1. Treatment Management Strategies

Instructor Notes: This module is the fourth part of a lesson that discusses Road Weather Impacts and Management Strategies. This presentation describes the treatment management strategies utilized by the transportation community. This presentation should take approximately 25 minutes.

Student Notes:

2. Learning Objective

Instructor Notes: There is one learning objective for this lesson: 1. Describe the techniques currently available for maintenance crews can use to treat roadways and mitigate the impact of a significant weather event.

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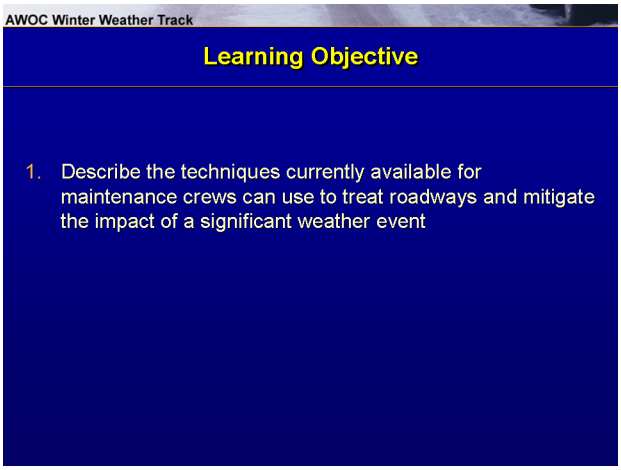

3. Description of Treatment Strategies

Instructor Notes: The third (and likely most familiar) set of techniques that can help mitigate the impacts of adverse weather are treatment management strategies. [CLICK] These strategies are generally implemented by maintenance departments and have direct impacts on increasing mobility and public safety. [CLICK] These strategies work by supplying resources to roads that minimize or eliminate weather impacts by improving pavement traction and clearing road surfaces of snow and ice. While it isn't the role of NWS forecasters to recommend specific treatment strategies to DOTs, it is important that forecasters understand the complexities of these strategies and how weather variables impact their implementation. Treatment management strategies are used primarily during winter weather events to clear off road surfaces. The goal is to improve the level-of-service (LOS) of roadways, or otherwise improve driving conditions, on a particular road segment in that maintenance department's area of responsibility. [CLICK] Treatment strategy techniques generally use similar technology and planning in most parts of the country. How implementation varies will depend primarily on the local resources available (e.g., number of plows and spreader trucks, types of chemicals used).

Student Notes:

4. How They Work & When They're Effective

Instructor Notes: During winter weather events, it is often necessary to apply chemical treatments to road surfaces. These chemicals work to lower the freezing point of water so that falling precipitation (or snow and ice already on the ground) will either melt or not freeze after reaching the ground. [CLICK] These chemicals can be applied dry, "pre-wetted", or as a liquid solution (or brine). These treatments are only effective once they dissolve and mix with the snow, ice, or liquid present. While this step is necessary, it is not the only way to judge a chemical's effectiveness. In fact, treatment effectiveness depends on many factors. Some factors are scientific, some economic, and others are societal in nature. [CLICK] The three most significant factors are often the chemical's cost, the road surface temperature, and the concentration of the chemical used because it impacts the eutectic temperature. For those of you who do not remember eutectic tem-

perature, or don't recognize the equilibrium phase diagram shown, the next slide provides a quick refresher.

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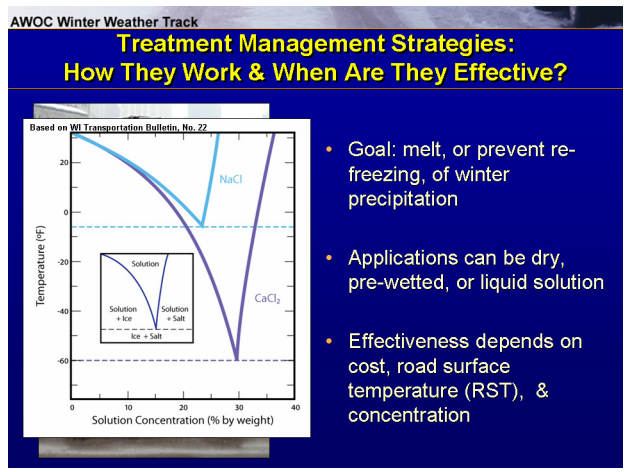

5. Theoretical vs. Actual Effective Temps

Instructor Notes: Equilibrium phase diagrams show how the freezing temperature of a solvent, in this case water, changes as you increase the concentration of a substrate in a solution. For each substrate, or chemical, there is a two-sided curve. [CLICK] The left-side of the curve shows how the freezing point, or eutectic temperature, decreases as the concentration increases. [CLICK] The bottom of the curve is the lowest point you can reduce the freezing point, or eutectic point, of the solvent for that chemical solution. After that point, the right-side of the curve becomes significant. [CLICK] The right-side of the curve shows the saturation curve for your solution. In other words, any point to the right of the curve indicates that you have excess substrate in your solution that cannot dissolve. Over use of treatment chemical can cause corrosion to metal structures and vehicles near roadways, among other problems. [CLICK] The job of maintenance crews is to apply enough chemical to reduce the eutectic temperature below the forecast road surface temperatures while at the same time not use so much that excess material remains on the road surface and never dissolves (or is wasted). [CLICK] In reality, the point where a chemical stops being effective for road treatment is often well above the eutectic point.

