APPENDIX A

FACTORS THAT EFFECT AN APPLICATION RATE DETERMINATION

TRAFFIC:

AADT – The higher the volumes the more mixing action you get along with heat from friction. Higher volumes are also an indication of your more important roads.

Rush Hour – This effect's your timing and your maneuverability as you try and get treatment down ahead of the rush. In extreme cases you may actually need to avoid a road because your trucks will be trapped and non-productive. Rush hours can also create a directional situation where you get a good mixing action in one direction and almost none in the other.

Day of the Week – Different days, especially the weekend create different traffic patterns and volumes and the application may need to be changed to adjust for this.

Corridors – This is an evolving issue from Transformation, but has always influenced level of response. Certain roads are key to the function of the system and if they are not open the rest of the system fails regardless of the conditions on the feeder roads.

ROAD CONDITIONS:

Geometrics – Steep grades, sharp curves, bridge decks, etc. all influence our application rates. Some of these situations determine the application rate for a whole beat, and others require the driver to make adjustments during his run.

Cold Spots – areas at higher elevations or shaded most of the day create cold spots which normally require more material than adjacent sections of the beat.

Length of Beat – This effects cycle time. The longer the time between plowings the more material is needed to prevent bonding. On long cycle times adding too much material will lead to a build up of slush which is more dangerous than packed snow that has not bonded to the pavement.

Plow Speed – While ideal plow speed is around 30 mph, it does vary considerably due to traffic adjacent buildings, pedestrians, high speed roadways, etc. This can create different cycle times between beats of the same length, or even the same beat at different times of the day.

Multiple Lanes – While in some cases a beat consists of a uniform number of lanes so that the assigned trucks can plow in echelon in one pass. However in most cases the number of lanes varies and trucks have to double back or trucks from other beats have to be assigned to help. This results in increased cycle time.

Pavement Surface – Some pavement treatments like Nova Chip and some Super pave mixes have an open graded surface which draws the brine away from the surface and you need more chemicals to prevent bonding.

WEATHER:

Time of Season – More chemicals are required in January than March because of colder temperatures and continued cold weather is likely.

Sunlight – The amount of sunlight influences the melting action and reduces the need for chemicals. Besides more sunlight in the beginning and end of the season the sun is at a higher angle.

Type of snow or ice – The wetter the precipitation the more dilution occurs which requires more chemicals to keep the freezing point reduced.

Intensity of the precipitation – The harder the snowfall the more material will be needed to prevent bonding before the next plowing

Pavement Temperature – While changes in air temperature are useful to watch, the pavement temperature is what really matters because this is where the bonding happens. When deciding application rates the expected trend in the temperature is important to be taken into account.

Note: The tables for application rates attempt to take into account the last three items.

GLOSSARY OF TERMS

Black Ice. Popular term for a very thin coating of clear, bubble free, homogenous ice which forms on a pavement with temperature at or slightly above 32^{o} f when the temperature of the air in contact with the ground is below the freeze-point of water and small super cooled water droplets deposit on the surface and coalesce (flow together) before freezing. Most often occurs when pavement temperature is 32^{o} F or below and is at or below Dew Point.

Chemical Spread Rate. Also known as chemical application rate. For solid applications it is simply the weight of the chemical applied per lane mile. For liquid applications it is in gallons per lane mile when applied straight and gallons per ton when used to pre-wet solid chemicals.

Freezing Rain. Super cooled droplets of liquid precipitation falling on a surface whose temperature is below or slightly above freezing, resulting in a hard, slick, generally thick coating of ice commonly called a glaze or clear ice. Non-super cooled raindrops falling on a surface whose temperature is well below freezing will also result in a glaze.

Frost. Also called hoarfrost. Ice crystals in the form of scales, needles, feathers or fans deposited on the surfaces cooled by radiation or other process. The deposits may be composed of drops of dew frozen after deposition and of ice formed directly from water vapor at a temperature below 32^{o} F (sublimation). Most often occurs when pavement temperature is 32^{o} F or below and is at or below Dew Point.

Light Snow. Snow falling at the rate of less than ½ inch per hour: visibility is not affected adversely.

Liquid Chemical. A chemical solution; with a specified percentage of chemical that is applied at the rate of gallons per lane when applied straight and gallons per ton when used to pre-wet solid chemicals.

Moderate or Heavy Snow. Snow falling a rate of ½ inch per hour or greater; visibility may be reduced.

Sleet. A mixture of rain and snow which has been partially melted by falling through the atmosphere with a temperature slightly above freezing.

