

FY 2025 Appropriation Report
Public Act 51 of 1951
MCL 247.661a, Section 11a
(as amended by Public Act 310 of 2020)

247.661a Use of agricultural additives pilot program; report to legislature.

Sec. 11a.

(1) As provided in this section, the department must implement a pilot program on the use of agricultural additives to control ice on public roads, highways, and bridges in this state and to review the potential efficacy and environmental impacts of agricultural additives, while maintaining the safety and mobility of the motoring public.

(2) At a minimum, the pilot program described in subsection (1) must be designed to study liquid-only plow routes and must do all of the following:

(a) Identify and utilize methods for the use of agricultural additives, including, but not limited to, liquid sugar beet by-products, that promote surface adhering and reduce the freezing point of applied substances.

(b) Examine results from expanded use of agricultural additives, including, but not limited to, potential environmental and fiscal impacts.

(c) Develop best practices and technical guidelines for the use of agricultural additives, and for the expansion of the use of agricultural additives in the pilot program.

(d) Convey program information and guidance to local road agencies.

(e) Use agricultural additives in at least 3 test locations, each containing public roads, highways, and bridges that may be impacted by corrosion and a body of water that may be impacted by other commonly used deicers.

(f) Include collaboration with at least 1 local road agency.

(3) Not later than June 30, 2025, the department must submit a report on the pilot program to the members of the house of representatives and senate committees with jurisdiction over transportation. At a minimum, the report must summarize all of the following:

(a) Pilot program activity.

(b) Review results.

(c) Potential best practices for the statewide use of agricultural additives based on the results of the pilot program.

The Michigan Department of Transportation has prepared the following comprehensive report, *Assessment of Direct Liquid Application (DLA) with Use of Agricultural Byproducts (ABPs) for Winter Road Maintenance*, which includes Pilot Program Activity, Review of Results, and Conclusions and Recommendations for Potential Best Practices.

Note: If you require assistance accessing this information or require it in an alternative format, contact the Michigan Department of Transportation's (MDOT) Americans with Disabilities Act (ADA) coordinator at [Michigan.gov/MDOT-ADA](https://www.michigan.gov/MDOT-ADA).

Assessment of Direct Liquid Application (DLA) with Use of Agricultural Byproducts (ABPs) for Winter Road Maintenance

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List of Abbreviations and Acronyms

ABP	agricultural byproduct
AWSSI	Accumulated Winter Season Severity Index
BH	Beet Heet
CaCl ₂	calcium chloride
DIMP	Deice Master+
DLA	direct liquid application
DOT	department of transportation
MDOT	Michigan Department of Transportation
MWB	mineral well brine
NaCl	sodium chloride
PA 310	Michigan Public Act No. 310 of 2020

Executive Summary

Ensuring the safety of roadway users is a primary mission of transportation agencies. This must be balanced with proper stewardship of environmental and financial resources as well, so the Michigan Department of Transportation (MDOT) continually seeks new methods that maintain or exceed expected service levels while protecting and optimizing the state's resources. Maintaining safe roadways in the winter regularly requires the application of salt to break or prevent the bond between ice and pavement. However, salt chemicals applied to roadways scatter, bounce off or run into the surrounding environment, affecting waterways and ecosystems. They also have corrosive effects on vehicles, equipment and pavement.

Solid rock salt (sodium chloride) has been scattered on pavement for decades as a deicing agent, but the application of liquid salt brine onto roadways, called direct liquid application (DLA), has been shown to require less quantities of salt chemicals to deliver the same or better ice-clearing results. In addition, liquid chloride can be applied before precipitation falls on the pavement as an anti-icing agent to prevent ice bonds from forming, which aids in mechanical snow removal with a plow or other implement. Substances made from agricultural byproducts (ABPs) can be added to the salt chemicals to increase the salt's effectiveness in certain weather conditions. Commonly available ABPs are manufactured from corn, beets and sugar cane. Another naturally occurring material, mineral well brine, may be used in DLA.

In awareness of these issues and methods, the Michigan State Legislature ratified [Michigan Public Act 310 of 2020 \(PA 310\)](#), mandating that MDOT conduct a pilot study to evaluate the effectiveness of ABPs used in DLA for winter plow routes in the state. The intention was to identify best practices for winter road maintenance with less environmental impact than traditional rock salt application as well as less corrosive damage to road surfaces. The study methodology included a literature review that examined the cost, application practices, performance, and environmental impact of DLA with ABP additives, comparing these to other materials and application methods. As a further preparatory step, a technical site visit to Jefferson County, Wisconsin offered guidance for the DLA method based on previous testing.

As mandated in PA 310, three stretches of Michigan highways in the central Lower Peninsula were identified for studying DLA with ABP over five winter seasons, 2020-2021 to 2024-2025. These are maintained by the Montcalm County Road Commission, MDOT Mt. Pleasant Garage and MDOT Grand Ledge Garage. For comparison, stretches of road were also identified by each maintenance group that were maintained using traditional rock salt. Data on materials used during the seasons and end-of-season comments on performance from field staff provide useful input for agencies considering adopting DLA routes and using ABP additives.

DLA, both with or without ABPs, can be a viable option for maintenance operators in certain weather conditions. ABPs are particularly well-suited to colder weather. Moreover, by the final season of the study, there was a measurable reduction in overall chloride use for the DLA routes compared with nearby routes treated with traditional rock salt. However, the high-cost investment for setting up DLA operational equipment and the cost difference between ABPs and other brine solutions, such as mineral well brine, are likely obstacles to broad adoption.

1. Introduction

Background and Key Concepts

MDOT's goal for its winter maintenance operations is to preserve road accessibility and safety for the motoring public, with careful stewardship of environmental and budgetary resources. This goal is accomplished by preventing or eliminating the bonding of ice with the road surface and removing snow and ice mechanically with plows.

Several key concepts and considerations that frame this research study are presented here. A fuller exploration of these concepts and supporting research citations appears in [Chapter 3](#).

Why salt? Salt has been the primary material for clearing paved roads to increase safety for travelers. It lowers the freezing point of water, melting ice when applied to covered roads and decreasing the amount of additional ice that is formed. This allows vehicles to keep in contact with the roadway and maintain traction.

What does the term "salt" refer to? "Rock salt," the common name for sodium chloride, is the most typical form of salt used in Michigan and nationally, but calcium chloride and magnesium chloride are other kinds of salts that are used. The term "salt" can refer to any of these chemicals.

Typical salt use. MDOT and local agencies have invested in material and equipment to apply tons of salt each winter season as a preventive measure before winter storms and in remediation afterwards. For example, in fiscal year 2023, the five-year salt use average on all trunkline roads (totaling 30,000 lane-miles) was 474,000 tons according to MDOT records.

Brine. For salt to melt ice and break the bond between ice and pavement, it must be in solution. A salt in solution is called a *brine*. When dry salt is spread on snow and ice, it must first be dissolved by moisture into a brine to become effective.

Direct liquid application (DLA) is the practice of adding a liquid brine directly on the roadway. The brine provides faster action in melting the ice bond, but it results in faster dilution and thus a shorter working time.

Liquid-only DLA routes describe the use of only DLA rather than rock salt to fight snow and ice.

Liquid-mostly routes involve the use of DLA almost all of the time, with the occasional use of rock salt when needed.

Deicing and anti-icing describe maintenance activities undertaken at different times during winter storm events.

Deicing describes a maintenance activity that places chemical on snow or ice that is already covering a road surface in order to break the bond with the pavement. Deicing has traditionally been performed with dry salt in Michigan. Most of the work performed in this study was a form of deicing.

Anti-icing is a pre-storm activity intended to prevent snow and ice from bonding to the pavement. When winter maintenance agencies are informed of approaching weather, they have the option to utilize DLA of salt brines on the road surfaces before precipitation falls.

Negative impacts of salt. Despite the usefulness of salt as a tool for road maintenance and safety, it also has corrosive properties that can damage pavement, equipment and the environment. Concern over roadway runoff and its potential to increase salt concentrations in neighboring ecosystems has raised awareness of salination levels for freshwater rivers and lakes. There are also efforts to track indigenous species that may experience the negative effects of these increased chemical concentrations.

“Sensible salting” and innovative practices. Cognizant of the need to balance environmental and cost factors while maintaining safety and access for road users, MDOT follows the principle of “sensible salting,” which means applying the optimal amount of material at the right time to minimize waste. MDOT conducted research in the early 2010s (MDOT, 2012) to evaluate ways to limit the amount of salt material that bounces and scatters off the roadway during application. From this research, MDOT incorporated new practices into its winter operations starting in the 2013–2014 season. The agency advises operators to pre-wet salt at 7–10 gallons per ton and to apply deicing materials at slower speeds to increase the amount that stays on the roadway.

Agricultural byproducts. Other potential options for lowering the amount of salt applied to roadways are additives made from agricultural byproducts (ABPs). These are currently available for use and have been studied for their benefits in brine mixtures. As an example, MDOT has maintained a statewide contract for Boost, which is liquid Calcium Chloride with an ABP additive derived from sugar cane, to use for prewetting and anti-icing applications. Two other products, Ice Ban and Beet Heet, made from corn and beets respectively, have demonstrated their ability to alter the deicing properties of brine mixtures, for example allowing the chemical salts to work at lower temperatures.

Limitations and Potential of ABPs.

KEY POINT

- ▶ It is important to note that ABPs alone do not melt ice. Chloride chemicals have ice-melting properties, and ABPs can lower the effective working temperatures of these chemicals. However, ABPs cannot be used as a replacement for salt chemicals.

The potential of the ABPs to mitigate the salt's damage to roadside ecosystems would depend on how well they perform supplementing the salt. Moreover, the potential protective benefits to the infrastructure, equipment and environment need to be assessed alongside the added cost of the ABP additives. Salt brines alone can be made or purchased for \$0.15 - \$0.60 per gallon, whereas the addition of ABPs like beet juice can increase the cost by \$1.00 per gallon.