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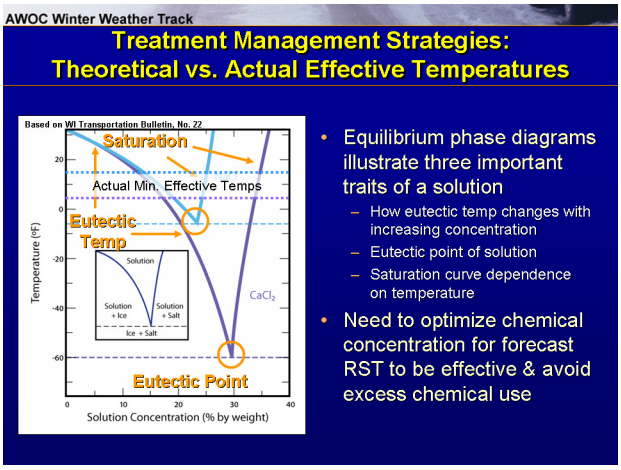

6. Common Chemical Treatments

Instructor Notes: There are five chemicals that are primarily used in the U.S. for road treatment: [CLICK] - Salt (NaCl), [CLICK] - Magnesium Chloride (MgCl2), [CLICK] - Calcium Chloride (CaCl2), [CLICK] - Calcium Magnesium Acetate (CMA), and [CLICK] - Potassium Acetate (KAc). The decision on which chemical to use, at what concentration, and in what form (i.e.,dry, pre-wetted, or liquid) depends on a variety of factors. These factors include chemical cost, forecast pavement temperature, precipitation type, roadway location, and other environmental conditions near the road surface (FHWA, 2008). [CLICK] As a general rule, road treatments are more effective when applied several times at lower concentrations than infrequently at higher concentrations (U.S. Roads, 1997). [CLICK] However, the frequency with which a treatment is applied can vary depending on road type, population, and climate. For instance, colder climates that regularly experience snow may apply chemical treatments as frequently as every 1-2 hours in highly urbanized areas and every 3-5 hours in rural areas. In warmer climates, the focus may be on treating only pre-described “snow routes” and other high volume roadways. In these areas, the frequency of treatment will vary from event to event due to the areal coverage of the event and the number of maintenance vehicles available to treat roads.

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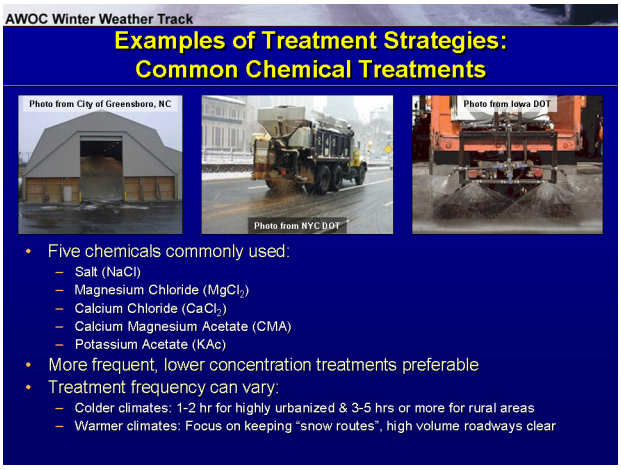

7. :Rock Salt & Magnesium Chloride

Instructor Notes: Salt and magnesium (or mag) chloride are the most common road treatment chemicals. [CLICK] The primary reason, as you might suspect, is cost. Salt is by far the cheapest of the chemicals used to reduce the eutectic point of water. It has also been around the longest. Mag chloride costs more, but is more effective at reducing the eutectic temperature of water than salt at similar concentrations (Keating, 2006). Mag chloride is also becoming more common because it is considered less environmentally damaging than rock salt and its easier for workers to handle. Both chemicals are generally effective down to temperatures of 15-20 degrees F. While both compounds are technically effective below these temperatures, the amount of substrate required (approximately 5-10 times more than at temps near freezing) prohibits their use (CNY-DPB, 2005). [CLICK] Both chemicals can cause significant damage over time to road and bridge infrastructure, vehicles, and metal utility equipment located near roadways. Rock salt, in addition to corrosion, has been shown to cause significant damage to roadside ecosystems and requires special handling issues. [CLICK] Rock Salt and Magnesium Chloride are generally the backbone of most DOT treatment plans. Most garages will use either one or the other, and they are the primary treatment option in most areas of the country at RSTs at or above 20 degrees F. If their corrosive and environmental impacts are not factored in to cost (which can be a big if), these are the most cost effective treatment options available to maintenance departments.

