Using GIS to Highlight Highway Segments Sensitive to Deicing Material

Final Report

CLEAR ROADS

research for winter highway maintenance

CR 20-05: Using GIS to Highlight Highway Segments Sensitive to Deicing Material

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16. Abstract:
To identify roadway-adjacent areas that are likely to have a greater sensitive to deicing chemicals, specifically chlorides, this project conducted a literature search to describe the effects of deicing chemicals, the factors which mitigate or increase their impacts, and constructed a geospatial model that uses a variety of descriptive data to estimate the relative sensitivity of the local environment. The model allows users to define roadways that are subject to deicing operations, adjust relative importance of various factors such as land use, and generate a high-medium-low thematic map of the roadways.

This tool will allow a more thoughtful and targeted approach to chloride use reduction by enabling an analysis of environmental impact that can be balanced against other concerns such as safety and pavement clearing time targets.

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Chapter 1. Executive Summary

1.1. Purpose

Understanding the effects of deicing materials is a key part of an overall strategy to minimize their use while maintaining a high standard of safety during winter road maintenance. This project advanced the understanding of deicing chemical use with four distinct actions:

1. Establish the current practices and tools used in road maintenance operations to reduce environmental impact.
2. Identify available datasets and determine their suitability for use.
3. Develop a model that ranks sensitive resources based on a wide variety of datasets.
4. Develop an interactive Geographical Information System (GIS)-based tool that allows analysis of roadways based on their relationship to sensitive resources.

Assess environmental sensitivity previously required custom techniques that were unique to each agency, and possibly each user. A standard approach makes it possible to assess chemical sensitivity in a uniform and comparable way. The tool is a functional proof of concept that is usable but is not intended for users unfamiliar with GIS software and data management.

1.2. Methodology

1.2.1. Literature Review

The project completed a literature search to identify the nature and extent of deicing chemicals on the environment near the roadway. Chlorides were the chemicals considered as they are the most commonly used, least expensive, and have the greatest environmental impact. Other deicers, such as acetates and carbohydrates, were not included in the literature review because they tend to be used in more specific applications, such as airport deicers, and in some cases are still being studied to better understand the effects.

Sources considered in the literature search include academic, governmental agency, and industry sources. Overall, 15 sources were cited, which are listed in the Literature Review document submitted in September 2021.

The literature search established the impact of chloride deicing chemical on the flora, fauna, and water systems near roadways and defined 10 factors that should be considered in a geospatial model.

1.2.2. Practitioner Survey

An online survey was conducted to assess the data collected by agencies related to deicing chemicals and the environment and their efforts to mitigate environmental impacts. Sixty four agencies were

invited to complete survey, of which 23 provided usable responses. Twenty two of these 23 were state agencies.

Most agencies actively track the amount and location of chloride application, and roughly half have an active program to reduce chloride deicing use. However, only one respondent was attempting to try to determine where there was an increased environmental sensitivity, which indicated a need for a tool like the one developed for this project.

1.2.3. Identify and Rank Model Inputs

The team collectively considered a wide variety of possible inputs to the model. Each possible input was evaluated on three criteria:

- **Availability** – Is the data accessible in an electronic format for all of the states that will be included in the model?
- **Utility** – Will the input have significant impact on the model outputs?
- **Quality** – Is the data complete in terms of geography and attributes, accurate, and up to date with appropriate data maintenance.?

Overall, 19 possible inputs were identified. These were organized into four groups.

- **Roadway** – physical characteristics of the roadway such as centerline location, average daily traffic and posted speeds.
- **Biological** – land cover, habitat, and other ecological data.
- **Geologic** – soil types.
- **Water Resource** – hydrology, special water designations, well locations, etc.

Four "mandatory" data types were identified as the minimum needed to assess environmental sensitivity.

- **Plow Routes** – the roadway network that defined the analysis area.
- **National Wetland Inventory** – indicating the location and type of wetlands.
- **National Land Cover Database** – showing location of land cover, such as agriculture that may be more sensitive.
- **Soil Types** – accounting for drainage conditions that could facilitate the movement of deicing chemicals from the roadway.

With the exception of the Plow Routes, all of the mandatory datasets are available in uniform, national coverages.

Optional inputs allow users to input data for special concerns, such as scenic waterways and wellhead protection areas. Some optional data types are unique to certain states or areas and may require some processing to be usable in the model.

1.2.4. Geospatial Tool

A software tool was developed as an Add-In for ArcGIS Pro, version 2.9.x. This tool incorporated a user interface that prompted users through the GIS environment set up, dataset selection and model parameter configuration.

The tool was tested internally by SRF and in two rounds of beta testing with members of the project committee. The testing revealed several installations and usability issues. A revised version of the tool was created after the first round of beta testing and a pre-installation system check tool was also created.

Other usability issues, such as configuring model parameters, were addressed with additional use guides and instructional videos.

1.3. Recommendations and Next Steps

Several lessons were learned through the development and deployment of the tools. Most importantly:

1.3.1. Lessons Learned

Using the ArcGIS Pro platform for users is limiting. Not all users who wish to identify sensitive areas have access to ArcGIS and the complex nature of the software presents a steep learning curve.

