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MS4 Survey of Best Practices for Winter Maintenance Implemented in Maryland

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Abstract

Sodium chloride is a growing pollutant of concern in waterbodies throughout the United States. As chloride continues to impair waterbodies, regulations to reduce the use of sodium chloride for road deicing will increase. The Center for Watershed Protection, Inc. (the Center) conducted a literature review and survey on best practices for winter maintenance to determine the most prevalent salt-reduction strategies and the amount of implementation in Maryland Municipal Separate Storm Sewer (MS4) communities. The literature review included a compilation of the latest information on salt-reduction practices around the country, and the Center used the findings from the literature review to develop the survey. With response rate of 37%, the survey results were able to capture a sample of best management practice implementation in Maryland's Phase I and Phase II communities. Some of the common concerns with salt-reduction practices are cost, manpower, education, and training. There is also a disconnect between the stormwater managers and the winter maintenance team, indicating a need for improved management and, potentially, implementation of automated data collection systems. This study highlights the tremendous opportunity for salt reduction in Maryland MS4 communities that can improve water quality without sacrificing public safety. Although contractor and private applicators are a large contributor to salt use, the scope of the survey was limited to understanding the baseline winter maintenance practices used in MS4 communities to understand where improvements can be made at the jurisdictional level.

Introduction

There are more than 500 impaired waterbodies in the United States with a total maximum daily load (TMDL) for chloride[1]. As of 2018, the Maryland Department of the Environment (MDE) has listed 28 waterbodies with a chloride impairment, and chloride regulations are expected[2]. There is an overall trend in increasing concentrations of salts in waterbodies throughout the United States (Kaushal et al. 2018). Concern is also documented in Corsi et al. (2015) that the increase in the rate of chloride concentrations was greater than the increase in urban land cover from 1990 to 2011, implying that more salt is being applied per acre of impervious cover than before.

Excessive salt in the environment is a hazard to both human and ecological health. Excessive chloride can negatively impact water, soils, vegetation, and aquatic organisms. Additionally, salt-contaminated water can damage infrastructure with its corrosive properties and impair drinking water sources, incurring additional costs and endangering public health. Although salt is a naturally occurring substance and widely used in everyday life (e.g., as a component in fertilizer and concrete, as a water softener), its use in urban areas for winter road maintenance is a major source of increasing concentrations of chloride and sodium in both surface and groundwater (e.g., Kelly et al. 2008; Moore et al. 2017; Bird et al. 2018; Overbo 2019). Due to the high solubility of chloride and the lack of natural mechanisms to remove it from waterways, it is assumed that reducing the use of road salts is the best way to reduce its impacts on human and aquatic life.

Study Background

This project, funded through the Chesapeake Bay Trust Pooled Monitoring Initiative's Restoration Research Grant Program,[3] included a literature review and a survey to document the existing knowledge and understanding of snow and ice removal best practices by winter maintenance providers. During the literature review process, more than 55 different resources pertaining to road salt winter maintenance were reviewed. The winter maintenance industry has an extensive inventory of well-documented best practices for minimizing costs and maximizing service. Practices in the literature review were categorized into four sections: winter preparation and before, during, and after the storm, as shown in Figure 1. A glossary is provided to define the specific terminology used in this study.

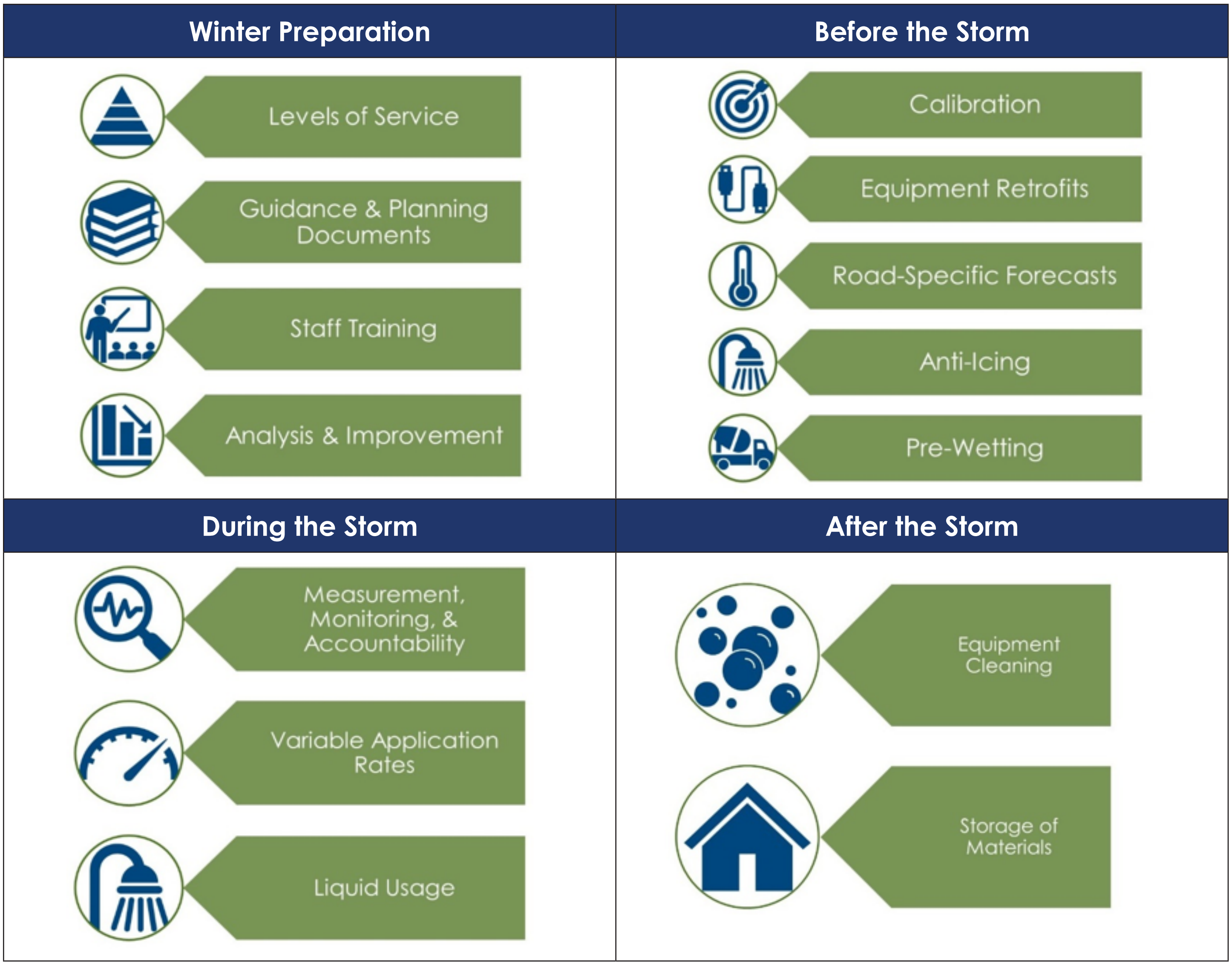


Figure 1. Overview of winter maintenance best practices organized chronologically.

While the above best practices have significant value, a fundamental switch from reactive deicing to proactive anti-icing is arguably one of the most realized cost-saving and environmental benefits (Mahoney et al. 2015). The ideal situation would be for winter maintenance providers to adopt all of these best practices, but practically, it is important to prioritize them to optimize resources.

To assist a community to begin to identify best practices, The Salt Institute (Nixon, n.d.) organizes 11 recommended winter maintenance best practices into a framework called the fundamental five and supplemental six. The fundamental five—calibration, output measurement, accountability, designated levels of service, and training—are essential practices that do not require any substantial upfront capital investment. In general, these practices require an investment in time and the

Glossary

Abrasive: Sand or another solid material placed on a slippery surface to temporarily improve traction for walking and/or driving. Abrasives alone do not melt snow and ice.

Anti-icing: The application of a deicer chemical (liquid or solid) to a surface (e.g., road, sidewalk, parking lot) before a storm starts to prevent ice from forming and bonding to the surface or to enhance plowing efforts. This is often referred to as "pre-treating" a site, but pre-treating has a separate, more specific definition (see below).

Deicing: The application of a deicer chemical (typically either a solid or pre-wet solid) to an existing accumulation of ice or snow to melt it and weaken its bond to the surface.

Direct Liquid Application: A designated snow route that uses only a salt brine solution to prevent the snow and ice from bonding to the pavement for the duration of an event.

Level of Service (LOS): A description of the expected road surface condition from the snow and ice maintenance activities. For example, "Provide snow and ice maintenance service to achieve bare pavement conditions" or "Clearing the pavement bare of ice and snow over its entire width will be accomplished as soon as reasonably possible after the winter storm event."

Pre-treating: The application of a liquid deicer to a solid deicer (like rock salt) to enhance deicer performance. This is different from anti-icing.

Pre-wetting: Coating solid materials with liquid directly prior to application to increase effectiveness. It can be achieved in three main ways: (1) liquid application at the spinner as material leaves the spreader, (2) liquid application to each load prior to placing it in the spreader, and (3) liquid application to the entire load of salt in the spreader.

willingness to change. The supplemental six includes variable application rates, road-specific forecasts, cold-temperature-specific practices, liquid material usage, pre-wetting, and anti-icing. These practices require some level of capital or financial investment; however, they typically pay for themselves in one to three winter seasons (Nixon, n.d.). The supplemental six practices are ancillary to the fundamental five and should be progressively adopted over time.

A common concern with salt usage is related to managing the salt application techniques utilized by operators from all affiliations, including jurisdictional employees, contractors, and private applicators. From the literature review, a method that other jurisdictions are using to reduce salt usage, including contractors and private applicators, is through a certification program. The certification would include requiring contractors to attend training and implement salt-reduction strategies, but also include "liability protection against damages arising from snow and ice conditions."[4] This creates an incentive for the contractors to reduce their salt usage because liability is a major factor in the overuse of salt. These certifications are typically done at a state level; therefore, they were not included in this study of implementable practices for MS4 communities. A variety of salt applicator certification programs exist; one prominent program, the Green SnowPro Program, is offered by the University of New Hampshire.[5] Although the Green SnowPro Program is only authorized to issue certificates to commercial applicators and not municipal employees, municipalities are encouraged to enroll their staff in the program voluntarily to implement salt-reducing snow and ice management techniques. Successful completion of the Green SnowPro Program is a pre-requisite for the New Hampshire Department of Environmental Services' Salt Applicator Certification. Staff from the University of Connecticut attended and implemented the Green SnowPro Program, and in the two years following implementation, they achieved nearly 3,500 metric tons of salt reduction, which equated to more than $450,000 in cost savings and measurable water quality impacts (Dietz 2020).