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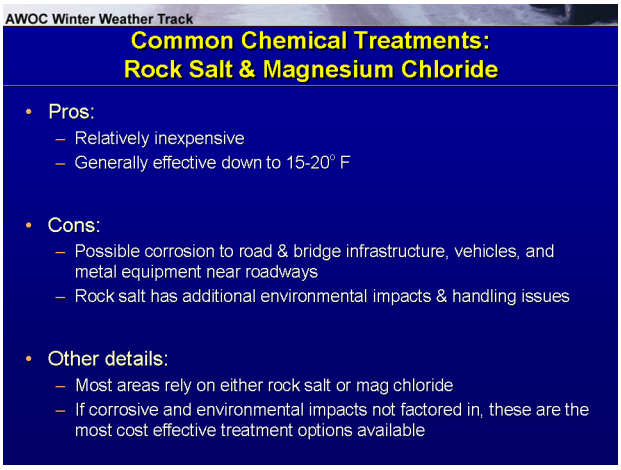

8. Calcium Chloride

Instructor Notes: Calcium chloride is another chloride-based compound that is used to treat roads, but it's a little different than the two previously mentioned. Calcium chloride has a far lower eutectic point than other compounds and is an effective option at lower temperatures than other chemicals used to treat roads. Calcium chloride also acts faster than other compounds in part because it is both hygroscopic (i.e., draws moisture out of the air to help it dissolve) and exothermic (i.e., releases heat as it dissolves). Both of these traits make other compounds mixed with calcium chloride more effective at melting snow and ice than they would be on their own (U.S. Roads, 1997). [CLICK] The big downside to calcium chloride is its cost. It's roughly 10 times more expensive than rock salt by weight (Keating, 2006). Also, due to its hygroscopic properties, calcium chloride needs to be stored in a special facility that maintains a very low humidity to avoid caking. [CLICK] Because calcium chloride is both hygroscopic and exothermic, other compounds can be mixed with it. For instance, CaCl2 might be mixed with mag chloride in a 1:3 ratio. This practice can help other chemicals, be more effective at lower RSTs than they would be otherwise, and at a much lower cost of using calcium chloride alone.

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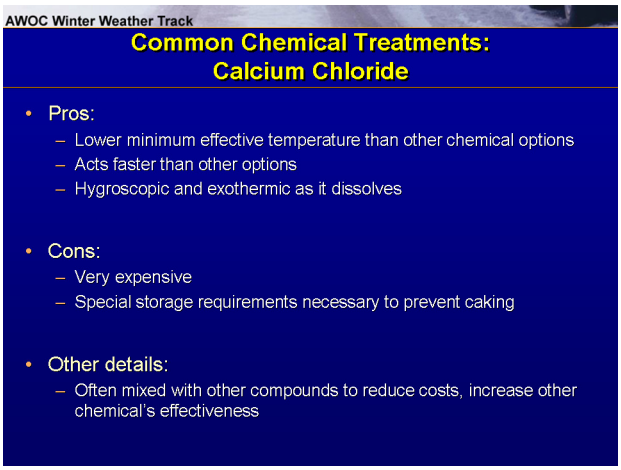

9. CMA & KAc (Acetate Solutions)

Instructor Notes: CMA and KAc are two treatment chemical that are growing in use around the country. Both are considered more environmentally friendly, are biodegradable, and do not cause corrosion like rock salt and other chloride compounds. To date, these chemicals are used primarily in liquid form as part of automated anti-icing devices built in to roads and bridges with a history of regular icing during winter weather events in order to prevent ice from bonding to the road surface (TRB, 1991; SIRWEC, 2008). [CLICK] The primary downside to these chemicals is again cost. CMA and KAc are the most expensive treatment options available. They are produced mostly from by-products of natural gas and petroleum processing, although newer techniques using other organic materials could make them more affordable in the future. In addition to their costs, they also take longer to act than traditional chloride compounds like rock salt. [CLICK] Due to their current cost and delayed reaction time, the use of CMA and KAc are generally limited to specific areas. These areas include bridges, curved overpasses, and key intersections in highly urbanized or environmentally sensitive areas. These chemicals are used at similar temperature ranges as rock salt and magnesium chloride (i.e., above 20 deg. F).

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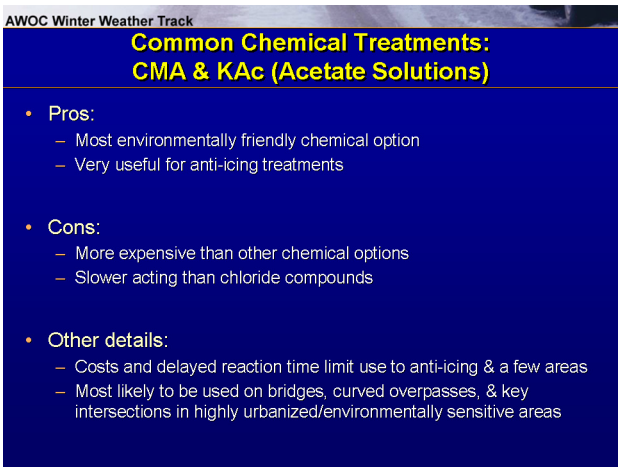

10. De-Icing Road Treatment

Instructor Notes: Besides the choice of chemical(s), the other important option when developing a plan to chemically treat roads is whether to perform anti-icing operations, de-icing operations, or both. [CLICK] Road treatment plans using de-icing operations apply chemicals at (or after) the onset of precipitation in order to induce melting of any snow or ice on the road. The choice of chemical compound used will depend on the observed or short-term forecast of pavement temperatures. [CLICK] Prior to applying de-icing treatments, road crews will likely plow excess snow off of the road surface. [CLICK] For de-icing operations, treatment compounds will likely be dry or pre-wetted. Pre-wetted chemicals act faster at melting snow and ice than dry chemicals and result in less wind

and traffic splatter or bounce off of road surfaces. As a result, pre-wetted treatments usually require less chemical than dry applications to treat the same road segment area.