2. Objectives

Legislative Directive

Michigan Public Act No. 310 of 2020, which went into effect on March 24, 2021, called for the implementation of a pilot program by the state of Michigan to study the use of “agricultural additives to control ice on public roads, highways, and bridges in the state.” This study was mandated “to review the potential efficacy and environmental impacts of the agricultural additives, while maintaining the safety and mobility of the motoring public.”

As described in PA 310, MDOT was required to “study liquid-only plow routes,” adhering to specific guidelines for implementation and reporting. The research goals and methodology were to include the following aspects:

- a. *Identify and utilize methods for the use of agricultural additives, including, but not limited to, liquid sugar beet by-products, that promote surface adhering and reduce the freezing point of applied substances.*
- b. *Examine results from expanded use of agricultural additives, including, but not limited to, potential environmental and fiscal impacts.*
- c. *Develop best practices and technical guidelines for the use of agricultural additives, and for the expansion of the use of agricultural additives in the pilot program.*
- d. *Convey program information and guidance to local road agencies.*
- e. *Use agricultural additives in at least 3 test locations, each containing public roads, highways, and bridges that may be impacted by corrosion and a body of water that may be impacted by other commonly used deicers.*
- f. *Include collaboration with at least 1 local road agency.*

Approach

In fulfillment of the PA 310 guidelines, the MDOT pilot team selected four commercially available mixtures with agricultural additives, which winter maintenance professionals conventionally refer to as ABPs: Deice Master+, Beet Heet, Boost and CS-26. MDOT set out to evaluate the operational use, performance and costs of these ABPs in liquid-only and liquid-mostly DLA routes for anti-icing and deicing. Michigan previously had significantly more experience using DLA for anti-icing.

MDOT also used the structure of this pilot to evaluate another alternative for DLA: mineral well brine. Available in certain geographical locations, mineral well brine is a naturally occurring resource that some DOTs utilize for DLA. This liquid predominantly contains calcium chloride, as

well as some sodium chloride and magnesium chloride; it does not contain ABPs. Traditionally MDOT has not allowed the use of mineral well brine as a deicing/anti-icing option but elected to study it in this pilot for its effects as a deicing/anti-icing agent and for cost comparison.

MDOT maintains safety as a critical priority. When clearing snow and ice, local operators must respond to the shifting weather conditions, temperature and equipment needs, using their judgment to select the best method for keeping drivers safe. In certain situations, application with liquid brine only (DLA) is not possible or optimal. Therefore, during the DLA study, winter maintenance operators had discretion to utilize a liquid-only or liquid-mostly method when clearing their stretches of road.

KEY POINT

- ▶ With safety as the guiding principle, another top priority in the study was to meet or exceed the winter level of service on the pilot DLA routes as compared to the traditional rock salt routes. Even if DLA methods prove to generate a savings of salt chemicals based on research results, the goal is not to use less material at the expense of service to the public.

With regard to final communication of research data and conclusions, PA 310 required submission of a report to the members of the Michigan House of Representatives and relevant Michigan Senate committees by June 30, 2025, with specified deliverables:

- Pilot program activity.*
- Review of results.*
- Potential best practices for the statewide use of agricultural additives based on the results of the pilot program.*

This research report documents MDOT's fulfillment of all requirements set forth in PA 310.

3. Literature Review

Due to the broad availability and low cost of salt, its use in winter road maintenance is well established for addressing hazardous road conditions caused by freezing temperatures and precipitation. Salt—typically sodium chloride, and less frequently magnesium chloride and calcium chloride—mixes with water molecules in snow and ice and prevents the formation of ice crystals, lowering the freezing point of water and reducing ice formation.

Direct Liquid Application for Deicing and Anti-Icing

While sodium chloride rock salt application remains a standard method for melting ice to increase vehicle traction, transportation agencies have improved upon this material by pre-mixing the salt with liquids and applying the resulting brines directly to roadways. Research has demonstrated that this method, DLA, increases the salt’s melting capacity and adherence, since the granules do not bounce off the pavement. Moreover, this technique has been demonstrated to generate significant reductions in the amount of salt applied to roadways (Claros, et al., July 2021). One study tracked a 60% reduction over four winters in one Wisconsin county (Koeppel, 2023), generating cost saving for the transportation agency and decreasing the amount of salt released into the environment.

Salt chemicals function as both deicers and anti-icers. Deicing entails applying salt, typically sodium chloride, to a road already covered in ice or snow. The salt lowers the freezing point of the water and forms a brine with it, preventing ice from forming and from becoming slippery for vehicles. Anti-icing application occurs before freezing precipitation has covered the pavement. By spraying the chemical brine beforehand, the salt prevents the ice or snow from adhering to the road, which facilitates plowing. Choosing the most effective method requires information on anticipated temperatures and weather conditions (O’Keefe and Shi, 2005; Jahan and Mehta, 2012). Guidance is available on application rates both for deicing and anti-icing (Claros, et al., December 2021).

Potential Harm to Environment and Equipment

Transportation agencies are also cognizant that runoff from conventional deicing salt infiltrates the ecosystem (Durickovic, 2019; Hintz, et al., 2022). Studies have shown that the increased salination of freshwater rivers and lakes can be attributed to the use of deicers, among other sources. This can have negative effects on the indigenous plants and animals (Cañedo-Argüelles, et al., 2019; Solomon et al., 2023), although tests reveal that different types of salt vary in their impact on freshwater plant life (Coldsnow, et al., 2023). Not only of concern for urban areas where traffic density is greater, the environmental effects of deicers have also been studied in more remote areas that attract drivers for winter recreation (Munck, et al., 2010; Shenton, et al., 2022). Concern has prompted some researchers to call for additional investigation and specific standard controls around chemicals released into these freshwater environments (Schuler, et al., 2018).

In addition to the effects on waterways and ecosystems, salt has a deleterious effect on pavement and equipment (Fay, et al, 2008). Deicing chemicals interact with pavement both physically and chemically, decreasing the strength and integrity of the concrete (Wu, et al., 2023). Cracks on the surface that may be exacerbated by the deicing chemicals allow these chemicals and moisture to reach the rebar within, causing corrosion (Sajid, et al., 2022).

Chemical Alternatives and Agricultural Byproducts

In an effort to choose more environmentally friendly alternatives or additives to sodium chloride, both magnesium chloride and calcium chloride have been studied for their effects on aquatic life and ecosystems, with varied results. On the one hand, magnesium and calcium may benefit plants that utilize them as nutrients (Coldsnow, et al., 2023). However, other data point to potential toxicity and impaired biological processes at increased levels (Seli, et al., 2024).

Two sources of brine other than rock salt are naturally occurring brine and brine as a byproduct from oil and gas fields. Natural mineral well brine already exists as a commercial product for deicing and dust control on roads in Canada, and significant sources have been identified in the United States (Sack and Eck, 1985).

A number of states have also explored the use of oil well brines or gas field brines for winter road maintenance. However, the presence of trace metals and other chemical pollutants in oil and gas brines has raised concerns about their environmental impact and has prompted interest in establishing limitations for use (Jahan and Mehta, 2012). The use of mineral well brines should pose much lower environmental risks versus oil well brines; nevertheless, monitoring of laboratory testing for mineral well brine sources is advised.

Various agricultural byproducts (ABP) have been investigated for their potential as deicers and anti-icers (Muthumani, et al., 2015), with MDOT-supported research on this topic extending back more than 20 years (Kahl, 2002).

KEY POINT

- ▶ ABPs alone are not chloride-based, so they are typically blended with chlorides. (Fay, et al., 2023).

Among the most promising ABP candidates, desugared molasses, a byproduct of the beet sugar refining process, has demonstrated beneficial properties. This source offers a readily available solution while providing enhanced ice-melting capacity, reduced corrosivity of metals and greater roadway adherence (Nazari, et al., 2016). In one side-by-side field study, a 30% sugar beet juice/70% salt brine mix performed similarly to pure salt brine as a prewetting agent but outperformed pure salt brine for DLA, with up to 20% greater traction (Jiang, 2017).

Other agricultural sources have been identified and evaluated as potential deicing agents, including corn juice (Abbas, et al., 2021), concord grape extract (Shi, et al., 2018), cheese brine

and apple pomace (Fay, et al., 2022), among others. As in the case of beet byproducts, corn juice/salt brine mixes have demonstrated beneficial deicing properties in a side-by-side comparison with pure salt brine (Abbas et al, 2021) and have shown “substantial corrosion inhibition (up to 92%)” in one investigation (Sajid et al., 2020).

Review of Peer Practices

In February 2020, the MDOT research team met with staff from Wisconsin DOT and Jefferson County, Wisconsin, who had measured DLA use and performance over four winters (Koeppel, 2023). This afforded MDOT the opportunity to learn about their equipment, materials and application practices. In addition, the team reviewed available research through the Clear Roads Transportation Pooled Fund study (clearroads.org) and other related studies. Guidance from these sources was directly incorporated into the pilot study described in this report.

4. Pilot Program Activity and Research Methodology

This chapter details the methodologies that MDOT developed and undertook for its five-year research pilot study to test the effectiveness of the use of different deicers on state highway routes in Michigan.

Research Approach

This study included elements of a research field test with deicers evaluated under real-world highway conditions. This means the deicers were used by maintenance crews during winter events on roads being used by Michigan motorists. Because of this, the primary goals for maintenance staff were to operate their equipment in a safe and correct manner while meeting the predefined level of service for any given route before, during or after a winter storm. Deicers were tested and evaluated as a parallel goal as feasible under these live conditions.

