NWSRG

NATIONAL WINTER SERVICE RESEARCH GROUP

SECTION FIVE

TREATMENT METHODS & TECHNOLOGIES

In association with IHE

INSTITUTE OF HIGHWAY ENGINEERS

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CONTENTS

KEY

Red text are warnings or especially important information

Green text are particular recommendations or key advantages to consider

CHECK LIST:

Have you considered alternatives to the de-icing materials you have been using to date? Cost-benefit analyses may indicate efficiency savings and lower spread rates could potentially lead to improved resilience.

Have you considered the performance of the different spreading technologies in the weather conditions your area experiences? (see section 5.8)

SECTION FIVE
Treatment methods and technologies

5.1 INTRODUCTION

5.1.1 This section provides guidance on the principal methods for the spreading of de-icing materials, applied by vehicles or other mechanical means.

5.1.2 It is recommended that authorities carefully consider the treatment methods they utilise in delivering their Winter Service. This is particularly important when large scale investment decisions are made, such as when fleet renewals are required. It is recognised that each UK authority has unique geographical, climatological and administrative characteristics and that therefore the most appropriate treatment method is best determined at a local level through individual cost-benefit exercises, whole-life costing reviews and/or other analyses.

5.1.3 Four main treatment methods are currently used in the United Kingdom:

TABLE 5.1.1 – MAIN UK TREATMENT METHODS/TECHNOLOGIES

Treatment type	Details
Dry Treatment	De-icer, most commonly sodium chloride salt, is spread in a dry form. Traditionally, this has been the main method utilised across the UK for many years and this is still the method currently utilised by the majority of UK local authorities.
Pre-wetted Treatment	Granular de-icer, most commonly sodium chloride salt, is mixed with a brine solution at the point of spreading. A treatment additive may be included in either or both of the brine and dry components. Pre-wetted treatment is a development that is now in relatively wide use across the UK, and is the main method currently used to treat the trunk road network in England and Scotland, for example, as well as being utilised by local authorities. In certain situations and conditions, it can offer benefits over dry treatments, including reduced spread rates.
Treated Salting	Sodium chloride salt in granular form is mixed with a treatment additive. Commonly, the treatment additive comprises an Agricultural By-Product (ABP), either used alone or mixed with other chemicals. Treated salting is also a development that is now in wide use across the UK. Again, in certain situations and conditions, it can offer benefits over dry treatments, including reduced spread rates.
Direct Liquid Application (DLA)	Liquid de-icer is applied directly to the road surface, usually by spraying. This method has been used for many years in the UK to treat short sections of the network, such as certain bridge decks, that are particularly susceptible to infrastructure damage through corrosion. DLA on larger sections of the network is much less common practice in the UK than the other treatment types discussed above. However, this technique is currently the subject of research and a number of on-going trials.

Further details or each of these main treatment types are given in the following sections.

5.2 COMMON TREATMENT METHODS

5.2.1 Preventative treatments to mitigate against ice formation or remedial treatments to melt ice on UK roads and footways are normally undertaken using a purpose-built vehicle equipped with a hopper for carrying granular material, and liquid storage tanks where applicable, or a demountable spreading module attached to a multi-purpose vehicle body. Large pedestrian areas and footways can be treated with smaller motorised, de-mountable, towed or manually powered vehicles.

5.2.2 When determining the appropriate treatment method, or combination of methods, to utilise authorities should consider the following:

- The ability to deliver the service over a wide range of conditions
- Initial capital costs of equipment purchase
- Economical and efficient spreading
- Ability to effectively deliver the service in accordance with policy and plans
- Ability to accommodate equipment and plant (e.g. brine production)
- Ongoing costs (e.g. storing and managing de-icers, maintenance)
- Service resilience (e.g. salt stocks in harsh conditions)
- Adverse impacts (e.g. vehicles, road assets and the environment)

5.3 DRY TREATMENTS

5.3.1 Dry salting is currently the most common treatment type used by local authorities across the UK. Many authorities have been using dry treatments for a considerable period of time and the initial capital and maintenance costs tend to be lower than those arising from the use of pre-wetted treatments, and the material costs per tonne are lower than treated salt. However, the overall material costs of dry treatments can be higher than these other treatment types due to the higher spread rates that are required in certain conditions in order to overcome greater de-icer losses (see Section 8). This is an issue that may not only impact considerations relating to economical and efficient spreading but also resilience, asset damage and the environment.