Student Notes:

11. Anti-Icing Road Treatment

Instructor Notes: Anti-icing operations are a relatively new treatment option that has grown in use over the last 20-25 years. Road crews will apply a pre-wetted or liquid chemical treatment prior to a winter weather event in order to prevent the bonding of ice and snow to the road surface. [CLICK] By preventing bonding, plowing operations are more effective and less chemical is required to maximize the roadway LOS. Anti-icing treatments are often applied 1-2 hrs or more prior to frozen precipitation onset. [CLICK] In some cases, residual anti-icing treatment remains on roadways and can have anti-icing benefits for several days (U.S. Roads, 1997). [CLICK] While anti-icing operations have significant benefits, they are not always practical to implement. When winter weather events are immediately preceded by a period of significant rainfall, the rain may dilute the anti-icing treatment making it ineffective. Also, strong surface winds (~20 mph or greater) can cause anti-icing treatments to not apply properly to the road surface (CNYPDB, 2005). As a result, many transportation operators will not use anti-icing operations if rain or strong surface winds are forecast to proceed the onset of winter precipitation. [CLICK] Automated anti-icing systems are becoming more and more common on lengthy bridges over water and curved overpasses that commonly experience traffic problems due to icing. The Minnesota DOT has installed some of these systems in their area. Local Environmental Sensing Station data are use by a control computer so that, when preset thresholds are met, treatment commences and flashing beacons are activated to alert drivers. An average treatment takes approximately 10 minutes to complete. During the first year of operations by the Minnesota DOT, there was a 68% decline in winter-weather related crashes in the areas with these systems (Goodwin, 2003).

Student Notes:

12. Plowing

Instructor Notes: Plowing operations are often used in conjunction with chemical treatments to remove snow, slush, and ice from road surfaces. [CLICK] In some cases (i.e., when pavement temperatures are above freezing or below 10-15 deg F), plowing will be performed without using chemical treatments. In either case, plowing operations will only begin once a “plowable” snowfall has occurred (U.S. Roads, 1997). [CLICK] Plowing operations vary from region to region depending on the equipment available. Some cities contract out plowing operations with service commencing once a pre-determined snow threshold has been forecast or observed. In these areas, knowing the service thresholds would be beneficial for forecasters. In areas that do not receive regular snow, there are often limited plowing resources. The available equipment usually works to keep only pre-determined routes, or snow routes, clear during the event. In these regions, a plowable snow may be as much as 3-4” (vs. 1/2-1” in other areas) and secondary routes may be cleared after precipitation has ceased, if at all. Conversely, regions that regularly experience winter weather may plan to plow all major roads every 1-2 hours and rural roads every 4-6 hours or so, depending on snow accumulation rates.

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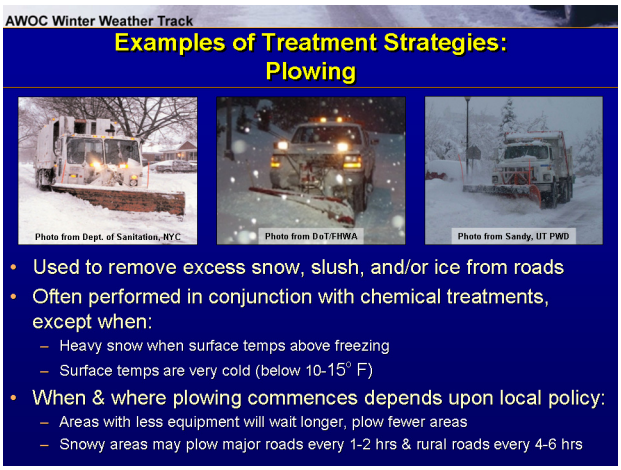

13. Sand Dispersal

Instructor Notes: During very cold or icy conditions, many maintenance departments use sand on curvy roads and near intersections to give vehicles extra traction. [CLICK] The sand is often coated with a brine or acetate solution to help prevent it becoming locked in the ice. [CLICK] Sand has the benefit of being inexpensive (i.e., an order of magnitude cheaper than rock salt), but it only provides a limited impact. In some cases, sand's effectiveness may be negligible after approximately 20 vehicles pass through an area (CNYPDB, 2005). [CLICK] Sand dispersal, while effective, can have negative environmental impacts (e.g., clogging storm drains, requiring post-event clean up on bridges and overpasses, and producing air pollution). Sand can also reduce the effectiveness of chemical treatments at melting snow and ice.