Survey Development

A survey for Maryland MS4 communities was developed using insights from the literature review. The purpose of this survey was to identify: (1) the extent to which best practices for winter road maintenance are currently being implemented by public agencies and the private industry and (2) the potential to reduce chloride inputs to local waters through the adoption of best practices. The survey aimed to assess the current state of winter maintenance operations in Maryland municipalities to develop a baseline for improvement. The survey included questions about respondents' use of the various best practices identified in the literature review. Stakeholder reviews and a pilot survey were used to ensure that the goals of the survey were being met. The survey was distributed to every MS4 jurisdiction within the state of Maryland, which includes 11 Phase I—including the Maryland Department of Transportation's State Highway Administration (MDOT SHA)—and 35 Phase II communities. Some information was redacted at the request of the respondents, and some of the information may only be estimates. The study acknowledges that contractors and private applicators can contribute up to half of the salt use in a state.[6] The original study included a survey to contractors, but because of the receipt of minimal responses, no data analysis was conducted. As a result of the poor response rate, limited resources, and salt-reduction requirements that will be included in MS4 permits, the study shifted solely to MS4 communities. States that have successfully implemented salt-reduction strategies for contractors and private applicators have typically done so at a state level, not at a local level.

Overview of Survey Results

This overview highlights some of the key findings in the survey and provides insights on related best practices, when applicable. In total, 24 responses were submitted; 17 were fully completed, and 7 were partially completed (Figure 2).

Table 1 is the summary of the size of jurisdictions' service area, split into roads, sidewalks, and parking lots or other areas. The cells in green indicate that the MS4 communities treat for snow and ice in those areas but did not provide the size. For sidewalks, different units were reported, as noted. As a result of the different units, unclear information, and missing information, these data could not be used to determine salt usage per unit area.

Maintenance Plans and Guidance Documents

Proper documentation of best practice and application guidelines, including adherence to those guidelines, are essential for effective winter maintenance. Respondents were asked to characterize the management plans, maintenance plans, and/or guidance documents utilized by their organization for winter maintenance operations. The majority (76%) of communities have some type of plan that provides direction on their winter maintenance operations. Of those with guidance documents, 50% are updated annually and 30% are updated less than annually. One respondent indicated that their organization's guidance documents have not been updated in 20 years.

Respondents provided a narrative response about factors that have limited or have the potential to limit their organization from achieving its level of service (LOS) requirements (Table 2). Weather was the major factor affecting both Phase I and Phase II, but Phase II communities more commonly noted resource-related limitations.

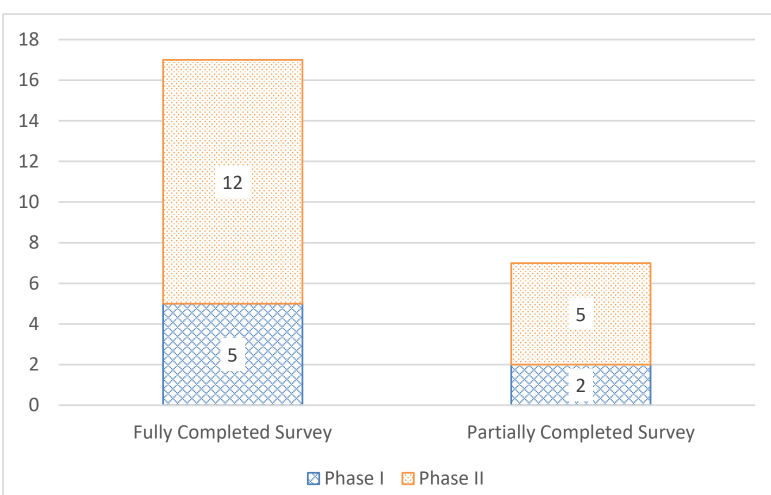


Figure 2. Survey responses by MS4 phase.

Table 1. Size of MS4 service area for winter maintenance.

	Jurisdiction	Roads (Lane Miles)	Sidewalk (Linear Foot)	Parking Lots/ Other Areas (acres)
Phase I	MDOT State Highway Administration	17,132	N/A	100
	19 (redacted)	6,722	N/A	N/A
	Prince George's County	5,500	N/A	N/A
	Montgomery County	5,200	316,800	N/A
	Anne Arundel County	4,300	N/A	N/A
	4 (redacted)	4,300*	N/A	
	Howard County	2,400	174 facilities	
Phase II	St. Mary's County	1,272		
	Wicomico County	700	N/A	N/A
	City of Frederick	451	95,000	92
	City of Gaithersburg	228	5680 sq. feet	
	15 (redacted)	120	3,000	6
	11 (redacted)	73	3,168	4
	City of Takoma Park	34	5,000	2 parking lots
	Town of Smithsburg	30	3 acres	
	Town of La Plata	29	8,500	2
	Town of Thurmont	25	600	1
	Town of Boonsboro	20	7,200	
	Town of Indian Head	14	9,240	
	Town of North East	7	1,000	

**The original number from the survey (22,000 lane miles) appeared to be incorrect. Because the respondent did not respond to the follow-up communication, the information was verified with a report from the jurisdiction and revised to 4,300 lane miles, as noted in the report.*

Table 2. Responses to the question: "Please provide a brief summary of the major factors that may limit (or have limited) your organization from achieving its Level(s) of Service."

Phase I	Phase II
• Major snowfall, blizzard conditions, or white outs • Extended periods of extreme cold (below 19°F) • Hard-packed snow or ice • Timing of the day (rush hour) traffic volume holding back operations • Salt availability • Resource limitations	• Length of storm • Speed and extent of storm • Difficult weather (freezing rain or ice) • Unpredicted rain preceding that removes pre-treatments • Personnel/manpower • Equipment failure • Equipment availability and accessibility • Salt availability • Funding • Conflict with residents

Products, Materials, and Equipment

Respondents were asked a series of questions that aimed to identify the types of products/materials and types of equipment used by their organization for winter maintenance. Most respondents indicated that sodium chloride (NaCl) is the most commonly used material. Solid calcium chloride ($CaCl_{2)}$ and magnesium chloride ($MgCl_2$) are only used by 35% and 47% of respondents, respectively. More than half of the respondents indicated that they do not use liquid materials. For those that use liquid materials, 88% most commonly use NaCl. One respondent indicated that liquid $MgCl_2$ and NaCl are mixed in storage and are not able to be separated. Using liquid materials for anti-icing is one of the most common and effective methods to reduce salt usage, as identified in the literature review.

Approximately 40% of respondents have *equipment* necessary to make brine or other liquid mixtures on site and under the operations of their organization. Of those respondents, 80% have brine-manufacturing *facilities* on site. Having a brine facility on site can optimize the efficiency of facility operations. Eight out of 18 jurisdictions use direct liquid application (DLA) for anti-icing, and of those eight, two also use it during active storm events (Figure 3). Of the eight respondents that use DLA, five own their own equipment to make brine, and three use a third-party manufacturer.[7] A best practice for DLA is to minimize use during an active storm event, as liquid precipitation can wash the applied liquid from the road surface.

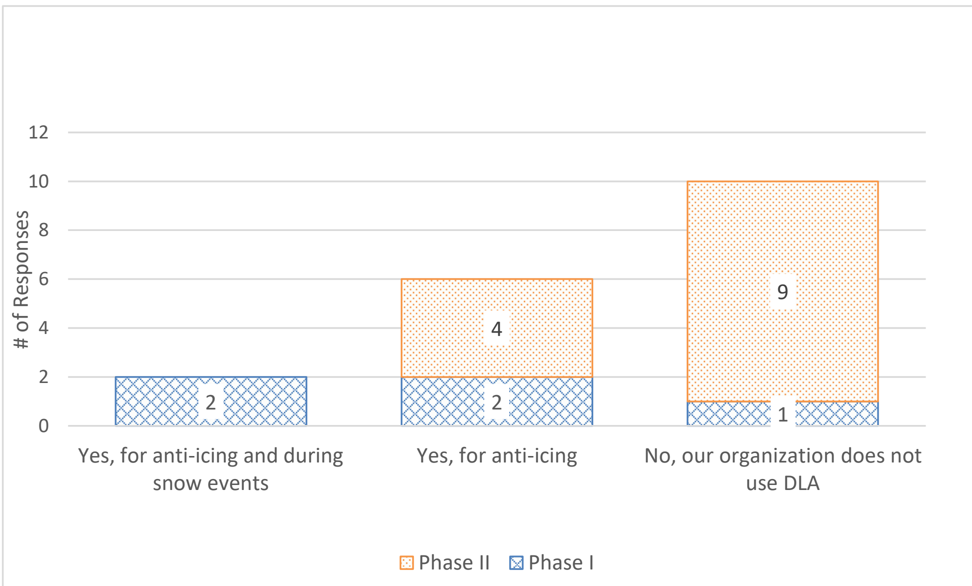
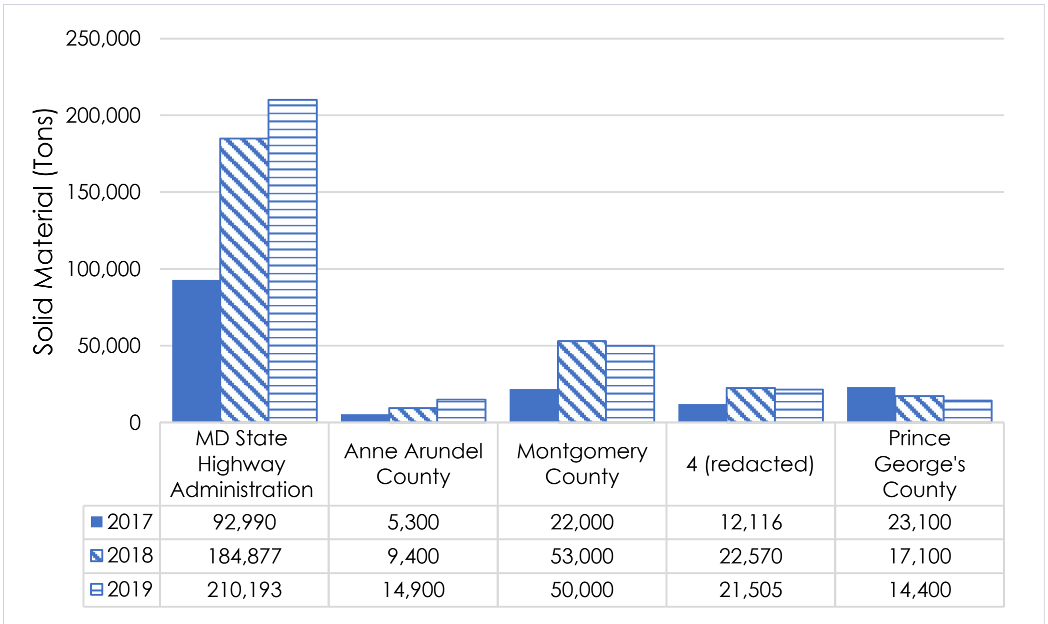