Managing the data needed by the model can be challenging. To use the model, the user must download data from nationally-curated sources. Network polices and storage limitations prevented some users from obtaining the data.

A relative measure of sensitivity may not be sufficient for all applications. The model is able to take into account a number of variables, calculate a sensitivity value, and group values into high, medium and low categories. However, these values cannot be directly interpreted as effects on the environment. This leaves managers to interpret values in terms of how much reduction is needed to avoid impacts.

1.3.2. Next Steps

Addressing data access and usability could be accomplished by moving the tool to an on-line, hosted implementation with a customized user interface. This would allow simpler use and provide access to a wider user base. Exploration of adapting the tool and underlying model should be considered as a future development.

Establishing an objective interpretation of the sensitivity score will require additional research from a water resources and environmental science standpoint. Calibration of the model outputs and translation into likely impacts at different levels of deicing chemical contamination can be undertaken as a related research project.

Chapter 2. Acknowledgements

The project committee and research team would like to acknowledge and thank the beta-test group for their assistance in creating the initial GIS Deicing Sensitivity Tool.

Beta test participants offered their time and cooperation with the development team to overcome numerous technical and administrative issues. The complexity of the software and depth of the datasets used created challenges that could only be discovered and addressed through direct, hands-on testing.

Chapter 3. Introduction

Clear Roads is a research organization comprised of 39 agencies that pool resources to conduct research on winter maintenance operations. Since its inception in 2004, the Clear Roads research program has supported dozens of research projects focused on the improvement and facilitation of winter weather maintenance operations. In addition to evaluating equipment and procedures, Clear Roads is concerned with the effect of operations on the environment near roadways.

Clear Roads initiated CR 20-05 to create a data-driven model to identify segments of roadway that have elevated sensitivity to deicing chemicals based on the surrounding, soil, water and land-cover characteristics. This project included preparation of a literature search, data analysis, software model development, and creation of instructional videos.   This Final Report summarizes the project's deliverables and offers recommendations for future development of the tool.

Chapter 4. Background

4.1. Deicing Chemicals

Deicing chemical are an effective tool for improving the safety of travel during and after ice and snow events. By lowering the freezing point of water, deicing chemicals allow for the roadway surface to maintain higher surface friction and enable faster clearance times.

The most commonly used deicing chemicals are chloride-based, typically sodium chloride, magnesium chloride or calcium chloride. These are typically very effective above temperatures of 15 degrees Fahrenheit, with effectiveness decreasing below that point. Other chemicals are in limited use, such as organic mixtures, but these are generally more expensive and less effective than chlorides.

Although effective, chlorides are contaminants that degrade soils, surface waters and underground aquifers. Excessive chloride levels can corrode water pipes and affect water taste, which results in higher treatment costs. More importantly, near the roadway, chlorides "burn" vegetation, decrease fish fertility, increase algal blooms, and attract wildlife to the roadway, resulting in more crashes.

Reducing chemical use will decrease the environmental impacts but can also affect safety. Finding ways to target chemical reduction without creating dangerous winter driving conditions is key.

4.2. Project Objectives

The project objectives are to build a body of knowledge that enables construction of a geospatial model to predict the sensitivity of the environments to deicing chemicals along the roadway. To accomplish this, four distinct objectives were identified.

4.2.1. Objective 1: Establish the current practices used to reduce environmental impact

- Identify current efforts related to deicing chemical sensitive environmental features
- Locate and describe existing data gathering / data sets related to deicing chemical sensitivity
- Gauge the level of concern related to sensitive features by winter maintenance practitioners

4.2.2. Objective 2: Identify available datasets and determine their suitability for use in a GIS tool

- Categorize and describe the effects of deicing chemicals on the roadway adjacent environment
- Identify features that affect the severity of effects
- Catalog the available data related to features (soil types, land cover, etc.)

4.2.3. Objective 3: Develop a model that ranks sensitive resources based on a wide variety of datasets

- Select model inputs based on overall influence and availability

- Create a geospatial model to manage inputs

- Develop a mathematical model that combines inputs and generates a sensitivity value

4.2.4. Objective 4: Create an interactive GIS-based tool that allows analysis of roadways and plow routes

- Design a software implementation of the model

- Create a tool to analyze and map results

- Create training and instructional materials

4.3. Methodology

To accomplish the project objectives a data collection phase was followed by a development and testing phase. Five distinct activities were undertaken:

4.3.1. Literature Search

A review of literature related to chemical application, transport into waterways, and affects on the natural and built environments was conducted by water resource professionals. The literature search included academic, governmental agency, and industry sources. Information is organized to explain the mechanisms of salt (chloride) transport and the environmental features affected.