5.3.2 **Dry treatment efficiency**
Arrangements for the storage of salt (as detailed in Section 4) should be carefully considered as it is important that salt is maintained in optimum condition for spreading. Salt stocks should also be managed, and the material loaded into vehicles in a manner that reduces the likelihood of increasing the fines content. The fines content affects distribution from the spreader and, in most conditions, dry treatments containing a higher fines content are also likely to suffer greater losses.

5.3.3 **Dry treatment salt condition**
The acceptable particle size range and moisture content for de-icing salt is provided in the relevant British Standard (BS 3247:2011).

As discussed above, dry treatments are particularly susceptible to higher losses when the material contains higher fines content. This situation is exacerbated when salt moisture content is low. Therefore, the lower limit for the optimum moisture content of dry treatments is linked to the fines content.

Too high a salt moisture content can lead to issues with 'tunnelling' or 'bridging' of the salt within hoppers, or the clogging of delivery chutes etc, which can prevent the correct amount of salt from reaching the spreader, and can also cause poor distribution of the salt that is spread.

The optimum moisture content range for sodium chloride salt being utilised as a dry treatment is dependent upon fines content. Where the maximum fines content (<0.3mm particle size) is less than or equal to 7.5%, optimum moisture content is within the range 1.5% to 4%. Where the maximum fines content is above 7.5%, optimum moisture content is within the range 2% to 4%. Dry treatment with salt outside of the above ranges is likely to exhibit higher losses and may well require higher spread rates (see Section 8).

It should be noted that, for dry treatments, the fines and moisture content of salt may be outside of the optimum range even though it conforms to the relevant British Standard.

Salt within the above ranges has a dry appearance, hence the term 'dry salting'.

Figure 5.3.1 – Dry salt

5.4 PRE-WETTED TREATMENTS

5.4.1 Pre-wetted treatments involve dry salt or a granular chemical de-icer being 'pre-wetted' with a brine solution at the point of delivery from the spreader. Typically, the brine comprises a sodium chloride and water solution. However, pre-wetted treatments can utilise 'treated' granular salt and/or brine made with alternative chemicals and/or additives.

5.4.2 Capital investment and maintenance costs for pre-wetted treatment can be higher than dry treatment as a result of the need for more sophisticated spreading equipment, brine production and/or storage and increased maintenance requirements. However, pre-wetted treatment may provide service delivery economies through the use of lower spread rates in certain conditions (see Section 8). As a result of these lower spread rates, pre-wetted treatment may also improve resilience and reduce environmental impact, when compared to dry treatment.

5.4.3 As a result of pre-wetted treatment involving the spraying of a liquid brine onto the granular material, potential problems arising from the use of lower moisture content salt are reduced when compared to dry treatment. For example, pre-wetted salt distribution is generally more uniform than dry salting, and losses due to wind, vehicle draughts and trafficking are also typically reduced.

5.4.4 Pre-wetted spreading equipment for use in the UK is designed so as to allow dry treatments to take place when this is advantageous.

5.4.5 **Pre-wetted granular salt condition**

The brine that is sprayed onto the granular salt material at the point of delivery holds the finer particles in suspension and reduces the potential impact of low moisture content in the granular salt affecting salt losses. Therefore, the minimum moisture content and maximum fines content is less important for pre-wetted treatments than dry treatments.

Optimum moisture content for sodium chloride salt being utilised as a pre-wetted treatment is less than 4%. Pre-wetted treatment with salt outside of this range may well require higher spread rates (see Section 8).

5.4.6 **Brine concentration**

Pre-wetted treatment in the UK typically utilises sodium chloride brine, but alternative de-icers can be used on their own or added to salt to improve performance, particularly in extreme cold (see Section 10).

The spread rates identified for pre-wetted treatments (see Section 8) are based on a 70:30 ratio by weight of dry salt to sodium chloride brine (sometimes denoted as FS 30) and a minimum brine concentration of 20%. If these ratios are varied for any reason, it is important that spread rates are adjusted and spreaders calibrated accordingly.