KEY POINT

- ▶ In order to maintain safety standards and ensure that the DLA routes met or exceeded the level of service provided for the traditional rock salt routes, operators were directed to apply material as generously as needed since they were testing new mixtures and methods.

Time Frame

The pilot study took place over five winters. For the remainder of the report, each winter season is designated by the calendar year of its ending date, as indicated.

- Winter 2020-2021 (“2021 Season”)
- Winter 2021-2022 (“2022 Season”)
- Winter 2022-2023 (“2023 Season”)
- Winter 2023-2024 (“2024 Season”)
- Winter 2024-2025 (“2025 Season”)

Routes

MDOT sought to test deicers in multiple settings: on both rural (two-lane) and urban, suburban, or exurban (multilane) highways, and on MDOT-owned pavements under the maintenance authority of both state and county government offices.

As detailed in Table 4.1, the pilot study investigated DLA routes in three locations, with one of these maintained by a local road agency, as specified in PA 310.

Table 4.2 shows a comparison of routes in each of these jurisdictions where only rock salt was used. This would allow for direct comparisons of quantities of chlorides used in each location by season.

The first season of the pilot study included only one location (Montcalm County Road Commission (CRC)), and the study was expanded to include all three locations (Montcalm CRC, MDOT Mt. Pleasant Garage and MDOT Grand Ledge Garage) for the remaining seasons.

Table 4.1. Pilot (DLA) Routes Studied

Jurisdiction	Location	Routes	Report Notation	Lane Miles	Highway Type	Study Seasons
Montcalm County Road Commission	Stanton outlying area	M-66 from Ionia County line to Stanton	M-66P	24	Rural two-lane	2021 to 2025
MDOT Mt. Pleasant Garage	Mt. Pleasant outlying area	M-20 from Summerton Rd. to Midland County line	M-20-P	30	Multilane	2022 to 2025
MDOT Grand Ledge Garage	Lansing	M-43 (US-69) from Canal Rd. to Rosemary St.	M-43-P	22	Multilane	2022 to 2025

Table 4.2. Non-Pilot (Traditional Rock Salt) Routes Studied

Jurisdiction	Location	Routes	Report Notation	Lane Miles	Highway Type	Study Seasons
Montcalm County Road Commission	Stanton outlying area	M-66 Stanton to Mecosta County Line	M-66-NP	28	Rural two-lane	2021 to 2025
Montcalm County Road Commission	Within Montcalm County	M-46	M-46-NP	73	Rural two-lane	2021 to 2025
Montcalm County Road Commission	Within Montcalm County	M-57	M-57-NP	58	Mostly rural two-lane	2021 to 2025
Montcalm County Road Commission	Newaygo County Line to US 131	M-82	M-82-NP	6	Rural two-lane	2021 to 2025
Montcalm County Road Commission	Within Montcalm County	M-91	M-91-NP	48	Mostly rural two-lane	2021 to 2025
MDOT Mt. Pleasant Garage	Mission to Summerton	M-20	M-20-NP-1	10	Multilane	2021 to 2025
MDOT Mt. Pleasant Garage	Isabella County Line 16 Miles to Currie Pkwy	M-20	M-20-NP-2	80	Multilane	2021 to 2025
MDOT Grand Ledge Garage	Canal Road to M-66	M-43	M-53-NP	57	Rural two-lane	2021 to 2025

The relative locations of the pilot routes to one another are depicted in Figure 4.1. Each of the specific pilots, together with their associated non-pilot routes by jurisdiction, are noted in Figure 4.2, Figure 4.3, and Figure 4.4. These map images are sourced from the CSS Street Map on the Michigan Department of Technology, Management and Budget website, <https://www.michigan.gov/dtmb/services/maps/interactive>.

Representative street view photographs of each of the three pilot routes are presented in Figure 4.5. These images are sourced from Google Maps.

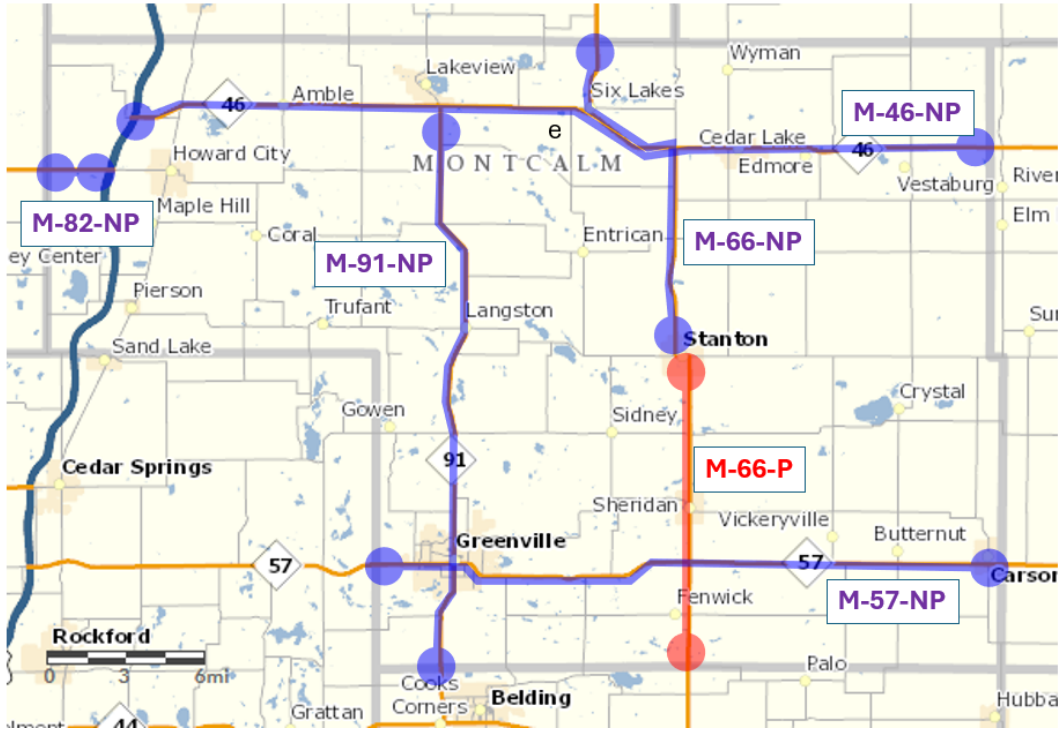


Figure 4.2. Montcalm Pilot and Non-Pilot Routes

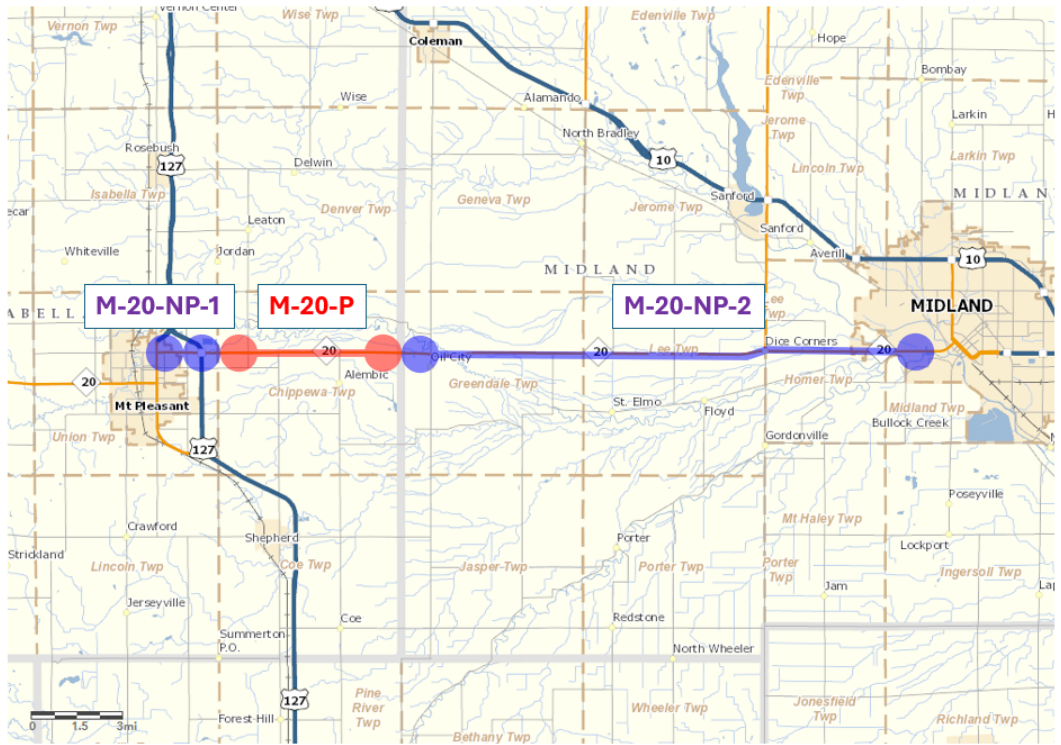


Figure 4.3. Mt. Pleasant Pilot and Non-Pilot Routes



Figure 4.4. Grand Ledge Pilot and Non-Pilot Routes



Figure 4.5. Street View Photographs of Pilot Sites

Materials

Over the course of study, the following deicers were evaluated, though not at all sites for all seasons. Abbreviations used in this report are not necessarily abbreviations used by manufacturers.

- **Deice Master+ (DIMP)**, a calcium chloride mineral well brine liquid with a corn-based agricultural byproduct (ABP).
- **Beet Heet (BH)**, a manufactured chloride liquid with a sugar-beet-based ABP.
- **Boost**, a manufactured calcium chloride liquid with a sugar-cane-based ABP.
- **CS-26**, a calcium chloride mineral well brine with a sugar-beet-based ABP.
- **Mineral well brine (MWB)**, a naturally occurring liquid chloride product sourced from underground water supplies. This material does not include an ABP. The mineral brine used on all pilot routes was typically 26% calcium chloride, with quantities of naturally occurring sodium and magnesium chloride as well.

