Usage and Scenario Building Guide

Using GIS to Highlight Highway Segments Sensitive to Deicing Materials

Version 1.0

Clear Roads Project No. 20-05

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Section 1 - Purpose and Introduction

Purpose

The purpose of this guide is to provide recommended settings as a starting point for using the Deicing Decision Support Tool. Depending on specific local concerns, weighting within the tool can be adjusted to more specifically focus on highlighted areas to protect drinking water, critical habitat, or vegetation health.

Datasets

The model has two mandatory datasets for "soils" and "waters":

1) **Soils Dataset:** USDA Natural Resource Conservation Service (NRCS) Soils
2) **Waters Datasets:** USFWS National Wetland Inventory (NWI) and National Hydrological Dataset (streams/rivers) (NHD): flowlines. These are combined in the model to make one Water_Raster Dataset.

The non-mandatory, optional datasets can be included and adjusted as well; these include the following:

1) Wellhead Protection areas (local datasets)
2) USFWS Critical Habitat
3) USFWS Wild and Scenic Rivers
4) National Land Cover Dataset (NLCD) in raster image format

Interactive effects of different data layers should be considered (i.e., be wary of weightings as data can be easily skewed). It is recommended to begin with just the mandatory datasets as a starting point before trying additional model runs with other datasets.

For additional background and information on this tool, review the *Deicing Decision Support Tool Help and Quick Start Guide (Beta)* and *Literature Review*.

Definitions

Buffer width: A recommended minimum buffer width is 15 to 20 meters. This will vary based on road width and local priorities. See Section 3 for more detailed information.

Weighted overlay: This tool will evaluate the raster datasets against each other as a percentage based on user defined importance. The total must sum to 100%.

Scale: Data within each raster can be assigned a scale. Scales default to a numerical ranking of 1 to 9. If desired, these can be adjusted in the tool to 1-3, 1-5, 1-10, or 1-100. Defaults are used throughout this guide.

Impact ranking: The results are ranked as "low", "medium", and "high" based on a simple weighted average formula for each raster (Weight x Scale).

Section 2 – Quick Start Guide

Quick Start Settings

The settings below are recommended as a starting place for new users to the tool to understanding the impacts of weighting to their locality. The goal of Quick Start Settings is to generally capture a broad range of important issues. It is recommended that the user review the results showing the percentage of the roadways meeting the threshold of a "high" impact ranking and adjust the values as needed to meet local goals. The model can be rerun with different inputs (e.g. raster datasets, weighting, and scaling) to target additional roads.

Table 1. Recommended Raster Dataset Weights and Scales for Tool Quick Start

		Quick Start Settings (required rasters only)		Quick Start Settings (all rasters)	
Raster	**Value Field**	Weight	**Scale**	**Weight**	**Scale**
Soils		50%		15%	
	Excessively Drained		9		9
	Somewhat Excessively Drained		5		5
	Well Drained		1		1
	Moderately Well Drained		1		1
	Somewhat Poorly Drained		1		1
	Poorly Drained		5		5
	Very Poorly Drained		9		9
Water		50%	9	15%	9
Wellhead				15%	9
Habitat (lines)				15%	9
Habitat (polygon)				15%	9
Scenic Rivers*				15%	5
Land Cover				10%	
	Developed				1
	Agriculture				9
	Forest				9
	Shrub/Scrub				1
	Barren Land				1

* This raster will "double count" National Scenic Rivers (because it will also be counted under the "water" raster); therefore, the maximum value was not assigned.

Settings for Focused Concerns: Drinking Water, Habitat, or Vegetation

The settings below are recommended as a starting place for new users to the tool who may have a specific contamination concern related to drinking water, habitat, or vegetation in mind for their locality. It is recommended that the user review the percentage of the roadways meeting the threshold of a "high" impact ranking and adjust the values as needed to meet local goals.