The literature search was delivered to the project committee in September, 2021 as both a written document and presentation. These documents included a number of key findings that informed the creation of the geospatial model, including:

- The movement of salt (chloride) transport from impervious surfaces is well documented. In urban areas salt will migrate from the roadway through curb/gutter systems and ultimately through storm sewers to waterways. In rural areas salt will migrate into shoulders and ditches, resulting in high concentrations in the ditch and receiving waterway.
- There are several factors that facilitate or restrict salt movement including soil type, gradients, waterway proximity, land use and population density.
- Salt contamination has several effects on water
    - Poor taste for drinking water
    - Anoxic conditions in lakes leading to phosphate release and algal blooms
    - Increased water treatment costs
    - Increased corrosion in water delivery systems

- o   Potentially increased lead exposure resulting from corrosion
- Salt also affects soils by degrading the structure and increasing inorganic matter mobility, which can result in heavy metal concentrations increasing. Soil moisture retention is also decreased, and overall fertility reduces as a result of salt contamination.
- Soil and water contamination affects nearby vegetation as well as direct exposure from salt contact on leaves. Reduced growth and increased plant mortality result.
- Nonnative, salt-tolerant plant species can invade contaminated areas, resulting in changes to the local ecology.
- Wildlife is affected directly by salt exposure resulting in increased mortality and reduced fertility, particularly for amphibians.
- Indirect wildlife impacts include decreased diversity of grazing plants for food and increased crashes with vehicles as salt attracts mammals to the roadway.

4.3.2. Survey

An on-line survey of winter maintenance agencies was completed to provide a baseline understanding of current practices related to the assessment of deicing chemical impacts and the reduction of chemical use. The survey included three general areas of questions.

- Identify current efforts related to sensitive features and anti-icing chemicals
- Determine what data gathering / data sets exist related to sensitive features
- Assess level of concern related to sensitive features by agencies

An invitation to complete the survey was sent to 64 potential respondents. Of these 22 provided usable responses, with 21 of those being U.S. states. The list of states responding is shown in Table 1.

Table 1 - Responding States

North Dakota	Minnesota	Idaho
Vermont	Pennsylvania	Utah
Illinois	Delaware	Kansas
Iowa	New York	Ohio
Arizona	Indiana	Rhode Island
Virginia	Nebraska	Oregon
Maine	Colorado	Massachusetts

The survey validated the effort to create a tool to help target chemical use reductions. In particular:

- 70% of all respondents use sodium chloride as a deicing material. Among those who said they used an alternative; it was used in conjunction with sodium chloride. Generally, alternatives are either magnesium or calcium chloride, so chloride chemistry is the primary concern for environmental sensitivity.
- 77% of respondents indicated that they track the locations of chloride application.
- 59% of all respondents indicated that they had an existing effort to reduce salt or chloride use.
- Only one respondent indicated that they had developed any sort of systematic scoring or mapping tool to help maintenance supervisors make decisions about chloride application and environmentally sensitive areas.

4.3.3. Development and Testing

Development of the geospatial tool occurred in two phases.

Phase 1 assessed the data available as inputs to an underlying analysis model. These were summarized and ranked in a Resource Prioritization Matrix (RMP). Model inputs from five different categories of data were assessed.

- **Roadway** – physical characteristics of the roadway such as centerline location, average daily traffic and posted speeds.
- **Biological** – land cover, habitat, and other ecological data
- **Geologic** – soil types
- **Water Resource** – hydrology, special water designations, well locations, etc.

19 separate data points were identified for assessment in the RPM, which assigned each a score based on three factors:

- **Availability** – Is the data accessible in an electronic format for all of the states that will be included in the model?
- **Utility** – Will the input have significant impact on the model outputs?
- **Quality** – Is the data complete in terms of geography and attributes, accurate, and up to date with appropriate data maintenance?

Based on the overall ranking in the RPM, model inputs were selected as shown in Table 2.

Table 2 Assess Model Descriptors

Descriptor Name	Included	Include if Data is Available	Not Included
Roadway Centerlines	X		
Roadway Lanes (lane miles)		X	
Roadway Surface Type			X
AADT			X
Posted Speed		X	
Drainage/Slope	X		
Shading (tree canopy)			
Land Cover Type (NCLD)	X		
Endangered/Listed Species		X	
Critical Wildlife habitat/ranges	X		
Soil Type	X		
Well Locations (proximity)			X
Wellhead protection areas		X	
Agricultural land Use	X		
Hydrology (streams)	X		
National Scenic & Wild Rivers	X		
Wetland Inventory (proximity)	X		
Watershed boundaries		X	
Aquifer vulnerability / karst formations			X

Once the model inputs were identified the team began development of the GIS tool using ESRI
Model Builder. Model Builder provides a visual interface describing how data is transformed,

combined and summarized. As a result, complex processes can be easily defined and linked, allowing the output of one process to be the input to another. The disparate nature of the input data required substantial normalization before being combined for computational processing. In addition, the model output was in the form of a raster "grid" of pixel values, which then had to be related to roadway segments.