Use by winter season and by location is detailed in Chapter 5. Liquid storage and application equipment was purchased or leased as necessary for the pilot sites. The associated costs are discussed in detail in Chapter 5 as well.

Reporting Procedures

At the end of a shift, operators were instructed to complete by hand a one-page pilot operator's application report. This is reproduced as Figure 4.6, with sample data included from one day's route.

<u>Garage:</u>		<u>DATE:</u>		<i>2/22/2023</i>	
<i>Mt. Pleasant</i>		<u>TIME IN: (AM/PM)</u>		<i>6:00 AM</i>	
<u>Truck #:</u>	<i>04-4125</i>		<u>TIME OUT: (AM/PM)</u>		<i>2:00 PM</i>
<u>ROUTE:</u>	<i>M-20</i>		<u>LANE MILES:</u>	<i>30</i>	
<u>EMPLOYEE NAME:</u>		<i>(Omitted)</i>			
<u>AIR TEMP @ START:</u>		<i>27</i>	<u>AIR TEMP @ END:</u>		<i>27</i>
<u>ROAD TEMP @ START:</u>		<i>18</i>	<u>ROAD TEMP @ END:</u>		<i>20</i>
<u>TYPE OF PRECIPITATION OR INCIDENT: (CIRCLE ONE)</u>					
<input type="checkbox"/> DRY	<input type="checkbox"/> RAIN	<input type="checkbox"/> FREEZING RAIN	<input type="checkbox"/> SLEET	<input checked="" type="checkbox"/> SNOW	
<u>SNOW DEPTH:</u>		<i>1-2"</i>		<u>HARD PACK:</u>	
<u>DRIVING SURFACE CONDITION: (CIRCLE ONE)</u>					
<input type="checkbox"/> WET	<input type="checkbox"/> DRY	<input type="checkbox"/> ICE	<input type="checkbox"/> DRIFTING SNOW	<input type="checkbox"/> HARD PACK	<input checked="" type="checkbox"/> SLIPPERY IN SPOTS
<u>LIQUID NAME:</u>		<u>LIQ1: DIMP</u>	<u>LIQ2: Brine</u>	<u>LIQ3:</u>	
<u>LIQUID BLEND %:</u>		<i>25%</i>	<i>75%</i>		
<u>DE-ICE or ANTI-ICE (circle one)</u>			<u>TANK REFILL TIME (NA or total minutes)</u>		
<u>APPLICATION RATE PER MILE:</u>		<u>APPLICATION #1:</u>		<i>60</i>	
		<u>APPLICATION #2:</u>		<i>80</i>	
		<u>APPLICATION #3:</u>			
<u>TOTAL GALLONS APPLIED:</u>		<i>2500</i>			
<u>APPLICATION SPEED:</u>					
<u>Solid USED (tons)</u>			<u>SALT</u>	<u>GRIT</u>	
<u>NOTES:</u>	<i>Treated slow and fast lane before the storm hoping snow would not stick to roadway. When the storm hit used 500 gal. Treated Leaton Rd. stop light and Michigan lefts.</i>				

Figure 4.6. Pilot Operator's Application Report Form

Additional items collected for each season included reported costs for maintaining the pilot routes versus non-pilot routes, total tonnage of rock salt applied on the pilot and non-pilot routes, and compiled listings of data from operator logs for each season.

In addition, at the end of each season, field staff were asked a series of questions to elicit qualitative feedback for compilation and analysis alongside the numerical field data. Questions typical of a given season follow.

1. *Were you able to apply liquids at the start of season? Why or why not?*
2. *How did operations work with liquid applications at beginning of season?*
3. *What adjustments did you make to operations during the season (application rates, spray patterns, etc.)?*
4. *Were operators comfortable with using liquid on the route? Did comfort/confidence with liquid grow with more experience throughout the season? Were opinions different between operators?*
5. *Did you have to adjust your approach between day and night shifts?*
6. *What liquid products did you use? Did you experiment with blending liquids? How did blending work?*
7. *Did you have success applying just mineral well brine (with no ABP)? In which scenarios does this approach work?*
8. *How did level of service compare on liquid route vs other routes in the areas?*
9. *Comments on liquid product performance and ease of use throughout the season?*
10. *Comment on equipment performance throughout the season?*
11. *Were there any concerns with liquid storage or having enough on hand?*
12. *Were there events where liquid use seemed to work better than others? Describe.*
13. *Were there events where liquid use didn't work as well as traditional salt use? What factors could have contributed to this?*
14. *Were there times when liquids were not applied to treat the route? Why?*
15. *Overall review of liquid as a deicer.*
16. *Overall review of liquid for anti-icing.*
17. *What are the goals for the next pilot season?*
18. *What products do you intend to use next season?*

5. Review of Results

Summary of Data

The findings include the following sections:

- **Winter Severity**, characterizing each of the five winters in the pilot study in terms of overall severity.
- **Annual Review of Pilot Study**, detailing on a year-by-year basis the amount and kind of liquid applied, the cost per lane-mile, and operational outcomes.
- **Product Pricing**, calculating the average price of products used.
- **Equipment Cost**, outlining the expenses required for storing and applying the liquids.
- **Chloride Impact**, measuring the total environmental chloride effect on each route by lane mile by season.
- **Operational Assessment and Observations**, synthesizing the end-of-season narrative reports from all locations.

Winter Severity

Understanding the severity of each winter during this pilot study will provide context for review of the findings. Winter severity can be characterized by an Accumulated Winter Season Severity Index (AWSSI) value, or severity index, at any weather station for a given season. The methodology, which incorporates temperature and precipitation into the severity index values, is described in more detail at the [Midwestern Regional Climate Center website](#). Higher index values are associated with more severe winters and higher seasonal material use and costs. Historical severity index values may be found here as well.

The three weather stations in Michigan closest to the pilot routes are those in Grand Rapids, Lansing and Saginaw. The severity index values for these three stations for the five seasons of the pilot study are shown in Figure 5.1. These correlate with one another, with 2022 generally being the most severe season of the study and 2024 being the least severe.

NOTE: Data collection for the 2025 Season concluded on March 1, 2025, to allow researchers to complete data analysis for the publication of this report. Figure 5.1 shows the AWSSI values for all three locations accumulated only through February 28 for the 2025 Season. For all three locations, these values were between 93% and 97% of the final accumulated severity value ultimately recorded by mid-March 2025.

In all cases, winter severity drove study outcomes, with light weather associated with low maintenance costs and salt use, and heavy weather with high costs and salt use.

Compared with historical data, the winter seasons were mild to moderate, with 2024 being the mildest on record for Lansing and Saginaw. Historically, average severity index values are around 710 for Saginaw, 740 for Grand Rapids, and 750 for Lansing.

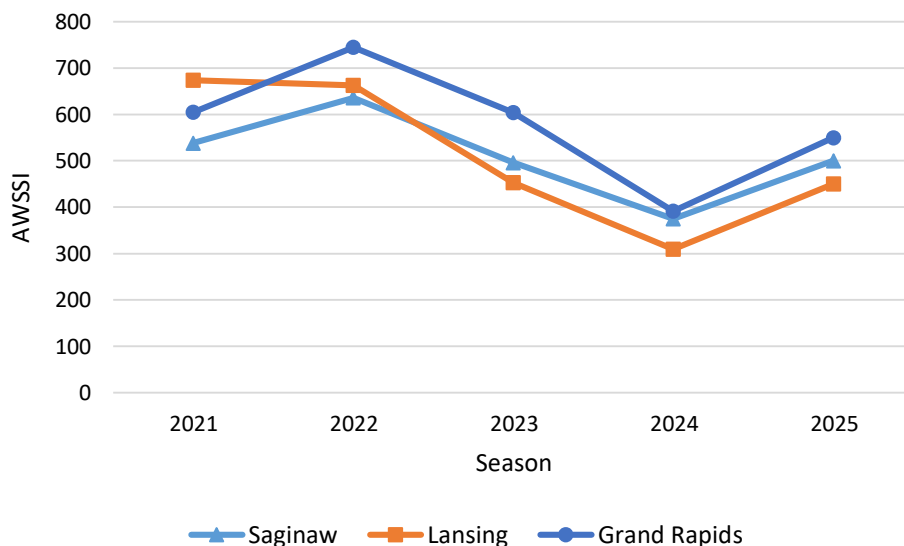


Figure 5.1. Winter Severity in the Pilot Study Region

Annual Review of Pilot Study

Logs of all applications for each route by year are available in Excel files format and may be found at <https://www.michigan.gov/mdot/-/media/Project/Websites/MDOT/Programs/TSMO/Maintenance/Operator-Logs.zip>.

2021 Season

The first season of the study aimed to prove and refine the study setup over the course of one winter. It was limited in scope to one location (Montcalm); the two MDOT garages that participated in future seasons of study did not have their new liquid tanks trucks ready for use in the 2021 Season.

Total DLA applications on pilot routes: 43.

Liquid applied on pilot routes: 69,570 gallons, as detailed in Table 5.1.

Table 5.1. Chemicals Applied in 2021 Season — Pilot Route

Route	DIMP (gallons)	BH (gallons)	Boost (gallons)	MWB (gallons)	Total liquid (gallons)	Total lane miles applied (ln-mi)	Application rate avg. (gallons/ln-mi)	Rock salt (tons)
Montcalm	19,025	1,128	—	49,418	69,570	1,032	67	Not reported

2022 Season

2022 was the most severe winter of the study and the first to include all three testing locations. These were studied for the remainder of this investigation. While the two MDOT garages (Mt. Pleasant and Grand Ledge) did not have liquid products for the entire 2022 Season, they did begin performing DLA this winter. Also, starting with this winter, MDOT implemented additional procurement contracts for the MDOT garages in the study.