Student Notes:

14. Strategic vs. Tactical Timeframes

Instructor Notes: In general, maintenance operations require both the most accurate spatial and temporal detail in weather forecasts of any other surface transportation agency. [CLICK] Weather information becomes most relevant to maintenance operations in the 24-48 hours prior to an event (FHWA, 2008). During this strategic time frame, the detailed event planning begins. [CLICK] Maintenance managers determine the specific treatment strategy they will implement, ensure chemical and equipment inventories are sufficient, and begin scheduling staff for the event. Winter storm (and other winter weather-related) watch and warning products generally impact the strategic planning phase. [CLICK] During and just prior to the event (~0-3 hours) is the tactical time frame. [CLICK] Tasks performed at this time frame include assigning staff and equipment to specific, road segments; anti-icing operations (if desired) begin; and other elements of the treatment strategy are implemented. Poor forecasts (or a lack of sufficient weather info) can lead to significant inefficiencies in maintenance operations. [CLICK] As a result, weather information in the tactical time frame is in great demand. By regularly updating forecasts, grids, and other relevant information during the 0-3 hour timeframe, WFOs can provide better support to maintenance crews and everyone else who relies on NWS

products and services during winter weather events. When unexpected adverse weather occurs, maintenance garages can usually get some crews out in 1-2 hours (Patterson, 2008).

Student Notes:

15. Wx Impacts on Anti-Icing/De-Icing

Instructor Notes: Precipitation type, precipitation amounts, and wind speeds are important for determining whether to perform anti-icing operations. [CLICK] An event that starts with a period of rain (or snow with significant QPFs) while road temperatures are above freezing prevents implementation of anti-icing strategies. [CLICK] Strong winds can also impact the application of anti-icing operations because they affect the chemical application process and limit their effectiveness. [CLICK] Strong winds that cause blowing and drifting snow can also cause problems for maintenance personnel because of reduced visibilities (making operations proceed more slowly) and possibly making treated roads icier than if they were untreated. [CLICK] The latter problem is most significant on rural highways prone to “ground snow” events. When chemical treatment remains on the road surface, blowing snow will melt and stick. When treatment is absent, the snow will often blow on and off the road surface.

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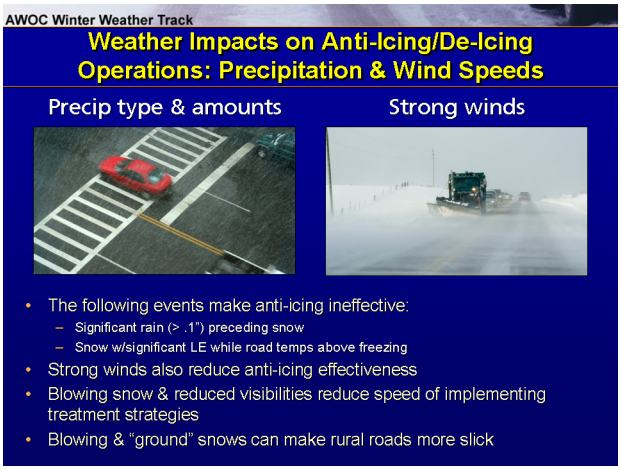

16. Mitigation Efforts During Rush Hour

Instructor Notes: Treatment strategy efforts will be significantly effected by two time-of-day-related issues: traffic patterns and insolation. [CLICK] In general, road crews treat roads to make them as safe as possible for the morning and afternoon peak traffic periods. In general, road crews prefer to apply chemical treatments to roads prior to either of these critical periods. [CLICK] Sometimes the weather doesn't cooperate (e.g., change over from rain to snow during evening rush hour) and treatment is started during these periods. [CLICK] Stationary vehicles can play a significant role in the melting and refreezing of snow and ice. While friction from tires often melts some frozen precipitation in the wheel wells, heat from the vehicle under carriage can also be significant. Near intersections or in other stop & go traffic, road temps can be 7-8 deg F higher than surrounding roads (Stern et al., 2006).

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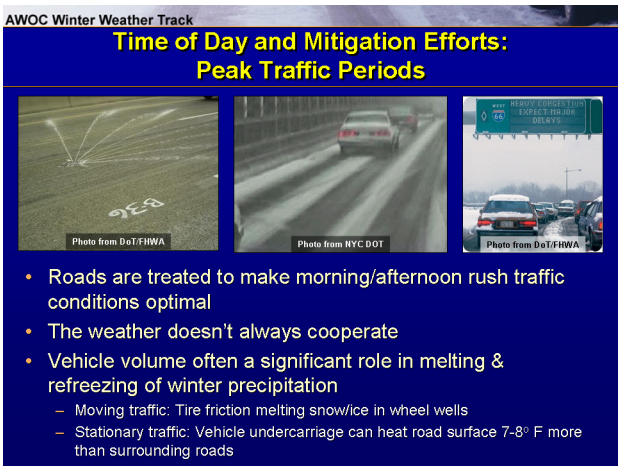