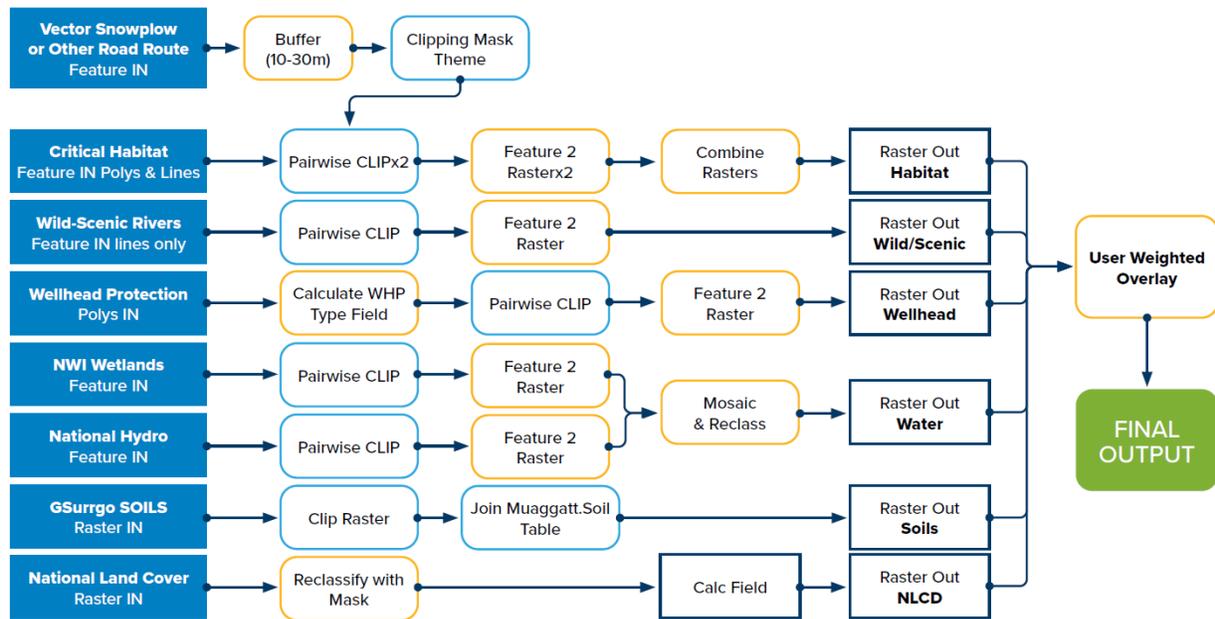Figure 1 gives a schematic representation of the model.

Figure 1 - Sensitivity Model

Once the basic model was developed, software development began using ESRI ArcGIS Pro as the platform. ArcGIS Pro was selected due to its prevalence in the Clear Roads states and the availability of development tools. Distribution of the software was determined to be as an ArcGIS "configuration" or add-in that would be installed on individual workstations.

After an initial version of the software was in a testable state, several committee members volunteered for an initial "beta" test. The testing revealed a number of installation difficulties, primarily related to agency IT policies regarding download of external files and installation of software. Initial tests also highlighted the steep learning curve for the tool and the need for experienced GIS professionals to assist with its use.

Based on feedback from the initial testers, a special "pre-install" tool was created to help identify issues that might prevent installation or retrieval of data needed to run the underlying model.

4.3.4. Documentation

Initially, the project focused on written documentation as activities were completed. Separate documents were produced for the Literature Seach and Survey, as well as a Summary Report that provided overviews of both.

Two separate documents were produced related to the GIS Tool itself: an installation guide that described how to set up the ESRI ArcGIS Pro configuration, obtain data and the workflow to run the tool, and a Usage Guide that explained the various parameters in the model and why one might make changes to their weighting and priority.

Following the initial testing and delivery of documentation, the project committee concluded that a narrated video version of the software guides would be beneficial. The development team created two video guides as a supplement to the written material.

All documentation for the GIS Tool will be available from the Clear Roads web site at the conclusion of the project.

Chapter 5. GIS Tool Overview

5.1. Technical Environment

The GIS Tool runs within the ESRI ArcGIS Pro workstation environment. As such it has a set of requirements to install, use, and perform satisfactorily.

5.1.1. Software

The minimum requirements for using the GIS Tool are:

- Microsoft Windows version 10 or later
- ArcGIS Pro Workstation version 2.9.x
- ESRI Spatial Analyst
  Or
- ESRI 3D Analyst

There are also minimum data requirements for the model to process data properly.

- Agency Plow Route Network

    The roadways to be analyzed by the tool; provided by agency.

- USDA Natural Resource Conservation Service (NRCS) Soils
- National Hydrological Dataset (streams/rivers) (NHD). FWS National Wetlands Inventory (NWI)
- National Land Cover Dataset (NLCD)

5.1.2. Hardware

Depending on the area analyzed for sensitivity, considerable processing and storage capabilities may be needed. During the test period, users experienced hardware limitations related to system RAM and processor speed. As a result, the following hardware configuration is recommended as a minimum.

Processor: Intel Core i7 87xx or later; AMD Ryzen 7 38xx or later

Memory: 16GB RAM or more

Storage: 200 GB available.

5.2. Tool Overview

5.2.1. Installation

Installation of the GIS Tool into an ArcGIS Pro environment is relatively straightforward.

1) The user downloads an archive ("ZIP file") from an on-line repository. Generally, this will be the Clear Roads web site.
2) The ZIP file is decompressed into a folder labeled "Deicing DS Tool" on the workstation.
3) Double-click on the "DeicingDSTool.proConfigX" file to start the installation wizard and click on the "Install Configuration" button to start the process. The user will see an "Installation Complete" message when the wizard has finished.
4) The GIS Tool can now be used from the ArcGIS Pro user interface.