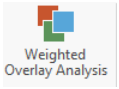
Table 2: Recommended Raster Dataset Weights and Scales for Tool Quick Start for Drinking Water Protection, Critical Habitat, and Vegetation Focused Concerns

		Drinking Water Protection		Critical Habitat		Vegetation Health	
Raster	**Value Field**	Weight	Scale	Weight	Scale	Weight	Scale
Soils		25%		10%		30%	
	Excessively Drained		9		1		1
	Somewhat Excessively Drained		7		1		1
	Well Drained		1		1		1
	Moderately Well Drained		1		1		1
	Somewhat poorly Drained		1		5		5
	Poorly Drained		1		7		7
	Very Poorly Drained		1		9		9
Water		25%	9	25%	9	30%	9
Wellhead		50%	9				
Habitat (lines)				25%	9		
Habitat (polygon)				25%	9		
Scenic Rivers*							
Land Cover				15%		40%	
	Developed				1		1
	Agriculture				1		9
	Forest				9		9
	Shrub/Scrub				1		1
	Barren Land				1		1

* This raster will "double count" National Scenic Rivers (because it will also be counted under the "water" raster); therefore, the maximum value was not assigned.

Section 3 - Process for Setting Layer Weights and Running Weighted Overlay

The following process can be used to run the weighted overlay analysis.

1) Complete setup process as outlined in the Deicing Decision Support Tool Help and Quick Start Guide (Beta). Proceed to Step 4.
2) Select "Weighted Overlay Analysis" at the top banner, under the Deicing Decision Support tab. 

3) Add input raster layers using the arrow down button. Datasets can be weighted equally (50%/50%) or set up to different values (e.g., 75%/25%, 90%/10%), as long as the sum is 100 percent. A good starting point is 50%/50%, since it assigns equal weighting. Within a dataset, a scale value of 1-9 can be assigned. The Water_Raster accounts for both the NHD and NWI data layers. It is based on presence/absence.

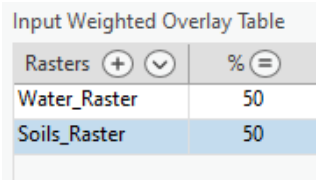


Figure 1: Example of Input Weighted Overlay Table

4) Assign remap values/layers. Make sure to select correct attributes for each layer. The Field should be set as "Value" unless it is the soils layer. Example of Remap Scale:
    a. 1 = Not affected by deicing material contamination (no influence)
    b. 9 = Most affected by deicing material contamination.

Tip: To see how one of the datasets is working, assign the remaining datasets values of one. For example, first code all the water as one; then code all the soil categories as one.

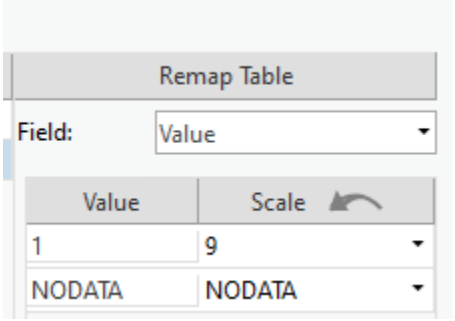


Figure 2: Water_Raster Scale of 9

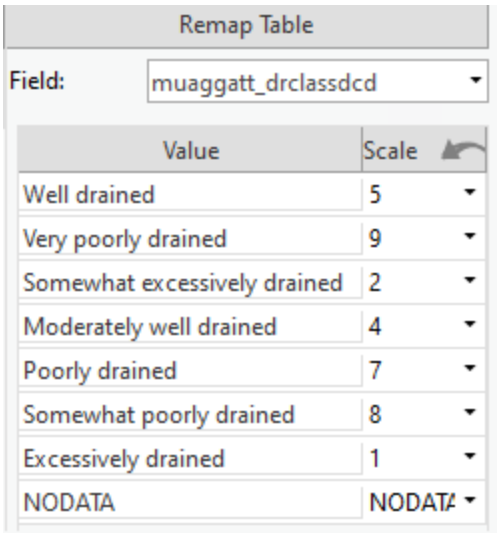


Figure 3: Soils_Raster Scales Assigned (poorly drained soils assigned higher scale numbers)

As an example model run, Water_Raster could be assigned a scale value of 9 (most affected). Most users assign a value of 9 if water is of high interest. For the Water_Raster dataset, the data is binary (based on presence or absence of water) so there is only one value. For the Soils_Raster, change field to soil types. There are seven values. Poorly drained soils could be considered most affected (e.g., if there are concerns about salt accumulating in the soil and harming roadside vegetation). Alternatively, excessively drained soils could be considered most affected if there are concerns about road salt quickly draining through the soil profile and harming groundwater/water resources).

5) In the Catalog pane, first create a Geodatabase; use a name with no spaces and add any identifiers, e.g., Test_Weighted_WellDrainingSoilsMostAffected. Next, run the model.