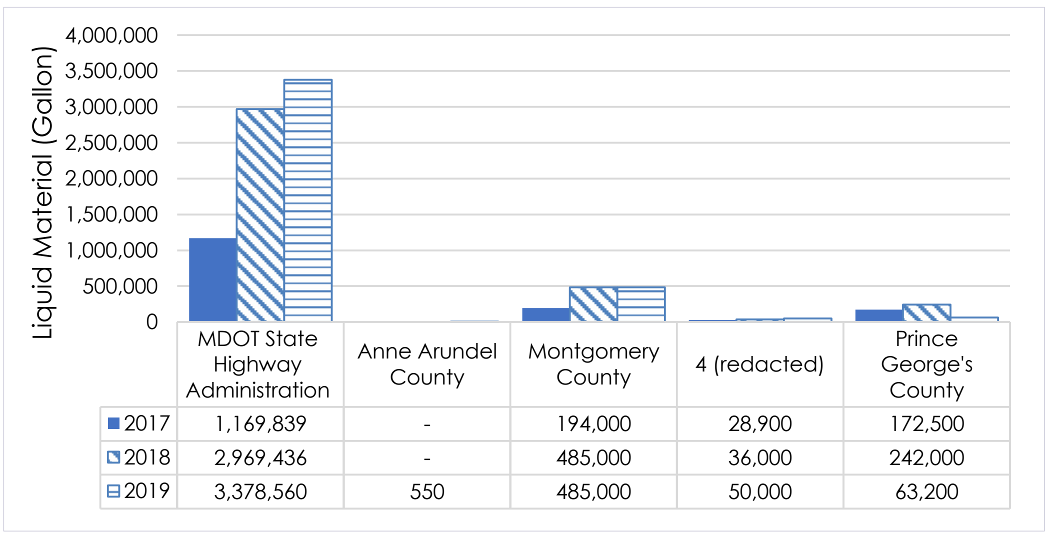
Figure 3. Usage of direct liquid application (DLA) in winter maintenance operations.

Respondents were asked how much solid and liquid material was used in 2017, 2018, and 2019. This includes the total of all types of solid and all types of liquid material. The results are shown below, separated by Phase I (Figure 4 and Figure 5) and Phase II (Figure 6 and Figure 7) jurisdictions. Note the scale difference between the Phase I and Phase II charts. It is important to note that annual increases in materials used does not necessarily represent poor winter maintenance practices. Various factors—such as availability, weather, snow type, precipitation amount, and temperature—all affect salt usage.



	MD State Highway Administration	Anne Arundel County	Montgomery County	4 (redacted)	Prince George's County
2017	92,990	5,300	22,000	12,116	23,100
2018	184,877	9,400	53,000	22,570	17,100
2019	210,193	14,900	50,000	21,505	14,400

Figure 4. Annual solid material used for winter maintenance operations by Phase I jurisdictions.



	MDOT State Highway Administration	Anne Arundel County	Montgomery County	4 (redacted)	Prince George's County
2017	1,169,839	-	194,000	28,900	172,500
2018	2,969,436	-	485,000	36,000	242,000
2019	3,378,560	550	485,000	50,000	63,200

Figure 5. Annual liquid material used for winter maintenance operations by Phase I jurisdictions.

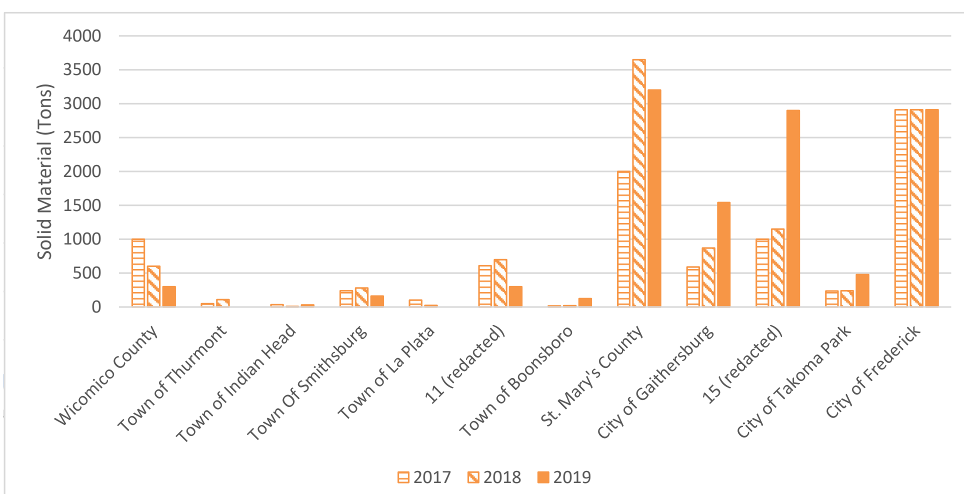


Figure 6. Annual solid material used for winter maintenance operations by Phase II jurisdictions.

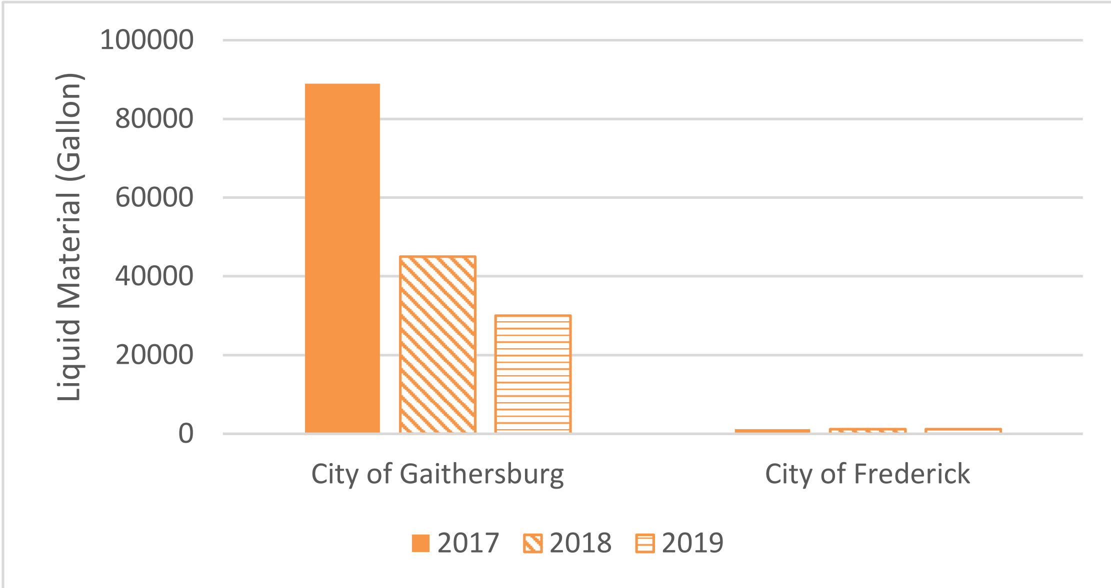


Figure 7. Annual liquid material used for winter maintenance operations by Phase II jurisdictions.

When asked if their fleet's vehicles have the capability to apply liquid materials, most respondents (41.7%) indicated that their vehicles are not capable and therefore do not use liquid materials. Four out of five Phase I communities indicated that their vehicles are capable of applying liquids, and the remaining Phase I communities indicated that while their organization's vehicles are not capable, they have access to vehicles for liquid application through contractors (Figure 8). Two Phase II respondents indicated that they have vehicles with liquid application capability, and one indicated that only one of their vehicles can apply liquid materials.

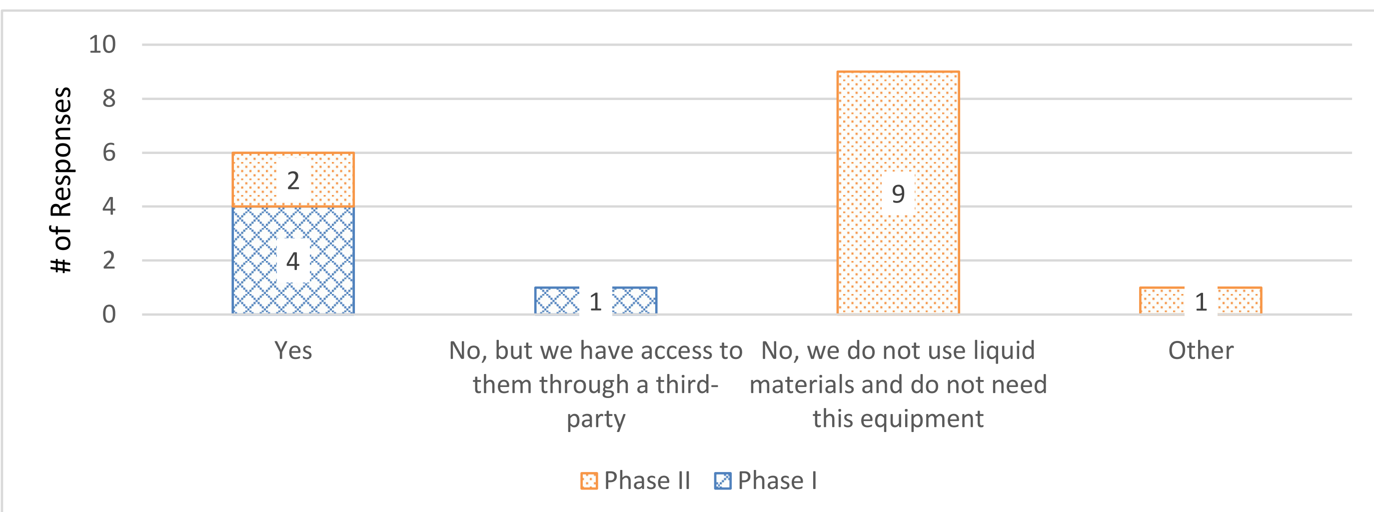


Figure 8. Vehicles with liquid application capabilities.

Figure 9 presents which equipment retrofits and technology advancements have been adopted by the jurisdictions. The most common retrofit that has been adopted are application regulators and automated vehicle location (AVL) technology. All of these technologies can help use salt more efficiently.