Total DLA applications on pilot routes: 193.

Liquid applied on pilot routes: 282,816 gallons, as detailed in Table 5.2.

Table 5.2. Chemicals Applied in 2022 Season — Pilot Routes

Route	DIMP (gallons)	BH (gallons)	Boost (gallons)	MWB (gallons)	Brine	Total liquid (gallons)	Total lane miles applied (ln-mi)	Application rate avg. (gallons/ln-mi)	Rock salt (tons)
Montcalm	10,831	3,934	—	65,450	—	80,215	1,387	58	0
Mt. Pleasant	147,085	—	—	—	4,475	151,560	2,610	58	11
Grand Ledge	44,633	—	6,408	—	—	51,041	770	66	309
Total	202,549	3,934	6,408	65,450	4,475	282,816	4,767	59	320

Use of ABPs and other liquids: 2022 saw the testing of corn- and beet-based ABPs. At the Montcalm site, mineral well brine was also used; Montcalm reported good results blending 75% well brine with 25% DIMP for deicing operations and 90% well brine with 10% BH for anti-ice operations.

Costs per lane mile: Costs on a dollar-per-lane-mile basis for the pilot and the most similar non-pilot route by site are shown Table 5.3. All costs are normalized to include materials, labor and equipment to allow like-with-like comparisons between state and county operations.

The total costs were significantly lower for the pilot route in Montcalm, but markedly higher in both Mt. Pleasant and Grand Ledge. Montcalm was the only location using MWB in 2022.

Table 5.3. Costs for 2022 Season

Route	Brine Pilot Cost (\$/lane-mile)	Non-Pilot Cost (\$/lane-mile)	Comparative Cost of Pilot to Non-Pilot (%)
Montcalm	959	2,412	60% lower
Mt. Pleasant	5,128	2,459	109% higher
Grand Ledge	2,896	1,382	110% higher

2023 Season

2023 was a lighter winter than 2022. However, the number of applications was higher with more gallons applied due to the 2023 Season being the first full winter where all garages had full access to equipment and liquid to apply.

Total DLA applications on pilot routes: 199.

Liquid applied on pilot routes: 290,023 gallons, as detailed in Table 5.4.

Table 5.4. Chemicals Applied in 2023 Season — Pilot Routes

Route	DIMP (gallons)	BH (gallons)	Boost (gallons)	MWB (gallons)	Total liquid (gallons)	Total lane miles applied (ln-mi)	Application rate avg. (gallons/ln-mi)	Rock salt (tons)
Montcalm	28,278	1,833	—	90,940	121,051	2,843	43	20
Mt. Pleasant	25,750	—	—	83,750	109,500	2,130	51	22
Grand Ledge	3,600	—	3,605	52,267	59,472	1,018	58	190
Total	57,628	1,833	3,605	226,957	290,023	5,991	48	232

Use of ABPs and Other liquids: Over 75% of the liquid applied on pilot routes was mineral well brine, applied on its own or blended with liquids that contained ABP. Montcalm, in particular, began evaluating the use of mineral well brine on its own to try to lower overall costs while meeting level-of-service targets. Each location reported success with using mineral well brine and noted that it helped lower costs.

Costs per lane mile: Costs on a dollar-per-lane-mile basis for the pilot and the most similar non-pilot route by site are shown in Table 5.5. All costs are normalized to include materials, labor and equipment to allow like-with-like comparisons between state and county operations.

In all three locations, the pilot routes were costlier than the non-pilot routes. The comparative costs were closer in both Montcalm and Grand Ledge, and the pilot routes were significantly higher in Mt. Pleasant.

Table 5.5. Costs for 2023 Season

Route	Brine Pilot Cost (\$/lane-mile)	Non-Pilot Cost (\$/lane-mile)	Comparative Cost of Pilot to Non-Pilot (%)
Montcalm	3,359	2,734	23% higher
Mt. Pleasant	2,688	1,399	92% higher
Grand Ledge	2,634	2,371	11% higher

2024 Season

2024 was one of the lightest winters on record in Michigan, which resulted in the lowest need for chemical applications.

Total DLA applications on pilot routes: 115.

Liquid applied on pilot routes: 199,817 gallons, as detailed in Table 5.6.

Table 5.6. Chemicals Applied in 2024 Season — Pilot Routes

Route	DIMP (gallons)	BH (gallons)	Boost (gallons)	CS-26 (gallons)	MWB (gallons)	Total liquid (gallons)	Total lane miles applied (lane-mile)	Application rate avg. (gallons/lane-mile)	Rock salt (tons)
Montcalm	17,065	1,505	—	—	50,030	68,600	1,328	52	0
Mt. Pleasant	375	—	—	19,725	73,000	93,100	1,650	56	54
Grand Ledge	—	—	—	9,784	28,333	38,117	462	83	81
Total	17,440	1,505	0	29,509	151,363	199,817	3,440	58	135

Use of ABPs and other liquids: Montcalm continued its focus on corn-based DIMP as the primary ABP in 2024. Both Mt. Pleasant and Grand Ledge switched focus to beet-based CS-26 to evaluate performance for the 2024 season. All three pilot routes continued to use mineral well brine in 2024, constituting about three-quarters of the liquid applied.

Costs per lane mile: Costs on a dollar-per-lane-mile basis for the pilot and the most similar non-pilot route by site are shown Table 5.7. Note that all costs are normalized to include materials, labor and equipment to allow like-with-like comparisons between state and county operations.

The total costs for the pilot study routes in Montcalm and Mt. Pleasant were close. Montcalm used less-expensive mineral well brine and had lower pilot-route costs compared with non-pilot routes. By comparison, the use of the more expensive CS-26 in Mt. Pleasant and Grand Ledge resulted in pilot routes costing significantly more than the non-pilot routes.

Table 5.7. Costs for 2024 Season

Route	Brine Pilot Cost (\$/lane-mile)	Non-Pilot Cost (\$/lane-mile)	Comparative Cost of Pilot to Non-Pilot (%)
Montcalm	1,812	2,574	30% lower
Mt. Pleasant	1,792	506	254% higher
Grand Ledge	2,349	1295	81% higher

2025 Season

The 2025 Season was similar to the 2023 Season in terms of severity. As previously noted, data were only collected through February 28, 2025, to allow time to complete this research study on schedule. There were few winter events in March and April; weather through February 28 represented about 95% of the severity index score for the whole season.

Total DLA applications on pilot routes: 176.

Liquid applied on pilot routes: 289,600 gallons, as detailed in Table 5.8.

Table 5.8. Chemicals Applied in 2025 Season — Pilot Routes

Route	DIMP (gallons)	BH (gallons)	Boost (gallons)	CS-26 (gallons)	MWB (gallons)	Total liquid (gallons)	Total lane miles applied (lane-mile)	Application rate avg. (gallons/lane-mile)	Rock salt (tons)
Montcalm	18,515	1,564	—	—	69,699	89,778	1,424	63	0
Mt. Pleasant	—	—	—	27,038	84,013	111,050	2,310	48	48
Grand Ledge	—	—	—	41,910	46,861	88,772	980	91	73
Total	18,515	1,564	0	68,948	200,573	289,600	4,714	61	121

Use of ABPs and other liquids: In the final year of this research project, all three pilot locations emphasized the use of blending mineral well brine with ABPs. Montcalm focused on blending mineral well brine with DIMP and BH, and the two MDOT garages blended it with CS-26

Costs per lane mile: Costs on a dollar-per-lane-mile basis for the pilot and the most similar non-pilot route by site are shown Table 5.9. Note that all costs are normalized to include materials, labor and equipment to allow like-with-like comparisons between state and county operations.

2025 was consistent with 2024, with Montcalm showing a lower cost on its pilot route, and Mt. Pleasant and Grand Ledge showing higher costs.

Table 5.9. Costs for 2025 Season

Route	Brine Pilot Cost (\$/lane-mile)	Non-Pilot Cost (\$/lane-mile)	Comparative Cost of Pilot to Non-Pilot (%)
Montcalm	\$2,236	\$3,316	33% lower
Mt. Pleasant	\$2,220	\$1,457	52% higher
Grand Ledge	\$3,190	\$1,204	165% higher

Product Pricing

While material costs varied over the course of the pilot study, the final prices for each type of product best represent what might be expected in the future. MDOT has maintained contracts for the liquid brine mixture supplemented with Boost that it already uses in prewetting and anti-icing applications. It established new contracts for the MDOT pilot garages for mixtures containing ABPs that had not been tried before: Deice Master+ (DIMP) and CS-26, along with mineral well brine (MWB). Montcalm CRC procured DIMP, Beet Heet (BH), and MWB for its pilot. All products were vetted against national standards defined in Clear Roads’ qualified products list.

Cost in dollars-per-gallon for different products is shown in Table 5.10. A range indicates that multiple vendors supplied the same product at different prices. Average prices across locations are calculated and sorted from lowest (mineral well brine) to highest (BH).

The high cost of ABPs motivated garages over the course of multiple winters to move away from products with ABPs or to cut ABPs with MWB.

Table 5.10. Final Material Prices

Product	Notes	Average price (\$/gallon)	Montcalm price (\$/gallon)	Mt. Pleasant price (\$/gallon)	Grand Ledge price (\$/gallon)
MWB	No ABP	\$0.23	\$0.16	\$0.20 – 0.24	\$0.24
DIMP	10% Corn ABP	\$0.55	\$0.53	\$0.55	\$0.58
CaCl ₂ with Boost	Boost is 5-20% sugar cane ABP based	\$1.09	—	\$1.20	0.98
CS-26	5% Beet ABP	\$1.10	—	\$1.10	\$1.10
BH	15% Beet ABP	\$1.66	\$1.66	—	—

Equipment Cost

Liquid application storage was already available at the Montcalm facility. The two MDOT garages required additional liquid storage, which was included with the liquid procurement each season. Each MDOT site required two 20,000-gallon storage tanks to keep enough product available for a pilot route during each winter season. Liquid trucks were also purchased for the MDOT pilot sites and rented for the Montcalm site. Approximate equipment costs are as follows.