6) View the results in the ArcPro Map. Results will show up as low, medium, and high impact. It may be helpful to add a basemap or additional data layers to analyze the results to see if they align with areas of concern such as waterbodies, farm fields, or natural areas adjacent to roadways.

7) Run the model again with different values as desired. Keep in mind that depending on the weighting selected, very few "high" sensitivity areas may end up in the resulting raster.

Section 4 – Weighting Considerations for Datasets

Buffer Distance

The buffer distance is based on the road centerline, so the width of most roadways in the study area should be considered. For example, if the roadway width is 34 feet, including the shoulders, then the distance from the roadway should account for the distance from the centerline (34/2 = 17 feet). Literature reviewed by the Minnesota Pollution Control Agency[1] indicates that road salt impacts vary in their distance from the roadway. Salt concentrations in soil are highest within 6 meters (20 feet) and can be found as far out as 10 meters (33 feet) from the road edge. Road salt impacts on vegetation have been seen at distances of 100 to 650 feet off the road. Some road salt may also be transported by air; the Connecticut DOT found road salt powder as far as 300 feet from the roadside under heavy traffic conditions. Based on this literature, a minimum buffer of 20 feet + Distance to the centerline should be used. Users may wish to widen the buffer if there are concerns about the impact on vegetation.

Soils Dataset

Metadata and Considerations for the USDA Natural Resource Conservation Service (NRCS) Soils Dataset

The seven soil values for this dataset range from very poorly drained to excessively drained.

Summary of Weighting Considerations for NRCS soils dataset

- Heavier weight if soil value is high (prime farmland)
- Heavier weight if vegetation health is of high priority in poorly drained soils
- Heavier weight if groundwater/drinking water protection is high in excessively drained soils

[1] Minnesota Stormwater Manual. Environmental impacts of road salt and other de-icing chemicals. November 2022. Accessed 16 December 2022 and available at https://stormwater.pca.state.mn.us/index.php/Environmental_impacts_of_road_salt_and_other_de-icing_chemicals.

Importance of NRCS Soils dataset

Road salt is known to have a negative impact on soil quality as well as vegetation. It can displace mineral nutrients and mobilize heavy metals present in the soil. This can impact plant health and increase soil density and compaction, thereby reducing infiltration and aeration.

Assigning a heavier weight to this dataset may be appropriate for conditions such as the following:

1) **Areas where road salt is likely to damage prime farmlands**: areas with large amount of soils and land use suitable for row crops or other vegetation that would be damaged by too much road salt (either because the land is immediately adjacent to the road, in the 'spray zone' or would receive a large amount of salt-laden waters due to concentrated runoff).
    a. Soil types in this category are typically non-urban soils that are loamy-textured, with relatively even contributions of sand, silt, and clay that can be easily cultivated.
    b. Soils are either currently used for row crops or have a high potential for being used for farming (i.e., not zoned for development).
    c. Maintaining soil health and fertility for prime farmlands and avoiding salt buildup may be a high priority for property owners and the public.
2) **Areas where road salt is likely to accumulate in poorly draining soils in agricultural or priority vegetated areas (landscaped or natural areas)**: areas where salt is unlikely to be effectively leached by freshwater, through rainfall/snowmelt or irrigation of affected soils, to remove sodium chloride from the soil profile. Leaching refers to the removal of soluble materials like salts by water passing through soil.
    a. Area may have tightly packed, clayey soils (poorly draining), in contrast to well drained or excessively drained soils. This may lead to accumulation of salts and harm to plants. Adequate drainage is key for allowing water to move through the soil and below the root zone, rather than just becoming runoff on the surface.
    b. This could be relevant for agricultural areas with poorly drained soils, or areas where healthy vegetation growth is a high priority, such as for boulevard/roadside trees or natural areas with rare and sensitive plants intolerant of high salt levels.
3) **Areas with well-draining soils where it is of concern that salt may enter groundwater or contaminate other water resources.**
    a. This could be of concern if the salt may quickly move through the soil profile and get into groundwater (and negatively impact drinking water).

Water Datasets

Metadata Considerations for Water dataset

The National Wetland Inventory (NWI) Dataset dataset contains wetlands, lakes, rivers, and streams and must be in a polygon geometry format. It is available through the U.S. Fish and Wildlife Service. New data is available on a biannual basis. Updates are reflected in their online Wetlands Mapper and in the data downloads in October and May of each year.