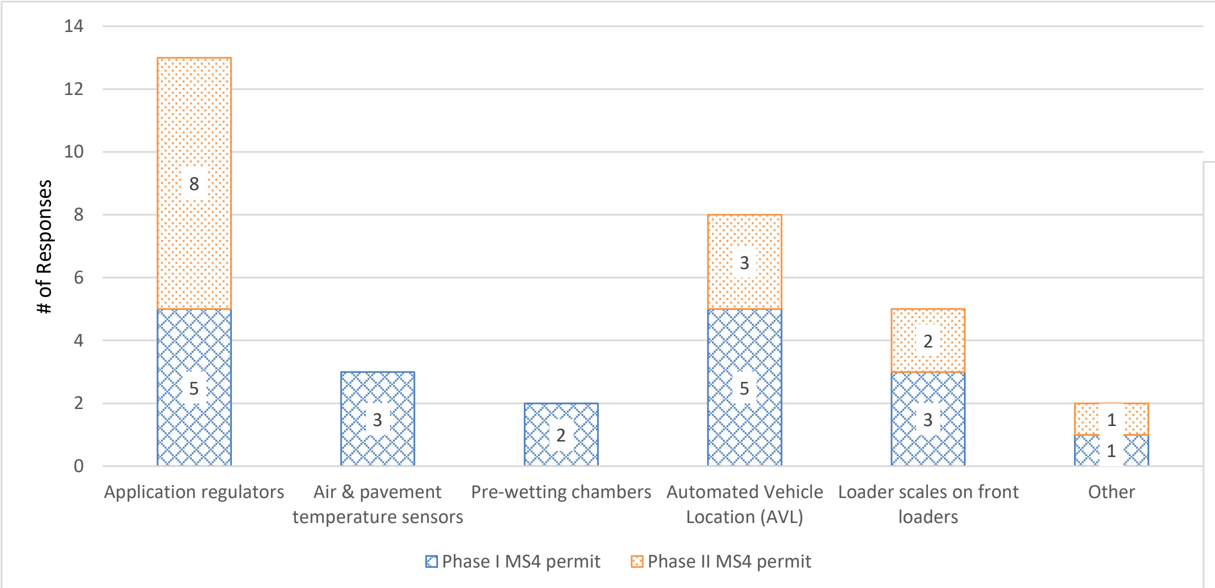


Figure 9. Number of jurisdictions with retrofits/advancements to the vehicles in their winter maintenance fleet.

The respondents were asked about the quantity of retrofitted vehicles in their fleet. All Phase I vehicles have AVL and application regulators/spreader controls. Phase II communities have a lower percentage of retrofitted vehicles, and none have air and pavement temperature sensors nor pre-wetting chambers.

Strategies & Methods

To understand the approaches to winter maintenance, respondents were asked to address core aspects of their specific strategies and methods, such as those related to calibration, tracking and accountability, training, application rate determination, and anti-icing. Table 3 shows the responses for the question, "How often does your organization calibrate its spreaders?" More than 50% calibrated all of their equipment at least annually. Calibration is one of the most important, cost-effective methods to ensure effective salt application.

Table 3. Response to the question: "How often does your organization calibrate its spreaders?"

Response	# of Responses
Calibration is checked before every event	1
All equipment calibrated yearly, if something looks wrong, or new equipment	2
All equipment calibrated yearly	6
Most equipment calibrated yearly	4
Only new equipment calibrated	1
Do not know	1

Equipment should also be recalibrated when material or product is changed in the equipment. Figure 10 shows that only 3 out of the 15 jurisdictions that change material recalibrate their equipment.

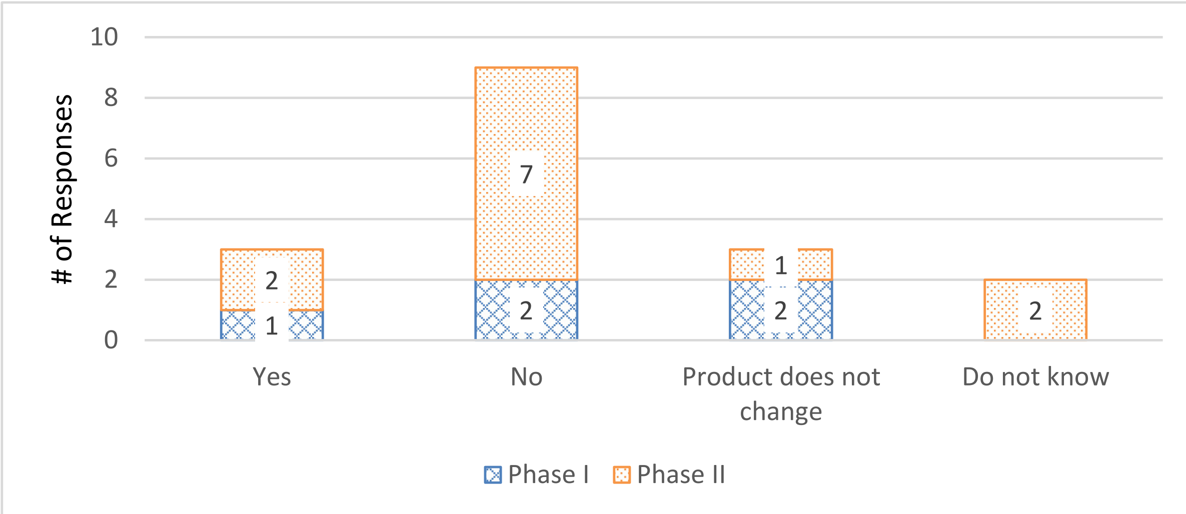


Figure 10. Equipment recalibrated after product change.

More than 50% of communities track their product/material usage on a per-storm-event basis, and more than 35% track it annually. Only one respondent indicated that their organization does not track product/material usage whatsoever. Figure 11 shows that 53% of jurisdictions only apply solid products or materials to targeted portion(s) of the roads that they are treating, as opposed to the entire road surface. Examples of these targeted portions are the centerline or crown of the road. Two Phase II respondents indicated that the portion of road treated was conditional on other variables, such as traffic volume and storm intensity. Treating only the necessary surface reduces the amount of salt applied.

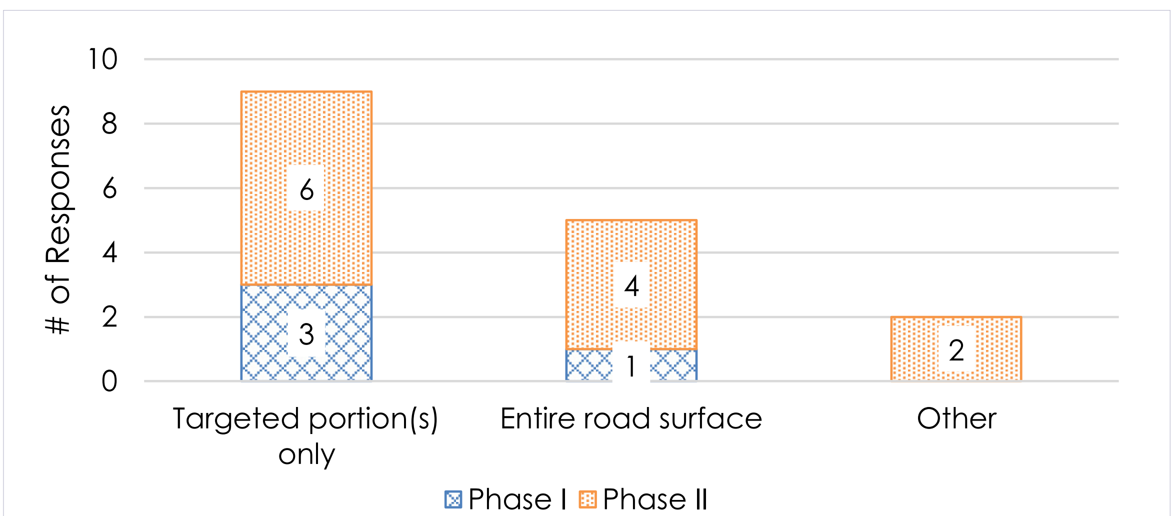


Figure 11. Placement of solid products/materials during the treatment of roads for winter maintenance.

Winter maintenance activities should also consider the limited effectiveness of many products/materials on cold and extremely cold pavements (classified as < 15°F and < 0°F, respectively). Sodium chloride significantly decreases in efficiency below 15°F. Table 4 illustrates the frequency of respondent organizations' application of dry granular salt when pavement temperatures are cold (< 15°F). Only one respondent (a Phase I jurisdiction) indicated that they frequently apply solid products/materials in cold pavement conditions. One jurisdiction indicated that they use a solid product/material and abrasive sand mixture in cold pavement conditions.

Table 4. Responses to the question: "When pavement temperatures are below 15°F, how often does your organization use dry granular salt?"

Response	# of Responses
Rarely or never	5
Sometimes	7
Frequently	1
Unknown	3
Other	1

Table 5 categorizes the application of solid products/materials in extremely cold (< 0°F) pavement condition winter maintenance operations. Only three respondents use products/materials that are more effective than NaCL in extremely cold pavement conditions.

Table 5. Responses to the question: "When pavement temperatures are extremely cold (below 0°F), how does your organization proceed?"

Response	# of Responses
We do not apply any solid or liquid materials	3
We apply abrasives only	2
We use products that work better in cold temperatures than salt or brine	3
We use whatever products we have	8
Other: Apply mixed loads	1

Anti-icing can be a very effective practice for minimizing chloride-contaminated runoff following winter maintenance operations. Respondents were asked to characterize which types of areas they treat using anti-icing (Table 6).

Table 6. Responses to the question: "In which types of areas does your organization perform anti-icing?"

Response	# of Responses
Almost all areas that are salted	3
Most areas that are salted	1
Some areas that are salted	5
None of the areas that are salted	8
Other: Only on emergency roads	1

Salt Storage and Facilities

Proper storage of both solid and liquid products/materials for winter maintenance is essential for minimizing chloride-contaminated runoff from storage facilities. Respondents were asked what their operators or crew do with leftover product or material at the end of a shift. All but one Phase II jurisdiction indicated that leftovers are brought back to the storage facility; the remaining Phase II jurisdiction indicated that they use up remaining product before returning to the storage facility. All of the Phase I communities have their own salt storage facilities, whereas 9 out of 12 Phase II communities do (Figure 12). One respondent that answered "No" noted that they have a long-term lease of an MDOT SHA Salt Dome.

Respondents were asked to describe the flow and management of runoff from storage facilities. Approximately 50% have some type of system that minimizes runoff from entering surface water or groundwater (Table 7).