5.2.2. User Interface

The user interface is designed to guide the user through the workflow of obtaining data, adjusting analysis parameters and generating model output. The primary addition to the ArcGIS Pro user interface is a "Deicing Decision Support" tab and an icon-based tool bar that appears when the tab is selected. These components are shown in Figure 2.
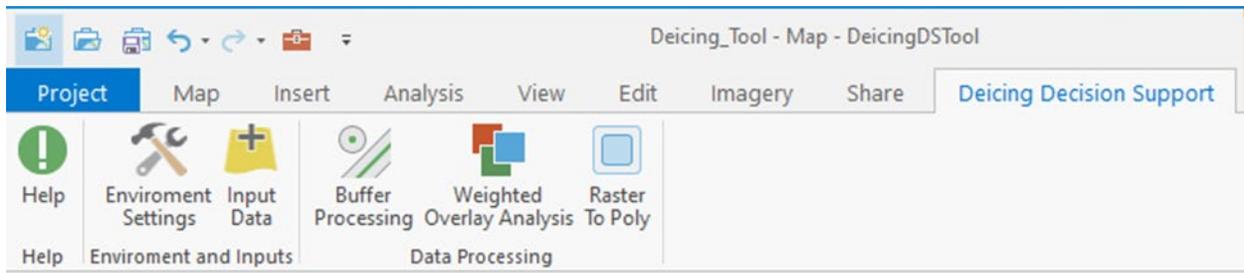
Figure 2 - User Interface Tool Bar

The toolbar allows users to work from left to right to complete each step of the analysis. Each selection leverages the existing ArcGIS Pro user interface elements to minimize the need to learn new software elements. Starting with the Environment Settings, the user defines where input data is stored and where the model outputs will be written. Environment Settings are shown in Figure 3.
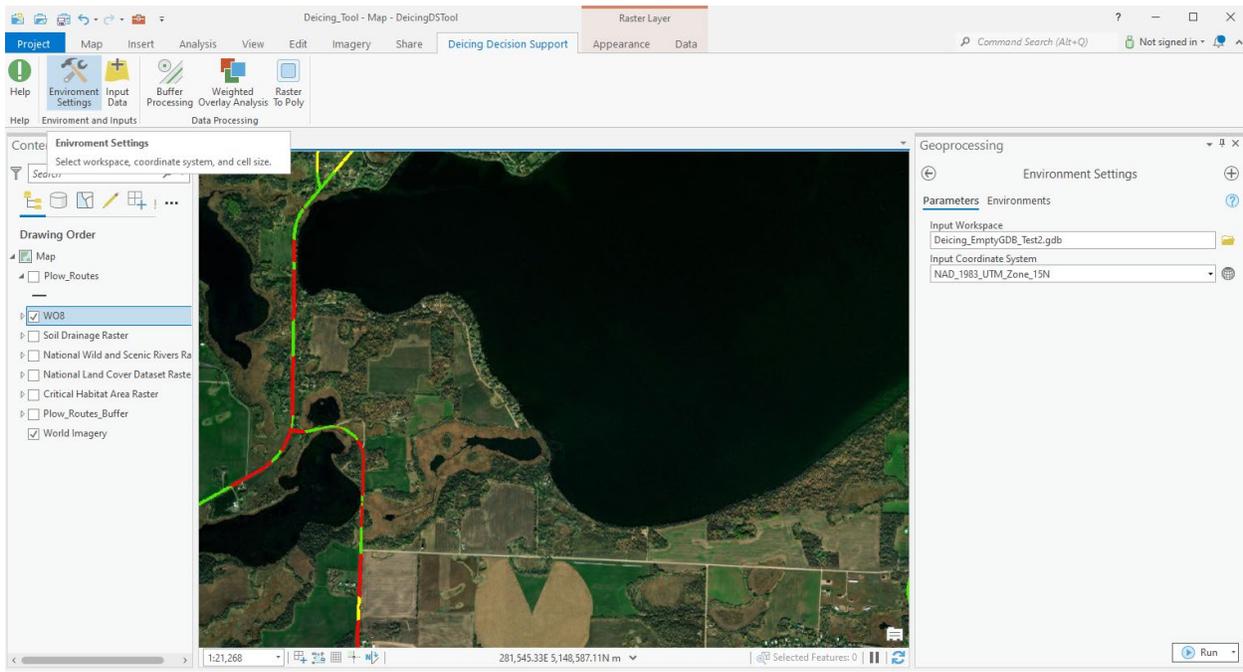
Figure 3 - Environment Settings User Interface