Slush. Accumulation of snow which lies on an impervious base and is saturated with water in excess of the freely drained capacity. It will not support any weight when stepped or driven on but will “squish” until the base support is reached.

BLACK ICE

Surface Temp. Range (^{o} F)	Surface Condition	Initial Maintenance Action	Dry Rock Salt Lbs./lm.	Pre-Wetted Rock Salt Lbs./lm	Follow Up Action	Follow Up Rock Salt Lbs./lm	Follow Up Pre- Wetted Rock Salt Lbs./lm	Comments
Above 32	Dry or Damp	Apply pre-wetted rock salt or direct liquids to prevent formation.		115	None, see comments.			Monitor pavement temperature closely; begin treatment if pavement temperature starts to fall toward 32 and it is at or below the dew point.
23 to 32	Frost or Black Ice	Apply pre-wetted rock salt or direct liquid; use dry salt if pre-wetted not available.	275	225	Re-apply pre-wetted rock salt as needed.	115	90	1) Monitor pavement temperatures closely; if pavement becomes wet or if thin ice forms re-apply chemicals. 2) Do not apply direct liquids on ice so thick that the pavement cannot be seen. 3) Heavier follow up application(s) may be necessary.
15 to 23	Frost or Black Ice	Apply pre-wetted rock salt; use dry rock salt if pre-wetted not available.	360	275	Re-apply pre-wetted or dry rock salt as needed	115	90	1) Monitor pavement temperature closely; if pavement becomes wet or if thin ice forms re-apply chemicals. 2) Do not apply direct liquids on ice so thick that the pavement can not be seen. 3) Heavier follow up applications(s) may be necessary.
Below 15	Frost or Black Ice	Apply abrasives			Apply abrasives			1) Refer to Snow and Ice Guidelines Section 5.4406, paragraph B. for abrasive application rates.

Notes: 1) Black ice or frost is normally a spot condition – these application rates would be applied to areas susceptible to the formation of black ice or areas where black ice has developed. Watch for freezing surface temperatures below dew point with sources of vapor, clear night skies and light winds. 2) Refer to direct liquid chemical application guide lines (Appendix A Page A – 10) if anti-icing liquids are used.

FREEZING RAIN

Surface Temp. Range (^{o} F)	Surface Condition	Initial Maintenance Action	Dry Rock Salt Lbs./lm.	Pre-Wetted Rock Salt Lbs./lm	Follow Up Action	Follow Up Rock Salt Lbs./lm	Follow Up Pre- Wetted Rock Salt Lbs./lm	Comments
Above 32	Wet or Slushy	Apply pre-wetted or dry rock salt, plow if plowable.	115	90	Monitor precipitation and temperature.			1) Monitor pavement closely and anticipate drops toward 32^{o} F and below. 2) Adjust application rates as surface conditions and precipitation intensities change.
Above 32, but dropping to 32 or below soon	Wet or Slushy	Apply pre-wetted or dry rock salt, plow if plowable.	180	115	Re-apply pre-wetted or dry rock salt as needed.	180	115	1) Monitor pavement temperatures and precipitation closely. 2) Treat icy patches and colder areas with higher applications. 3) Increase applications if precipitation intensity increase or surface shows signs of icing.
23 to 32	Wet or Slushy	Apply pre-wetted or dry rock salt, plow if plowable.	275	225	Re-apply pre-wetted or dry rock salt as needed.	275	225	1) Monitor pavement temperatures and precipitation closely and adjust application rates as surface conditions and precipitation intensities change. 2) Treat icy patches and colder areas with higher applications. 3) Increase applications if precipitation intensity increase or surface shows signs of icing.
23 to 32	Icy	Apply pre-wetted or dry rock salt.	360	320	Re-apply pre-wetted or dry rock salt as needed.	360	320	1) Use Application Rate for "wet and slushy" when icing condition is removed. 2) Increase application rate if precipitation intensity increases or if pavement shows signs of re-freezing.
15 to 23	Wet or Slushy	Apply pre-wetted or dry rock salt, plow if plowable.	360	275	Re-apply pre-wetted or dry rock salt as needed.	360	275	1) Monitor pavement temperatures and precipitation closely and adjust application rates as surface conditions and precipitation intensities change. 2) Treat icy patches and colder areas with higher applications. 3) Increase applications if precipitation intensity increase or surface shows signs of icing.
15 to 23	Icy	Apply pre-wetted or dry rock salt.	450	360	Re-apply pre-wetted or dry rock salt as needed.	450	360	1) Use Application Rate for "wet and slushy" when icing condition is removed. 2) Increase application rate if precipitation intensity increases or if pavement shows signs of re-freezing.
Below 15	Dry, wet or icy	Apply abrasives			Re-apply abrasives			Refer to Snow and Ice Guidelines Section 5.440 (B) for application rates.