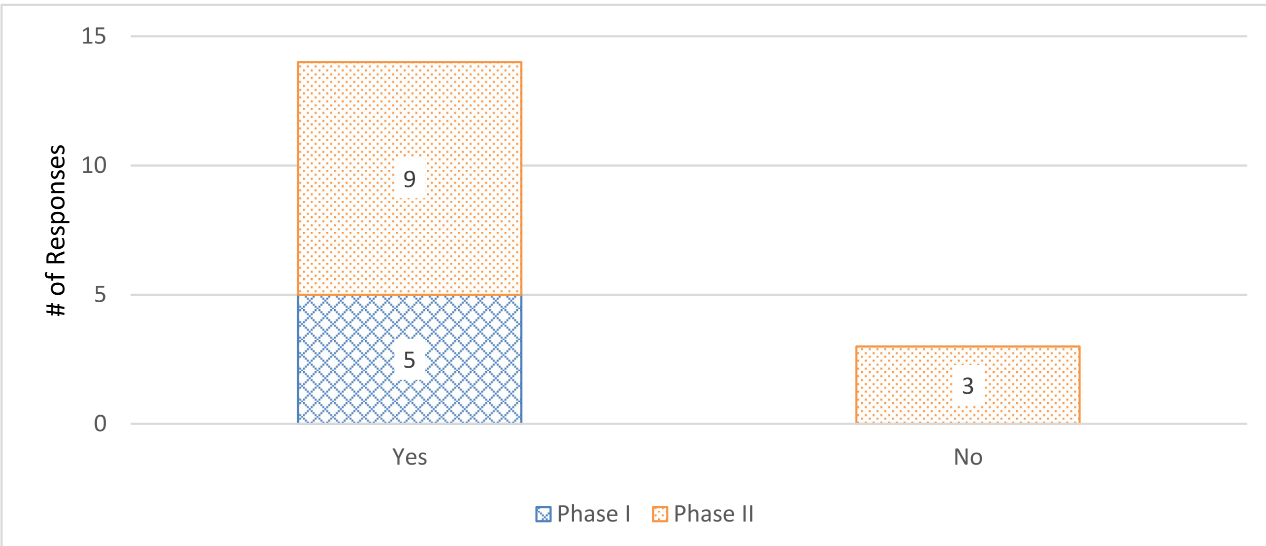


Figure 12. Number of jurisdictions that own and manage at least one salt storage facility.

Table 7. Responses to the question: "Where does the majority of the runoff from your storage facility go?"

Response	# of Responses
Runoff is collected and reused in a brine system	1
Runoff enters a treatment facility	1
Runoff flows into a pond with no connections to any other surface or groundwater systems	5
There is minimal runoff from the site	2
Runoff is permitted to flow into a pond with connections to another surface or groundwater system	3
Runoff is permitted to flow onto the surrounding landscape	3
There is no storage facility	1
Unknown	1

Budget and Contracts

Respondents were asked to characterize the frequency that third-party contractors are typically hired by their organization for winter maintenance operations. Nearly 30% of respondents hire contractors for every storm event, 41% sometimes hire contractors, and 29% never hire contractors (Figure 13).

Respondents were asked whether the contractors that they hire use the same management/maintenance plan(s) and guidance document(s) as internal operators. All jurisdictions that hire contractors responded yes, except one who did not know.

Discussion of Results

The survey allowed for an initial understanding of the best practices for winter maintenance that Maryland MS4 communities currently implement. The implementation of this survey also allowed for an understanding of the process the municipalities took to obtain the information. Although many MS4 contacts were willing to participate in the survey, obtaining the information proved difficult. Because winter maintenance is typically performed by a different department, winter maintenance staff did not have incentive to provide the information in a timely manner. Some of the information has not been documented in one consolidated location, or it was not documented at all, making it time-consuming or infeasible to complete. The MS4 department may want to start gathering information and building relationships with the winter maintenance team to allow for better data collection and access, as pending regulations will likely require them. Automated data collection will help alleviate some of the logistical burden of tracking the necessary data.

The best practices surveyed were compiled from the most common practices found in the literature review. This list is not exhaustive; it contains the most common, effective, and useful practices. Figures 14 through 31 show a compiled list of the best practices surveyed, with the respective percentage of Phase I and II jurisdictions that are:

- Fully implementing the practice
- Partially implementing the practice
- Not implementing the practice
- Unknown if they are implementing the practice
- Not applicable to the jurisdiction

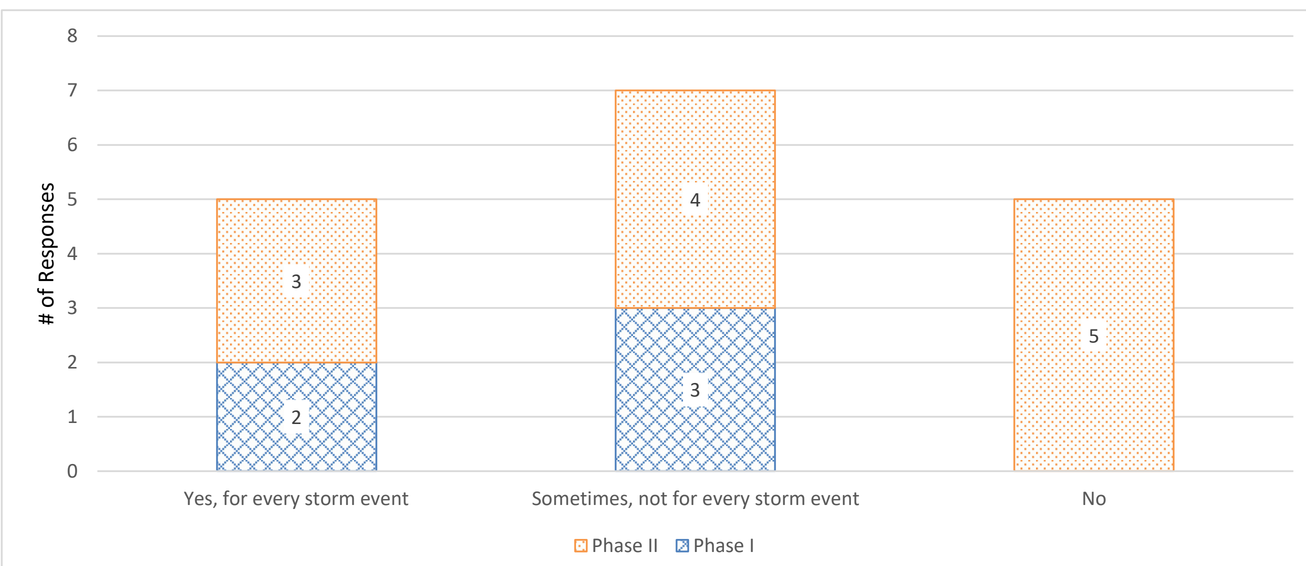


Figure 13. Frequency of third-party contractor hiring for winter maintenance operations.

Figures 14 through 31 are organized by type of best practice, including:

- Administrative Documentation
- Staff Training
- Equipment Retrofits
- Calibration
- Tracking
- Variable Application Rates
- Liquid Usage
- Storage of Materials
- Other Techniques

It is important to note that if the practice is not currently applicable to the jurisdiction, it is labeled as "Not Applicable." For example, a jurisdiction that does not use different products in equipment would not implement the practice to recalibrate equipment after products are changed. Unclear or no responses from jurisdictions are categorized as "Unknown."

To reduce the amount of salt used for winter maintenance, the goal would be to move the "Implementing" bar toward 100%, when applicable. There likely is some response bias in terms of jurisdictions who responded to the survey. Municipalities that are already advanced in salt management have easier access to the information collected, as tracking usage is a management practice in and of itself. The actual management practices implemented across all jurisdictions may be lower than what was found in the survey.

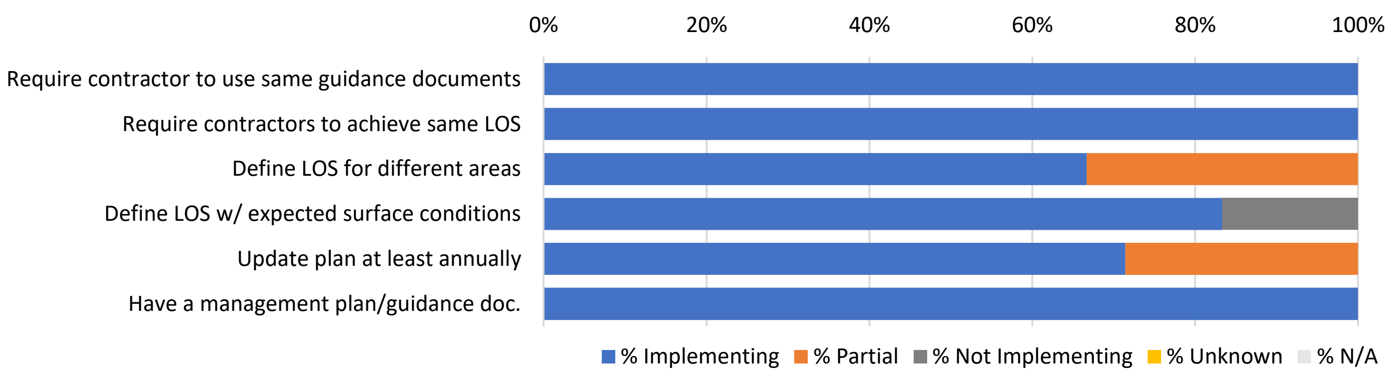


Figure 14. Percentage of Phase I Communities implementing best practices for winter maintenance operations: administrative documentation.

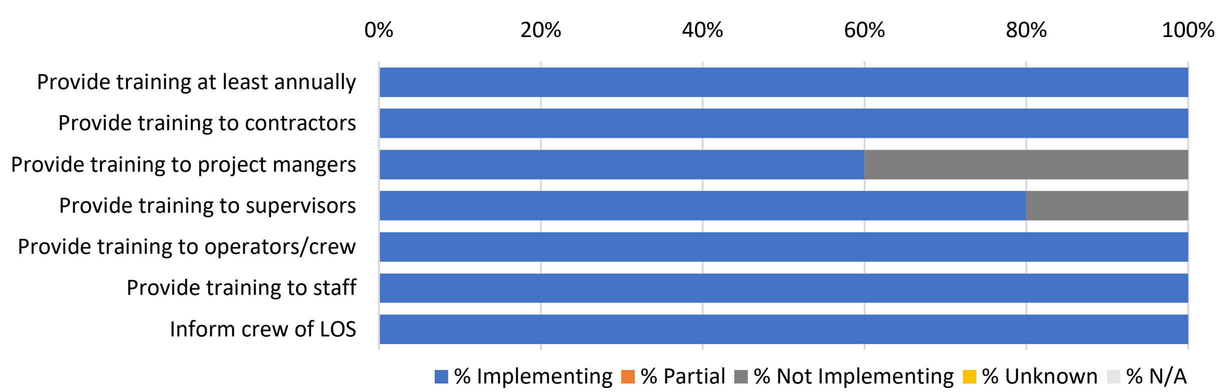


Figure 15. Percentage of Phase I communities implementing best practices for winter maintenance operations: staff training.

