NWSRG

NATIONAL WINTER SERVICE RESEARCH GROUP

SECTION EIGHT

SPREAD RATES FOR PRECAUTIONARY SALTING

In association with IHE

INSTITUTE OF HIGHWAY ENGINEERS

www.nwsrg.org

CONTENTS

KEY

Red text are warnings or especially important information

Green text are particular recommendations or key advantages to consider

CHECK LIST:

Has the guidance in other sections of the NWSRG Practical Guide, (Treatment Methods, Salt Storage, Spreader Management and Winter Service Decision Making etc), been properly considered?

Does the process for determining precautionary spread rates on your network follow an appropriate risk-based approach?

SECTION EIGHT
Spread Rates for Precautionary Salting

8.1 INTRODUCTION

8.1.1 This section of the NWSRG Practical Guide contains information regarding spread rates for precautionary salting operations undertaken in response to predictions of frost and ice formation in normal winter weather conditions on the UK road network.

8.1.2 Treatments undertaken in response to snowfall and freezing rain, as well as treatments for 'extreme cold' situations, are discussed in other sections of the guide.

8.1.3 Delivering accurate and appropriate salt spread rates is crucial for effective, efficient and sustainable operations. This is best achieved when spreader performance is good and in-calibration, and salt is in good condition. These issues are discussed in more detail in earlier sections of the NWSRG Practical Guide and it is important that authorities carefully consider the guidance contained within those other sections before considering the treatment rates appropriate for use on their networks. In particular, the sections of the guide relating to Treatment Methods, Salt Storage, Spreader Management and Winter Service Decision Making are important in this respect.

8.1.4 In line with the approach advocated in the national Code of Practice 'Well-Managed Highway Infrastructure' the guidance contained within this section of the NWSRG Practical Guide is not prescriptive and is designed to assist authorities in taking a risk based approach to the determination of appropriate precautionary salt spread rates for use on their networks.

8.1.5 Following consideration of the relevant factors that are discussed within this, and other, sections of the NWSRG Practical Guide, authorities may choose to adopt the spread rates provided here. However, risk assessments undertaken at a local level, as well as other considerations, may result in some authorities adopting precautionary salt spread rates that differ from those provided here. In such instances, authorities should document their risk assessment process and their reasons for adopting different rates.

8.1.6 The recommended spread rates provided in the matrices of sub-section 8.6 relate to spreaders that provide 'Good' or 'Fair' coverage and 'Medium Traffic' situations. In other situations, and when other relevant factors dictate, these rates should be modified in accordance with the guidance provided.

As a result of the inevitable variabilities in coverage and losses that occur, even when using spreaders providing 'Good' or 'Fair' coverage, it is recommended that authorities do not utilise lower precautionary spread rates than the lowest rates provided in the matrices of sub-section 8.6, i.e. 8g/m² for dry salt and pre-wetted salt applications, and 7g/m² for treated salt applications.

8.2 SCOPE AND BASIS

8.2.1 As it is by far the most common road de-icer used by authorities across the UK, the spread rates discussed in this section of the guide focus on treatments using salt (NaCl). Alternative de-icers are discussed separately in the 'De-Icer Types' and 'Treatments for Extreme Cold' sections of the guide.

8.2.2 Guidance for 'Direct Liquid Application' (DLA) treatments in UK conditions is currently still being developed as research and further information becomes available. Annexe 3 includes salt brine spread rates that have been developed from ongoing trials and a comparison with rates successfully implemented in other European countries. These are provided as interim guidance to assist authorities considering the use of brine treatments until potentially more definitive guidance for DLA treatments will be provided at a later date.

8.2.3 The spread rates provided in the main body of this section of the Practical Guide have been determined on the basis of research carried out by the NWSRG, TRL, Highways England and Transport Scotland over a number of years. Other research in the UK and overseas, combined with the knowledge of expert practitioners, has also been taken into account. Practical experience of using these and/or similar rates on local roads has demonstrated their effectiveness in preventing the formation of frost and ice across the range of typical UK winter weather conditions.

8.2.4 The guidance contained within this section, and other sections of the NWSRG Practical Guide, is designed to assist authorities in providing good service levels and complying with their legal obligations and duties with respect to winter weather conditions.

8.2.5 However, it should be noted that there are many factors which affect the ability of treatments to prevent hazardous conditions from arising on the road network, and no treatment can be guaranteed to prevent ice or frost formation in all situations and in all weather conditions.

8.2.6 In order to optimise salt usage, improve stock resilience and reduce the impact of salt on vehicles, infrastructure and the environment, it is important that precautionary salt spread rates are no higher than necessary.

8.2.7 It is also crucial that all day-to-day decisions regarding precautionary treatments are based on good quality weather predictions, and authorities should obtain weather forecasting services specifically designed for these purposes.

8.2.8 In many instances, the timing of treatments can be an important factor in determining whether or not a particular precautionary treatment will prove effective in preventing the formation of frost or ice, and should be carefully considered in addition to the spread rate to be utilised.

8.2.9 Further information relating to weather forecasting services and winter service decision making is contained in other sections of the guide.

8.3 THE AMOUNT OF SALT REQUIRED TO PREVENT ICE FORMATION

8.3.1 The amount of salt required to prevent ice forming on a road surface is dependent upon the temperature of the surface and the amount of water present.

8.3.2 When insufficient moisture is available to freeze, no salt is required to prevent ice from forming regardless of the road surface temperature. However, the amount of salt required to prevent ice from forming increases rapidly with the amount of surface water present. Therefore, water film thickness is an important issue in this respect and further information relating to this issue is provided in Annexe 1.

8.3.2 As is discussed at Annexe 1, for the purposes of this guidance a 'Damp' road surface is defined as one where the amount of surface water present is insufficient for traffic to produce spray, i.e. a water film thickness of no greater than 0.05mm; and a 'Wet' road surface is defined as one where traffic produces spray but not small water droplets, i.e. a water film thickness of between 0.05 and 0.10mm.

8.3.3 The table below shows the amount of salt required at any particular time on damp and wet roads to prevent ice from forming.