Notes: 1) Freezing Rain requires a timely and aggressive response to prevent ice formation; application rates should be increased if not effective or cycle times are increased due to difficult driving.

SLEET

Surface Temp. Range (^{o} F)	Surface Condition	Initial Maintenance Action	Dry Rock Salt Lbs./lm.	Pre-Wetted Rock Salt Lbs./lm	Follow Up Action	Follow Up Rock Salt Lbs./lm	Follow Up Pre- Wetted Rock Salt Lbs./lm	Comments
Above 32	Dry	Patrol and spot treat as needed. See comments.			Patrol and spot treat as needed. See comments.			1) Monitor pavement temperatures closely and anticipate drops toward 32 F and below. 2) Treat icy patches with pre-wetted rock salt at 115 lbs./lm.
Above 32	Snow, slush, or wet.	Apply pre-wetted or dry rock salt, plow if plowable.	115	90	Re-apply pre-wetted or dry rock salt as needed.	115	90	1) Monitor pavement temperatures closely and anticipate drops toward 32F. 2) Treat icy patches and colder areas with higher applications. 3) Increase rates if precipitation intensity increases.
Above 32, but dropping to 32 or below soon.	Snow, slush, or wet.	Apply pre-wetted or dry rock salt, plow if plowable.	180	115	Re-apply pre-wetted or dry rock salt as needed.	180	115	1) Monitor pavement temperatures and precipitation closely. 2) Treat icy patches and colder areas with higher application rates. 3) Increase application rates if precipitation intensity increases.
23 to 32	Snow, slush, or wet.	Apply pre-wetted or dry rock salt, plow if plowable.	225	180	Re-apply pre-wetted or dry rock salt as needed.	225	180	1) Monitor pavement temperatures and precipitation closely. 2) Treat icy patches and colder areas with higher application rates. 3) Increase application rates if precipitation intensity increases.
15 to 23	Snow, slush, or wet.	Apply pre-wetted or dry rock salt, plow if plowable.	275	225	Re-apply pre-wetted or dry rock salt as needed.	275	225	1) Monitor pavement temperatures and precipitation closely. 2) Treat icy patches and colder areas with higher application rates. 3) Increase application rates if precipitation intensity increases.
Below 15	Any condition.	Apply abrasives.			Re-apply abrasives.			1) Refer to Snow and Ice Guidelines Section 5.4406 (B) for abrasive application rates.

Notes: 1) Sleet that creates accumulating ice will require more aggressive treatment.

LIGHT SNOW

Surface Temp. Range (^{o} F)	Surface Condition	Initial Maintenance Action	Dry Rock Salt Lbs./lm.	Pre-Wetted Rock Salt Lbs./lm	Follow Up Action	Follow Up Rock Salt Lbs./lm	Follow Up Pre- Wetted Rock Salt Lbs./lm	Comments
Above 32	Wet, slush or light snow covered.	Patrol and spot treat as needed. See comments.			Patrol and spot treat as needed. See comments.			1) Monitor pavement temperature for drops toward 32 F. 2) Blast isolated icy patches with salt, treat slushy areas beginning to freeze with 225 dry/180 pre-wet, lbs./lm and plow as needed
Above 32, but dropping to 32 or below soon.	Dry	Apply pre-wetted rock salt or direct liquids. Patrol and spot treat as needed. See comments.		180	Patrol and spot treat as needed. See comments.			1) Monitor pavement temperature and precipitation and use select appropriate follow up as conditions change. 2) Refer to Snow and Ice Guidelines for appropriate direct application of liquid anti-icing chemicals.
Above 32, but dropping to 32 or below soon.	Wet, slush, or light snow covered.	Apply pre-wetted or dry rock salt, plow as needed.	225	180	Plow and re-apply pre-wetted or dry rock salt as needed.	115	90	1) Application will need to be more frequent at lower temperature and higher snowfall rates. 2) Adjust application rates as surface conditions and precipitation intensities change.
23 to 32	Dry	Apply pre-wetted rock salt or direct liquids.		180	See comments.			1) Monitor pavement temperature and precipitation and use select appropriate follow up as conditions change. 2) Refer to Snow and Ice Guidelines for appropriate direct application of liquid anti-icing chemicals.
23 to 32	Wet, slush or light snow covered.	Apply pre-wetted or dry rock salt, plow as needed.	225	180	Plow and re-apply pre-wetted or dry rock salt as needed.	115	90	1) Application will need to be more frequent at lower temperature and higher snowfall rates. 2) Adjust application rates as surface conditions and precipitation intensities change.
15 to 23	Wet, slush or light snow covered.	Apply pre-wetted rock salt, plow as needed.	275	225	Plow and re-apply pre-wetted rock salt as needed.	180	115	1) If sufficient moisture is present, dry rock salt can be applied. Dry pavement at these temperatures is better left untreated if snow does not track to surface.
Below 15	Dry or light snow covered.	Plow as needed.			Plow as needed.			1) Abrasives can be applied to enhance traction, a heavy salt mix will create glazing. Refer to Snow & Ice Guidelines Section 5.4406 (B) for abrasive application rates. Apply rock salt in anticipation of rising temperatures.