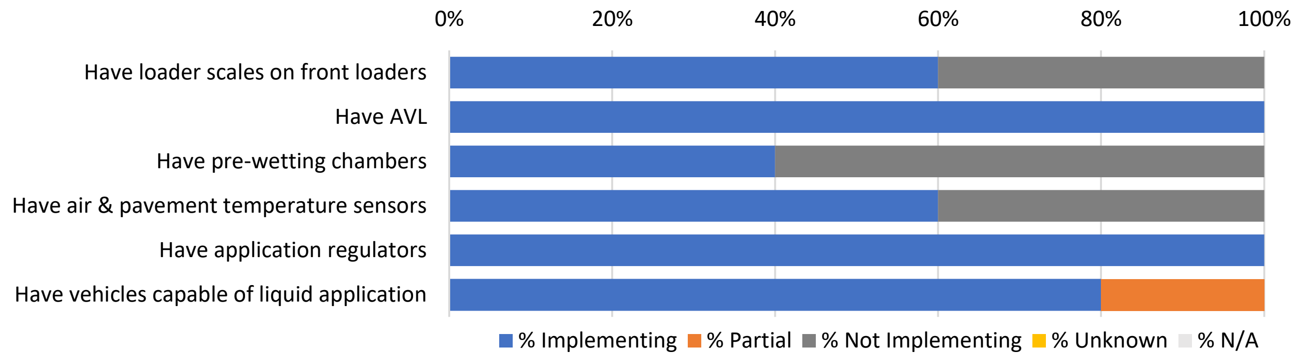


Figure 16. Percentage of Phase I communities implementing best practices for winter maintenance operations: equipment retrofits.

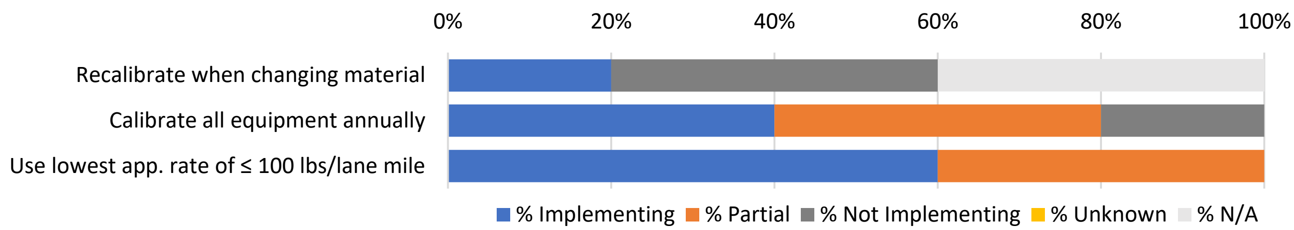


Figure 17. Percentage of Phase I communities implementing best practices for winter maintenance operations: calibration.

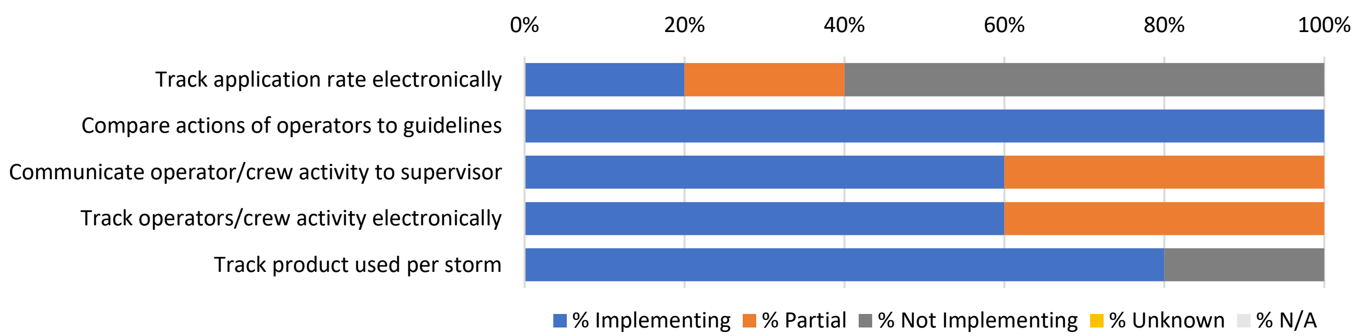


Figure 18. Percentage of Phase I communities implementing best practices for winter maintenance operations: tracking.

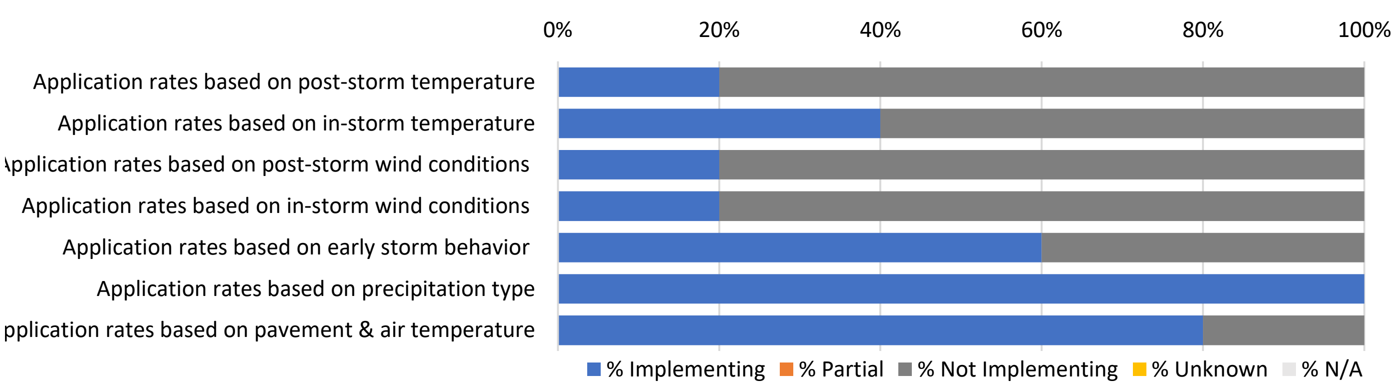


Figure 19. Percentage of Phase I communities implementing best practices for winter maintenance operations: application rates.

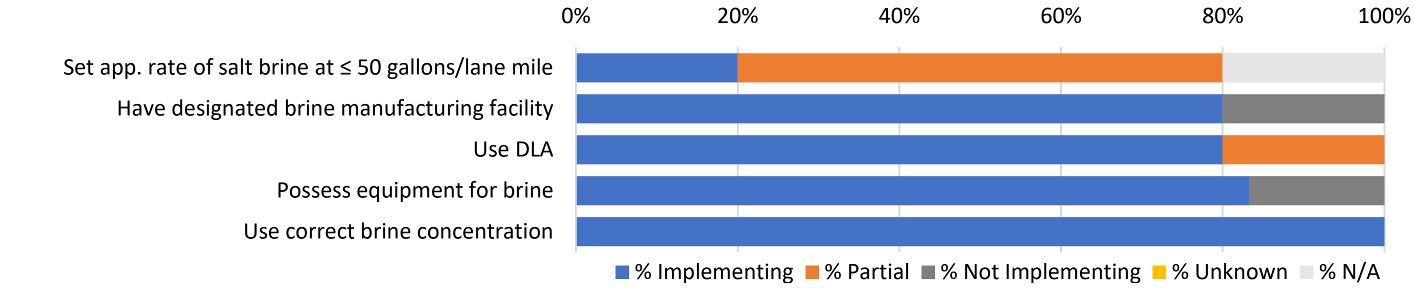


Figure 20. Percentage of Phase I communities implementing best practices for winter maintenance operations: liquid usage.

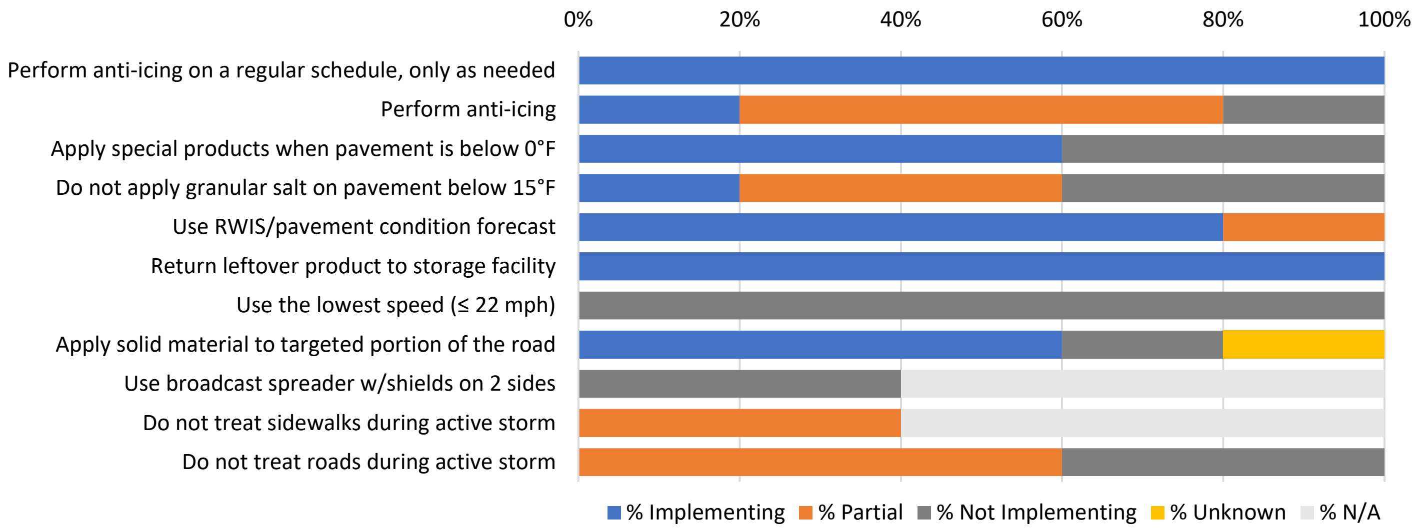


Figure 21. Percentage of Phase I communities implementing best practices for winter maintenance operations: other during-storm techniques.