TABLE 8.3.3 AMOUNT OF SALT REQUIRED IN SOLUTION ON A ROAD SURFACE TO PREVENT ICE FORMING

Road Surface Temperature (°C)	Road Surface Wetness at Forecast Event	
	Damp	Wet
0.0 to -1.0	1g/m^2	2g/m^2
-1.1 to -2.0	2g/m^2	4g/m^2
-2.1 to -5.0	5g/m^2	10g/m^2
-5.1 to -7.0	7g/m^2	13g/m^2
-7.1 to –10.0	9g/m^2	18g/m^2

8.3.4 As can be seen from the above table, relatively small amounts of salt are required to prevent ice from forming in most conditions. However, precautionary salting operations are designed to protect road users by preventing frost and ice formation over a period of time following treatment, and considerable salt losses are likely to occur during this period as a result of weather conditions and the action of traffic. Therefore, the rate of spread of salt utilised when undertaking precautionary salting operations needs to be higher than the amounts shown in the table above.

8.3.5 In fact, determination of appropriate spread rates for precautionary salting operations should properly account for the capability of the spreader, as well as the factors that influence the rate that salt is lost after it has been spread.

8.3.6 These factors, and how they can be accounted for when determining appropriate spread rates for precautionary salting operations, are discussed below.

8.4 IMPORTANT INFLUENCING FACTORS

8.4.1 The factors that determine the most appropriate spread rates for precautionary salting operations include:

8.4.2 **The salting technology utilised, i.e. dry, pre-wetted or treated salting;**

8.4.3 **Type and condition of the salt, including grading and moisture content;**

8.4.4 **Performance and serviceability of the spreader, including whether the spreader is calibrated for the salt being used and if the spreader is within calibration at the time of spreading;**

8.4.5 **Road surface temperature throughout the period under consideration;**

8.4.6 **The amount of liquid water present at the time of spreading and during the following period;**

The amount of water present on the road surface at the time of treatment and expected afterwards will have a significant effect on appropriate precautionary salt spread rates as, along with the action of traffic, surface water reduces brine concentration and increases 'wash-off' after spreading.

Effective highway drainage is important and, if a road surface is well drained and has been trafficked for several hours after rainfall, relatively little water should be present on the road surface.

Normal dispersion rates of salt following spreading are accounted for in the recommended spread rates. However, it is important that the timing of precautionary salting operations is carefully considered so that, when practicable, spreading takes place when there is the minimum amount of water on the network, as this will maximise the effectiveness of the treatment.

The amount of salt required to prevent ice from forming on road surfaces exhibiting a water film thickness of greater than 0.1mm is very high. The recommended spread rates provided in this section reflect the practicalities of delivering an effective winter service and are only intended for use on dry, damp or wet roads, where the water film thickness is up to a maximum of 0.1mm.

Precipitation after a treatment takes place will increase the rate of salt dispersal and reduce the brine concentration. Depending upon the amount of precipitation and its timing, higher treatment rates or additional treatments may therefore be required.

8.4.7 **Traffic levels before, during and after spreading;**

Traffic levels on the network before, during and after treatment are an important factor influencing the appropriate precautionary salting spread rates.

Traffic effects vary with conditions and timing, and can increase or reduce the amount of salt required to prevent frost or ice from forming. These effects include:

- Removal of water from the road surface prior to spreading;
- Deflection of salt by obstruction and vehicle draughts during spreading affecting uniform distribution;
- Redistribution of salt potentially aiding more uniform distribution across and along the carriageway;
- Removal of salt and brine from the road surface after spreading;
- Crushing of salt particles aiding faster dissolution of the salt.

Further information relating to traffic effects is provided in Annexe 2. However, it is important that traffic levels are properly accounted for when authorities are determining appropriate precautionary salting spread rates on their road networks.

For the purposes of this guidance, traffic levels are categorised into 'Light', 'Medium', 'High' and 'Congested'. These categories relate to those anticipated around the time of the precautionary salting operation and are defined in the table below.

It should be noted that these categories are not the same as the traffic categories generally used for other highway maintenance purposes.

TABLE 8.4.3 TRAFFIC LEVEL CATEGORIES (RELATING TO THE PERIOD AROUND THE TIME OF THE PRECAUTIONARY SALTING OPERATION)	
Level	**Vehicles per lane per hour**
Light	Less than 20
Medium	20 to 250
High	250 or more and moving at normal traffic speeds
Congested	250 or more moving slower than normal traffic speeds

It is anticipated that traffic levels on the great majority of local authority road networks will fall within the 'Medium Traffic' category during the times periods that most precautionary salting operations are undertaken. Therefore, the recommended spread rates provided in the matrices contained within sub-section 8.6 relate to the 'Medium Traffic' category.

It is not anticipated that many local authority roads will fall into the 'High Traffic' category and research has shown that salt losses do not increase significantly for traffic levels beyond 250 vehicles per lane per hour, as long as this traffic is moving normally.

However, it is likely that some precautionary salting operations undertaken by local authorities will include routes that fall into the 'Light Traffic' and 'Congested Traffic' categories. In these situations, it is important that spread rates are modified accordingly.

Examples of the above include situations where overnight traffic levels on rural precautionary salting routes fall into the 'Light Traffic' category and, if undertaking operations on these routes late at night or during the early morning hours, it is important that spread rates are modified to account for this, even if operations undertaken on the same routes at other times do not require modification. Other examples include situations where precautionary salting operations are required to be undertaken during 'rush hour' periods, when traffic levels in urban areas may well fall into the 'Congested Traffic' category, and again it is important that spread rates are modified to account for this.

Advice on the recommended modifications to spread rates when traffic levels around the time of spreading are not expected to fall within the 'Medium Traffic' level is provided in sub-section 8.6.

8.4.8 **Wind speed and direction;**

High wind speeds can affect the salt distribution at the time of spreading and, in dry conditions, lead to increased salt losses after spreading as a result of the salt particles being blown from the road surface.

Some spreaders offer facilities to compensate for the wind field. However, in order to be effective, it should account for variations in the wind direction and the heading of the spreading vehicle etc.