When utilising a pre-wetted treatment of 70:30 ratio by weight, 10g of pre-wetted salt mixture (as spread) will contain 7g of dry salt plus 0.69g of (pure) salt in the 3g of brine when the brine concentration is 23%.

The target concentration of sodium chloride brine should be between 20% and 23%.

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.

Nearly saturated brine solutions may create issues through recrystallization of salt in storage or spreading equipment as temperatures drop. The solubility of sodium chloride brine reduces at lower temperatures and, 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.

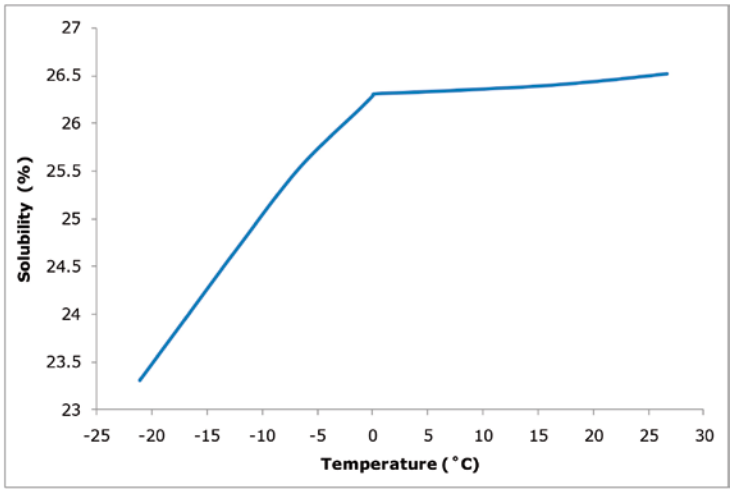

Figure 5.4.1 - The variation in the solubility of salt with temperature

Figure 5.4.2 - Pre-wetted salt (dry salt to brine ratio 70:30 by weight)

5.5 TREATED SALTING

5.5.1 Treated salting involves the spreading of dry salt that has been pre-treated with an additive. Typically, the treatment comprises an agricultural by-product (ABP) that may also have other additives to provide particular performance characteristics, and the treated salt is often purchased by the service provider pre-mixed from the salt supplier.

5.5.2 The treatment tends to bind the finer salt particles and help prevent them being removed from the road surface by wind or vehicle draughts. This therefore reduces losses when compared to dry salting and can also improve flow characteristics and the uniformity of salt distribution.

As a result, and in the same way as pre-wetted salting, treated salting allows the use of lower spread rates in certain conditions (see Section 8) and may therefore also provide improved resilience when compared to dry treatment.

5.5.3 Treated salting does not require the production, storage and spreading of brine, and can utilise the same spreading equipment as employed in dry, or pre-wetted, treatment (although it is important that the equipment is calibrated for the material being spread (See Sections 6 and 7)). Therefore, the capital investment and maintenance costs associated with treated salting are typically less than those for pre-wetted treatment. However, the cost per tonne of de-icing material is higher than that for dry salting. The relative costs of dry and treated salt vary over time, as well as with salt supplier and treatment type/manufacturer. As with pre-wetted treatments, treated salting is becoming more widespread across the UK.

5.5.4 **Treated salt condition**

As a result of treated salt binding the finer salt particles together, it reduces the potential negative impact of low moisture content in the salt in a similar way to that of pre-wetted treatment. Therefore, the minimum moisture content and maximum fines content is less important for treated salt than dry treatments.

Optimum moisture content for treated sodium chloride salt is less than 4%. Treated salting with salt outside of this range may well require higher spread rates (see Section 8).

5.5.6 **Potential environmental impact**

As with all de-icing materials, the storage of treated salt requires careful consideration and it is typically necessary for service providers to contact the relevant environmental agency/authority to obtain permission for its use. During such liaison, it is important that the composition of the relevant salt treatment is properly understood by both parties.

Having stated the above, treated salt is increasingly being used by service providers across the UK and they are not reporting any particular difficulties in obtaining permission to use the most commonly utilised treated salt products.

Figure 5.5.1 Treated salt

5.6 DIRECT LIQUID APPLICATION (DLA)

5.6.1 Direct Liquid Application (DLA) involves a salt brine, or other liquid de-icer, being applied directly onto the road surface without any accompanying solid de-icing material. The liquid may be a mixture of de-icing chemicals and/or include corrosion inhibitors, an ABP, acetates etc in addition to one or more chlorides.
The term 'Brine Spreading' is normally used in relation to the specific use of sodium chloride brine.