The next step is to define the locations for data inputs of the model. The user moves to the next icon to the right and opens an interface that allows input of file locations for each dataset the model will use.
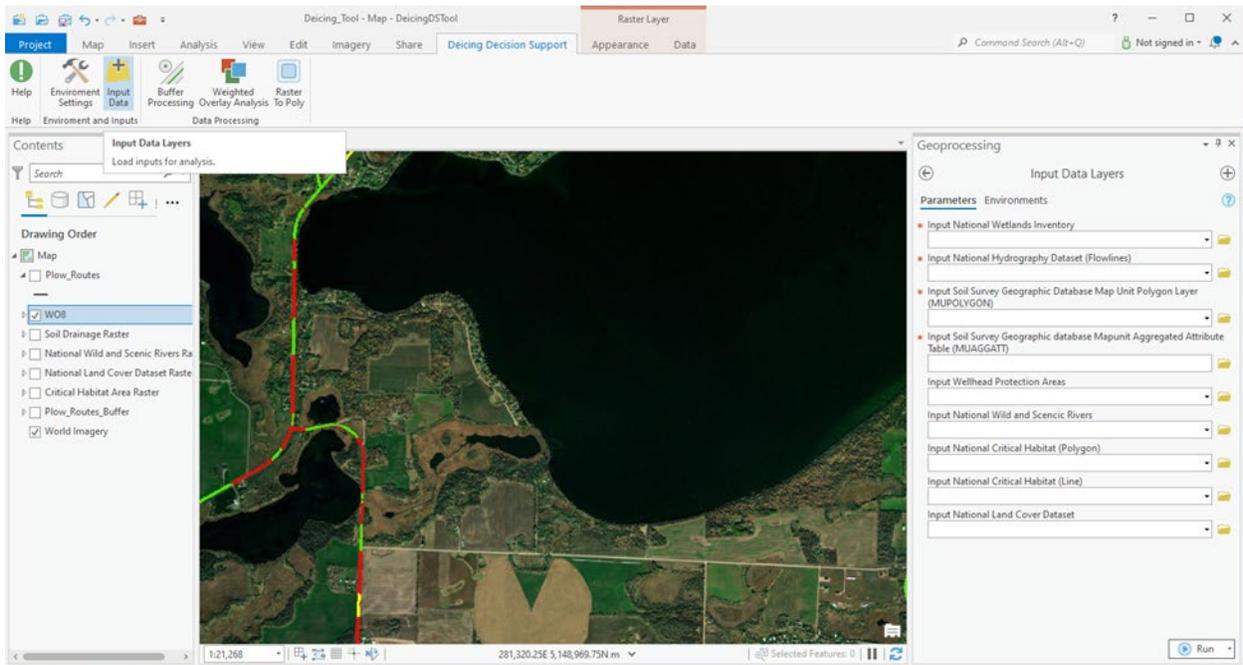

Figure 4 - Input Data Settings User Interface

As shown in Figure 4 defining Input Data is a simple process of selecting a data source location for each item. The mandatory data is indicated with an asterisk (*) next to the input box.

Once the environment is defined and data locations set, initial process begins by selecting the Buffer Processing icon. The user interface gives options to define the roadway network ("Plow Routes") and set the distance from the roadways where the input datasets will be considered ("Buffer Distance"). Once these parameters are set, the user clicks "Run" as shown in Figure 5.
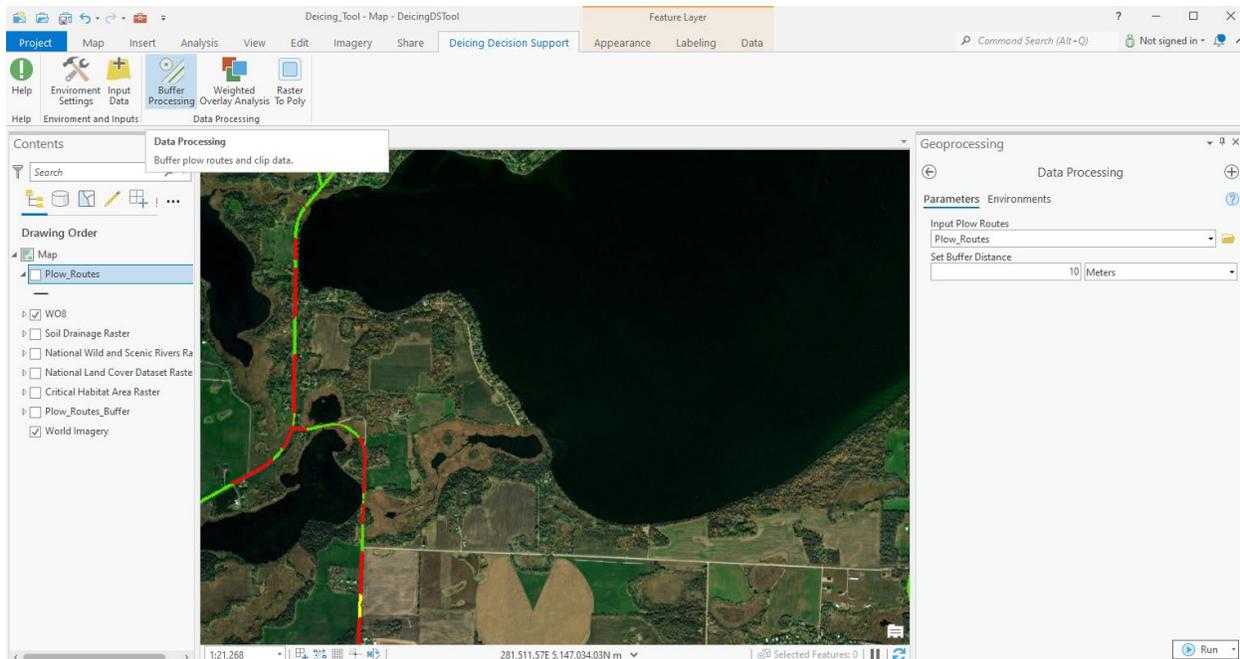

Figure 5 - Buffer Processing User Interface

The actual determination of sensitivity in an area is part of the Weighted Overlay Analysis. When the user selects this icon, each model input (and the specific categories of data in it) can be assigned different weights, which determine their overall influence on model outputs. This process produces a "raster" or grid of values that give a numeric value to the relative sensitivity of an area to deicing chemicals. The specific adjustments available will depend on the datasets loaded and the attributes included in each. After adjustments, the user clicks "run" to generate the model output.