Dry salting tends to be more susceptible to the effects of high winds than treated salting or pre-wetted salting because of the dispersal of the finer particles in dry salt and the reduced tendency of salt particles to 'bounce' on the road surface and be transported by air movements during the spreading operation when using treated and pre-wetted salt.

Salt losses due to wind effects are likely to be higher when road surfaces are dry or damp, rather than wet, because the loss of fines after spreading will be reduced by the water present on the road surface.

High wind speeds are also likely to affect some routes, and some parts of some routes, significantly more often than others. Local knowledge will assist authorities in identifying those parts of the network that are most susceptible to the effects of wind and, if necessary, develop methodologies to mitigate these effects.

Authorities may find that it is not practicable to change spread rates along individual routes to account for the effects of wind. However, even in these situations it may be possible to use different spread rates on different routes.

The most effective method of reducing these effects is to undertake precautionary salting operations at times that avoid the period when high winds are predicted to occur. However, this will not always be practicable or achievable, as there are other important factors in determining the most appropriate timing of these operations.

Advice on recommended spread rate modifications when wind speeds are high is provided in sub-section 8.6.

8.4.9 **Residual salt present on the network from previous treatments;**

In favourable conditions it is likely that some salt will remain on road surfaces for a considerable period following treatment and, for example, residual salt levels on the network may build up if there are treatments on successive days and no precipitation occurs.

In these situations, where the level of residual salt can be accurately assessed and confirmed as being present, this can be taken into account when determining the need for, the timing of, and the appropriate spread rates to utilise, in further precautionary salting operations.

However, the combined action of traffic and weather conditions, especially precipitation, reduces residual salt levels over time, and the rate at which these losses occur may vary markedly across the road network. Residual salt levels across the network are also notoriously difficult to measure accurately and this issue is still very much in focus as an area for ongoing and future research.

Therefore, authorities should carefully consider whether or not they will take residual salt levels into account during the winter service decision making process and, if so, the precise circumstances when they will do so, as well as the information sources they will rely upon to ascertain, confirm and monitor residual salt levels on their networks. For example, these could potentially include: direct network observations; available data from road weather stations; the length of time since previous treatments took place, and the weather and traffic conditions that have occurred since that time; coupled with the local experience of authority staff.

The potential to take account of existing residual salt levels when considering further operations is greatest on 'marginal' nights, when road surface temperatures are close to zero Celsius and relatively little salt is needed to ameliorate the risk of frost and ice formation.

If taken into account, it is crucial that the information utilised regarding existing residual salt levels is reliable. In this regard it should be noted that the types of surface sensor typically utilised by road weather outstations are only effective when moisture is present on the sensors, and these only provide information relating to a small area of the road surface so may not accurately reflect residual salt levels across a larger part of the network. Primarily, the consideration of taking existing residual salt levels into account is dependent on an assessment requiring good knowledge of the routes in question, as well as the experience of the decision maker.

Authorities should keep full and accurate records of their winter service activities, and it is important that these incorporate all relevant details of the decision making process and the information utilised and relied upon. This should include specific reference to information relied upon relating to existing residual salt levels.

8.4.10 **Road surfacing type, i.e. whether this is porous or impermeable, or whether it is a bridge deck etc;**

The porosity of road surfacings can affect the amount of de-icer required for treatment. The reasons for this include its effects on road surface temperature, the amount of surface water present, and the loss of de-icer into void structures within the surfacing. Road construction, including the lower layers as well as the surfacing, can also affect the thermal properties and thermal behaviour of the road.

Road surfaces on the majority of local roads across the UK are of the less porous, positively textured variety, such as those comprised of Hot Rolled Asphalt (HRA) and/or are commonly dressed with chippings and a bituminous binder. These types of surface exhibit characteristics that tend to have the least impact on the amount of de-icer required to prevent ice formation, and the recommended spread rates provided in the matrices in sub-section 8.6 are based on surfaces of these types.

On porous surfaces, salt particles and brine may travel into the voids within the surfacing material and be less effective in preventing ice formation. Therefore, higher spread rates may be required on porous asphalt and negatively textured thin surfacing with a high air void content, although it should perhaps be noted that older negatively textured surfaces may not exhibit the same porosity as they did when newer, as the voids tend to fill with detritus over time.

Research has shown that, in winter conditions, porous asphalt can attain temperatures up to 2°C lower than denser surfaces such as HRA and, in some areas that cannot drain freely, porous asphalt tends to remain wetter for longer. This increases the risk of ice formation on porous asphalt and consequently more salt is needed to keep porous asphalt free from ice.

In some situations, porous asphalt may allow water to drain through the voids to pool at the lowest point. This may then present problems if the water is available to form ice at the road surface through natural flow or through a 'pumping' action induced by traffic. Water draining through the voids may also rise to the surface on meeting a barrier such as a construction 'day joint' or a different form of surfacing.

Figure 8.4.4 - Water ponded on surfacing at interface between a negatively textured thin surfacing and dense surfacing

In other situations, salt in solution can be 'pumped' back to the surface by the action of traffic, but this effect will not be significant if the level of traffic is low and this mechanism should not be relied upon because of the uncertainties involved.

When water or weak brine solution are 'pumped' back to the surface it has the potential to freeze; also ice 'mushrooms' may form in the pore structure when insufficient salt is present.

Where a length of dense surfacing such as hot rolled asphalt immediately follows one of porous asphalt, salt can be transported for over one kilometre along the dense surfacing due to the action of traffic, but this action does not occur to the same extent on porous asphalt because de-icers are largely retained in the voids of the surface. Thus, there is a tendency for sections of dense surfacings following sections of porous asphalt to lose de-icer over time (due to the action of traffic) which is not replenished because of the absence of the tracking effect from the porous asphalt.

Certain other types of surfacing can also sometimes require special consideration with regard to their winter treatment. For example, concrete roads can exhibit different thermal properties to flexible pavements and will tend to retain heat in their core for longer than Hot Rolled Asphalt (HRA) roads due to their denser construction. This can be beneficial during cold spells after warmer periods, particularly during the early part of the winter season. However, after a prolonged cold spell, concrete surfaces tend to be slow to warm and can be colder than other roads in the same weather conditions.

Advice on spread rate modifications for porous asphalt and other negatively textured surfacings is provided in sub-section 8.6.