DLA has the potential to offer particular advantages over other forms of treatment when road surface temperatures are close to zero, as well as in situations of very low traffic flows. Certain liquids have also been specifically developed for use in extreme cold and low humidity conditions, when solid de-icers (including the solid element of pre-wet spreading) enter solution at a very slow rate.

DLA can be used as a precautionary treatment in advance of forecast snowfall and can provide an effective method for treating cycleways and/or footways, as liquids are active immediately after spreading and without the need for traffic.

DLA can be achieved by way of spray nozzles or dribble bars, and can also utilise a spinning disc system designed for this purpose. However, DLA using a spinner solely designed for dry or pre-wetted delivery should be avoided, as trials have shown poor distribution and coverage using this method.

When applied in longitudinal lines on snow and ice by dribble bars, some liquid de-icers can successfully penetrate through considerable thicknesses of ice and compacted snow layers, and assist in their break up and removal. Such conditions can be difficult to deal with by other methods.

TABLE 5.6.1 – TYPICAL DIRECT LIQUID APPLICATIONS (DLA)
Details
Sodium chloride brine with a target concentration of between 20% and 23% by weight
Calcium chloride brine of concentration 26% to 33%
Magnesium chloride brine of concentration 25% to 34%
Sodium chloride brine mixed with ABP
Liquids including a blend of sodium chloride and/or magnesium chloride and/or other de-icer with an ABP
Liquid acetates

Liquids are effective immediately after spreading and are generally more effective than other treatment methods in particularly low traffic situations. DLA can also be effective in very cold conditions (less than -10°C), depending upon the liquid de-icer. However, the limit of effectiveness for Brine Spreading (sodium chloride brine) is typically assumed to be -15°C).

When DLA is used as a precautionary treatment, the effect of wet roads can be significant, as the surface water lowers the concentration of the de-icer and renders it less effective. Where practical, it is therefore recommended that DLA as a precautionary measure be delayed after rainfall until roads are determined to be damp, rather than wet.

Figure 5.6.2 - A DLA spreader with spray nozzles for treating three lanes

Figure 5.6.3 – A combination spreader that can deliver DLA only treatments as well as pre-wetted treatments

Figure 5.6.4 DLA using three nozzles

5.7 POTENTIAL BENEFITS OF USING ADDITIVES WITH PRE-WETTED SALTING BRINE OR DIRECT LIQUID APPLICATION (DLA) TREATMENTS

5.7.1 In addition to the four main treatment methods discussed above, some service providers in recent years have been trialling and using additives to pre-wetted salting brine and DLA treatments. It is reported that the use of additives with pre-wetted salt brines can assist the pre-wetting of the salt, and some additives are also reported to assist in reducing corrosion. In addition, on the basis of reported operational practices in other countries, the use of additives in pre-wetted brines or chloride-based DLA may be effective in extreme cold conditions in the UK.

5.7.2 If considering the use of such additives, service providers should ensure that the materials are entirely suitable for the intended purpose and that this does not adversely affect the brine production, storage or delivery mechanisms, as experience indicates that blocked pumps, pipework and spray nozzles can be susceptible to such issues.

5.7.3 Service providers should also contact the relevant environmental agency/authority and seek permission to store and use the additives.

5.8 METHODS AND CONDITIONS

5.8.1 The four main treatment methods discussed above, i.e. dry treatment; pre-wetted treatment; treated salting and DLA, offer different advantages and disadvantages in different winter conditions.

5.8.2 In addition, a single treatment method is unlikely to be most effective across all of the winter conditions experienced in any particular area of the country. Therefore, authorities and service providers should decide upon the methods they will use to combat unusual and severe conditions, as well as those for the precautionary salting operations undertaken in more typical conditions (see Sections 8 and 9 for more information). It is also important that the content of all documented policies and plans relating to the delivery of the winter service are consistent in this respect. Whatever treatment methods are utilised, it is important that spreaders are calibrated for the de-icer being used and its condition (see Sections 6 and 7).

5.8.3 When deciding upon the most appropriate treatment methods, authorities and service providers should consider the range of conditions encountered for the particular network they manage, and how often these conditions occur, including:

- Road surface temperatures (range and frequency)
- Road surface wetness
- Precipitation quantity, frequency and timing
- Traffic levels (range and timing)
- Humidity (range and frequency)
- Wind gust levels and exposure to wind
- De-icer condition (range and available storage facilities for improvement if necessary)

Tables 5.8.1 and 5.8.2 below are intended to provide a general guide to the strengths and weaknesses of the four main treatment methods over a range of conditions for both precautionary and reactionary treatments. These assessments are made on a comparative basis across the methods, rather than being absolute values. Other methods of treatment may be more appropriate in specific or specialised circumstances or conditions.

TABLE 5.8.1 –RELATIVE TECHNOLOGY STRENGTHS AND WEAKNESSES FOR PRECAUTIONARY TREATMENTS

Condition	Dry	Treated	Pre-wet	DLA
Marginal Temperatures - RST close to 0°C	A	A	A	G
Dry Roads– RST to -7°C	A	G	G	G
Damp Roads – RST to -7°C	A	G	G	G
Wet Roads – RST to -7°C	G	G	A	N to A [1 & 2]
Extreme Cold – RST below -7°C (but above -15°C)	A	A	A to G [1]	N to G [1]
Very light traffic after spreading – RST to -7°C	A	A to G [2]	A to G [2]	G
High Wind Gusting over 20mph when spreading	A	G	G	A to G [3]
High Wind Gusting over 20mph after spreading	A	G	G	G
Hoar Frost and Freezing Fog	G	G	G	G
De-bonding Layer Before Snow	A	G	G	G

Key	
Relatively good performance, compared to other treatment methods	G
Appropriate for use, although not necessarily as efficient as other methods (see Section 8 for recommended minimum spread rates)	A
Not recommended for use in these conditions	N

[1] Dependent upon the precise liquid de-icer / pre-wetted brine utilised

[2] Dependent upon the precise meteorological conditions

[3] Dependent upon the delivery system, e.g. low set spray bar with nozzle system, standard spray bar with nozzle system, spinner etc

Further information relating to the performance of different de-icers in different conditions is provided in Section 3 of the Guide

Sections 8 and 9 of the guidance provide detailed recommendations and comments regarding treatments for snow and ice, and treatments during extreme cold. Reactionary treatments during or following moderate or heavy snowfall should involve ploughing, as treatment with de-icers alone is not very effective in these conditions. Other considerations, such as the removal of hard packed snow by alternate methods can also be important, as treating hard packed snow with salt alone can be ineffective, will be inefficient and require high spread rates with, preferably, larger salt grain sizes (10mm rather than 6mm). However, Table 5.8.2 below provides some outline guidance regarding the comparative reactive treatment performance of the four main treatment methods.

TABLE 5.8.2 –RELATIVE TECHNOLOGY STRENGTHS AND WEAKNESSES FOR REACTIONARY TREATMENTS

Condition	Dry	Treated	Pre-wet	DLA
Ice Formed - RST close to 0°C	G	G	G	G
Ice Formed – RST between -2°C to -7°C	G	G	G	N to G [1]
Ice Formed – RST below -7°C (but above -15°C)	A	A	A to G [1]	N to G [1]
Hard Packed Snow – RST to -7°C	G	G	A to G [1]	N to G [1]
Hard Packed Snow – RST below -7°C (but above -15°C)	A	A	A to G [1]	N to G [1]
Freezing Rain (due to the nature of freezing rain, the effectiveness of all practicable treatments in these conditions is likely to be limited)	A	A	A	N to A [1]

Key	
Relatively good performance, compared to other treatment methods	G
Appropriate for use, although not necessarily as efficient as other methods (see Section 8 for recommended minimum spread rates)	A
Not recommended for use in these conditions	N

[1] Dependent upon the precise liquid de-icer / pre-wetted brine utilised and / or application method

Further information relating to the performance of different de-icers in different conditions is provided in Section 3 of the Guide

5.9 EQUIPMENT AND FACILITIES REQUIRED FOR DIFFERENT TECHNOLOGIES

5.9.1 A wide range of suitable spreading vehicles and equipment is available, and some of this is capable of delivering more than one treatment method. For example, as long as they are appropriately calibrated for the material being spread (see Sections 6 and 7), the spreaders of pre-wetted salting vehicles can also be used to spread dry or treated salt. Salt storage is also an important consideration, regardless of whether dry, pre-wetted or treated salt is used (See Section 4).

5.9.2 However, other facilities, equipment and resources are also required that are dependent upon the particular treatment method employed. For example, this may require brine production plant and/or liquid de-icer storage facilities; equipment for loading and handling the various materials; equipment necessary to satisfy Health and Safety requirements; as well as appropriate drainage facilities and other environmental safeguarding measures.

5.9.3 When determining the most appropriate treatment methods to employ, authorities and service providers should consider the whole life costs of all of the necessary facilities, equipment and materials. Changing from one main treatment method to another is likely to involve additional costs and is therefore likely to be most cost effectively achieved at a point when major investment is already required, such as when a significant proportion of the vehicle fleet is due for replacement, or when a new depot facility is under construction etc.

5.9.4 Minimising capital and ongoing maintenance costs should be considered against the economies and other potential benefits of utilising different treatment methods, and the methods decided upon should be able to deliver across the range of conditions likely to be experienced in that particular area of the country.

5.9.5 Section 10 of the guidance discusses treatments for extreme cold and, even if it considered uneconomical to store and utilise alternative de-icers for only occasional use in rarely occurring conditions, the methods that will be employed to combat extreme conditions when they do occur should be detailed within the documented winter service policy and plan.

5.9.6 It is recommended that, when reviewing the potential benefits of alternative spreaders and vehicles, authorities consider the comparative performance capabilities and inclusion of technology that enhances efficiency and operational effectiveness. This technology includes comprehensive data logging; vehicle tracking; GPS navigation; automatic variable spreading; the use of multiple calibration levels etc, as this can provide longer term operational cost benefits.

5.9.7 **Spreading equipment for dry treatments (dry salting) and treated salt**
Although it is important that the equipment is calibrated to the material being spread (see Section 6), the spreading of dry and treated salt utilises the same equipment.

This normally utilises a vehicle equipped with a hopper to hold the salt and a mechanism to deliver a specific quantity of salt onto a spinning disc system (the 'spinner') which distributes the salt to the carriageway. The amount of salt being delivered to the spinner varies with vehicle speed, and spinner speed and orientation are adjusted to produce a specific distribution, e.g. symmetrically to Lanes 1 to 3 when travelling in Lane 2, or asymmetrically from Lane 1 to Lanes 1 and 2.

5.9.8 **Pre-wetted treatments (pre-wet salting)**
Pre-wetted salt is usually spread by a vehicle equipped with a hopper to hold the dry salt component with a spreader mechanism to distribute the salt to the carriageway in a similar way to dry and treated salting. However, in addition to the system for storing and delivering the granular salt component, vehicles for pre-wetted salting also require tanks for the pre-wetting agent, a pump and associated pipework, and nozzles to spray the agent onto the granular salt just before or at the spinner.
Spreaders designed for pre-wetted salt can also be used to spread dry and treated salt, and some also have the potential to deliver a low level of liquid only treatment.

5.9.9 **Direct Liquid Application (DLA)**
DLA can involve dedicated spray systems, dribble bars or combination spreaders (capable of distributing dry salt on its own or as a pre wet method) that have been designed with this purpose in mind and are equipped with brine tanks, a brine pump and sets of nozzles or spinning disc to spray the brine onto the road. As discussed earlier in this section, it is not recommended that liquid spreading is carried out using a spinner designed only for dry, treated or pre-wetted salt, as this is likely to result in poor distribution and coverage.

Where liquids are spread using spray bars, one set of nozzles targets the driven lane and other sets target the lane to the left and/or to the right of the driven lane. It is not normally possible to spread brine further than one traffic lane from the spreading vehicle.

TABLE 5.9.10 – SPREADER TYPES SUITABLE FOR TECHNOLOGIES

Spreader Type	Dry	Treated	Pre-wet	DLA
Standard Dry Salt Spreader	✓	✓	×	×
Pre-wet Spreader	✓	✓	✓	?
Combination Spreader	✓	✓	✓	✓
Liquid Spreader	×	×	×	✓

? May be used for top-up treatments over one lane width in lightly trafficked areas

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