The National Hydrological Dataset (i.e., streams/rivers) (NHD) is considered to be the most up-to-date and comprehensive hydrography dataset for the United States. The data is updated and maintained through Stewardship partnerships with states and other collaborative bodies. Note that USGS is planning to transition to the 3D Hydrography Program (3DHP). This change will eventually affect updates to the NHD and may require revision to data acquisition.

Summary of Weighting Considerations for Water dataset

Assign a heavier weight for this dataset if there are concerns about:

- aquatic wildlife (threatened and endangered species),
- aquatic invasive plants,
- increased salinity on wildlife species,
- agricultural irrigation, or
- drinking water for humans.

Importance of Water Dataset

The NWI Dataset and National Hydrological Dataset (i.e., streams/rivers) (NHD) datasets may be of higher interest if there is sensitive wildlife known to be living in wetlands, streams, or rivers near roadways or if there are concerns about reduced native plant diversity and costs associated with managing non-native, invasive plant species. There could also be salt sensitive wildlife species that are important for recreational fishing. There may also be concerns if the surface waters are used as drinking water sources (typically larger rivers, lakes, or reservoirs).

1) **Aquatic wildlife concerns:** proximity or drainage to high-quality wetlands with many species of aquatic wildlife including fish, amphibians, and invertebrates.
    a. High concentrations of chloride can cause acute toxicity to wetland species and harm for some aquatic species even at lower levels. High salt levels can lead to reduced growth, survival, and reproductive capacity of many species dependent on surface waters.

b. Toxic metals in sediment may also be released due to increased salinity and the road salt itself may have impurities harmful to wildlife.

c. This may include concerns about the impact of increased salinity on rare species as well as more common species important for recreation like trout. The decline of lower trophic level organisms such as aquatic mayflies can also reduce food availability for game fish and other animals.

2) Aquatic invasive plant species concerns: proximity or drainage to wetlands vulnerable to invasion by invasive plant species

a. The influx of road salt into wetlands can lead to the increased success of salt-tolerant non-native and invasive species such as the common reed/Phragmites (*Phragmites australis*) and narrowleaf cattail (*Typha angustifolia*), particularly along roadsides.

b. The threat of invasive species may be prevalent in areas where there are modified/disturbed habitats with exposed soils and shallow water such as roadside ditches, man-made dikes, and abandoned hay roads.

c. The spread of invasive species like Phragmites may coincide with reduced biological diversity, reduced property values, increased fire hazards, and altered hydrology due to thick vegetation growth.[2]

1) **Proximity to surface waters used for irrigation for agricultural purposes.**

a. If surface waters become too salty, they may no longer be good sources of water for irrigation.

2) **Proximity to surface waters used for drinking water.**

a. Withdrawal of water from nearby rivers with high salinity levels can negatively impact the taste of water as well as lead to the mobilization of lead or other contaminants from old pipes used for conveyance. Keep in mind that there are many factors associated with elevated chloride concentrations in waterbodies, including river volume, type of highway drainage system, and natural drainage patterns.

Wellhead Protection Areas Dataset

Summary of Weighting Considerations for Wellhead Protection Area Dataset

If a local dataset is available, you may wish to consider wellhead protection areas within the tool. Assign a heavier weight for this dataset if there are concerns about:

- Drinking water contamination
- Close proximity or high connectivity to public drinking water sources

[2] Phragmites invasions harm riparian ecology: Part 2. Michigan State University. November 2015. Accessed 16 December 2022 and available at https://www.canr.msu.edu/news/phragmites_invasions_harm_riparian_ecology_part_2.

Importance of Wellhead Protection Areas Dataset

The wellhead protection areas dataset may be of higher interest if the application of road salt is near a public water supply well or private wells, where road salt may contaminate water supplies.

1) **Areas where wellheads are nearby and vulnerable to road salt pollution.** Areas where road salt is likely to flow into soils and aquifers when it's washed off road surfaces and make its way into well water supplies. Wells may be less vulnerable if they are deep drilled with long casing, are located far enough away from the roadway, or are placed in an area where the ground slopes away from the wellhead to prevent pooling of runoff.
2) **Areas where monitoring wells/testing has confirmed road salt contamination issues.** Testing of groundwater and water supplies can confirm whether there are high sodium or chloride levels. A seasonal spike in levels may help confirm whether road salts or another source such as a storage shed may be the source.