8.4.11 **Snow and freezing rain events (which are dealt with in a different section of the Practical Guide).**

Other factors associated with the weather and the nature of the local road network can also affect appropriate precautionary spread rates and, crucially, these are also dependent on high quality winter service decision making that includes optimising the timing of the treatments.

The amount of residual salt present on the network from previous treatments is included within the above list, as it can potentially be considered an important factor in determining appropriate spread rates and can reduce the amount of additional salt required to be spread. However, reliable information concerning the amount of residual salt present on the network can be difficult to determine and it may not be practicable for residual salt levels to be taken into account, either fully or at all, during the decision making process.

Further information and recommendations regarding how individual factors can be accounted for during the decision making process to determine the appropriate spread rates for precautionary salting operations are provided below.

Bridge decks tend to cool more quickly and reach lower minimum temperatures than adjacent sections of road as a result of the exposure of the soffit to cooling. These effects can be particularly marked where the bridge is in a valley or exposed to winds where evaporative cooling effects may be greater.

However, these effects vary markedly from bridge to bridge and the treatment of bridge decks should reflect local knowledge of how they respond to winter conditions.

Advice on spread rate modifications for those bridge decks where such modification is appropriate is provided in sub-section 8.6.

8.5 DETERMINING APPROPRIATE PRECAUTIONARY SPREAD RATES

8.5.1 The determination of appropriate precautionary spread rates requires authorities to carefully consider a number of factors and involves decision making at a planning level, as well as at an operational level.

8.5.2 The guidance contained within this section of the NWSRG Practical Guide is designed to assist authorities in developing their own spread rate schedules or matrices that are appropriate for use on their own networks, as well as assisting them in determining which of those spread rates to utilise in response to a particular weather forecast, expected traffic and road conditions.

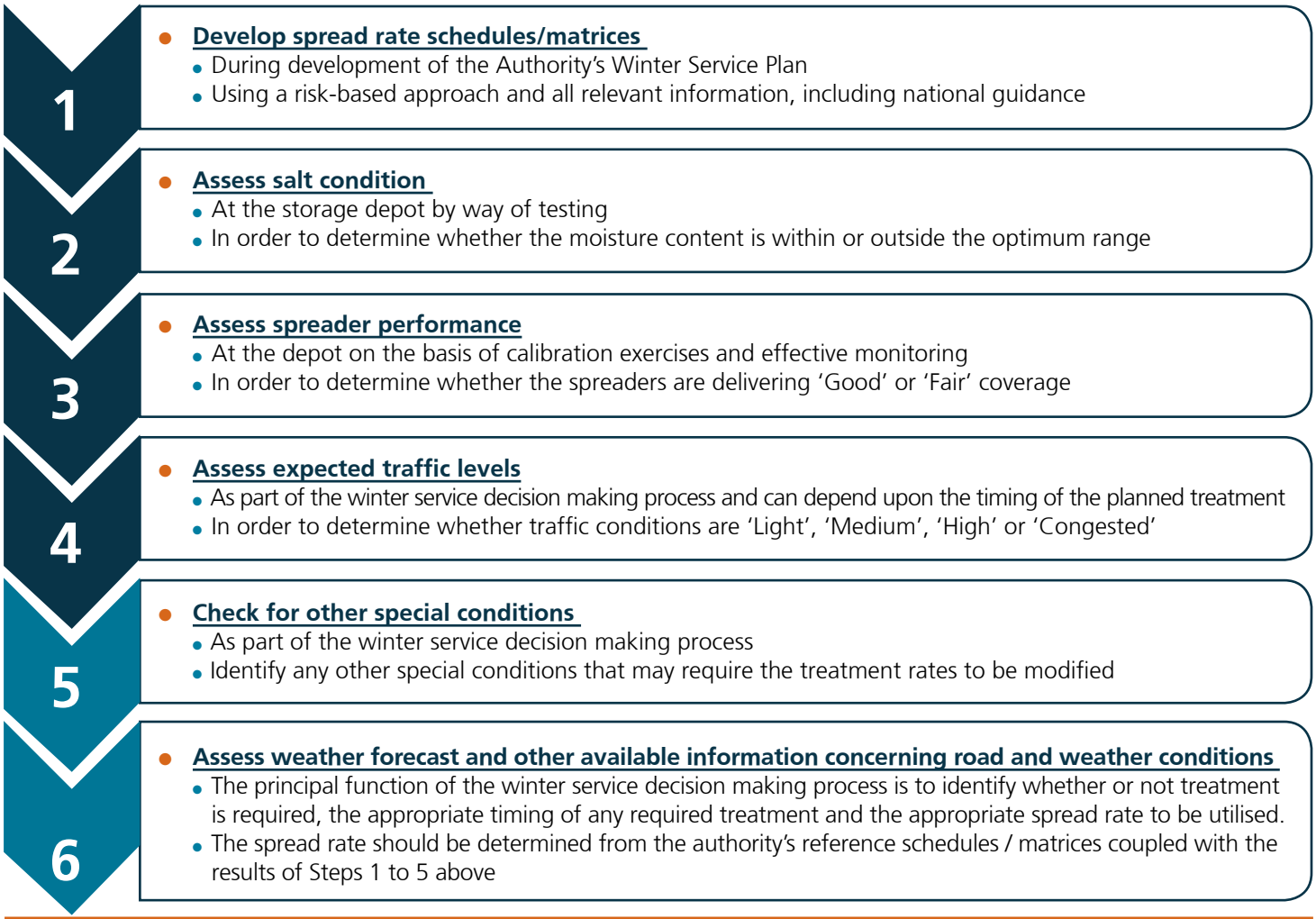
8.5.3 Authorities should take a risk-based approach to the development of their precautionary salting spread rate schedules or matrices and, to some extent, these will be based upon each individual authority's 'risk appetite'.

8.5.4 As well as the content of national guidance documents such as this NWSRG Practical Guide, the development of these schedules or matrices should take into account all of the relevant important local climatic, geographic, network composition, resourcing and administrative factors, as well as their own experience of maintaining the road network in that area. During this process, authorities may also find it beneficial to liaise with neighbouring authorities that, although differing in certain respects, may well be considering the same or similar issues.

8.5.5 As discussed above and in other sections of this Guide, there are a number of important factors that should be accounted for when determining appropriate precautionary spread rates. These include, for example, the salting technique to be employed, i.e. dry salting, treated salting or pre-wetted salting; the condition of the de-icing salt, i.e. whether this is within the optimum range or not; spreader performance, i.e. whether this is 'Good' or 'Fair'; and traffic conditions on the network. This is by no means an exhaustive list and, of course, this also does not include the crucial information relating to the predicted weather conditions. The above factors, and others, are discussed further in sub-section 8.6, which includes matrices providing recommended minimum precautionary salting spread rates for a range of weather and road surface conditions, as well as detailing recommended modifications that should be applied to these rates in certain circumstances.

8.5.6 The flowchart below shows a process for determining appropriate precautionary salting spread rates at a local level and illustrates the factors requiring consideration.

FIGURE 8.5.6 – FLOW DIAGRAM SHOWING PROCESS FOR DETERMINING APPROPRIATE PRECAUTIONARY SALTING SPREAD RATES



8.6 RECOMMENDED PRECAUTIONARY SPREAD RATE MATRICES

8.6.1 This sub-section provides information regarding recommended spread rates for precautionary salting operations undertaken in response to predictions of frost and ice formation in normal winter weather conditions on the UK road network.

8.6.2 Three separate matrices are provided for dry salting, treated salting and pre-wetted salting operations, and relate to dry/damp and wet road conditions for surface temperature ranges down to -15°C.

Based on research, it is considered that -15°C is the lowest temperature at which salt without special additives can be considered as a practicable and effective de-icer on the road surface.

However, it should be noted that salt becomes less effective when spread in conditions where the surface temperature is below -7°C (-5°C in 'low humidity' situations), and it is recommended that, whenever practicable, authorities avoid spreading salt in these conditions and utilise alternative de-icers in these situations when temperatures are very low. Further information relating to this issue is contained within the 'Treatments for Extreme Cold' section of this guide.

8.6.3 It is anticipated that, following a risk-based approach, authorities will develop their own schedules or matrices of precautionary salt spread rates appropriate for use on the networks in their local areas. Authorities may choose to adopt the spread rates provided here. However, some authorities may adopt different spread rates and, in such instances, the risk assessment process and the reasoning for adopting different rates should be documented.

8.6.4 The spread rates provided in the matrices here are intended to apply to the most common scenarios faced by local authorities when determining appropriate precautionary salting spread rates and it is important to note that they relate to spreaders that are providing either 'Good' or 'Fair' coverage, and 'Medium Traffic' level situations.

8.6.5 There are a number of factors that can potentially cause the spread rates provided in the matrices to be modified. These factors are discussed below as a series of 'Key notes' and it is crucial that authorities properly consider the content of these notes when utilising the spread rates contained within the matrices.

8.6.6 Key guidance notes regarding potential spread rate modifications

Note 1 – 'Rounding'

The recommended spread rates provided in the matrices are derived from applied research and scientific analyses. It is recognised that authorities may consider 'rounding' some of the recommended rates in order to satisfy issues of practicability, which is an important factor in delivering an efficient and effective winter service.

However, during this process and as discussed earlier in this section, it is recommended that authorities do not utilise lower precautionary spread rates than the lowest rates provided in the matrices, i.e. 8g/m² for dry salt and pre-wetted salt applications, and 7g/m² for treated salt applications.

In determining the spread rates to be used on their networks, authorities should utilise the matrices as a basis, along with their experience and expertise in dealing with the conditions and circumstances prevailing in their local areas, so as to ensure that risks and resources are appropriately managed.

Note 2 – Interpolation within individual temperature bands

The amount of de-icer required to prevent frost/ice formation does not increase by way of step changes as surface temperature reduces. Therefore, when considering specific minimum road surface temperature predictions, authorities may decide to interpolate between the relevant recommended spread rates shown in the matrices.

Note 3 – Higher spread rates

In certain weather and road conditions, the spread rates provided in the matrices may be higher than the spread rate(s) utilised by the authority during their salting route optimisation exercises. Therefore, it may not be possible to deliver the recommended spread rate in a single application. In this situation, ensuring sufficient de-icing material is present on the road surface is likely to require more than one treatment.

Note 4 – Very low temperatures

Due to the amount of salt needed to prevent frost/ice from forming at very low temperatures, it is recommended that the use of alternative de-icing materials is considered on all roads when minimum road surface temperatures are predicted to fall below -7°C. These rates for salt are therefore shown in red in the matrices. When spreading salt for these conditions (and when lower than -5°C in low humidity conditions), it is important that the timing of spreading operations allows sufficient time for the salt to enter solution before these temperatures are reached (see 'Treatments for Extreme Cold' for more information).

Note 5 – Salt chloride content

The spread rates provided in the matrices are based on the use of UK indigenous rock salt. If salt with higher purity is used, spread rates can be reduced. For example, the recommended spread rates can be reduced by 7.5% if salt purity is 99% or higher. However, as discussed earlier in this section, a minimum spread rate of 8g/m² (7g/m² for treated salt) should be maintained in order to account for the inevitable variabilities that occur in coverage and losses.

Note 6 – Salt moisture content

The spread rates provided in the matrices relate to salt exhibiting a moisture content within the optimum range. Information relating to optimum moisture content of de-icing salt is provided in the Salt Storage section of the NWSRG Practical Guide.

For pre-wetted and treated salting, the optimum moisture content is less than 4%.

The optimum moisture content range for dry salting is dependent upon its fines content. Where the maximum fines content (<0.3mm particle size) is less than or equal to 7.5%, the optimum moisture content for dry salting is within the range 1.5% to 4%. Where the maximum fines content is above 7.5%, the optimum moisture content is within the range 2% to 4%.

When undertaking precautionary salting operations with salt that falls outside of the optimum range, the spread rates provided in the matrices should be increased by 20%.

Note 7 – Porous Asphalt

When spreading on porous asphalt, the spread rates provided in the matrices should be increased by 25% and the increased spread rate should be maintained for a distance of 1 kilometre 'downstream' of each porous section (in two-way traffic situations, the increased spread rate should be maintained for a distance of 1 kilometre at both ends of each porous section).