Notes: 1) Rush Period Traffic on high volume highways may require more aggressive initial treatments. 2) Use weather information to anticipate changes in storm intensity, surface temperatures and adapt the storm treatment accordingly. Use guidelines for moderate/heavy snow during periods of heavier intensity. . 3) Refer to direct liquid chemical application guides lines (Appendix A, Page A – 10) if anti-icing liquids are used.

MODERATE OR HEAVY SNOW

Surface Temp. Range (^{o} F)	Surface Condition	Initial Maintenance Action	Dry Rock Salt Lbs./lm.	Pre-Wetted Rock Salt Lbs./lm	Follow Up Action	Follow Up Rock Salt Lbs./lm	Follow Up Pre- Wetted Rock Salt Lbs./lm	Comments
Above 32	Wet, slush or light snow covered.	Patrol and spot treat as needed. See comments.			Patrol and spot treat as needed. See comments.			1) Monitor pavement temperature for drops toward 32 F. 2) Blast isolated icy patches with salt, treat slushy areas beginning to freeze with 225 dry/180 pre-wet, lbs./lm and plow as needed.
Above 32, but dropping to 32 or below soon.	Dry	Apply pre-wetted rock salt or direct liquids. Patrol and spot treat as needed. See comments.		180	Patrol and spot treat as needed. See comments.			1) Monitor pavement temperature and precipitation and use select appropriate follow up as conditions change. 2) Refer to Snow and Ice Guidelines for appropriate direct application of liquid anti-icing chemicals.
Above 32, but dropping to 32 or below soon.	Wet, slush, or light snow covered.	Apply pre-wetted or dry rock salt, plow as needed.	225	180	Plow and re-apply pre-wetted or dry rock salt as needed.	225	180	1) If normal cycle times can not be maintained, the application rates can be increased to 275dry/225 pre-wet, lbs./lm to accommodate longer cycles. 2) Rates may be reduced during periods of light snow but use full applications in anticipation of heavy intensities/falling surface temperatures.
23 to 32	Dry	Apply pre-wetted rock salt or direct liquids.		180	See comments.			1) Monitor pavement temperature and precipitation and use select appropriate follow up as conditions change. 2) Refer to Snow and Ice Guidelines for appropriate direct application of liquid anti-icing chemicals.
23 to 32	Wet, slush or light snow covered.	Apply pre-wetted or dry rock salt, plow as needed.	225	180	Plow and re-apply pre-wetted or dry rock salt as needed.	225	180	1) If normal cycle times can not be maintained, the application rates can be increased to 275dry/225 pre-wet, lbs./lm to accommodate longer cycles. 2) Rates may be reduced during periods of light snow but use full applications in anticipation of heavy intensities/falling surface temperatures.
15 to 23	Wet, slush or light snow covered.	Apply pre-wetted rock salt, plow as needed.	275	225	Plow and re-apply pre-wetted rock salt as needed.	275	225	1) If normal cycle times can not be maintained, the application rates can be increased to 360dry/275 pre-wet, lbs./lm to accommodate longer cycles. 2) Rates may be reduced during periods of light snow but use full applications in anticipation of heavy intensities.
Below 15	Dry or light snow covered.	Plow as needed.			Plow as needed.			1) Abrasives can be applied to enhance traction, a heavy salt mix will create glazing. Refer to Snow & Ice Guidelines Section 5.4406 (B) for abrasive application rates. Apply rock salt in anticipation of rising temperatures.

Notes: 1) Rush Period Traffic on high volume highways may require more aggressive initial treatments. 2) Increased cycle times will require heavier application rates. Anticipate changes in storm intensity and surface temperatures and use appropriate chart selection. 3) Refer to direct liquid chemical application guides lines (Appendix A, Page A – 10) if anti-icing liquids are used.

ANTI-ICING WITH STRAIGHT LIQUID CHEMICALS

The strategy of anti-icing is to be proactive in the application of chemicals to prevent the formation or development of bonded snow and ice to the pavement surface. This tactic is used to "buy time" prior to the onset of a snow and ice event or anticipated black ice conditions. When the event actually begins, conventional reactive strategies are then used.

This strategy can be particularly useful on A1 type highways where conventional methods may be slowed due to high traffic volumes. These methods are also useful for unique trouble areas such as bridge decks, high elevations, and shaded areas that freeze quicker than adjoining segments.

Anti-icing can be done by applying conventional solid and pre-wetted solids. This tactic is prone to wasting material, particularly if the pavement surface is dry. High volumes and speeds will scatter most of the material off of the travel lanes. The preferred material for anti-icing is the use of salt brine or liquid chemicals such as magnesium chloride sprayed directly on the pavement surface using a tank and spray bar system. Various slide in tank and spray bar systems are now available.

Liquid Chemicals:

Liquid ice control chemicals are made up of solid ice control chemicals in a water solution. After application, the water evaporates and a residual dry chemical is left on the pavement surface. This material is not prone to scattering or dispersal from traffic conditions.

Salt brine is most effective at a 23% solution. It can be produced in house by agitating solid NACL in water. It is also a byproduct of the oil and gas industry and can be acquired in certain geographic areas at little or no cost.

Liquid Magnesium Chloride, Liquid Calcium Chloride, Potassium Acetate, Calcium Magnesium Acetate, and a variety of proprietary formulas that contain anti-corrosion inhibitors and agricultural byproducts are also available. Although generally higher in cost than salt brine, they can be more effective at lower temperatures.

Application Criteria:

Straight liquid chemical applications can be made up to 3 days prior to the onset of a winter weather event if the chemical is allowed to dry on the pavement surface. Rain events and particularly high traffic volumes will lesson the anti-icing effects. Table A gives a general range of application rates. The rates to achieve effective results can vary significantly with the type of liquid chemical used and pavement temperatures. Too little material will not produce desired results. Too much material can result in hazardous slippery conditions before the material has fully dried. It is recommended that new users start at the lower end of the range and gradually increase application rates until desired results are achieved. It is also very critical that liquid spray units are calibrated at the beginning of each snow and ice season. This can be accomplished

by collecting liquid at the spray bar over a pre-measured distance. Because results are very sensitive to application rates, calibration is critical.

Liquid chemicals should only be applied as an anti-icing strategy when the pavement temperatures are 20^0 F or higher. Application of salt brine at lower temperatures would require excessive application rates and may be prone to rapid refreeze. Liquid chemicals such as magnesium chloride and other proprietary products may be used at lower temperatures, but again, application rates may negate any cost benefit. Conversely, liquid applications should not be made if pavement temperatures are much above freezing. Above 38^0 F and at high humidity, liquid chemicals will not properly dry on the surface and can result in hazardous slippery conditions.

De-icing:

Straight liquid chemicals may be applied as a de-icing strategy during low moisture, light snowfall at pavement temperatures above 20^o F. Cycle times should be minimized as dilution of straight liquids occurs much quicker than solid chemical applications. At temperatures near freezing, it can be very effective at melting thin ice in the absence of precipitation.

Liquid chemicals are more sensitive to temperature and dilution than solid abrasives. If used as a de-icing strategy, more caution is required to avoid refreeze without the friction enhancement characteristics of a solid material.

Table A

SUGGESTED APPLICATION RATES FOR STRAIGHT LIQUID ANTI-ICING			
Temperature ^{0} F	*Application Rate gals/lm		
	23% Salt Brine	27% Mag Chloride	32% Calcium Chloride
32^0 F	30	28	33
20^0 F	40	30	36

* *Application rates as high as 60 gal/lm have been successfully used in salt brine straight liquid applications. It is strongly recommended however, to start with the application rates as illustrated by this table to avoid the potential for hazardous conditions as a result of friction loss from the chemical application itself. If desired results cannot be achieved at these rates, incremental adjustments can be made upward until results are achieved.*