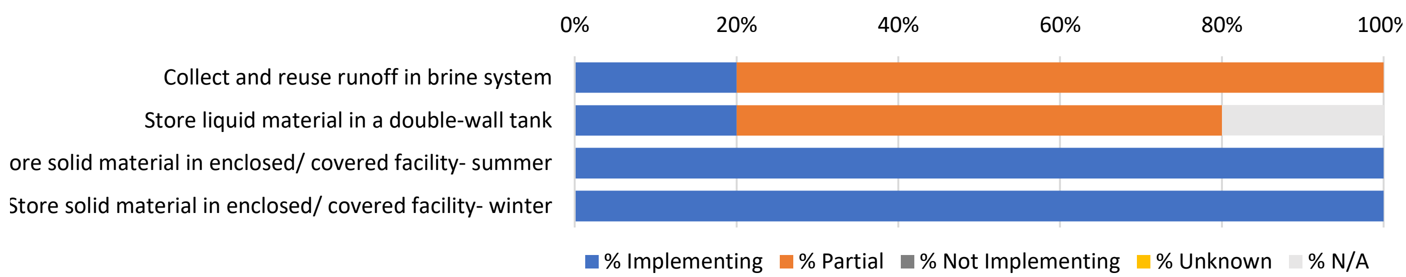


Figure 22. Percentage of Phase I communities implementing best practices for winter maintenance operations: storage of materials.

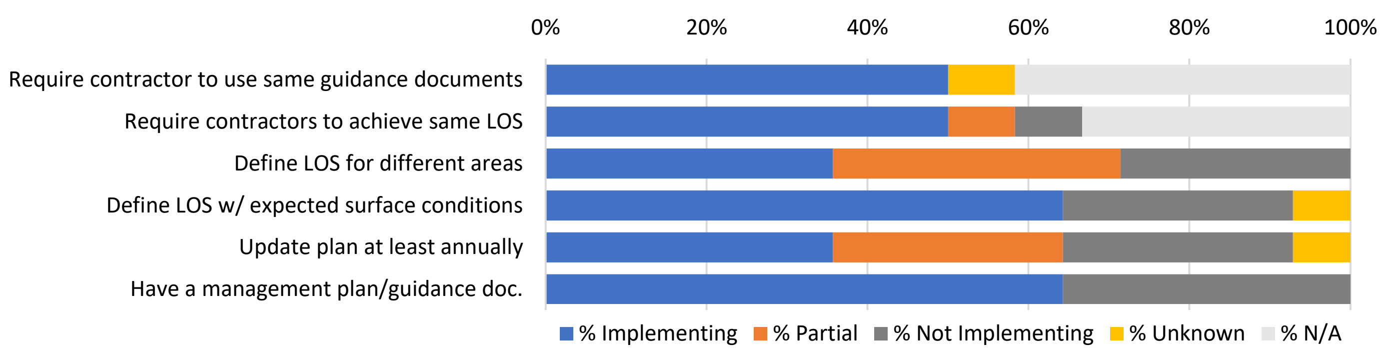


Figure 23. Percentage of Phase II communities implementing best practices for winter maintenance operations: administrative documentation.

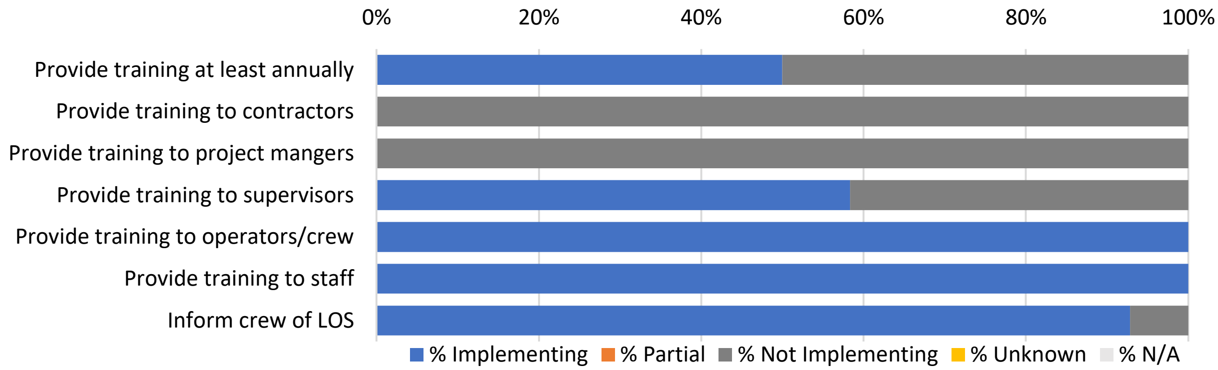


Figure 24. Percentage of Phase II communities implementing best practices for winter maintenance operations: training.

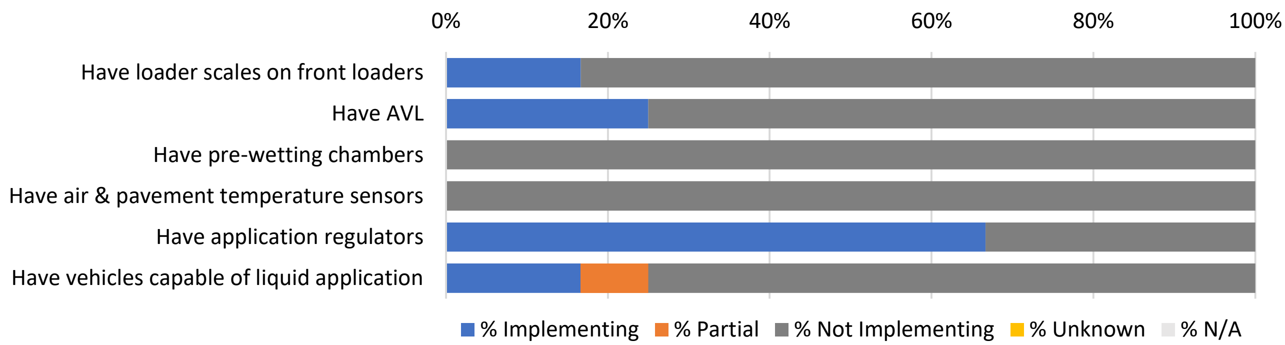


Figure 25. Percentage of Phase II communities implementing best practices for winter maintenance operations: equipment retrofits.

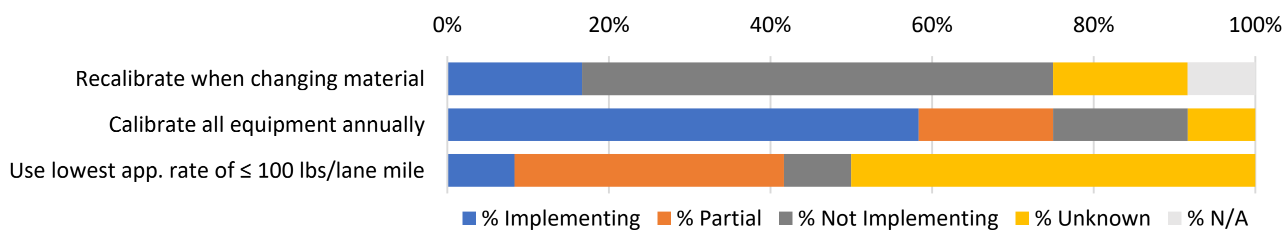


Figure 26. Percentage of Phase II communities implementing best practices for winter maintenance operations: calibration.

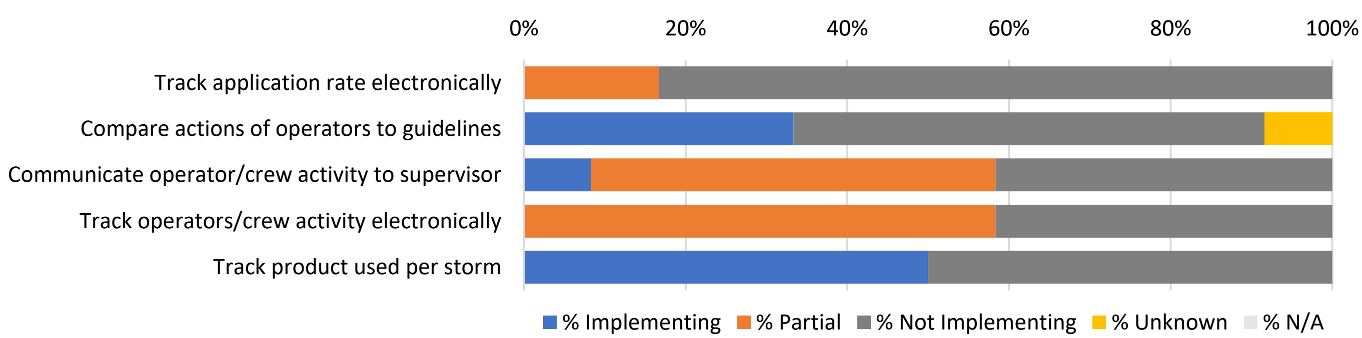


Figure 27. Percentage of Phase II communities implementing best practices for winter maintenance operations: tracking.

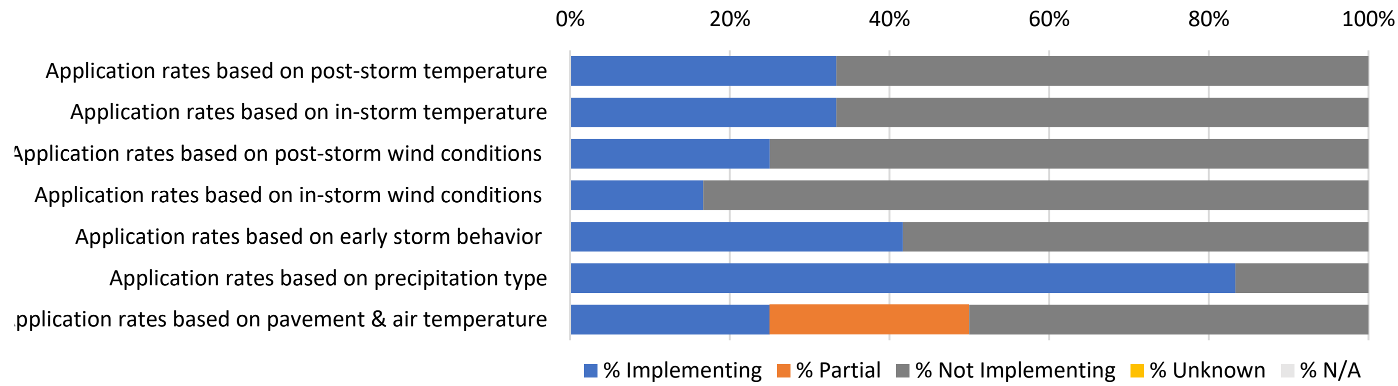


Figure 28. Percentage of Phase II communities implementing best practices for winter maintenance operations: variable application rates.

