PHOTO: CLEAR ROADS

Snow States Pool Funds to Solve Winter Maintenance Challenges

Clear Roads Research Produces Immediate, Practical Applications

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Every winter, transportation agencies face the enormous logistical challenge of clearing ice and snow to keep roads passable and safe for the traveling public. At the heart of the effort is technology—long gone are the days of horse-drawn snowplows, invented in the 1800s. Agencies today maintain fleets of winter maintenance vehicles equipped with a variety of technologies, from carbide plow blades to sophisticated computer systems that precisely determine the application rates of laboratory-formulated deicing chemicals.

By the early 2000s, states were making great progress in upgrading winter maintenance programs. In 1994 and 1998, international scans on winter maintenance practices had explored new equipment, technologies, and practices not yet used in the United States.[1] States were applying improved methods of weather forecasting in their maintenance deci-

[1] http://onlinepubs.trb.org/onlinepubs/circulars/ec013/1BSmithson.pdf.

(*Above:*) Since 2004, Clear Roads has focused on evaluating winter maintenance equipment and materials in the laboratory and on the field. Snow removal technology has progressed since 1908 (*below*), when teams of horses pulled snowplows down Chicago roads.

PHOTO: CHICAGO DAILY NEWS NEGATIVES COLLECTION, CHICAGO HISTORY MUSEUM

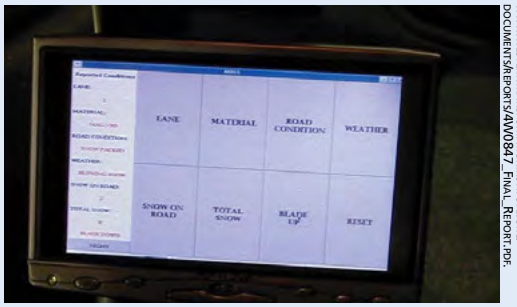
sion support systems, to target responses to weather-related road conditions.

A concept snowplow vehicle developed in the 1990s provided the foundation for the use of the Global Positioning System (GPS), automatic vehicle location systems, and other sensors to optimize snowplow operations. States also made advances in the chemistry of deicing materials, operator training, and other methods for improving the efficiency and environmental friendliness of winter maintenance (see *TR News*, November–December 2009[2]).

[2] www.trb.org/Publications/Blurbs/162781.aspx.

Developing Interface Specifications for Mobile Data Platforms

Many winter maintenance fleets use intelligent systems that allow control centers to track the location, health, and use of vehicles. The systems rely on the Global Positioning System (GPS), as well as on sensors that record plow usage, the application of salt or other deicing materials, the pavement temperature, the oil pressure, and other aspects of the vehicle's health.



WWW.WESTERNTRANSPORTATIONINSTITUTE.ORG/DOCUMENTS/REPORTS/4WV0847_FINAL_REPORT.PDF.

Touch screen device in a snowplow cab; compatibility between the complex technologies on winter maintenance vehicles can be a challenge.

Integrating these control and monitoring systems has raised problems, often because vendors use proprietary communication protocols and data formats. Collecting data from different vendors' components into a single database can be difficult. As a result, most maintenance fleets use a single-vendor system, but this approach can limit upgrades to components and may require investing in an entirely new system when the vendor cannot provide the needed technology.

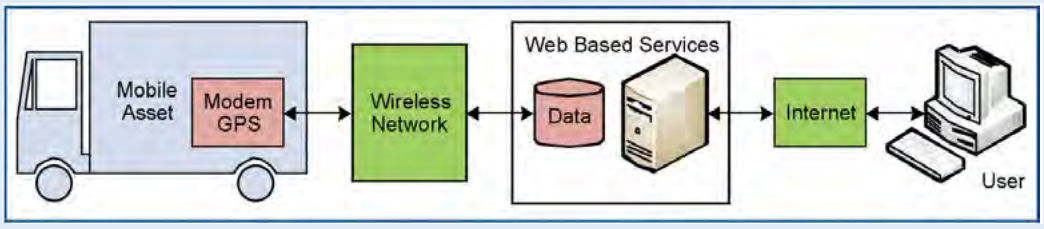
"State DOTs operate under a low-bid procurement process—a fleet easily can end up with 15 different kinds of controllers," observes Clear Roads Chair Dave Wieder. "The controllers need to be able to talk to each other and to work with newly purchased trucks."