Critical Habitat

Summary of Weighting Considerations for US Fish and Wildlife Service (USFWS) Critical Habitat Dataset

Assign a heavier weight for this dataset if there are concerns when:

- Road salt application may negatively impact habitat for Threatened and Endangered species.

Importance of USFWS Critical Habitat Dataset

This dataset may be of high importance if there are concerns about the impact of road salt on critical habitat (geographic regions) for listed Threatened and Endangered species in the area. In some instances, it may be worth checking whether the habitat is for a particular species and conferring with a biologist to verify whether road salt is a likely stressor, either through direct or indirect impacts (i.e., impacts to aquatic prey). Freshwater mussels, particularly the early life stages, are likely to have a heightened sensitivity to salt.

Wild and Scenic Rivers

Summary of Weighting Considerations for USFWS Wild and Scenic Rivers Dataset

Assign a heavier weight for this dataset if there are concerns about:

- Aquatic plant and animal species in these habitats
- Natural, cultural and recreational values

Importance of USFWS Wild and Scenic Rivers Dataset

This dataset is likely to be of higher importance if there are concerns about impacts to nearby designated rivers and streams, and their natural, cultural and recreational values. As of 2019, the designation protects 13,413 miles of 226 rivers in 41 states and the Commonwealth of Puerto Rico. This represents less than one-half of one percent of the nation's rivers, so may apply in relatively few instances.

National Land Cover Dataset (NLCD)

Weighting Considerations for NLCD dataset

Assign a heavier weight or value for this dataset, or layers within the dataset, if there are concerns about:

- impacts of road salt on non-water land cover types (e.g., forest, herbaceous, developed, crops, or shrub/scrub)

Metadata and Considerations for the NLCD dataset

The NLCD dataset provides nationwide data on land cover and land cover change at a 30m resolution in raster format. It allows the user to understand current and historical land cover changes. The original dataset has 16 classes in its legend and is updated approximately every five years. For the purposes of this model, they have been combined into six. In addition, this dataset removes water as a type since it is already covered in the NHD/NWI datasets (higher resolution) and would essentially be double counting. Other datasets have higher accuracy, so this should be taken into account when making decisions on inclusion in the model or weighting. It is not required to run the model.

Importance of NLCD Dataset

This dataset may be of higher importance when there are concerns about impacts to particular land cover types. This may of particular interest when considering impacts to vegetation. Trees and other roadside vegetation are typically injured by salt either due to increased salt concentrations in the soil and water (resulting in absorption through roots) or by splash and spray (resulting in accumulation on foliage and branches). Impacts on vegetation may be of concern for several reasons: 1) more difficult establishment of vegetation for erosion control, 2) reduced native plant diversity and diminished aesthetics due to stress on roadside trees, and 3) increased prevalence of non-native invasive plant species that are more salt tolerant.

Within the dataset, there may be elevated concerns about the social, ecological, or economic impacts of road salt on different land types, which have been combined into the following groups:

- **Developed, Open Space/Developed, Low Intensity** – may be concerns about stressed looking vegetation in more manicured areas (e.g., lawn grass and street trees) by roads, sidewalks, and buildings that are used by pedestrians and businessowners. In developed areas, road salt may also make its way quickly via storm sewers to nearby waterbodies.
- **Hay/Pasture/Cultivated Crops** – may be concerns about reduced health and economic value of croplands if the vegetation is stressed by road salt.
- **Deciduous Forest/Evergreen Forest/Mixed Forest** – may be concerns about tree die off or stress if the trees are harvested for timber or are important as a component of natural areas/parks
- **Herbaceous** – may be concerns about whether salt-tolerant invasive species may become more dominant over time
- **Barren Land** – unlikely concerns about impact of road salt
- **Shrub/Scrub** – may be similar concerns to herbaceous land

Section 5 – Conclusion

Assigning locally tailored weights can help further refine the GIS tool's ability to highlight sensitivity of highway segments to deicing. It can help better account for priority concerns varying from drinking water contamination to vegetation die off. This tool helps better understand locations where there is sensitivity and the degree of sensitivity (low, medium, or high) in order to help develop appropriate mitigation strategies. As priorities and concerns may change, the tool can be rerun for better customization.