The output raster is automatically loaded into the "Contents" pane on the left side of the user interface. The raster values are classified using a "Natural Breaks" method into three groups representing high, medium, and low sensitivity. The output raster can be viewed in the GIS Tool, or loaded with other data for analysis.

The Weighted Overlay Analysis interfaces is shown in Figure 6.
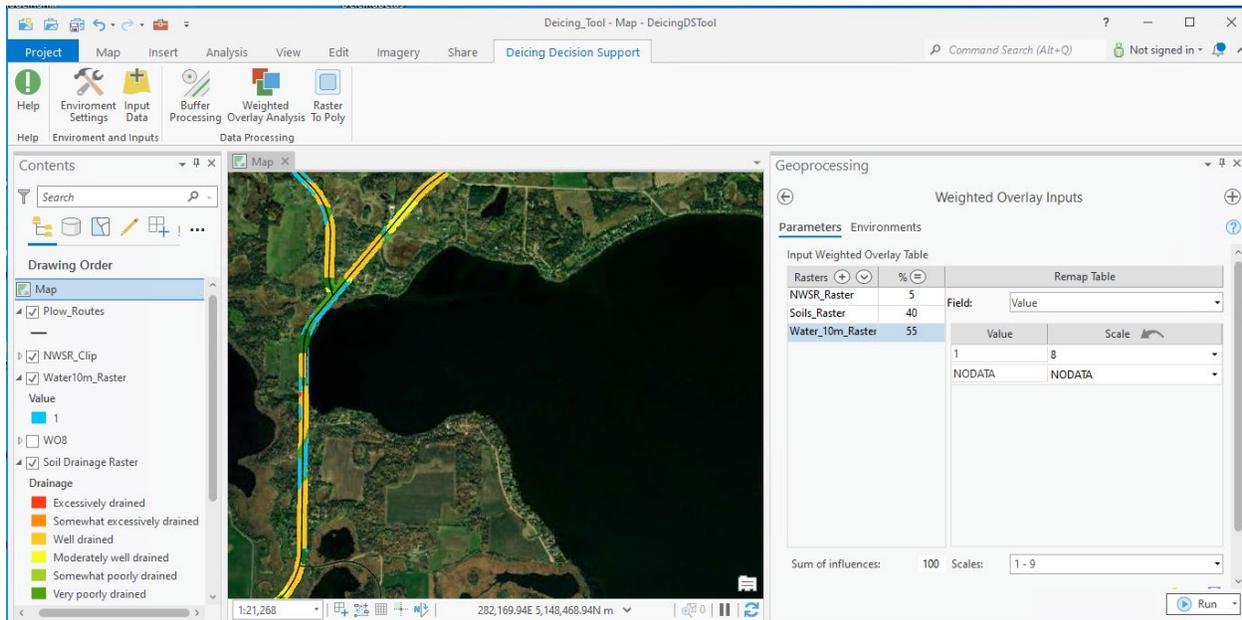
Figure 6 - Weighted Overlay Interface

Finally, it may be better suited for some analytical purposes to segment the roadway itself and assign an average value for sensitivity. The "Raster to Poly" icon activates a tool that generates a "polyline" GIS layer, segments it and assigns a sensitivity value to the roadway itself.

5.2.3. Options and Output

The GIS Tool provides a high level of customizability to tailor a sensitivity analysis to both the local environmental features and the priorities of stakeholders. The specific options are detailed in the Usage Guide.

Outputs are GIS Layers. Both a raster showing sensitivity and a polyline roadway layer with sensitivity scoring can be created by the tool. Since these are layers, they can be reviewed within the tool itself or added to other GIS projects that may include mapping, analysis or incorporation into other applications.

5.3. Testing and Revisions

The GIS Tool was extensively tested by SRF staff prior to enlisting beta test volunteers from the Clear Roads project committee.

Beta testers revealed a number of issues related to software version incompatibility, network configuration and policy restrictions. Some testers also found that older, notebook-style computers were unable to complete the Weighted Overlay Analysis due to lack of memory or poor CPU performance. SRF staff worked with testers directly to get through the initial set up of the GIS Tool, but the troubleshooting process was time-consuming and delayed development of the final version of the tool.

Key issues were:

- Workstations using version 3.x of ArcGIS Pro, which were incompatible with add-ins developed for version 2.9.x
- Firewall policies that prevented downloading of the ZIP archive containing the GIS Tool files.
- Firewall policies that prevented using the File Transfer Protocol (FTP) to retrieve model data from some government sources
- Network and server configurations that prevented users from defining an environment that allowed them to save output from the tool

While all of these items present substantial obstacles for usability, they are generally not items that can be addressed by software within the ESRI environment. Most require some level of coordination between the user and the Information Technology groups within their organization.

In an effort to make coordination more efficient for users, the SRF team created a small software script that checked for the ArcGIS Pro version and attempted to connect to data sources prior to installing the add-in. While this did not in itself resolve the issues noted, it provides the user with the information needed to address them with the appropriate support group.