A 2010 Clear Roads project has developed specifications for integrating sensors and other mobile data devices into a single system.[a] The proposed mobile data platform includes two types of wireless connectivity—wi-fi and cellular—and integrates GPS data with data from other sensors. These data can be sent in real time to a database for display via a web-based interface.

The specifications will simplify the process of adding new components to vehicles, ensuring competition among equipment vendors, and allowing users to build on their equipment inventories. The specifications also will reduce the costs of developing and maintaining a mobile data platform.

A follow-up Clear Roads project will develop testing software for approving plug-and-play technologies. "We're working toward equipment that interfaces seamlessly," Wieder reports. "Industry has listened and is working with us to make this a reality."

[a] http://clearroads.org/research-projects/08-02interface specifications.html.



A mobile data platform and data collection system includes an on-board modem and GPS unit and exports data from the vehicle's sensors via a wireless network to a database with a web-based interface.

Clear Roads focuses on practical outcomes, such as optimizing the rate at which salt and other deicing materials are applied to roads by winter maintenance vehicles.

Evaluating Technologies

But the advances in winter maintenance technologies and operations increased the challenge of evaluating effectiveness. How can a transportation agency know that the latest innovation proposed by a vendor or a researcher is actually an improvement?

With national and state winter maintenance organizations focusing research funds on the laboratory testing of materials and equipment, field research was needed to evaluate performance under conditions typically encountered by state DOTs.

Dennis Burkheimer, then winter operations administrator at the Iowa Department of Transportation (DOT), recognized this need and spearheaded the formation of an annual winter maintenance workshop in the Midwest in the early 2000s. The workshop served as a roundtable peer exchange for discussing successful technologies and practices.

In 2004, workshop participants decided to initiate a formal collaborative research effort under the Federal Highway Administration's (FHWA's) Transportation Pooled-Fund Program, establishing the Clear Roads Test and Evaluation of Materials, Equipment, and Methods for Winter Highway Maintenance.[3] Initial participants included Wisconsin as the lead state, Iowa, and Minnesota; Missouri and Indiana joined in 2005.

"Our interest was in testing equipment and materials in winter weather conditions, not just in the laboratory," notes Tom Martinelli, former winter maintenance engineer at Wisconsin DOT and the first chair of Clear Roads. "No one else was doing that."

The pooled-fund study grew significantly in the next six years, and members sought to expand the scope to include technology transfer and training. In 2010, the participating states reestablished the study as the Clear Roads Winter Highway Operations Pooled Fund.[4] The membership comprised 14 states, and Minnesota assumed the lead responsibilities. The focus is on practical outcomes, such as optimizing the rate at which winter maintenance vehicles apply salt and other deicing materials to roads.

"There was a need for research with immediate, practical applications," observes Dave Wieder, branch manager of maintenance and operations for Colorado DOT and current chair of Clear Roads. "How do you calibrate ground-speed-control spreaders to regulate deicing materials output? What is the best plow blade design?"

According to Martinelli, vendors were proposing alternatives to salt for deicing in the early 2000s, but uncertainty prevailed about the benefits in comparison with the costs. "Test procedures were needed to compare products, so that we wouldn't have to take the vendor's word on effectiveness," he explains.

Leveraging Research Dollars

Clear Roads leverages the contributions of its members—$25,000 a year—to fund research that states cannot afford on their own. "At Colorado DOT, our entire research budget is around $400,000 for six programs," Wieder explains. "We can't afford the kind of research possible through Clear Roads. Our $25,000 contribution gains more than $600,000 of winter maintenance research."