Vehicle

- Base winter maintenance truck cab, chassis and Swaploader brand hook lift hoist: **\$160,000 each.**
- Liquid tank and sprayer control system and set-up for truck: **\$130,000 each.** Note that conversion of existing trucks not equipped with Swaploader hardware would likely cost a similar amount.
- This brings the total cost per vehicle to **\$290,000 each.**

Storage

- 10,000-gallon double-walled polymer storage tank: **\$30,000 each.**

Typical equipment is illustrated in Figure 5.2 and Figure 5.3.



Figure 5.2. Truck Outfitted with a Liquid Chemical Tank and Spray Equipment



Figure 5.3. Salt Shed Liquid Storage Tanks

Cost Scaling

The equipment costs are significant, and scaling equipment costs for a statewide DLA program would require a very high cost outlay. This is illustrated both for storage tanks and for vehicles.

Storage Tanks

The tables above show that on average 40,000 to 60,000 gallons of storage met the needs for the DLA pilot for routes of up to 30 lane miles. A conservative estimate is four tanks at a cost of \$120,000 per 30 miles. MDOT's highway trunkline is 32,000 lane miles.

*Providing liquid storage alone for statewide DLA operations would then cost **\$128 million.***

Vehicles

MDOT makes direct use of 350 winter maintenance trucks to service about a quarter of the 32,000 lane miles noted above. The Michigan counties and municipalities that service the remaining lane miles use about 1,000 trucks. A conservative combined estimate of these vehicles is 1,200 total. As noted above, the cost to switch from using a dump box truck to a sprayer truck is approximately \$290,000 each.

*Therefore, switching 1,200 trucks for statewide DLA operations would cost an additional **\$348 million.***

Chloride Impact

As noted previously in this report, operators' top priority was clearing roads and making them safe and passable for motorists. This likely resulted in higher-than-needed application rates of liquids, particularly in the early years of this study, with operators erring on the side of caution. As operators gained comfort and confidence with using liquids for deicing and anti-icing over the course of the study, application rates became more finely-tuned. For the purposes of evaluating total chloride use and fairly evaluating liquids, the last three years of the study (2023, 2024 and 2025 seasons), associated with lower application rates, were analyzed.

Table 5.11, Table 5.12 and Table 5.13 tabulate chemicals applied each season on each route. This includes calcium chloride brines and rock salt on the pilot routes, and rock salt only on the non-pilot routes.

To determine the total environmental impact of chlorides on each route and allow like-with-like comparison of routes, the calcium chloride brine values were converted to equivalent tonnage of rock salt that would represent the same amount of chlorides. Assumptions, calculations and an illustration describing this conversion follows:

Assumptions and conversion factors

- 2.7 lb. of CaCl₂ per 1 gallon of 26% CaCl₂ solution
- Pure rock salt (100% NaCl)
- 110.98 lb. of CaCl₂ contains 70.91 lb. of elemental chloride
- 58.44 lb. of NaCl contain 35.45 lb. of elemental chloride

Conversion calculation

The following equation shows that the use of 1,000 gallons of calcium chlorine brine has the same chloride impact as 1.42 tons of solid sodium chloride.

$$1,000 \text{ gal. CaCl}_2 \text{ soln.} \times \frac{2.7 \text{ lb. CaCl}_2}{1 \text{ gal. CaCl}_2 \text{ soln.}} \times \frac{70.91 \text{ lb. Cl}}{110.98 \text{ lb. CaCl}_2} \times \frac{58.44 \text{ lb. Cl}}{35.45 \text{ lb. NaCl}} \times \frac{1 \text{ ton}}{2000 \text{ lb.}} = 1.42 \text{ tons solid NaCl}$$

Illustration

On route Montcalm Route M-66-P in 2023 (Table 5.11, Row 1), the following amounts of chemicals were used in the season:

- 121,051 gallons of liquid CaCl₂
- 20 tons of rock salt (NaCl)

Using the conversion calculation above, the 121,051 gallons of CaCl₂ are equivalent to 172 tons of rock salt.

The second-to-last column of each table, “total chloride impact,” is a measure of total environmental chlorides, expressed as rock salt equivalent tons. In this example 172 + 20 = 192 tons.

The last column is **chloride impact per lane mile**. This is the most useful measure value to measure chloride impact between routes. In this example, 8.0 tons per lane mile.

Table 5.11. Chemicals Applied in 2023 Season — Pilot versus Non-Pilot Routes

Location	Route	Route Lane Miles	Actual Liquid CaCl ₂ (gallons)	Liquid CaCl ₂ as equivalent rock salt (tons)	Actual rock salt applied (tons)	Total chloride impact (equivalent + actual, tons)	Chloride impact per lane mile (tons per mile)	Comparative impact of pilot to non-pilot
Montcalm	M-66-P	24	121,051	172	20	192	8.0	4% lower
Montcalm	(5) M-Routes	214.3			1781	1781	8.3	
Mt. Pleasant	M-20-P	30	109,500	156	22	178	5.9	21% higher
Mt. Pleasant	(2) M-Routes	90			441	441	4.9	
Grand Ledge	M-43-P	22	59,472	85	190	275	12.5	18% lower
Grand Ledge	M-43-NP	57			869	869	15.2	

Table 5.12. Chemicals Applied in 2024 Season — Pilot versus Non-Pilot Routes

Location	Route	Route Lane Miles	Actual Liquid CaCl ₂ (gallons)	Liquid CaCl ₂ as equivalent rock salt (tons)	Actual rock salt applied (tons)	Total chloride impact (equivalent + actual, tons)	Chloride impact per lane mile (tons per mile)	Comparative impact of pilot to non-pilot
Montcalm	M-66-P	24	68,600	98	0	98	4.1	6% lower
Montcalm	(5) M-Routes	214.3			930	930	4.3	
Mt. Pleasant	M-20-P	30	93,100	132	54	186	6.2	4% higher
Mt. Pleasant	(2) M-Routes	90			539	539	6.0	
Grand Ledge	M-43-P	22	38,117	54	81	135	6.1	12% lower
Grand Ledge	M-43-NP	57			396	396	6.9	

Table 5.13. Chemicals Applied in 2025 Season — Pilot versus Non-Pilot Routes

Location	Route	Route Lane Miles	Actual Liquid CaCl ₂ (gallons)	Liquid CaCl ₂ as equivalent rock salt (tons)	Actual rock salt applied (tons)	Total chloride impact (equivalent + actual, tons)	Chloride impact per lane mile (tons per mile)	Comparative impact of pilot to non-pilot
Montcalm	M-66-P	24	89,778	128	3	131	5.4	21% lower
Montcalm	(5) M-Routes	214.3			1,481	1,481	6.9	
Mt. Pleasant	M-20-P	30	111,050	158	48	206	6.9	30% lower
Mt. Pleasant	(2) M-Routes	90			878	878	9.8	
Grand Ledge	M-43-P	22	88,772	126	73	199	9.1	49% lower
Grand Ledge	M-43-NP	57			1,009	1,009	17.7	

Key data from Table 5.11, Table 5.12 and Table 5.13 are illustrated in Figure 5.4 below, which compares the chloride impact of each pilot route to its appropriate non-pilot route(s), expressed as a ratio, for Seasons 2023 through 2025. Numbers lower than 1.0—also shown in green in Figure 5.4—indicate a lower impact of the pilot routes for a given location and season. Numbers higher than 1.0—shown in red—indicated a higher chloride impact.

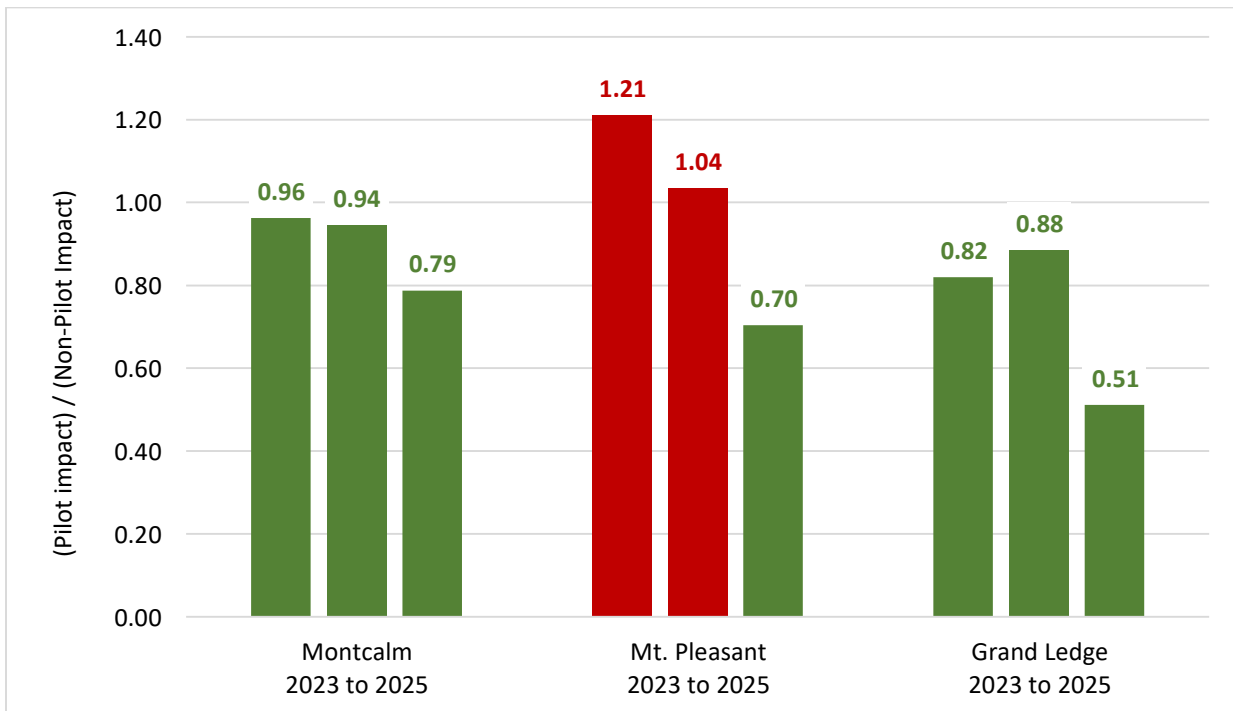


Figure 5.4. Comparison of Chloride Impact of Pilot Routes to Non-Pilot Routes by Location and Year

Compared with non-pilot routes, pilot routes maintained by Montcalm and Grand Ledge showed a lower chloride impact in Seasons 2023 and 2024. By contrast, the Mt. Pleasant pilot route had higher chloride impact in both of those years.