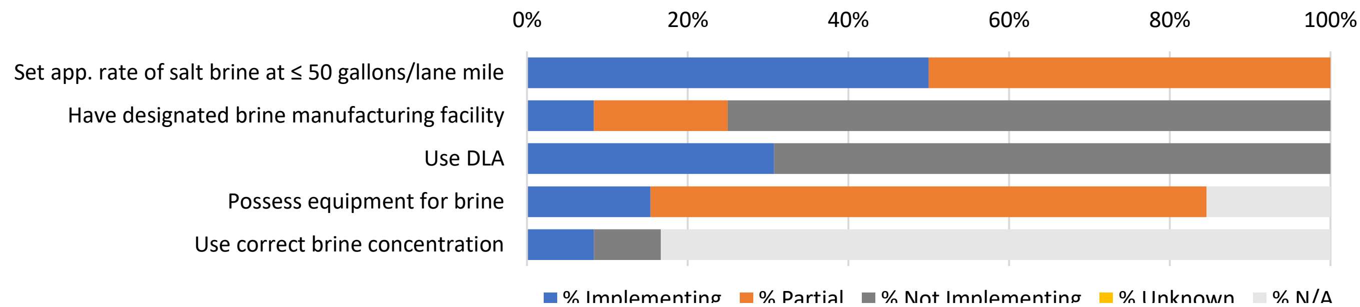


Figure 29. Percentage of Phase II communities implementing best practices for winter maintenance operations: liquid usage.

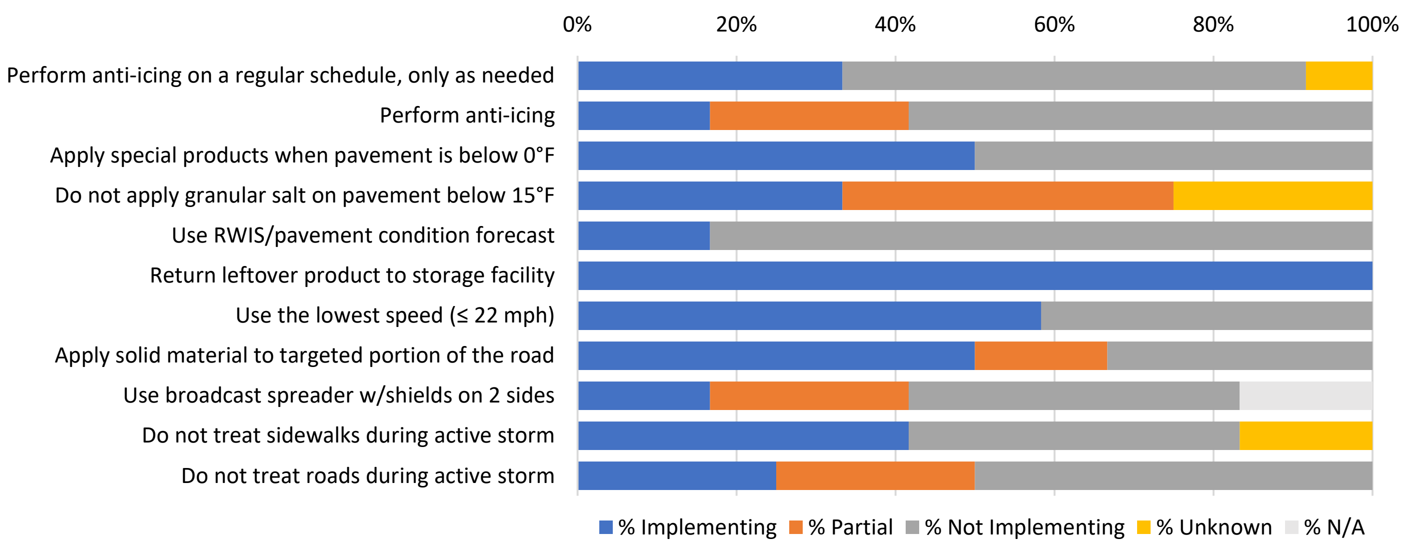


Figure 30. Percentage of Phase II communities implementing best practices for winter maintenance operations: other during-storm techniques.

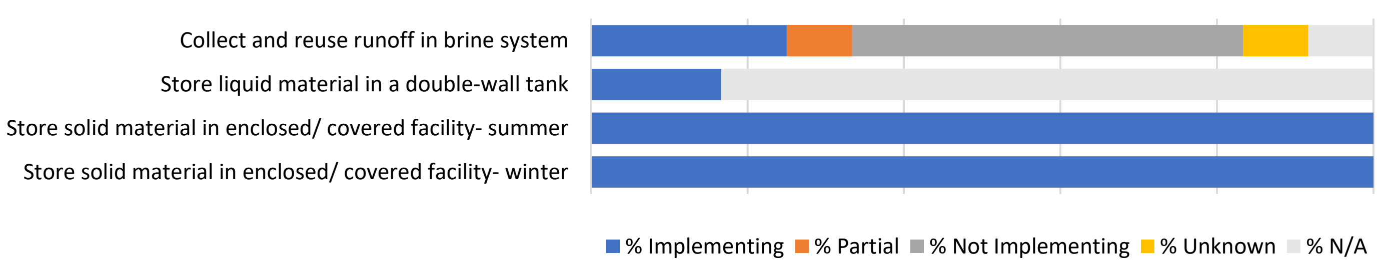


Figure 31. Percentage of Phase II communities implementing best practices for winter maintenance operations: storage of materials.

Figures 14 through 31 show a large variability of best practice implementation. Phase I communities have implemented more practices than Phase II, likely a result of their larger budget and service area. From the literature review, it was shown that there is no “silver bullet” when it comes to salt management. Not all practices are applicable for every community, as various factors such as service-area size, resources, and local climate can all impact feasibility, implementation, and results. Some practices do not have a direct reduction rate (e.g., salt management plan), making it difficult to directly compare practices.

The survey responses also highlighted some factors hindering small jurisdictions from implementing some of these best practices. The lack of resources—such as manpower, vehicles, and funding—indicate that the jurisdictions are already stretched thin. They will likely need additional resources to allow them to adopt additional best practices or make programmatic changes.

Conclusion

Although there is limited research on fate and transport of chloride from road salts to streams, there is consensus that source reduction is the best way to decrease salinization of local waterways. The literature review compiles the most effective types of chloride-reducing winter maintenance practices, and the survey was able to gather insight on the scale of implementation of those practices in Maryland MS4 communities. One of the key findings from the project was that recordkeeping and accountability of salt usage and practices are not implemented across all municipalities. Through follow-up conversations with MS4 contacts, many expressed that gathering the information would be difficult and time consuming. Without usage information, it is difficult to determine where improvements can be made. This should be a first step for some municipalities. Implementing automated data collection systems may make it easier to track and analyze salt usage.

The survey process also indicated a disconnect between the MS4 managers and the salt operators, as salt usage has not historically been considered in stormwater management. Some winter maintenance staff incorrectly identified their MS4 phase, further supporting the need for further communication and education. Although MS4 managers will be responsible for reducing salt usage if regulated under the MS4 permit, the winter maintenance staff, typically in the highway maintenance or public works department, will be the ones implementing the practices. Many survey respondents stated that education and buy-in from staff are major factors that would improve adoption of best practices. Lack of staff buy-in can become a barrier when municipalities are required to make changes. Public perception and political pressures are also barriers but are not addressed in this research.

Although this survey was not able to assess contractors directly, some best practices could be implemented by MS4 communities to improve their contractors’ salt efficiency, such as requiring the contractor to use the same guidance documents and adhere to the same LOS designations. As previously discussed, a certification program can be implemented by the state to reduce salt usage across the board. MDE has considered implementing a program similar those currently underway in New Hampshire[8] and Minnesota.[9]

Other popular practices that have shown reduced salt usage are anti-icing with liquids, calibrating equipment regularly and properly, and measurement, monitoring, and accountability practices (such as electronic spreader controls and AVL). Most respondents will also require staff training and likely an update to guidance documents. Some may require capital costs for equipment, but many other jurisdictions have found that the cost can be recouped over a few years.

The survey was able to take a snapshot of current implementation, but it does not address prioritizing practices for future implementation. An abundance of guidance is available on salt management, but communities, especially Phase II communities, may have a difficult time determining which is best suited for their organization. The MDOT SHA published the “Maryland Statewide Salt Management Plan” in 2019, which is a great resource for municipalities, although some practices may not be feasible because of size and budget constraints. As mentioned in the background section, the “fundamental five” and “supplemental six” are salt-reduction practices from the Salt Institute that would be a good place to start for those without a robust winter maintenance program.

Fundamental Five	Supplemental Six
Calibration Output measurement Accountability Designated levels of service Training	Variable application rates Road-specific forecasts Cold-temperature-specific practices Liquid material usage Pre-wetting Anti-icing

Additional research is needed to determine which practices would be most efficient based on different characteristics of the jurisdictions (such as weather, topography, size, land use, budget, etc.), especially for smaller municipalities. Additional research can be performed to prioritize the list of practices in Figures 14-31. Because salt usage is highly weather-dependent, measuring the actual annual salt used is not necessarily an accurate indicator of efficient salt usage. A more qualitative approach of tracking best practice implementation is a better indicator of improved salt management. One measurement that MDOT SHA uses to normalize salt usage based on snow amount is “pounds of salt used per lane mile per inch of snow.” Some states have implemented or are in the process of developing a Weather Severity Index to account for temperature, wind, ice, freezing rain, and depth of snow instead of relying on individual metrics (Farr & Sturges 2012). With the current science, there is no replacement for road salts, but there are various methods to reduce salt usage and the impacts of chloride in the waterways, while still maintaining public safety.

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Endnotes

[1] https://ofmpub.epa.gov/waters10/attains_nation.tmdl_pollutant_detail?p_pollutant_group_id=966&p_pollutant_group_name=SALINITY/TOTAL DISSOLVED SOLIDS/CHLORIDES/SULFATES

[2] https://mde.maryland.gov/programs/Water/TMDL/Integrated303dReports/Pages/303d.aspx

[3] This grant program includes funding partners from the Maryland Department of Transportation State Highway Administration, Maryland Department of Natural Resources, National Fish and Wildlife Foundation through the U.S. Environmental Protection Agency's Chesapeake Bay Program Office, and Chesapeake Bay Trust.

[4] https://www.des.nh.gov/organization/divisions/water/wmb/was/salt-reduction-initiative/salt-applicator-certification.htm

[5] https://t2.unh.edu/green-snowpro-salt-applicator-certification-training

[6] https://www.des.nh.gov/organization/divisions/water/wmb/was/salt-reduction-initiative/documents/wmb-26.pdf

[7] The variation of answers to liquid-related questions implies that some respondents may not have understood the questions or terminology used.

[8] https://www.des.nh.gov/organization/divisions/water/wmb/was/salt-reduction-initiative/salt-applicator-certification.htm

[9] https://www.pca.state.mn.us/water/smart-salting-training