[3] TPF-5(092); www.pooledfund.org/Details/Study/317.

[4] TPF-5(218); www.pooledfund.org/Details/Study/446.

Calibration Accuracy of Ground-Speed-Control Spreaders

Transportation agencies are careful about controlling the amounts of salt, abrasives, and other chemicals applied to roads in winter. These materials have important benefits for safety but in excess can harm the environment and accelerate metal corrosion in vehicles and highway infrastructure. Overuse also leads to unnecessary expenditures from already overburdened winter maintenance budgets.

To regulate the delivery of treatments, the spreading systems on winter maintenance vehicles commonly are equipped with ground-speed controllers. This technology monitors the vehicle speed and automatically adjusts the rate of materials delivery to apply only the necessary amount. Before the development of controllers in the 1990s, truck operators used manual controls to adjust the delivery rate of salt or other materials.

How precise are these automated controllers, and do they perform better than manually controlled spreaders? Will a controller-equipped truck apply the same amount of salt per lane mile at 10 mph as at 45 mph?

In a 2008 Clear Roads project, researchers compared manual controllers against two types of ground-speed controller: open-loop systems, which monitor truck speed during operation, and closed-loop systems, which monitor both truck speed and spreader discharge and adjust the spreader speed accordingly.[a] Most of the seven controllers in the test could distribute solid materials, such as salt and sand, as well as liquid materials, such as brine.

A ground-speed controller in calibration mode.

The researchers reviewed DOT practices nationwide, calibrated controllers with the assistance of manufacturers, and conducted field tests to compare the intended to the actual discharge amounts of solid and liquid materials at a range of vehicle speeds and material application rates.

Results showed that automatic controller systems were superior to manual systems. Moreover, the study found that closed-loop systems can yield as much as 47 percent in materials savings at an application rate of 400 pounds of salt per mile. Closed-loop systems were much more accurate than open-loop systems, as expected, and the greatest savings were achieved in the stop-and-go conditions typical of urban environments.

The project also produced valuable hands-on calibration experience and led to the development of a spreader calibration guide,[b] including step-by-step procedures and checklists.

[a] www.clearroads.org/research-projects/05-02calibration.html.

[b] http://clearroads.org/research-projects/05-02calibration_files/Final-Calibration-Guide-02-09.pdf.

The Clear Roads goals have expanded into technology transfer, including a training video on the testing of deicing materials.[5]

Clear Roads also helps states avoid duplication of effort by producing solutions that take every state's needs into account and that influence the private sector. "Vendors will listen when 26 states ask for a solution," notes Mark DeVries, superintendent of the Division of Transportation for McHenry County in Illinois and liaison to Clear Roads for the American Public Works Association (APWA).

Each year, at a spring biannual meeting, members of the Clear Roads Technical Advisory Committee (TAC) submit research ideas for funding consideration. TAC members then vote to select five or six of the projects for funding; formal requests for proposals are developed for each project.

At the fall meeting, TAC members review the competing proposals and choose investigators to perform the projects. The TAC subsequently monitors the progress and ultimately approves the final reports and other deliverables.

Minnesota DOT, as the pooled fund's lead state agency, administers the contract agreements. The consultant firm CTC & Associates LLC provides administrative support for the research projects and for the TAC meetings, as well as technical communication services, including the study website, www.clearroads.org.

Rapid Growth

The goals of Clear Roads have expanded into technology transfer, including a training video on the testing of deicing materials.[5] In nine years, Clear Roads has grown from four to 26 members.

"More states are realizing that Clear Roads' work is offering solutions to day-to-day problems," says Lee Smithson, former deputy director of maintenance for Iowa DOT and liaison to Clear Roads for AASHTO's Snow and Ice Pooled-Fund Cooperative Program (SICOP). "States are interested in becoming part of the decision-making process for identifying research needs."