17. Interactive Question

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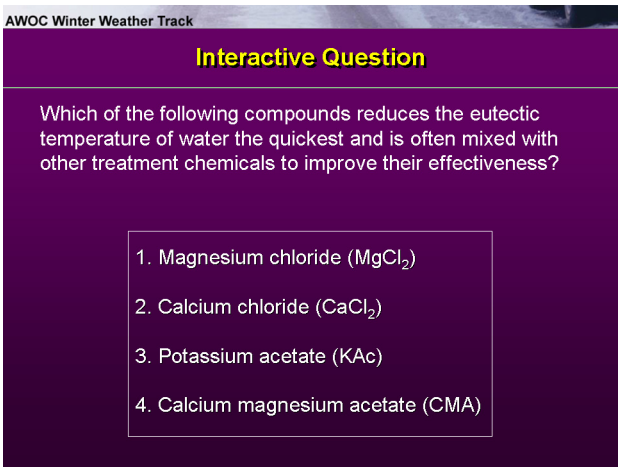

18. That's Correct!

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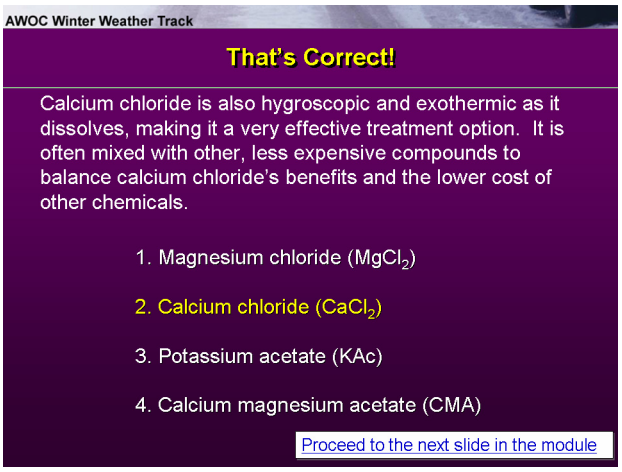

19. That's Incorrect

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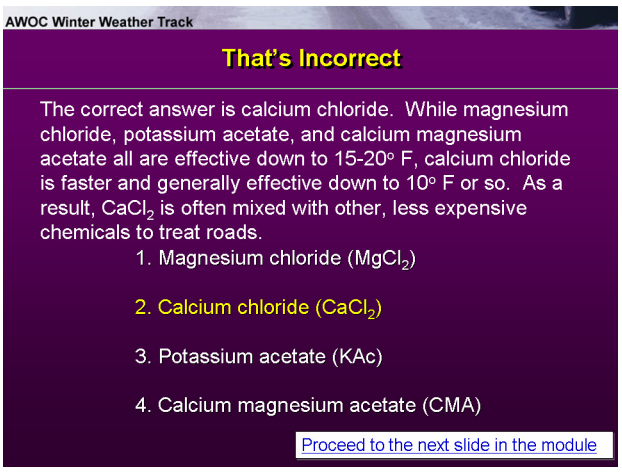

20. Wx Sensitive Details of Treatment Strategies

Instructor Notes: Road treatment strategies affect the impacts of adverse weather, but can also be impacted by the weather. Treatment plans are highly dependent on weather forecasts and observations of road surface and near-road conditions. [CLICK] Winter weather events are often categorized primarily based on the total snow and ice accumulations, but this method can be flawed. [CLICK] While events that produce large snow and/or ice accumulations (i.e., warning criteria events) are clearly significant and cause problems, there are also winter weather events with relatively small accumulations (i.e.,

sub-advisory events) that can also produce significant impacts. Warning-criteria events have been well-studied and addressed heavily in training by both NWS forecasters and other researchers. [CLICK] On the other hand, far less time has been spent addressing the conditions in sub-advisory winter weather events that delineate when an event will be relatively mundane or result in significant impacts. The rest of this module will focus on these events and this specific issue.

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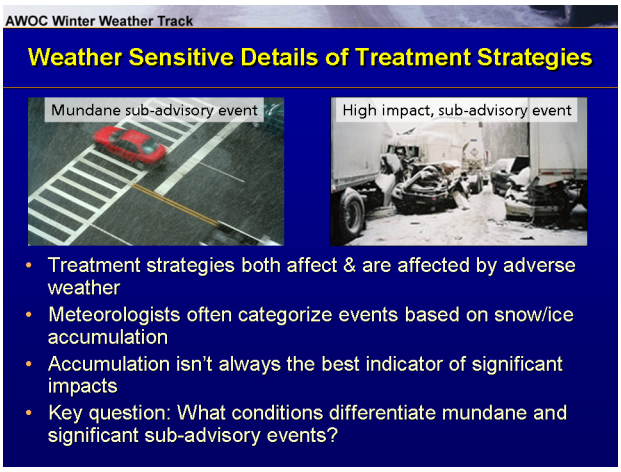

21. Sub-Advisory Events

Instructor Notes: Sub-advisory events, because they are more common, don't get people's attention as much as the warning-criteria storms. [CLICK] Drivers are less likely to change their behavior during these events, even when road conditions become treacherous quickly. To impact driver behavior, advisory and control management strategies often must be implemented in conjunction with treatment strategies to notify drivers of the dangerous situation. Forecasting which of these events will produce significant impacts with lead time can be difficult. Although the accumulation totals are less, maintenance vehicles can still have significant workloads. A missed forecast (or an ineffective treatment strategy) can be devastating for these events because many people overlook, or are ignorant, of the potential danger. [CLICK] Because of this combination of factors, a sub-advisory event that can produce significant impacts to road conditions and traffic is the most likely issue to cause planning and implementation problems for maintenance crews in many parts of the country.