Note 8 – Other negatively textured surfaces

With regard to its effects on de-icing materials, negatively textured surfacing can potentially exhibit similar properties to porous asphalt and authorities may wish to consider increasing spread rates by between 10% and 25% on negatively textured surfacing that is less than two years old. However, the porosity of such surfacing varies considerably with type and over time, and experience indicates that it is often impractical and unnecessary to increase spread rates on negatively textured surfaces, especially where these comprise only relatively short sections of treatment routes.

Note 9 – Bridge decks

In certain weather conditions, some bridge decks can exhibit lower minimum surface temperatures than those of adjacent sections of road. Some bridge decks can also cool down at an increased rate compared to other road sections. Therefore, it is recommended that authorities use their experience and/or a process of risk assessment to identify any bridge decks that exhibit significantly different thermal characteristics during winter conditions than the adjacent sections of road. It is further recommended that those authorities that maintain such bridges obtain weather forecasts that include specific reference to the bridge deck temperatures, and treat them accordingly. Due to the materials used in bridge construction, such treatment may include the use of alternative de-icing materials (see 'De-Icer Types' section for more information).

Note 10 – Traffic levels

The matrices assume 'Medium Traffic' around the time of the precautionary salting operation.

For 'Light Traffic' situations, the spread rates provided in the matrices should be increased by 25%.

Research has shown that salt losses do not increase significantly in 'High Traffic' situations and it is therefore considered that the spread rates provided in the matrices are suitable for use in these situations. However, where authorities maintain roads that regularly fall into the 'High Traffic' category for precautionary salting operations, they may opt to utilise the spread rates developed for Trunk Roads, although it is important to note that these only apply to 'Good' spreader capability.

Undertaking precautionary salting operations in 'Congested Traffic' situations should be avoided whenever practical considerations allow. However, when it is necessary to undertake precautionary salting operations in 'Congested Traffic', the spread rates provided in the matrices should be increased by 20%.

When undertaking precautionary operations in 'Congested Traffic' situations, it may be necessary to implement additional measures to aid the passage of spreaders and/or to consider undertaking additional treatments in order to ensure proper distribution of the de-icers.

Note 11 – Precipitation

Precipitation will adversely affect de-icing materials on the road surface, reducing their effectiveness and, along with the action of traffic, significantly increase the rate at which they are removed from the road surface. It is therefore recommended that, whenever practicable, treatments are delayed and undertaken after any predicted or actual rainfall has ceased and before freezing road surface temperatures are expected.

It is recognised that a band of frontal rain crossing the area presents a different situation to that of scattered showers, for example, and that it is sometimes difficult, or even impossible, to undertake and complete an operation in the available time period after the cessation of precipitation. In these situations, which can be some of the most challenging of all for decision makers, it will be necessary for winter service decision makers to use their judgement, along with all of the relevant information available to them, to determine the optimum timing for these salting operations.

Note 12 – Wind speed and direction

Wind speed and direction can affect the spreading of salt and, in dry conditions, also affect the length of time that the salt will remain on the road surface. When practical, it is therefore recommended that authorities avoid spreading during the predicted high wind period, i.e. periods when mean wind speeds are predicted to be 20mph or more.

This issue is likely to affect some locations on the salted network more than others, and the precise effects of high winds are difficult to quantify due to the nature of the wind field close to the road surface and the number of variables involved which include, amongst other factors, the direction of the wind field relative to the salting vehicle, the treatment type being utilised (dry, treated or pre-wetted etc) and the grain size of the salt etc.

Authorities should also be aware that forecast mean wind speeds typically relate to those at a height of 10 metres above the ground and these are not likely to be the same as those closer to the ground and care should be taken when comparing wind data from RWIS to forecasts etc.

When treatments are carried out during high wind conditions, it is recommended that authorities monitor residual salt levels and carry out re-treatments if and where necessary. If this issue is considered to pose a significant risk, authorities may also wish to increase spread rates when carrying out precautionary salting operations during periods when forecast mean wind speeds are 20mph or higher.

Note 13 – Residual salt

Residual salt from previous operations can reduce the spread rates required to prevent frost/ice formation. However if, when decision making, residual salt levels are relied upon to reduce instructed spread rates, it is important that such decisions are evidence based. As with all other pertinent information relating to winter service decision making, the supporting data should be recorded and retained.

8.6.7 Precautionary Spread Rates for Dry Salting

The matrix below provides recommended spread rates for precautionary dry salting operations on local authority roads in response to predictions of ice and frost formation.

When utilising these rates, it is crucial that the content of all of the 'Key Notes' above is properly considered, as these notes provide information regarding the interpretation of the matrix and discuss situations when the spread rates should be modified.

Recommended Spread Rates – Dry Salting (g/m²) Treatment Matrix 8.6.7				
Road Surface Temperature (RST) when frost/ice is predicted	Spreader Capability			
	Fair		Good	
	Dry/Damp Road	Wet Road	Dry/Damp Road	Wet Road
At or above -1.0°C	8	8	8	8
-1.1°C to -2.0°C	8	11	8	8
-2.1°C to -3.0°C	9	17	8	13
-3.1°C to -4.0°C	12	23	9	17
-4.1°C to -5.0°C	14	28	11	21
-5.1°C to -7.0°C	20	39	15	30
-7.1°C to -10.0°C	27	54	20	40
-10.1°C to -15.0°C	38	75	28	56

8.6.8 Precautionary Spread Rates for Treated Salting

The matrix below provides recommended spread rates for precautionary treated salting operations on local authority roads in response to predictions of ice and frost formation.

Treated salt incorporates an additive designed to improve performance and distribution, as well as reducing the rate of salt loss after spreading. Before adopting the treated salt spread rates in the matrix below, authorities should therefore satisfy themselves that the material is suitable for purpose and meets the manufacturer's performance claims. This includes manufacturers providing evidence of appropriate independent testing etc.

When utilising these rates, it is crucial that the content of all of the 'Key Notes' above is properly considered, as these notes provide information regarding the interpretation of the matrix and discuss situations when the spread rates should be modified.

Recommended Spread Rates – Treated Salting (g/m²) Treatment Matrix 8.6.8				
Road Surface Temperature (RST) when frost/ice is predicted	Spreader Capability			
	Fair		Good	
	Dry/Damp Road	Wet Road	Dry/Damp Road	Wet Road
At or above -1.0°C	7	7	7	7
-1.1°C to -2.0°C	7	8	7	7
-2.1°C to -3.0°C	7	12	7	10
-3.1°C to -4.0°C	9	17	7	13
-4.1°C to -5.0°C	11	21	8	16
-5.1°C to -7.0°C	15	29	11	22
-7.1°C to -10.0°C	20	40	16	31
-10.1°C to -15.0°C	26	55	22	43

8.6.9 Precautionary Spread Rates for Pre-Wetted Salting

The matrix below provides recommended spread rates for precautionary pre-wetted salting operations on local authority roads in response to predictions of ice and frost formation.

The spread rates in the matrix below apply to pre-wetted treatments comprising a 70:30 ratio by weight of dry salt to sodium chloride brine (sometimes denoted as FS 30), with a maximum dry salt component moisture content of 4% and a brine concentration of between 20 and 23%. Before adopting the pre-wetted salting spread rates in the matrix below, authorities should therefore satisfy themselves that the treatments they are using meet these criteria.

When utilising these rates, it is crucial that the content of all of the 'Key Notes' above is properly considered, as these notes provide information regarding the interpretation of the matrix and discuss situations when the spread rates should be modified.

Recommended Spread Rates – Pre-Wetted Salting (g/m²) Treatment Matrix 8.6.9

Road Surface Temperature (RST) when frost/ice is predicted	Spreader Capability			
	Fair		Good	
	Dry/Damp Road	Wet Road	Dry/Damp Road	Wet Road
At or above -1.0°C	8	8	8	8
-1.1°C to -2.0°C	8	10	8	8
-2.1°C to -3.0°C	8	16	8	12
-3.1°C to -4.0°C	11	21	9	17
-4.1°C to -5.0°C	14	27	11	21
-5.1°C to -7.0°C	19	37	15	30
-7.1°C to -10.0°C	27	53	21	42
-10.1°C to -15.0°C	n/a	n/a	n/a	n/a

SECTION 8 ANNEXE 1

Water Film Thickness

The amount of water on a road surface considerably affects the ability of salt to prevent frost and ice from forming. Surface water reduces the concentration of brine and, in conjunction with the action of traffic, increases the rate at which salt is removed from the road surface.

Table 8.A1 below classifies the amount of water present on a road surface into four main categories of 'Water Film Thickness' (WFT). These are termed 'Dry', 'Damp', 'Wet' and 'Very Wet' surface conditions, and are significant to the spread rate guidance contained within the main body of this section of the Practical Guide.

Table 8.A1 - Road surface wetness

Definition	Description	Water film thickness (for when using WFT instrumentation)
Dry Road	A road that shows no signs of water or dampness at the surface but may be just detectably darker. It may have moisture contained in pores below the surface that is not 'pumped' to the surface by traffic.	0 to 0.03mm (=0-30 g/m^2)
Damp Road	A road which is clearly dark but traffic does not generate any spray. This would be typical of a well-drained road when there has been no rainfall after 6 hours before the treatment time.	0.03 to 0.05mm (=30-50 g/m2)
Wet Road	A road on which traffic produces fine spray but not small water droplets. This would be typical of a well-drained road when there has been rainfall up to 3 hours before the treatment time.	0.05 to 0.1mm (=50-100 g/m^2)
Very Wet Road and Flowing Water on Road*	A road on which traffic produces droplets of water in the air to visibly flowing water on the surface	Greater than 0.1mm (=>100 g/m^2)

** The amount of salt required to prevent ice from forming in these conditions is considered impractical for authorities to deliver during normal precautionary salting operations*

The amount of salt required to prevent ice formation increases with WFT and, when road surfaces are 'Very Wet', i.e. the WFT is greater than 0.1mm, the amount of salt required to prevent ice formation is very high. During normal precautionary salting operations it is considered impractical for authorities to deliver sufficient salt to prevent ice formation in these conditions, and therefore the spread rate guidance contained within this section of the Guide only relates to 'Dry', 'Damp' and 'Wet' surface conditions.

Thankfully, in the UK 'Very Wet' road surfaces rarely occur when temperatures are cold enough for frost or ice to form and, as long as highway drainage is relatively effective, road surface wetness declines rapidly after precipitation. Therefore, when other practical considerations allow, it is recommended that authorities do not undertake precautionary treatments during or shortly after rainfall events.

Further advice relating to the appropriate timing of salting operations is contained within the Winter Service Decision Making section of the Guide.

In situations involving 'Very Wet' conditions and, in particular, where flowing water is present on the road surface and a risk of ice exists, actions other than spreading salt may be required, such as:

- Remedial measures to prevent water, such as field runoff, reaching the road surface
- Remedial measures to improve drainage of the road surface
- Warnings of possible ice formation (e.g. temporary signage)
- Road closure (in extreme circumstances e.g. burst water main)

SECTION 8 ANNEXE 2

Traffic levels and de-icer loss

For purposes of simplification and the issues involved in accurately estimating traffic levels across any part of the network and at any time, this guidance considers four levels of traffic for the purposes of precautionary treatment decision making. These are 'Light', 'Medium', 'High' and 'Congested'.

These categories bear no relation to the actual or theoretical traffic capacities of the roads and are also different to Average Daily Traffic levels (ADT), or similar categorisations of traffic levels that may be associated with other highway maintenance considerations.

Knowledge of likely traffic conditions at the time of the precautionary salting operation is a key part of the process of determining appropriate salt spread rates and this is discussed in the main body of this section of the Guide.

With regard to its effects on residual salt levels, and depending upon timing and conditions, the level of traffic is sometimes beneficial and sometimes disadvantageous.

Traffic aids the dispersion of water (where present) on the road before treatment and, typically, the heavier the traffic (up to about 250 vehicles per lane per hour), the greater the dispersion. Traffic also assists in the dissolution of salt, particularly in dry conditions. However, salt may also be removed from the road surface by the action of tyres and vehicle draughts (draughts are more of an issue for dry salting or pre-wetted salting in dry and windy conditions).

The effects of trafficking on spread rates considered within this guidance is based on loss of de-icers observed in trials. Research shows that de-icer losses do not increase significantly for traffic levels beyond 250 vehicles per lane per hour.

Sometimes importantly, 'Light Traffic' does not create conditions conducive to dissolution, and this should be taken into account during the decision making process. The main body of this section of the Guide discusses the increased precautionary salting spread rates that should be applied in these conditions.

In 'Congested Traffic' conditions, spreading is highly unlikely to be optimal and may be compromised by de-icer being deflected by vehicles or moved by vehicle draughts and not reach all of the target area. When spreading in 'Congested Traffic, overall losses due to trafficking will tend to be higher when dry salting and particularly if the road is not sufficiently damp to retain the smaller salt particles or hasten the dissolution of the salt

If precautionary treatment in 'Congested Traffic' is unavoidable, it may be necessary to implement additional measures to aid the passage of spreaders and/or to consider treatment in more than one application in order to ensure proper distribution of the de-icers.

Where there are sufficient differences between lane traffic levels all treatment scenarios should be considered and the worst case should be used for defining the treatment rate. Whereas trafficking may help to redistribute salt from the over/well-salted to the under-salted areas, the redistribution may be insufficient and should not be relied upon, especially when spread rates are low. Trafficking may also remove salt from an under salted area exacerbating the situation

Where practical, when frost and ice weather conditions are forecast and humidity conditions are beneficial to dissolution, spreading is preferable at a time when the amount of traffic within the first hour after spreading is lower. (This is because the rate of loss of salt from the target area through trafficking is likely to be higher before the salt has dissolved, particularly for dry salting)

Table 8.A.2 below provides a summary of the effects attributable to differing traffic levels before, during and after salting.

Table 8.A2 - Effect of trafficking		
Traffic Level & Timing	**Pros**	**Cons**
Before treatment **High**	Removes water from wet road surfaces Reduces water film thickness on damp roads	None
Before Treatment **Low/Medium** **Light/None**	None	Little water removed from a wet road surface Higher water film thickness for damp and wet roads
At Treatment **High**	None	May deflect salt from target areas, vehicle draughts may remove salt from road, particularly in dry conditions. Operation of spreader may be less than optimal in slow moving or stop/start conditions
At Treatment **Low/Medium** **Light/None**	Little loss due to traffic Salt spreading unhindered by vehicles adjacent to spreader	None
Shortly After Treatment **High**	Will help dissolution by crushing salt grains and reduce loss due to	Much salt may be removed from road by tyres and vehicle draughts before it enters solution
Shortly After Treatment **Low/Medium**	Less losses due to traffic	Dissolution may be slow particularly for dry roads and low humidity conditions. Some salt will be removed from the road before dissolution takes place.
Shortly After Treatment **(and up to forecast event)** **Light/None**	Less losses due to traffic	Dissolution **will be slow** particularly for dry roads and low humidity conditions. Dissolution **may not be complete** by the time of the forecast event

SECTION 8 ANNEXE 3

Interim spread rate guidance for salt brine treatments

Trials of sodium chloride brine spreading have been carried out on the Transport Scotland Network each year since the 2014/15 winter season. These trials have enabled the assessment of brine spreading in a range of conditions across different areas of Scotland.

Brine Spread Rates

Brine spread rates, shown in Table 8.A3, have been developed based on a comparison with rates successfully implemented in other European countries and experience from the ongoing brine spreading trials in Scotland.

Important general notes when considering the spread rates include:

- The spread rates in Table 8.A3 are dependent on a brine concentration in the range of 20 to 23%, with a recommended target concentration of 23%.
- Maintaining the correct brine concentration is critical for effectiveness of brine treatments, with the amount of salt spread directly proportional to this concentration. If the brine concentration is below the target range, less salt will be spread onto the carriageway and lower concentration brines are also more likely to freeze in extreme cold conditions. If the brine concentration exceeds 23%, there is a risk of salt re-crystallising within the pumps, pipes and nozzles of the spreader, particularly at very low temperatures.
- Other spreading equipment to that used in these trials may offer different spreading performance. When deciding spread rates and conditions for which liquid spreading will be used, Authorities should consult with manufacturers to understand the capability of the spreading equipment.

Table 8.A3 Brine spread rates for frost events

Road Surface Temperature (RST) when frost/ice is predicted	Recommended Spread Rates – Brine Spreading (ml/m²)	
	Dry/Damp Road	Wet Road
At or above -2.0°C	10	20
-2.1°C to -5°C	20	30
-5.1°C to -7.0°C	30	N/A

Key notes:

- Spread rates are for road surface wetness up to 0.1mm thick, i.e. a road on which traffic produces fine spray.
- Roads can remain wet after rain for significant periods (2-3 hours) before effective brine treatments are possible.

Implementing brine or other direct liquid applications

When deciding spread rates and conditions for which brine or other DLA treatments will be utilised, Authorities should consult with manufacturers to understand the capability of the spreading equipment.

A staged approach to implementing DLA treatments on selected routes should enable authorities to build experience and assess the suitability of the treatment method before more significant capital expenditure.

Initial treatments should be carefully monitored to assess performance.

Brine spreading or other DLA treatments can provide a useful tool for a wide range of conditions, but may not be suitable under all conditions. A dry, treated or pre-wetted spreading capability must also be available for routes considered for liquid treatments.

Route characteristics most suitable for brine spreading include:

- High proportion of precautionary treatments in marginal surface temperatures above 2°C.
- Infrequent snow and/or road surface temperatures below -5°C.

Brine concentration must be monitored and kept within acceptable agreed ranges (typically 20-23% but saturator technology may enable tighter tolerances)

All brine spreaders must be calibrated; this includes monitoring the discharge rate and carrying out a visual check of the distribution.

NATIONAL WINTER SERVICES RESEARCH GROUP
Website www.nwsrg.org
Email nwsrg@trl.co.uk