KEY POINT

- ▶ **As the study progressed by season, the pilot routes conclusively trended toward outperforming the non-pilot routes in terms of chloride impact.** By the 2025 Season, all three locations showed a lower chloride impact on the pilot route compared with the non-pilot route(s) in the same location, and all three locations showed the lowest chloride impact—as compared with the pilot routes—for any season.

Possible operational factors to consider that impacted the use of both solid and liquid chemicals include the following:

- Early in the study, over-application of brine on liquid routes was possible due to lack of driver experience or confidence with its effects. This factor would tend to decrease over time and seasons and operators became more familiar with the application of these materials.
- Instances of garages switching to rock salt were possible during heavy winter events, whether based on perceived or actual need. The data show that this occurred more frequently with the two MDOT garages.

Initial Operational Assessment and Observations

The following observations are based on end-of-season assessments from staff in the field and MDOT’s Central Office for the 2021 Season through 2024 Season. While some are anecdotal in nature, they provide valuable insights into the challenges and knowledge gained for various aspects of this project. Additional end-of-study observations follow in the next section.

Application

- DLA application rates ranged from 45 gallons per lane-mile to 85 gallons per lane-mile, with 100 gallons per lane-mile required to maintain levels of service overnight.
- Two pilot groups replaced their spray nozzles with larger ones to prevent atomization of the liquid and to apply more volume to the roadway.
- There is a learning curve for spray application of DLA. For example, for roads with a center-line rumble strip, the liquid needs to be applied next to the corrugation in a narrow band.
- Utilization of a long spray bar with additional nozzles allowed for the application of more liquid volume to the roadway.

- It is possible to apply liquids on roads that have temperatures of 15 degrees Fahrenheit if concentrated in a narrow band. This does not clear the entire lane but improves driver safety.

Effectiveness

- The level of service for the DLA pilot routes matched the salt routes; however, this required more applications of the liquid than the product needed for salt routes.
- Compared with dry chemicals, liquids stick to the pavement surface better and work more quickly under the right conditions.
- Two pilot groups concurred that DLA worked better than rock salt when applied to a thin layer of ice due to elimination of salt scatter and bounce.
- Liquid required greater volume and more frequent application when temperatures dropped overnight.
- Rock salt remained the better option for some applications, such as wet snow, hardpack on the roads, and quick snowfall accumulation events. It also did not require as frequent reapplication.
- DLA with ABPs generally worked best in colder conditions approaching zero degrees Fahrenheit.
- Increasing the amount of ABP carbohydrates blended with the brine did not “seem to help” with their deicing or anti-icing effects.
- Operators found they could blend the ABP with additional brine to save costs without affecting the level of service.
- One pilot location reported that mineral well brine worked as well as the ABP product except in extremely cold temperatures. Another location switched to using only mineral well brine in the 2023 Season, also indicating that it worked better at higher temperatures.

Materials, Equipment and Storage

- Product availability (including delays and longer distance delivery) impacted assessment of DLA with ABPs.
- Storing liquid products requires additional tanks. For this study 20,000-gallon capacity frac tanks were used. These carry a rental or storage cost.
- Garage plumbing and pumping equipment for each liquid is required, and some system troubleshooting may be needed.
- Similarly, issues and calibration can be expected with liquid supply lines, filters and nozzles on the liquid application vehicles.

- The option of making salt brine for \$0.10 per gallon is roughly half the cost of the cheapest mineral well brine available.

Anti-icing

- Locations had varied levels of experience with DLA for anti-icing.
- Montcalm reported in the 2022 Season that “pre-treating prior to the event is a large part of the program,” applying 28-30 gallons per lane mile the day before the event.
- Compared to routes that did not receive anti-icing pre-treatment, Montcalm reported a “much better” driving surface during the day. Comparison also indicated that Beet Heet pre-treatment performance was “slightly better” than pre-treatment using chloride brine with no ABP.
- Mt. Pleasant used a blend of 75% brine, 25% DIMP for most anti-ice applications in the 2023 Season, observing that it seemed to work better than rock salt for anti-ice.
- Grand Ledge observed in the 2023 Season that mineral well brine worked well for anti-icing with temperatures above 25 degrees, but the operators struggled in colder nighttime temperatures.
- Applying a blend of 75% mineral well brine and 25% CS-26 before one 2024 Season storm, Grand Ledge found that the anti-icing treatment worked well. Although the rate of snowfall eventually overwhelmed the chemical, the pre-treatment preserved road conditions at the beginning of the storm.
- Application rates reported by Grand Ledge in the 2024 Season ranged from 45 gallons per lane mile to 85 gallons per lane mile.
- Anti-icing applications worked well when pavement temperatures were dropping below freezing.

Environmental

- Adhesion of liquids to the roadway compared with the bounce/scatter of rock salt results in less wasted chlorides.
- Liquid requires more frequent application as compared to rock salt, which takes longer to form a brine but also lasts longer as a melting agent.
- The additional applications and truck passes required for DLA compared with rock salt consumes more fossil fuels.

Staffing

- Adjustment to using liquid on the routes varied by location. As staff gained experience from one season to the next, there were fewer issues with using liquid on the routes.

- Some staff turnover showed the need for ongoing training and new training each season.
- The commitment of the operators was key to the success of the pilot project. “They want to make it work.”
- Due to the need for more frequent application of DLA to achieve at least the same level of service compared to traditional rock salt routes, staffing hours may need to be adjusted accordingly.

Final Operational Assessment and Observations

With the submission of final data for Season 2025 by the three pilot route locations, site participants were given a survey of nine questions asking their views of the DLA method with ABP based on their experiences in the multi-year pilot study. The survey was to be filled out by one person representing the maintenance operations team at that location. The responses to these questions are summarized below.

Overall Evaluation

All three pilot locations agreed that the study increased their familiarity with DLA combined with ABP, but there was not full agreement regarding benefits to their operations. Two locations, Montcalm and Mt. Pleasant, concluded that DLA with ABP is a viable tool for winter maintenance for the right weather conditions. Grand Ledge currently has no plans to continue use of DLA with ABP, indicating that liquid was generally inferior to rock salt.

Uses of DLA with ABP

All three locations agreed that liquids work well for pre-treating salt. Montcalm and Mt. Pleasant also found liquids work well for anti-icing and deicing, with Mt. Pleasant offering that their effectiveness can depend on the weather and road conditions.

Material Preference

When asked to rank their preferences for materials to treat winter roads, all three locations indicated pre-wet rock salt as their first choice; Mt. Pleasant and Grand Ledge listed dry rock salt as their second choice. Montcalm identified Beet Heet or CS-26 as its second choice. Mineral well brine with no added ABP was the third preference for Montcalm and Mt. Pleasant, and the fourth preference for Grand Ledge.

Despite the higher ranking of pre-wet rock salt over ABP-enhanced mixtures, Montcalm and Mt. Pleasant both indicated their preference for ABPs (Beet Heet and Deice Master+, respectively) in colder temperatures due to better performance. Grand Ledge noted that ABP products keep pre-treatment in place, but when applied to snow the mixture thickens and becomes difficult to remove.

Environmental Impact

Montcalm answered positively when asked about environmental benefits to liquids versus rock salt for winter road maintenance. Mt. Pleasant and Grand Ledge indicated the need for further evaluation of the question to make a valid determination. They pointed to the required application of more liquid to keep roads clear. Noting that chemicals enter the environment in both methods, Grand Ledge also cited the varying percentages of chloride in different liquid products.

Limitations of DLA

All three pilot locations raised the issue of cost in addressing the limitations of DLA. Although Montcalm referenced that cost savings may be possible in some instances, it identified cost as a general challenge. In addition to the cost of the ABP products themselves, Mt. Pleasant and Grand Ledge also identified the costs associated with acquiring or retrofitting the necessary equipment and the storage facilities.

Complete survey responses are presented in Table 5.14.

Table 5.14. End of Pilot Survey Results

Questions	Montcalm County	Mt. Pleasant	Grand Ledge
1. Do you feel the liquid pilot was successful?	Yes.	Yes, learning to use ABPs with MWB.	
1a. What did you learn by participating in the effort?	Same results as salt, in some instances with cost savings. Better at colder temperatures.	Blended 75% MWB and 25% ABP for good results and cost savings. Two 20,000-gallon frac tanks plus 20,000 tanks from salt shed helped to move available liquid.	Use of liquids, pros and cons
1b. How has your opinion of direct liquid application changed since beginning the pilot?	Positively, another tool for winter maintenance.	Have previously used MWB; would favor Deice Master+ for colder temperatures.	Less cost effective due to small scale use; less benefit than for states without 24/7 storm operations.
2. Do you plan to continue using liquid mostly applications after the pilot?	Yes.	Yes.	No.
2a. What are your plans for liquid equipment after pilot is completed?	Continue with liquid truck, expand in other areas.	Will continue using it for both trucks.	Not sure.
3. Do you wish to invest more in liquid applications?	No, the system works well for our needs; we will build a new truck to replace current.	Not at this time.	