Chapter 6. Summary and Next Steps

This project successfully described the key effects of chloride deicing chemicals on the environment, identified the factors that determine how sensitive the local environment is to chemical contamination, constructed a model to predict sensitivity at a given location, and incorporated that model into a GIS software tool that allows users to selectively include and weight different factors for analysis.

6.1. Sensitivity Model and GIS Tool

The underlying model is highly flexible. In addition to the datasets included in this first iteration, it can be modified to incorporate additional data sources as needed. For example, if there is specific habitat information that is generally non-public to protect a listed species or if high-resolution elevation models are needed to address direction of runoff from a roadway surface.

With the flexibility of the model comes an unavoidable level of complexity. The ability to adjust the weight of each dataset as well as the items within each dataset (e.g. agricultural vs. urbanized areas in the land cover dataset) requires that users thoroughly understand both the underlying data and how the model weighting system works. This has been addressed in the initial version of the model by including a default set of values that create a usable, if generic sensitivity score.

The GIS Tool offers a detailed interface to the model parameters and generates GIS layer files that contain sensitivity scores either in a raster that shows sensitivity adjacent to the roadway, or assigns a sensitivity value to a roadway segment. Depending on the type of analysis, either output may be more useful.

For example, if a maintenance manager wants to determine the total miles of roadway that have high sensitivity, the roadway segment layer would be more useful. The raster layer enables a more granular view of how sensitivity changes along and away from the roadway.

6.2. Lessons Learned

The internal testing at SRF and by the beta test group revealed a number of important insights into how the tool can be used and potentially improved.

1) The nature of the tool (an ESRI ArcGIS Pro Add-In) will create distribution, installation and on-going maintenance issues. Users may be blocked from downloading the add-in ZIP archive and may face compatibility issues and organizations move to newer versions of ArcGIS. In addition, future revisions to the tool must be individually downloaded and installed on each users workstation.

2) The complexity of parameter weight adjustments was challenging for users. Both the number of possible parameters and significance of each in the analysis led to some level of confusion when attempting to use the GIS Tool

3) Processing large areas is resource intensive. The desire for high spatial resolution of sensitivity resulted in processing very large datasets. Although using a buffer function to limit the input data to areas near plow routes helped reduce processing time, a single run over a large area (large county with many routes, for example) may take up to 45 minutes to complete, even on a high-end workstation.

4) Data management was an issue for some users. The project focused on using data that was available as a national, uniform dataset that could be retrieved by any user. While this simplified the overall architecture of the GIS Tool, it became apparent that individual users may be blocked from accessing download sites. In addition, it may not be obvious when a downloaded dataset has been superseded.

5) Leveraging the ESRI ArcGIS Pro platform simplified tool development but requires that users be familiar with ArcGIS and be relatively sophisticated in its use. A fully custom user interface could make the tool more accessible to non-GIS users. In addition, organizations may face licensing restrictions that make it difficult to deploy the tool to every user who wishes to use it as they would have to have an ArcGIS Pro license available.

6) The GIS Tool generates a sensitivity ranking, but the ranks are entirely relative within the model. That is, there is no objective definition of what "High" sensitivity means in terms of measurable effects on the environment. The tool is useful for alerting maintenance managers of more or less sensitive locations, but in its current form cannot make recommendations on suitable levels of chemical application.

6.3. Next Steps and Future Directions

The GIS Tool provides analytical functionality that previously required custom techniques that were unique to each agency, and possibly each user. By creating a standard model and using common datasets, it is now possible to assess chemical sensitivity in a uniform and comparable way.

However, the lessons learned strongly suggest avenues for improvement to make the tool easier to use, maintain, and access.

1) Adapt the tool so it can be hosted in a central location and accessed as an on-line application. Migration to an on-line application has five major benefits:
   a. It eliminates the need for individual distribution and installation of the tool software.
   b. It ensures a common version is used by all users.
   c. Upgrades are made to a single installation
   d. Custom, optimized user interfaces can be developed to make the tool simpler and more accessible to a wider user base.
   e. Datasets can be curated to ensure that all analyses use the most current and consistent data.

Development and deployment of an on-line version of the tool represents a substantial investment in time and resources. In addition, the on-going cost of hosting the application and maintaining the underlying datasets will have an operations and maintenance cost component. However, moving to

an on-line version will enable the tool to be used by not only Clear Roads member agencies, but by any other partner to whom Clear Roads may offer access.

A more widely available, simpler to use tool will enhance the ultimate environmental impact of chemical reduction strategies.

2) Develop an understanding of the relationship between model sensitivity scores and real-world effects of chemical contamination.

Additional research is needed to understand how the outputs of the model translate into actual environmental impacts. Without a more formal relationship, maintenance organizations may know where higher sensitivity exist, but lack guidance on the severity of impacts and therefore lack a basis for how much chemical reduction is needed.

Ultimately the model can provide low-medium-high scores, but cannot answer the question of "How high is high"? A more thorough analysis from biology/ecology and water resources perspective can provide more definitive guidance and make the tool more useful to organizations that do not have extensive environmental expertise available to assist with chemical reduction planning.

CLEAR ROADS

research for winter highway maintenance

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