits low values of specific conductance. For example, distilled water produced in a laboratory has a specific conductance in the range of 0.5 to 3.0 microSiemens per centimeter (μS/cm), a very low value. The ability of water to carry a current depends upon the presence of ions in the water, and on their chemical identities, total concentration, mobility, and electrical charge. Solutions of many inorganic compounds, such as salts, are relatively good conductors. As a result, specific conductance gives a measure of the concentration of dissolved solids in water, with higher values of specific conductance indicating higher concentrations of dissolved solids.

Under certain circumstances, measurements of specific conductance may act as a useful surrogate for measurements of the concentrations of individual dissolved substances. For example, measurements of specific conductance may be able to give indications of chloride concentrations in receiving waters. Specific conductance can be measured in the field using a hand-held meter while measuring chloride concentration

[1] *Acronyms and abbreviations used in this report are defined in Appendix A.*

requires laboratory analysis. In addition, specific conductance in a waterbody can be measured continuously using dedicated data logging equipment. The use of specific conductance as a surrogate would allow the substitution of specific conductance measurements for chloride measurements in water quality monitoring. Such a substitution would allow for monitoring of chloride concentrations at substantially lower costs than could be achieved through direct monitoring of chloride using less robust equipment such as chloride probes or chemical analysis. In addition, the availability of automated monitoring equipment for specific conductance enables monitoring of chloride concentrations at much finer time scales than would be possible through sampling for chemical analysis. This potentially provides a more detailed understanding of the dynamics of chloride in stream and river systems, especially in relation to events such as winter storms and snowmelts.

Data analysis by the U.S. Geological Survey (USGS) found a linear relationship between specific conductance and chloride concentration at higher values of conductance and chloride concentration.[2] This suggests that during periods when chloride is being carried into receiving waters by discharges of stormwater or snowmelt, ambient chloride concentrations could be estimated using specific conductance.

The USGS regression model was developed using data from 17 Wisconsin streams, including streams located in the urban and rural areas. Comparison of the chloride concentrations predicted by the USGS regression model to actual historical chloride concentrations in samples collected from the Root River in Milwaukee and Racine Counties, Wisconsin found that the regression model was a poor predictor of chloride concentrations in the Root River. The model usually predicted higher chloride concentrations based on specific conductance than were observed in the River, with an average difference between predicted and observed concentrations of about 25 percent of the observed concentrations and a maximum difference of about 277 percent of observed concentrations.[3]

As part of the Chloride Impact Study, Commission staff developed and refined regression models for predicting chloride concentration from specific conductance for portions of the Region. These models were developed using simultaneous specific conductance and chloride data collected by Commission staff at 41 stream and river sampling stations throughout the Southeastern Wisconsin Region over the period October

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[2] *S.R. Corsi, D.J. Graczyk, S.W. Geis, N.L. Boot, and K.D. Richards, "A Fresh Look at Road Salt: Aquatic Toxicity and Water Quality Impacts on Local, Regional, and National Scales,"* Environmental Science and Technology, *44: 7,376-7,382, 2010.*

[3] *SEWRPC Community Assistance Planning Report No. 316,* A Restoration Plan for the Root River Watershed, *July 2014.*

2018 through May 2021.[4] These models will be used throughout the Chloride Impact Study to estimate chloride concentrations from measurements of specific conductance.

1.2 RELATIONSHIP OF THIS REPORT TO THE CHLORIDE IMPACT STUDY

This technical report presents some of the findings from the Commission's Chloride Impact Study.[5] This study was initiated due to heightened public concern over the growing use of road salt and evidence of increasing chloride concentrations in surface water and groundwater within the Southeastern Wisconsin Region. The findings of this study are being presented in a series of reports.

Major objectives of the chloride impact study include:

1. Documenting historical and existing conditions and trends in chloride concentrations in surface and groundwater in the Southeastern Wisconsin Region

2. Evaluating the potential for increased amounts of chloride in the environment to cause impacts to surface water, groundwater, and the natural and built environment in the Region

3. Identifying the major sources of chloride to the environment in the Region

4. Investigating and defining the relationship between the introduction of chloride into the environment and the chloride content of surface and groundwater

5. Developing estimates of chloride loads introduced into the environment under existing conditions and forecasts of such loads under planned land use conditions

6. Evaluating the potential effects of climate change on the major sources of chloride under planned land use conditions

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[4] *Data collection is described in detail in SEWRPC Technical Report No. 61,* Field Analyses for the Chloride Impact Study, *September 2023.*

[5] *SEWRPC Planning Report No. 57,* A Chloride Impact Study for Southeastern Wisconsin, *in preparation.*

7. Reviewing the state-of-the-art of technologies and best management practices affecting chloride inputs to the environment and developing performance and cost information for such practices and technologies

8. Exploring legal and policy options for addressing chloride contributions to the environment

9. Developing and evaluating alternative chloride management scenarios for minimizing impacts to the environment from chloride use while meeting public safety objectives

10. Present recommendations for the management of chloride and mitigation of impacts of chloride on the natural and built environment

This report presents regression models that were developed to estimate chloride concentrations in surface water from measurements of specific conductance. These models were applied to develop estimates of chloride concentrations that were used in analyses in other stages of the Study. These analyses will be presented in other technical reports.

1.3 REPORT FORMAT AND ORGANIZATION

This report documents the development of regression models for estimating concentrations of chloride from specific conductance. It is organized into three chapters.

Following this initial chapter, Chapter 2 summarizes the methods used to develop the regression models. This summary begins with a discussion of the statistical background regarding regression techniques. This is followed by descriptions of the data and statistical methods used to develop the regressions. The chapter also discusses methods used to evaluate the resulting regression models.

Chapter 3 shows the results of the regression analysis, presenting two models for estimating the concentration of chloride from specific conductance. The chapter then provides an evaluation of each model. Finally, the chapter provides guidance for the use of the models.

This report includes two appendices. Appendix A defines acronyms and abbreviations used in this report. Appendix B discusses development of site-specific linear regressions to estimate chloride concentrations from specific conductance for the six lakes sampled by Commission staff as part of the Chloride Impact

Study. It also provides some guidance for developing estimates of chloride concentration in other lakes of the Region.