[5] www.youtube.com/watch?v=cIPTRCXRBDM.

As Clear Roads has grown and completed more projects, technology transfer efforts have become an important part of its mission. For instance, after developing a field testing guide for deicing chemicals, Clear Roads produced a related video for DOTs to use in training maintenance staff.[6]

This growth has also led to the logistical challenges of collaboration among a large group, and Clear Roads recently updated its operational procedures to accommodate the increasing number of participants. But this growth has made information exchange even more valuable; the Clear Roads distribution list serves as a resource on state winter maintenance practices.

"States can turn to members on various issues, from legislation to products," reports Tom Peters, maintenance research and training engineer for Minnesota DOT. "The pooled fund has improved communication among snow and ice states and between practitioners and decision makers."

Project Impacts

Clear Roads has completed 14 research projects, with seven more in progress and six to begin soon (see sidebar, page 8). These projects have produced practical solutions to common problems faced by snow and ice states. For example, an emerging technique, the direct application of liquid deicers during storms, had little field testing before a Clear Roads project.

One project developed a web-based analysis tool to help state maintenance managers calculate the benefit-to-cost ratio of selected winter maintenance technologies, including equipment, such as carbide blades, plows, and spreaders; deicing and anti-icing practices; and various systems critical to operations. With this toolkit, Iowa DOT determined that GPS on snowplows would yield a benefit-to-cost ratio as high as 10 to 1, saving millions of dollars. The project's recently completed second phase increases the number of winter maintenance materials, equipment types, and methods that can be analyzed.

A 2010 project identified the most effective methods and circumstances for the use of liquid deicers during winter storms, identifying pavement temperature, storm intensity, and storm moisture content as critical parameters. Applying the quick-reference guide and field testing guidelines, state DOTs are expanding the use of liquid deicers to save costs and reduce the environmental impacts.

Another project developed testing procedures to predict the performance of carbide inserts for snowplow blades. Many agencies found that the blades were wearing down quickly, requiring costly replace-

[6] www.clearroads.org/research-projects/10-01training-video.html.

Winter Safety Campaign Targets High-Risk Drivers

Winter weather can create hazardous road conditions. Many winter-weather crashes are preventable, however, if drivers are aware of the road conditions and develop the kinds of driving habits that winter weather requires.

Winter weather driving safety campaigns therefore are a key component of state and local transportation agencies' strategies for public safety. Yet the budget constraints of individual agencies often have limited the scope of safety campaigns.

Clear Roads member states decided to leverage their combined resources to create a professional campaign with a unified message targeting the most critical audience via the most effective formats. The Winter Driver Safety Campaign developed the now well-known slogan, "Ice and Snow … Take It Slow," along with a range of campaign materials that state and local agencies can customize for their winter safety programs.[a] Materials include logos, posters, videos, public safety announcements, flyers, and bumper stickers.

In 2010, Clear Roads conducted a follow-up effort to refine the campaign by learning about and targeting the high-risk drivers who would benefit the most from the message. Researchers analyzed highway crash data to identify the high-risk drivers typically involved in winter-related crashes and conducted an online survey of these drivers to evaluate the effectiveness of various message types.

From the findings, the researchers developed new campaign materials that built on the previous "Ice and Snow … Take It Slow" campaign. Also provided was guidance for the effective use of the new materials, including two Internet banner ads and a TV ad for use on air or on the weather-related pages of a local TV station's website in 30-, 15-, and 7-second segments.

The products from the project help transportation agencies make the most effective use of limited resources by customizing materials without having to develop original campaigns. Agencies also communicate and share the goal of reducing winter-related crashes, injuries, and deaths.

"These materials are more than we could have afforded on our budget in Colorado," notes Clear Roads Chair Dave Wieder. "Nearly every snow and ice state is using these materials to help increase the safety of the traveling public."

[a] www.clearroads.org/driver-safety-resources.html.

Analysis of crash data showed that failure to control speed was one of the leading causes of winter-related crashes.

Directly applying liquid deicers during storms is an emerging technique that had received limited field testing before a Clear Roads project.

ment. The standardized testing procedures have helped states purchase higher-performing blades and save on replacement costs.

"States spend a lot of money on snowplow blades," DeVries reports. "This project helped answer questions about which blades last longer and do a better job. The project results were implementable almost immediately."

Partnerships

Other organizations also conduct winter maintenance research, and memberships often overlap. To

The Clear Roads Project Portfolio

Research in Progress[a]

◆ Establishing Effective Salt and Anti-Icing Application Rates will update national guidelines for snow and ice control materials and methods.

◆ Understanding the Chemical and Mechanical Performance of Snow and Ice Control Agents on Porous or Permeable Pavements will determine optimal winter maintenance strategies for porous or permeable asphalt pavements.

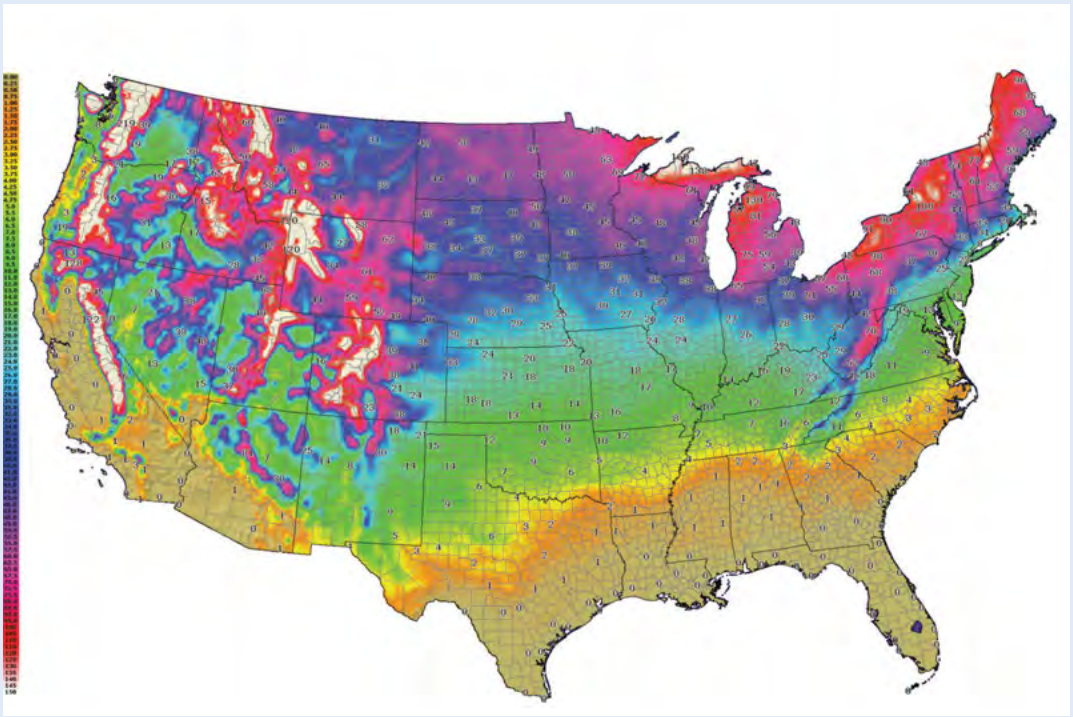
◆ Comparison of Materials Distribution Systems will catalogue and develop a field testing plan for solid materials distribution systems.

◆ Environmental Factors Causing Fatigue in Snowplow Operators will develop a series of cost-effective, realistic recommendations for reducing or eliminating equipment operator fatigue during winter operations.

◆ Determining the Toxicity of Deicing Materials will develop a quick-reference guide to the toxicity of deicing chemicals in several categories.

◆ Development of a Totally Automated Spreading System will evaluate the feasibility of a system for automatically dispensing deicing materials.

◆ Understanding the True Costs of Snow and Ice Control Operations will develop a tool to help winter highway professionals estimate costs for snow and ice removal, make cost comparisons with states that have similar climates and roadways, and consider new budget scenarios based on the successes of other agencies.



A recently completed project mapped the relative severity of winter weather across the United States; the results will facilitate understanding of each agency's snow and ice control costs. (Map generated by Meridian Environmental Technology for Clear Roads.)

avoid duplicating efforts, these organizations coordinate tasks and focus on different missions:

◆ The Aurora Pooled Fund Study aims at improving road and weather information systems,[7]

◆ The Winter Maintenance Committee of the Transportation Research Board (TRB) explores a range of winter maintenance research topics,[8] and

◆ AASHTO's SICOP identifies and evaluates the latest winter maintenance technologies, domestic and international.

Clear Roads complements these efforts by focusing on immediately implementable, short-term field testing. "In some cases, SICOP and TRB will give us an idea of what research needs to be pursued," Wieder reports. "In other cases, they conduct larger research projects that are outside our scope."

Through its collaboration with Clear Roads, Aurora gains insights into the kinds of data that road

[7] www.aurora-program.org/knowledgebase/Winter%20Operations.Default.aspx.

[8] www.trb.org/CommitteeandPanels/OnlineDirectory.aspx#DetailsType=Committee&ID=1593.

Completed Projects

◆ Cost–Benefit Analysis Toolkit, Phase II, expanded a previously developed toolkit for analyzing and justifying materials and equipment costs.

◆ Snow Removal at Extreme Temperatures reviewed best management practices for maintaining clear roads at extremely low temperatures.

◆ Mapping Weather Severity Zones developed a method for mapping winter weather severity across regions and states.

◆ Developing a Training Video for Field Testing of Deicing Materials produced an instructional video to demonstrate the three levels of field testing that determine the effectiveness of deicing chemicals.

◆ Development of a Toolkit for Cost–Benefit Analysis of Specific Winter Maintenance Practices, Equipment, and Operations produced a web-based tool for cost–benefit analyses of the components of winter maintenance programs.

◆ Identifying the Parameters for Effective Implementation of Liquid-Only Plow Routes described the circumstances and the most effective methods for using liquid deicing during winter storms.

◆ Development of Standardized Test Procedures for Carbide Insert Snowplow Blade Wear produced testing procedures to predict the performance of snowplow blade carbide inserts.

◆ Correlating Lab Testing and Field Performance for Deicing and Anti-Icing Chemicals, Phase I, laid the groundwork for developing a laboratory test to evaluate the performance and friction coefficient of deicing chemicals.

◆ Development of Interface Specifications for Mobile Data Platforms on DOT Vehicles determined specifications for plug-and-play integration of sensors and other devices with mobile platforms into DOT vehicles (see sidebar, page 4).

◆ Development of Standardized Test Procedures for Evaluating Deicing Chemicals established laboratory tests and procedures to identify the relative performance of deicers.

Snowplow operators often must work long shifts, and fatigue is a safety concern for transportation agencies. A Clear Roads research project is under way.

◆ Developing and Evaluating Safe Winter Driving Messages produced winter driving safety public service announcements and web advertisements targeting high-risk drivers (see sidebar, page 7).

◆ Determining Effectiveness of Deicing Materials and Procedures developed testing guidelines for evaluating the performance of various winter road chemicals.

◆ Calibration Accuracy of Manual and Ground-Speed-Control Spreaders developed guidelines to help snowplow operators establish and maintain accurate calibration of ground-speed controllers, reducing salt usage and improving efficiency (see sidebar, page 6).

◆ Synthesis of Best Practices for Eliminating Fogging and Icing on Winter Maintenance Vehicles conducted a comprehensive survey that identified effective methods for combating or preventing moisture on windows and mirrors while maintaining the comfort and safety of the plow operator.

[a] For links to full project descriptions, go to www.clearroads.org/research-projects.html.

A Clear Roads partner organization, the Pacific Northwest Snowfighters Association, is at the forefront of laboratory testing of deicing materials.

and weather information systems could collect that would be useful to winter maintenance programs. "The back-and-forth with the other groups makes for an effective balance," Smithson observes.

For example, input from APWA's Subcommittee on Winter Maintenance[9] provides Clear Roads with a practical city and county perspective on winter maintenance technology needs. "Local agencies often can try out new technologies and practices more easily than state DOTs, offering experience useful to Clear Roads," notes DeVries.

Interface with FHWA ensures a higher-level perspective for Clear Roads. "Keeping a clear line of communication between our agency and Clear Roads is helpful to both organizations," reports FHWA liaison Gabe Guevara.

Productive Collaborations

Clear Roads has engaged in productive collaborations with partner organizations. These efforts include:

◆ Maintaining materials testing and standards for deicing chemicals in support of the Pacific Northwest Snowfighters' widely used Qualified Product List;[10]

◆ With Aurora, developing a Wiki-style knowledge base for road weather and winter operations research and innovations,[11] to capture information—such as surveys of the salt specifications of member states—often not available in academic studies; and

◆ With SICOP, developing computer-based training modules for snowplow drivers and maintenance crews.[12]

[9] www.apwa.net/technical_committees/Transportation-Committee/Subcommittees/Winter-Maintenance.
[10] http://pnsassociation.org/.
[11] www.aurora-program.org/knowledgebase/Winter%20Operations.Default.aspx.
[12] http://sicop.transportation.org/Documents/CBT_Flyer_v2b[1].pdf.

Clear Roads also collaborates with SICOP and Aurora to organize the National Winter Maintenance Peer Exchange every two years to discuss winter maintenance research needs and innovations with all snow and ice states.[13]

Moving Forward

Research in progress by Clear Roads is addressing needs from updating National Cooperative Highway Research Program guidelines for snow and ice control materials and methods to the development of a totally automated spreader system (see sidebar, page 6).

Of particular note is a project to develop recommendations for reducing the fatigue of snowplow operators.[14] Researchers are currently surveying DOT management personnel and snowplow operators and are instrumenting operators to collect fatigue-related information. "Fatigue is a significant problem that needs a proactive solution," states Peters.

Another project is determining the toxicity of deicing chemicals. "Our watershed is small in Colorado," Wieder explains. "We have to be sure that the chemicals will not negatively affect the environment."

Upcoming projects include the development of a manual on environmental best management practices in snow and ice control, research into the effectiveness and environmental impacts of nonchloride liquid agricultural by-products in deicing, and establishing best practices to prevent the corrosion of DOT equipment from deicing chlorides. These projects continue the Clear Roads mission of providing practical solutions that can be implemented quickly and that are environment friendly.

"The emphasis at the federal level is on performance measures and environmental sustainability," Smithson observes. "Clear Roads is headed in this direction, working to determine what kinds of practices and equipment are necessary." With continued growth, Clear Roads can meet these goals with increasing effectiveness.

"My hope is that states that are not members will get involved in Clear Roads," Wieder notes. "The buying power of all snow and ice states can support research that benefits not only the maintenance personnel working tirelessly to keep us safe, but also the traveling public that must get from point A to point B in winter weather."

[13] www.westerntransportationinstitute.org/professional development/national-winter-maintenance-peer-exchange.
[14] www.clearroads.org/research-projects/11-05 environmental-factors.html.

PHOTO: IDAHO DOT

The environmental effects of anti-icing and deicing practices are a major concern for state DOTs.