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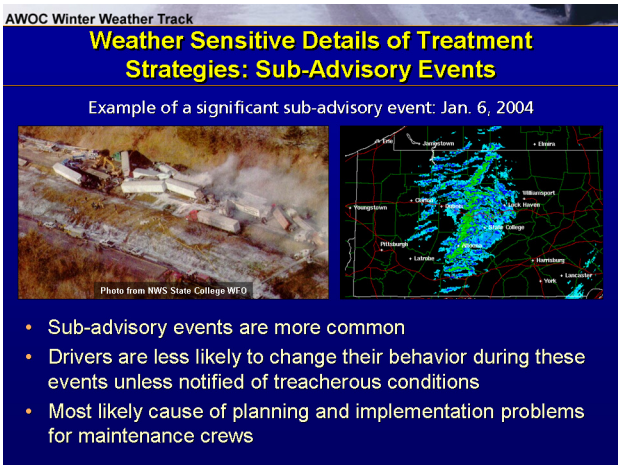

22. Sub-Advisory Event Significance Traits

Instructor Notes: So what conditions are most likely to differentiate a mundane sub-advisory event from a significant one. While research on these events is not complete, several studies (Moore and Miller, 2008; DeVoir, 2008; Puhakka, 2005) have identified some common characteristics to significant sub-advisory events in different areas. [CLICK] What often separates significant sub-advisory events from mundane ones is the presence of ice on road surfaces. The ice formation can occur due to snow melting and re-freezing, freezing rain, or even the freezing of residual moisture on roadways. When that ice formation occurs quickly, or unexpectedly, a significant sub-advisory event can result in major impacts. [CLICK] In addition to ice on the roadway, near-zero visibilities (often due a sudden increase in snow rate) can also result in significant impacts during sub-advisory events. These events, referred to as High-Impact, Sub-Advisory (HISA; DeVoir, 2008) events, can occur under a variety of situations.

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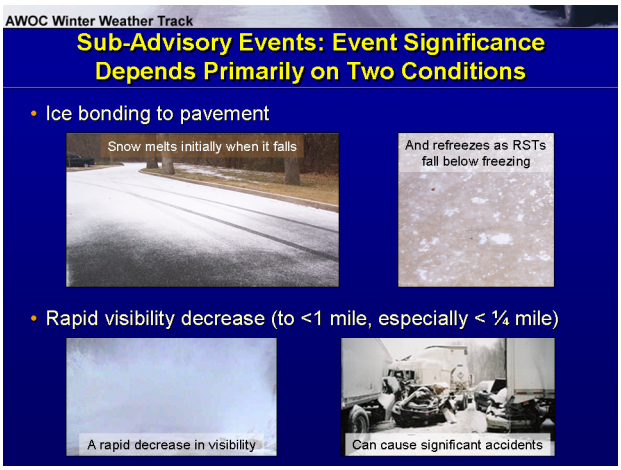

23. Flash & Other Freezing HISA Events

Instructor Notes: The most commonly identified situation for high-impact, sub-advisory (or HISA) events with roadway ice is the rapid freezing of precipitation on road surfaces which is also known as a flash freeze. Flash freezes are most likely to occur when RSTs start above-freezing and decrease quickly over a period of hours. One example of a flash freeze situation is when snow squalls occur in an area with above-freezing RSTs ahead of an arctic front. The winter precipitation ahead of the front starts melting as it falls on the warm road surfaces. After the frontal passage, however, the RSTs drop rapidly causing the melted precipitation to refreeze on the road surface. Road crews can have a hard time implementing de-icing operations in time to prevent the formation of ice. The risks are likely highest on bridges, elevated curved roadways, and arterial intersections. On high-volume highways, chain-reaction accidents become a significant risk. [CLICK] Here's another example from an actual event. This event occur in Billings, MT during the early part of the winter weather season. [CLICK] The chart shows the RSTs for two sensors, the air temperature, and soil temperature at a single RWIS site. There is a lot of information on this chart, so let me label [CLICK] the freezing temperature, [CLICK] sunset, and [CLICK] sunrise to help make things a little clearer. During the afternoon of the 29th, air temeperatures were near 70 def F with RSTs into the 80s. A frontal passage around midday sent the air temperature plummeting, with the RSTs for both sensors quickly following suit. [CLICK] Around 2 am local time, it began to snow. At this point, the air temperatures had fallen into the mid-20s, but the RSTs were still above freezing. The snow that fell on the road surface initially melted until the RST reached freezing. [CLICK] After that point, ice on the roadways made this road section very treacherous. While this event only produced 2" of snow in the area, nearly a quarter of the monthly accidents for the morning commute in the Billings area occurred on this day (Moore and Miller, 2008).