Questions	Montcalm County	Mt. Pleasant	Grand Ledge
a. Additional tank trucks, brine makers, tank farms?	No, the system works well for our needs; we will build a new truck to replace current.	Did request a tanker truck, but not available now.	
3b. What challenges do you anticipate for liquid mostly expansion?	Challenge will be keeping enough product on hand and reordering.	Cost of product, storage, additional retrofitted trucks, product availability. Liquid mostly is not a "one size fits all" solution.	Cost for equipment and storage for liquids
4. Do you feel liquids work well for: a. Pre-treating salt b. Anti-icing c. Deicing d. All of the above e. None of the above	All of the above.	a. Pre-treating salt: yes. b. Anti-icing: yes, depends on storm and humidity. c. Deicing: depends on temperature, presence of ice, other factors.	a. Pre-treating salt
5. Based on your experience, please rank your material preference for treating routes: a. Dry rock salt b. Pre-wet rock salt c. Mineral well brine with no ABP d. BOOST (chloride w/ABP) e. Deice Master+ (MWB w/Iceban) f. Beet Heet or CS-26 (chloride w/ABP)	1. Pre-wet rock salt 2. Beet Heet or CS-26 3. Mineral well brine no ABP 4. Deice Master+	1. Pre-wet rock salt 2. Dry rock salt 3. Mineral well brine no ABP 4. Deice Master+ 5. Beet Heet or CS-26 6. BOOST	1. Pre-wet Rock Salt 2. Dry rock salt 3. Beet Heet or CS-26 4. Mineral well brine no ABP 5. BOOST 6. Deice Master+
6. What impacts do Agricultural Byproducts (ABP) offer to snow and ice operations (pros and cons)?	Pros: treatment at lower temperatures/ longevity. Cons: price.	Pros: colder temperature; less scatter, concentration more direct on the road. Cons: price; keep the product mixed once a week; does not store well over the summer; hard to clear off windshield for motorists.	Pros: keeps pre-treatment in place Cons: when applied to snow, causes it to thicken, difficult to blade off.
7. Do you feel all ABP liquids performed the same?	No.	No.	No significant difference.
7a. If not, which ABP worked better and why?	Beet Heet for colder temperatures, longevity.	Preference for Deice Master+ for colder temperatures.	

Questions	Montcalm County	Mt. Pleasant	Grand Ledge
8. Do you think there are environmental benefits to using liquids versus rock salt?	Yes.	Still to be determined. It takes more liquids versus rock salt, but depends on amount used for an event.	Unclear. It still enters waterways, needs more applications, and chloride levels differ by product.
9. Please provide additional insights regarding pilot and direct liquid applications, not already covered.	<p>FY25 deiced 33 times, very satisfied with results, especially less than 2" of snow, colder temp.</p> <p>Nine anti-ice applications, "great" results, no overtime needed for a couple of events because it prevented ice from bonding to the road.</p>	<p>75% MSB/25% CS-26 blend worked well as a deicer, but did not last as long as rock salt, so required more frequent application.</p> <p>Liquid used for anti-icing several times, giving more time to call in the staff.</p>	<p>Liquid application had a one hour working time on average, so almost continuous treatment was required to keep clear. Pretreatment only delayed accumulation by one hour, not seen as an advantage.</p> <p>Liquid was generally inferior to rock salt.</p>

6. Conclusions and Recommendations for Potential Best Practices

Conclusions from the Study

The following conclusions take into consideration both the analytical data and qualitative assessments provided by staff involved in this pilot study.

Operational

Change is difficult, and time to implement change is limited. Commitment by field staff managers and operators is critical for the successful deployment of any new product or technology. This proved to be true for ABPs for DLA. The desire to succeed is needed from all parties in order to work through technical challenges when implementing ABPs for DLA.

Efficacy of ABPs for DLA

From a technical standpoint, ABPs were effectively incorporated into the overall winter deicing and anti-icing program. It is noted, however, that there are no vendors providing 100 percent ABPs as a standalone product. Vendor products include chlorides for the resulting brine to be effective for melting ice. Mixes in this study ranged from 5% to 15% ABP. Operators reported that further decreasing the levels of ABP carbohydrates by further blending with additional brine did not decrease effectiveness.

As the literature indicated and this study also demonstrated, the carbohydrates in ABPs appear to assist the chlorides with melting, especially at lower temperatures. Yet applying brines with ABPs at warmer (near-freezing) temperatures can be detrimental, creating a sticky, slippery mixture that impedes traction.

This study also demonstrated that there is an optimal time and place for DLA, but there are storm events where liquid deicing and anti-icing—with or without ABPs—will not be sufficient or the best choice. For example, during very wet winter events, precipitation may wash liquids off the road before they can take effect. Alternatively, in blowing snow conditions, prewet roads might cause snow to stick to the pavement where it might otherwise be blown off. Practitioners are advised to draw from experience and printed guidance to determine when to use DLA.

Cost of ABPs

This pilot study was an effective way to help uncover the true costs of using ABPs in Michigan. As with other studies of this type, the first years of this multiyear study required special attention to startup and related “growing pains” of trying a new technology or practice: identifying chemical suppliers; contracting for and acquiring chemicals; identifying or acquiring chemical storage; acquiring or adapting chemical spreading equipment; operator training;

maintenance staff training and troubleshooting. All of these come with associated costs, whether direct or indirect.

However, by the final season of the study the three locations had well-established practices for using ABPs and other liquid chemicals of interest, and it became possible to understand the costs of using these chemicals. Key price data are shown in Figure 6.1.

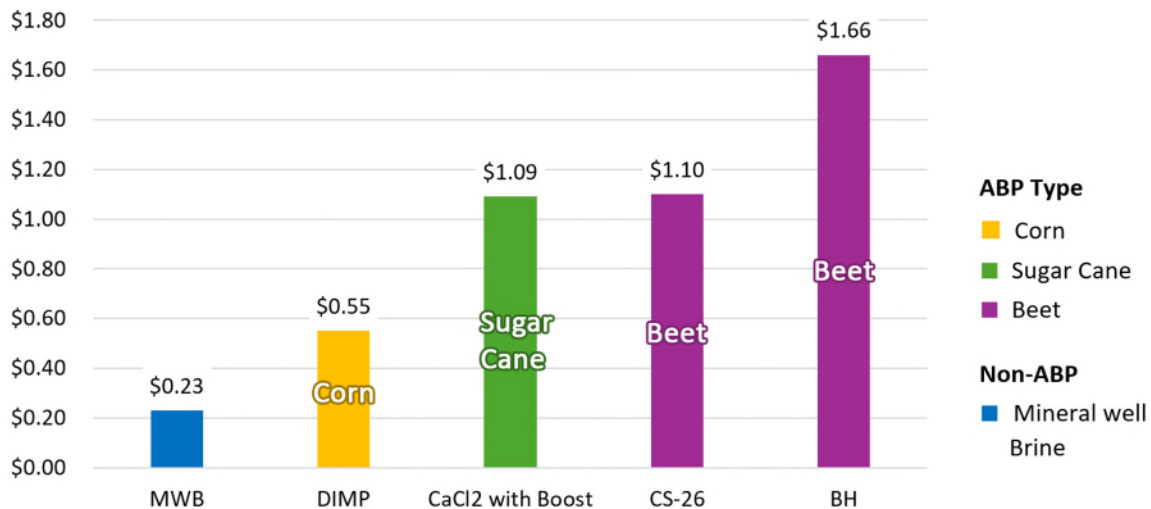


Figure 6.1. Cost Per Gallon of Chemicals Studied

The costs of ABP liquids are high: DIMP is almost two-and-a-half times the cost of mineral well brine, and BH is more than seven times the cost of MWB. These numbers make it challenging to construct a business case for using ABPs.

Added to this are the storage and equipment costs discussed in Chapter 5—upwards of \$100 million to provide for liquid storage statewide, and almost \$300,000 for every added DLA truck. This is a barrier to complete statewide implementation of DLA, with or without ABPs.

Environmental Impact of Salt Use

The use of ABPs for DLA resulted in a significant decrease in chloride impact by the end of the study. However, in this study, the realities of clearing winter roads required that rock salt be used on the pilot routes some of the time. DLA—with or without ABPs—is not a sufficient tool on its own to keep Michigan’s roads clear of snow and ice in heavy winters. Rock salt remains a necessary tool.

Recommendations for Further Research

No additional research is recommended at this time.

Recommendations for Implementation

The primary goal for winter operations is to keep roads safe by preventing snow and ice from bonding to the pavement. This study showed that ABPs can be helpful with DLA operations to keep roads clear under certain conditions, but they are very expensive, particularly the beet-based ABPs, compared with ABP-free chloride brines. MDOT will continue to promote the use of liquid ABPs to treat rock salt for more efficient salt applications. MDOT also practices and advocates for “sensible salting,” which means placing the right amount of material at the right time to eliminate waste.

The least costly and most environmentally friendly way to clear roads is to mechanically remove the snow and ice with plows. Sensible salting and the right use of ABPs—the right amount in the right conditions—can assist with plowing operations.

Due to the cost of ABPs, MDOT does not recommend statewide implementation at this time.

Region offices or county and municipal agencies interested in using ABPs should:

- Reach out to MDOT Central Office as a resource for trying DLA with ABPs.
- Seek operational guidance from the maintenance field offices involved in this study.
- Identify the best locales where ABPs can do the most good.

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