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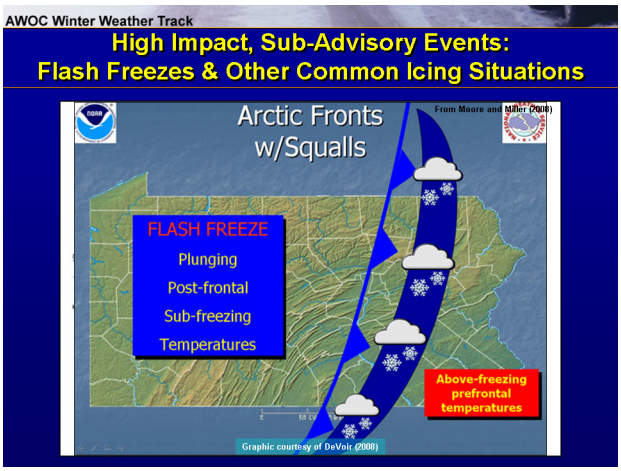

24. Rapid Visibility Decreases in HISA Events

Instructor Notes: Periods of brief, heavy snow showers can also cause significant problems during sub-advisory events by reducing visibility to near zero along the roadway. [CLICK] As visibilities drop, an increase in driver speed variance occurs as overly cautious drivers slow down dramatically while less cautious drivers may not slow down at all. This increase in driver speed variance often results in a crash frequency increase. If the rapid visibility drop occurs at the same time as flash freeze conditions, there's a good chance that you are going to have major travel problems. [CLICK] Two situations where rapid drops in visibility can occur rapidly are in strong snow showers and squalls during lake effect snow and also during periods of intense warm advection (DeVoir, 2008). In areas prone to blowing snow (or even "ground snow" events), small-scale low visibilities can cause similar problems.

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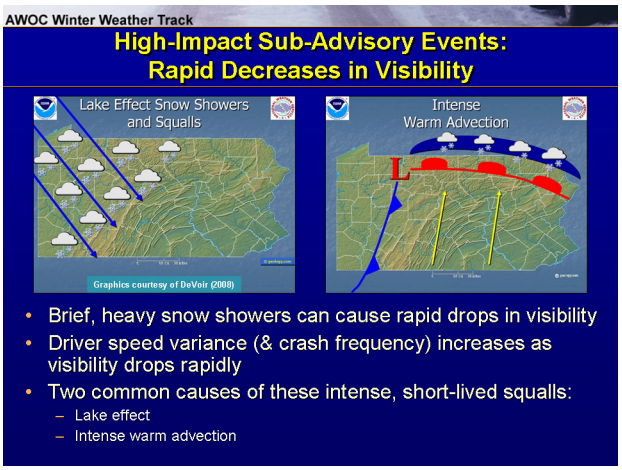
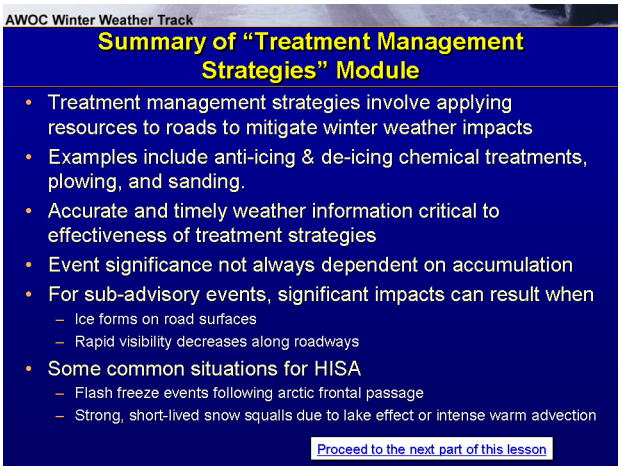


25. Summary

Instructor Notes: In summary, treatment management strategies involve applying resources to roadways prior to, during, and after winter weather events in order to improve mobility and public safety. [CLICK] Examples of treatment management strategies include anti-icing and de-icing chemical treatments, plowing, and sanding. [CLICK] Treatment strategies help mitigate the impacts of adverse weather, but they are also affected by it. As a result, accurate and timely weather forecasts and observations are critical to the effectiveness and overall success of treatment strategies. [CLICK] Winter weather event significance is often based on total snow and ice accumulation. Unfortunately, total accumulation often has no bearing on whether a sub-advisory event is significant or not. [CLICK] Instead, event significance for sub-advisory events is often determined by whether or not ice forms on road surfaces and if the visibilities along roadways decrease rapidly to near zero. [CLICK] For these sub-advisory events with major impacts, called HISA events, there are several circumstances where they can occur. Some of the more common ones are flash freeze events following strong arctic frontal passages, and during strong, short-lived snow squalls during intense warm advection or

lake effect snow events. [CLICK] To proceed to the next part of this lesson, click on the link at the bottom of the slide or use the link on the NWS Learning Center course page.

Student Notes: