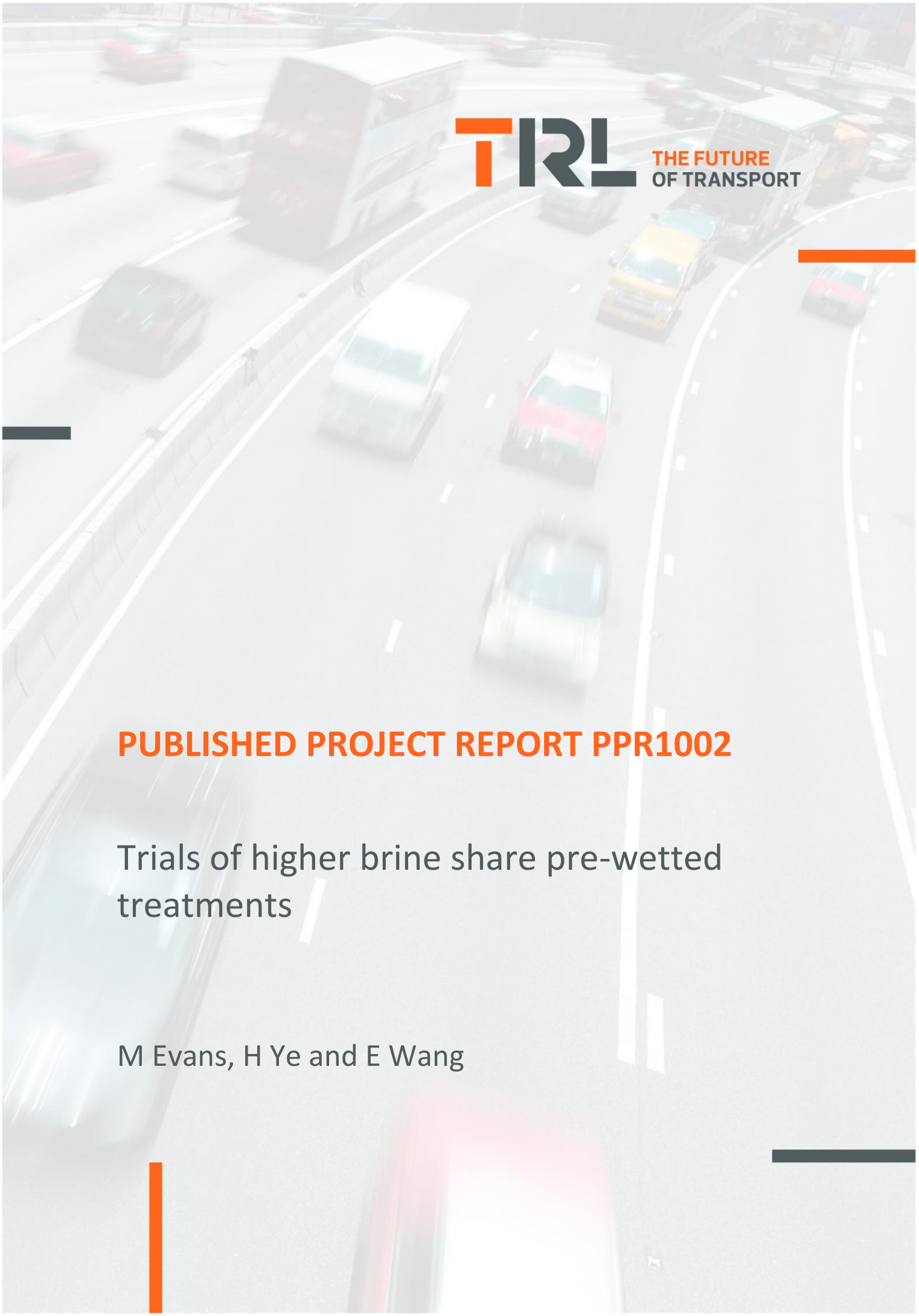

THE FUTURE OF TRANSPORT

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Trials of higher brine share pre-wetted treatments

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Executive Summary

The series of trials carried out over recent winters has enabled experience to be gained in the use of brine only and higher brine share pre-wetted salt across a range of conditions on the Scottish Trunk Road network. For the 2019/20 winter season further spreading was carried out on the A835 trial route using pre-wetted salt with a 50:50 ratio of dry salt:brine.

Sensor measurements and records of road conditions were used to assess the conditions under which effective treatments were carried out and to provide a comparison with the current standard pre-wetted treatments. Data was collated from all previous trial phases to enable comparison of residual salt measurements (from embedded road sensors) and freezing point temperatures (from active road sensor) between different treatment methods at the same sensor location. Because of the large number of treatments now carried out, a comparison can be made from analysis of the sensor data from multiple treatments for each treatment method under similar conditions.

Over the trial phases the following treatment methods have been used on the same trial route:

- Standard pre-wetted (FS 30) using a 70:30 ratio of dry salt:brine
- High brine share pre-wetted (FS 50) using a 50:50 ratio of dry salt:brine
- High brine share pre-wetted (FS 70) using a 30:70 ratio of dry salt:brine
- Brine only (FS 100)

The measurements indicated that comparable freezing point temperatures were achieved by the FS 30 and FS 50 pre-wetted salt, with a minimum freezing point around -20^{o}C achieved on damp roads (<0.05mm) and -15^{o}C on wet roads (<0.1mm). The amount of salt that can be spread by FS100 provides effective treatments to -5^{o}C on wet roads, and much lower on dry and damp roads. FS 70 provides effective treatments down to around -7^{o}C on wet roads.

The road surface wetness is a key factor influencing the effectiveness of treatments. For dry, damp and wet roads i.e. water thickness less than 0.1mm for the duration of the treatment, FS50 provides very similar performance to FS30 while spreading around 20% less salt.

Because brine is spread with a maximum of 23% concentration, there is a limit on the amount of salt that can be retained on the road after brine only spreading even with very low losses. In comparison the FS 30 is spreading over 3 times the amount of salt.

As road wetness increases, all treatment types show reduced freezing points of the road surface moisture, tending towards very low suppression at around 0.5mm water thickness and 2mm of precipitation (water equivalent).

The A835 trial route can provide a severe challenge irrespective of the treatment method applied, with precipitation, high winds and very wet road surfaces occurring during many of the treatments carried out. On a number of occasions this resulted in the need for follow up treatments, either for the full route or targeted treatments from the patrol spreaders. This was the case both for standard FS30 pre-wetted spreading and the FS 50 high brine share treatments during the 2019/20 season.

With regard to the pros and cons of solid and liquid treatments, higher brine share treatments which involve the simultaneous spreading of solid salt (pre-wetted from a spinner) and a liquid only treatment (applied directly to the road surface from a spray bar) can offer the benefits of both approaches while mitigating against the disadvantages of any one approach in isolation.

The embedded road sensors are detecting the amount of salt in solution, and the higher liquid share pre-wetted salt and brine only treatments provided immediate freezing point depression, an advantage in the first hour or two after spreading in low traffic conditions or for treatment of thin layers of ice/frost.

In the low traffic morning treatments FS 50 shows the highest initial salt level and freezing point reduction, with FS 30 exhibiting greater salt and lower freezing point after approximately 3 hours and longer.

While all treatment methods showed low effectiveness for more than 0.5mm water thickness and 2mm of precipitation, higher solid share treatments (FS50 and FS30) showed some advantage over higher liquid shares treatments (FS70 and brine only) in the very wet conditions leading up to these limits.

For all treatment methods, the freezing point behaviour tends to show a much flatter response as compared to the residual salt. The initial dissolution of salt will decrease the freezing point. This depression appears to be maintained over the duration of the treatment for damp and wet roads. Salt may be lost as solution, resulting in the reduction in salt amount shown by the sensors, however the freezing point of the solution remaining is maintained, except on very wet roads where precipitation or heavy dew formation will dilute and/or wash away the salt solution.

Guidance has been developed on limiting factors (e.g. minimum temperatures, amount of precipitation etc.) for different road conditions including very wet roads and precipitation, very light traffic after spreading, high wind speed when spreading.

1 Introduction

The series of trials carried out over recent winters has enabled experience to be gained in the use of brine only and higher brine share pre-wetted salt across a range of conditions.

The 2018/19 trial results showed that higher brine share pre-wetted treatments, using a ratio of 30:70 dry salt: brine, provided improved performance over brine only spreading on very wet roads and before precipitation events and snow conditions. It was further concluded that spreading at a 50:50 ratio of dry salt:brine might offer further improvements in severe conditions from increased residual salt levels.

Based on these results, and other reported research in Europe with higher brine share pre-wetted salt, it was proposed to carry out further trials with 50:50 salt:brine ratios to provide a comparison between the treatments and suitability for typical conditions on the Scotland network.

Data was also collated from previous trial phases on the A835, to enable comparison of residual salt measurements (from embedded road sensors) and freezing point temperatures (from active road sensor) between all the different treatment methods used at the same location under similar conditions. Because of the large number of treatments now carried out, a comparison can be made from averaging of the sensor data from multiple treatments for each treatment method and condition grouping.

2 Trial Site

Following the same procedure as the previous trial phases, treatments were carried out as part of the routine winter treatments on Precautionary Treatment Route 20-8 within the North West Trunk Road Unit, the location shown in Figure 1.

The route has a treatment length of 79km and an average width of 6.5m.

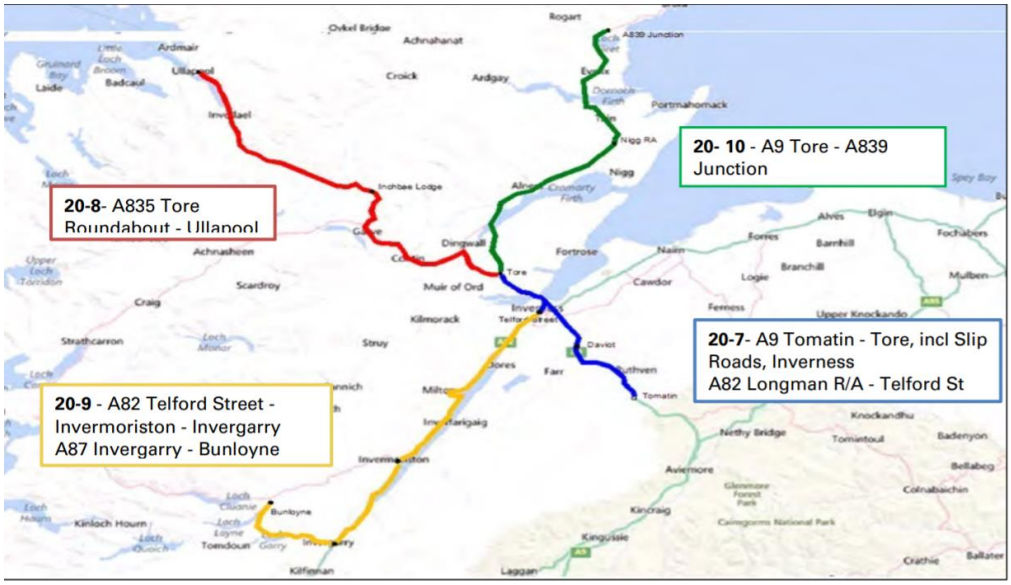

Figure 1: Route 20-8 and other precautionary routes operating from Bridgepoint Depot (Inverness) – taken from North West Unit Winter Service Plan 2019/20

3 Trial methodology

Brine spreading was carried out using a Schmidt Stratos Combi Flex Spreader, the same vehicle as used in the previous phases of the A835 winter trials as shown in Figure 2. Further details of the spreader are available in Evans (2019).

Figure 2: Schmidt Stratos Combi Flex Spreader

Treatments were carried out in accordance with the standard decision matrix shown in Figure 3.

Spread rates for precautionary treatments and snow clearance are shown in Table 1.

Records of treatment timings and spread rates were obtained from the Vaisala RoadDSS Manager system.

<table>
<tr><th colspan="4">Decision Matrix</th></tr>
<tr><th></th><th colspan="3">Predicted Road Conditions</th></tr>
<tr><th>Road Surface Temperature</th><th>Wet</th><th>Wet Patches</th><th>Dry</th></tr>
<tr><td>May fall below 1ºC</td><td rowspan="3">Salt before frost</td><td>Salt before frost (see Note A)</td><td>No action likely, monitor weather (see Note A)</td></tr>
<tr><td rowspan="4">Expected to fall below 1ºC</td><td colspan="2">Salt before frost (see Note B)</td></tr>
<tr><td colspan="3">Salt after rain stops</td></tr>
<tr><td colspan="3">Salt before frost and after rain stops (see Note C)</td></tr>
<tr><td colspan="2">Salt before frost</td><td>Monitor weather conditions</td></tr>
<tr><td>Expected snow</td><td colspan="3">Salt before snow</td></tr>
<tr><td rowspan="3">Freezing rain</td><td colspan="3">Salt before rain (see Note C)</td></tr>
<tr><td colspan="3">Salt during rain (see Note C)</td></tr>
<tr><td colspan="3">Salt after rain (see Note C)</td></tr>
</table>

Figure 3: Decision matrix - taken from North West Unit Winter Service Plan 2018/19

The decision to undertake precautionary treatments may be adjusted to take account of residual salt or surface moisture.

Note A: Particular attention should be given the possibility of water running across carriageways. Such locations will be monitored and treated as required.

Note B: When a weather warning contains reference to expected hoarfrost close monitoring will be required, with particular attention given to timings of precautionary treatments as salt deposited on dry roads may be dispersed before it can become effective.

Note C: Under these circumstances rain will freeze on contact with running surfaces and full pre-treatment should be provided even on dry roads, with continuous monitoring throughout the danger period.

Table 1: Spreading rates for precautionary treatments

Spreading rates for precautionary treatments with FS50 (g/m²)		
Road surface condition	**Frost Susceptible/surface water run-off area**	**Road Surface Wet**
A. RST higher than plus 1°C	0	0
B. RST lower than or equal to plus 1°C but higher than minus 2°C	10	20
C. RST lower than or equal to minus 2°C but higher than minus 5°C	10 to 20	20
D. RST lower than or equal to minus 5°C	10 to 20	20
E. RST lower than or equal to plus 1°C but higher than minus 2°C following rain (see note 1)	20	30
F. RST lower than or equal to minus 2°C but higher than minus 5°C following rain (see note 1)	30	30
G. RST lower than or equal to minus 5°C following rain (see note 1)	30	30
H. Hoar Frost	20	20
I. Freezing Fog	10	20
J. Freezing Rain	30	30
K. Snow Accumulations up to 30mm	30	30
L. Snow Accumulations over 30mm	30	30
M. Hard Packed Snow/Ice	See clearance matrix	See clearance matrix

Note 1 Treatments will be carried out after water has dispersed and road surface classed as damp.

4 Monitoring of road conditions

4.1 Fixed monitoring sites

The Braemore, Aultguish and Brahan fixed weather stations were used to monitor road surface conditions on the A835. The locations of the weather stations are shown in Figure 4. Monitoring equipment included:

- Non-invasive DSC111 and DST111 sensors to remotely monitor road condition (wetness, snow, ice) and surface temperature (Aultguish only)
- Road weather station including wind speed, embedded DRS 511 sensor (road condition and temperature), CCTV
- Addition of an active freezing point sensor at Aultguish

The road condition from the fixed sensors was continuously and automatically monitored every 10 minutes and the data collated and analysed.

All weather station and patrol data were fed back to the Operating Company control centre and access to weather station data was available through the Vaisala RoadDSS system.

Figure 4: Weather station locations – taken from North West Unit Winter Service Plan 2017/18

4.2 Patrols

The trial site was a Category B patrol route. Category B Patrols are designed to monitor conditions, provide salt treatments and plough as required with a 3 hour cycle: once during the 00.00 – 03.00, 03.00 – 06.00 and 06.00 – 09.00 periods specified.

5 Treatment method terminology

In this report, the different treatment methods are referred to as FS 100, FS 70, FS 50 and FS 30. The proportion of dry salt and brine making up each treatment are shown in Table 2.

Table 2: Relative amounts of salt delivered by each treatment method

Treatment method	% Dry salt (Purity 92%)	% Brine (23% concentration)	Total amount of NaCl in 20g/m²	% of NaCl amount from FS30
FS 30 (Standard pre-wetted)	70%	30%	14.26	100
FS 50 (High brine share)	50%	50%	11.5	81
FS 70 (High brine share)	30%	70%	8.74	61
FS 100 (Brine only)	0	100	4.6	32

6 Review of 2019/20 spreading events – FS50 and FS30

Sensor measurements and records of road conditions were used to assess where treatment effectiveness limits had been reached for the FS50 and FS30 treatments carried out during the 2019/20 season.

Details of weather and road conditions are provided in Appendix A for spreading events where one or more of the following conditions was observed or measured following the treatments:

- Ice and low 'Grip' reported (non-invasive sensor)
- Road surface temperature measured to be lower than freezing point temperature (active sensor)
- Ice reported from embedded passive sensors
- Ice reports from spreader drivers/public/police
- No freezing point suppression – treatment diluted from wash off

These events have been classified into different categories depending on spread rates, road and weather conditions with the categories explained in Table 3.

Table 4 provides a summary of the duration of treatments and temperature limit of effectiveness for these events.

The A835 trial route can provide a severe challenge irrespective of the treatment method applied, with precipitation, high winds and very wet road surfaces occurring during many of the treatments carried out. On a number of occasions this resulted in the need for follow up treatments, either for the full route or targeted treatments from the patrol spreaders. This was the case both for standard FS30 pre-wetted spreading and the FS 50 high brine share treatments.

Where treatment effectiveness limits were reached this was in nearly all cases where very wet roads and some degree of precipitation occurred.

The temperature limit of effective treatments was seen to be above -5°C in a lot of these events, and for a number of treatments above -1°C, and this was the case for both the FS30 and FS50 treatments.

Where the temperature limit fell was above -2°C this was predominantly where high winds occurred during spreading (around 20mph average or higher)

Table 3: Spreading event classification

Parameter	Categories	Values
Spread rate		10, 20, 30, 40 g/m²
Time of spreading	Afternoon	12pm to 7pm
	Evening	7pm to 12am
	Morning	12am to 9am
Road wetness	Dry	0 mm Water thickness
	Damp	0 < Road wetness <= 0.05mm
	Wet	0.5 < Road wetness <= 0.1mm
	Very wet <0.5	0.1 < Road wetness <= 0.5mm
	Very wet < 1	0.5 < Road wetness <= 1mm
	Very wet > 1	1mm < Road wetness
Precipitation amount (water equivalent)	None	Amount = 0mm
	Low	0 < Amount <= 1mm

	Medium	1 < Amount <= 2mm
	Heavy	2mm < Amount

Table 4: Summary of treatment events

Treatment	Rate	Time	Surface	Precipitation	Low temperature (°C)	Duration (hrs)	Other factors
P50	10g/m²	Evening	Wet	Low	-1.4	9	
P50	10g/m²	Evening	Wet				Max wind speed 24.2mph at time of treatment, average speed 15.4 mph
P	20g/m²	Afternoon	Damp	Low	-2.9	7.5	High humidity and RST<Dew point for duration
P50	20g/m²	Afternoon	V Wet < 0.5	Low	-1.9	9	
P50	20g/m²	Afternoon	V Wet < 0.5	Low	-1.9	5.5	High Wind
P50	20g/m²	Afternoon	V Wet < 0.5	Low	0	2.5	Max wind speed 18.6mph at time of treatment, average speed 13.9 mph
P50	20g/m²	Afternoon	V Wet < 0.5	Low	-1.5	4.5	

P	20g/m²	Afternoon	V Wet <0.5	Low	0	3.5	
P	20g/m²	Afternoon	V Wet <0.5	Low	-3.5	5.5	
P50	20g/m²	Afternoon	V Wet <1	Low	-3.3	9	
P50	20g/m²	Afternoon	V Wet <1	Low	-0.3	2	
P50	20g/m²	Afternoon	V Wet <1	Medium	-2	8	High Wind
P	20g/m²	Afternoon	Wet	Low	-1.3	4	Max wind speed 23.3mph at time of treatment, average speed 15 mph
P50	20g/m²	Evening	V Wet > 1	Heavy	-1.3	6	
P50	20g/m²	Evening	Wet	Low	-0.7	4.5	Max wind speed 21.3mph at time of treatment, average speed 13.6mph
P	20g/m²	Morning	Damp	None	-7.1	0	
P50	20g/m²	Morning	V Wet < 0.5	Low	-4.2	1.5	
P	20g/m²	Morning	V Wet < 1	Low	-0.5	3.5	
P	30g/m²	Afternoon	V Wet <0.5	Low	-1.9	3	

P	30g/m²	Afternoon	V Wet <1	Low	-0.8	2	Max wind speed 23.3mph at time of treatment, average speed 15 mph
P	30g/m²	Evening	V Wet <0.5	Low	-0.2	3	High Wind
P	30g/m²	Evening	V Wet <0.5	Low	-0.4	4.5	Max wind speed 21mph at time of treatment, average speed 14.3 mph
P	30g/m²	Morning	V Wet >1	Low	-0.2	2	

7 Comparison of sensor data – all year summary

7.1 Data consolidation

Data was collated from all trial phases on the A835, to enable comparison of road sensor measurements (from embedded and remote road sensors) for the different treatment methods across the range of conditions encountered on the trial site.

As has been noted before, some caution is needed when drawing conclusions from measurements from sensors. Only a small area is measured which might not be representative of the conditions across the full carriageway width or along the length of road at that location. The embedded road sensors also require moisture to provide a representative reading.

Spreading events were grouped into similar conditions, using the categories outlined in Table 3. Because of the large number of treatments now carried out, a comparison can be made from averaging of the sensor data from multiple treatments for each treatment method and comparison made between the different treatment methods for a range of different factors including:

- Road surface wetness
- Precipitation amount
- Time of spreading (traffic level)

These plots show the trend line fitted to the sensor data. The shaded area shows the full range in the readings at each time after spreading.

The effect of different road and weather conditions on the relative performance of the different methods is discussed in the following sections.

7.2 Freezing point suppression

Figure 5 and Figure 6 summarise the road wetness and freezing point measurements taken at Aultguish for each of the treatment methods, spreading at 10 and 20g/m² respectively. For each point on the plots, the road wetness reported is the maximum value that occurred at any time between spreading and the time of the freezing point measurement.

Figure 7 and Figure 8 summarise the amount of precipitation that occurred and freezing point temperatures, spreading at 10 and 20g/m² respectively. For each point on the plots, the amount of precipitation reported is the total amount measured between spreading and the time of freezing point measurement.

The measurements indicate that comparable freezing point temperatures were achieved by the FS 30 and FS 50 pre-wetted salt, with a minimum freezing point around -20°C achieved on damp roads (<0.05mm) and -15°C on wet roads (<0.1mm).

For the FS70 pre-wetted salt, lower freezing points were measured, with a minimum around -7°C measured for wet roads.

For the brine only, the lowest freezing point suppression was measured, with a minimum around -5°C measured for damp and wet roads. Lower freezing points were measured on drier roads down to below -10°C.

As road wetness increases, all treatment types show reduced freezing points of the road surface moisture, tending towards very low suppression at around 0.5mm water thickness and 2mm of precipitation (water equivalent).

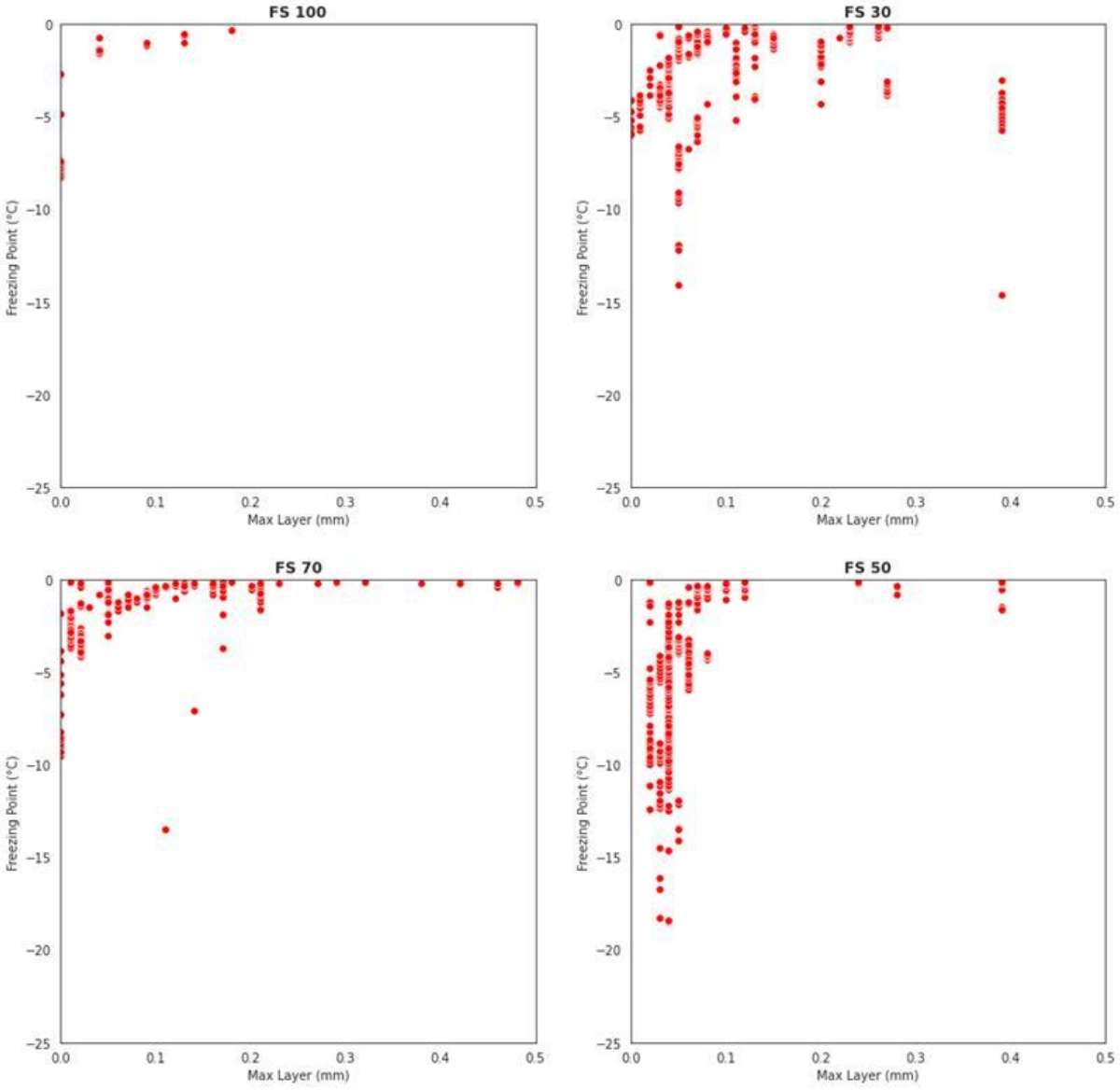

Figure 5: Freezing point change with water thickness, 10g/m²

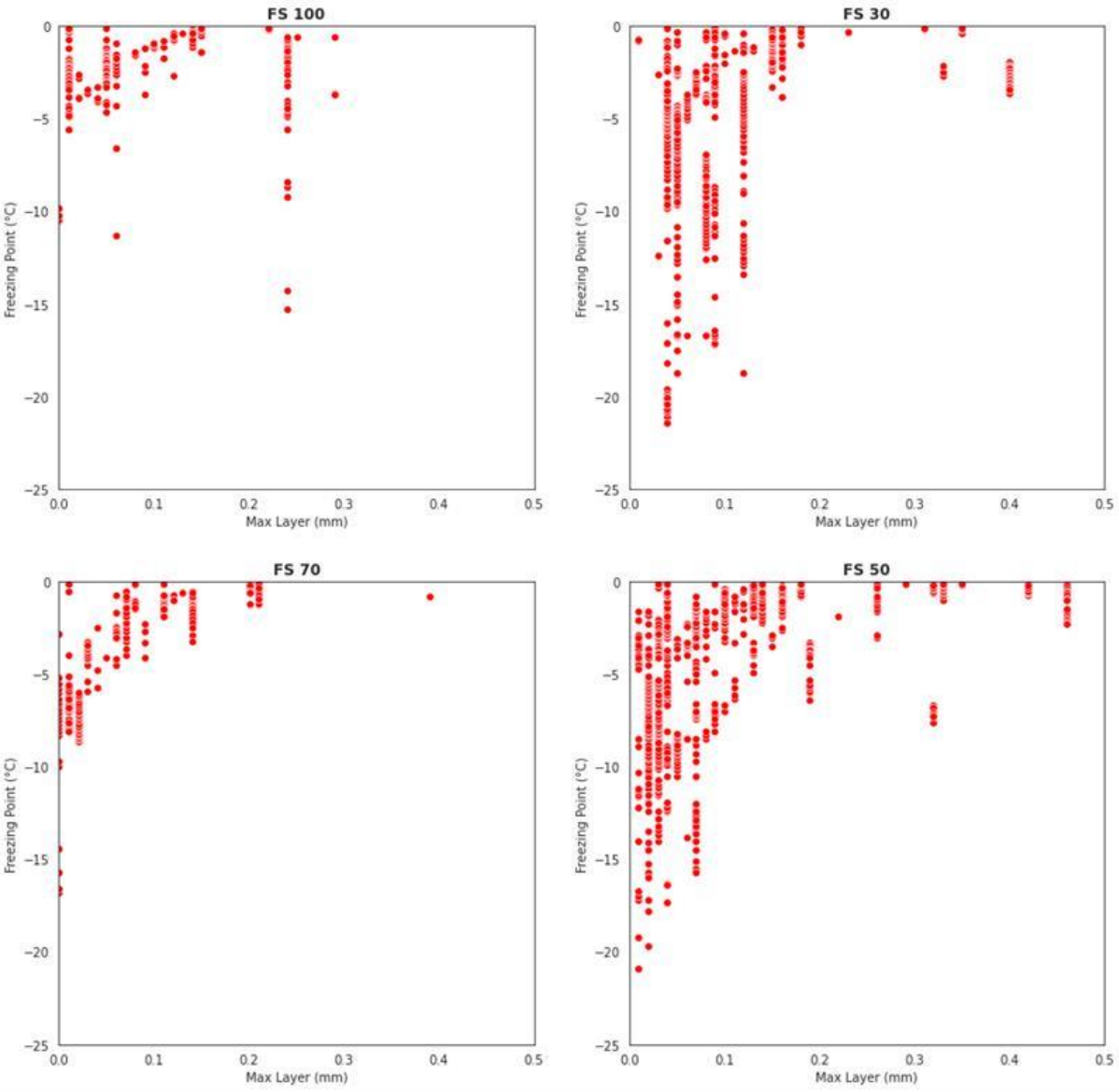

Figure 6: Freezing point change with water thickness, 20g/m²

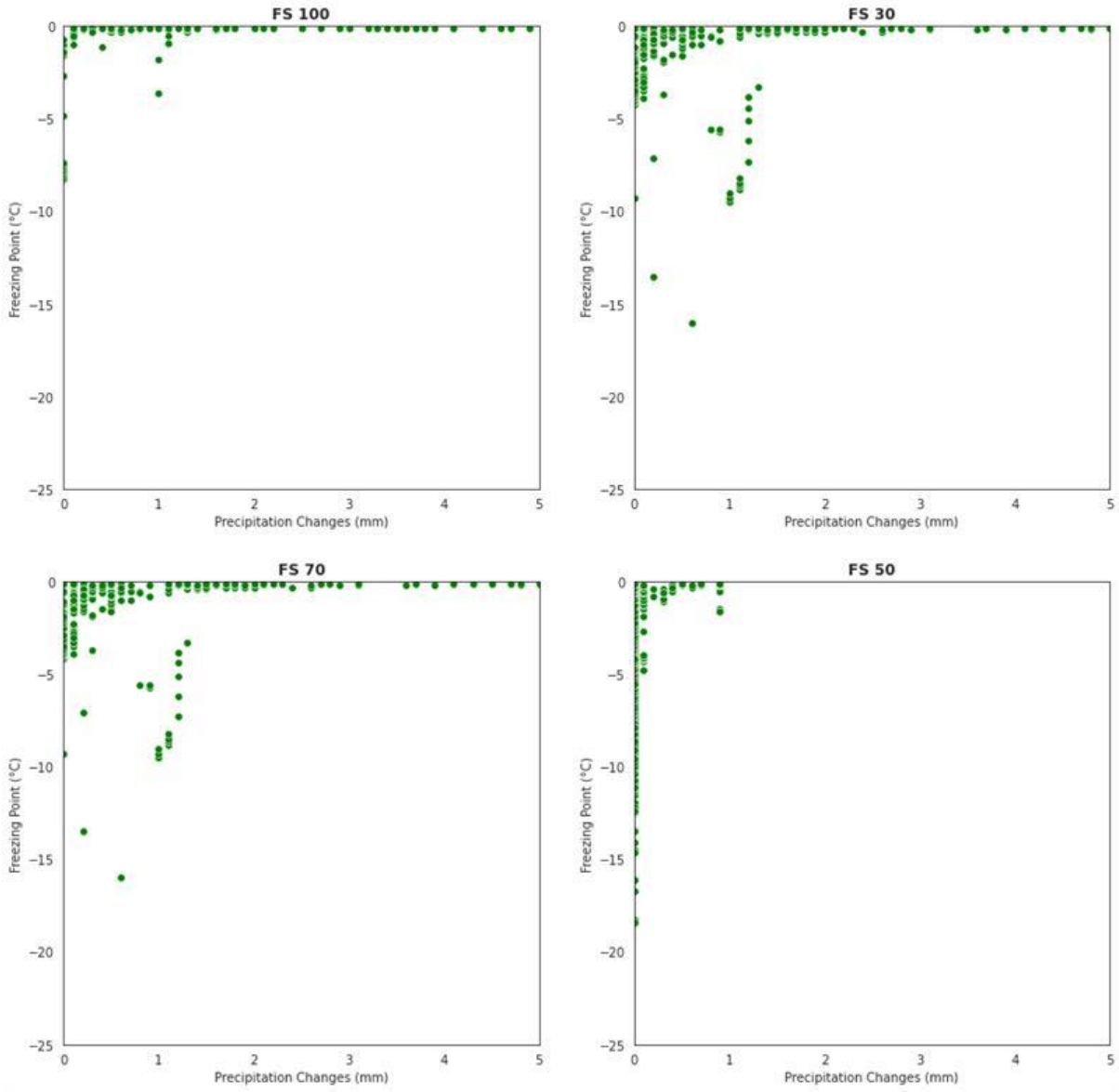

Figure 7: Freezing point change with precipitation amount, 10g/m²

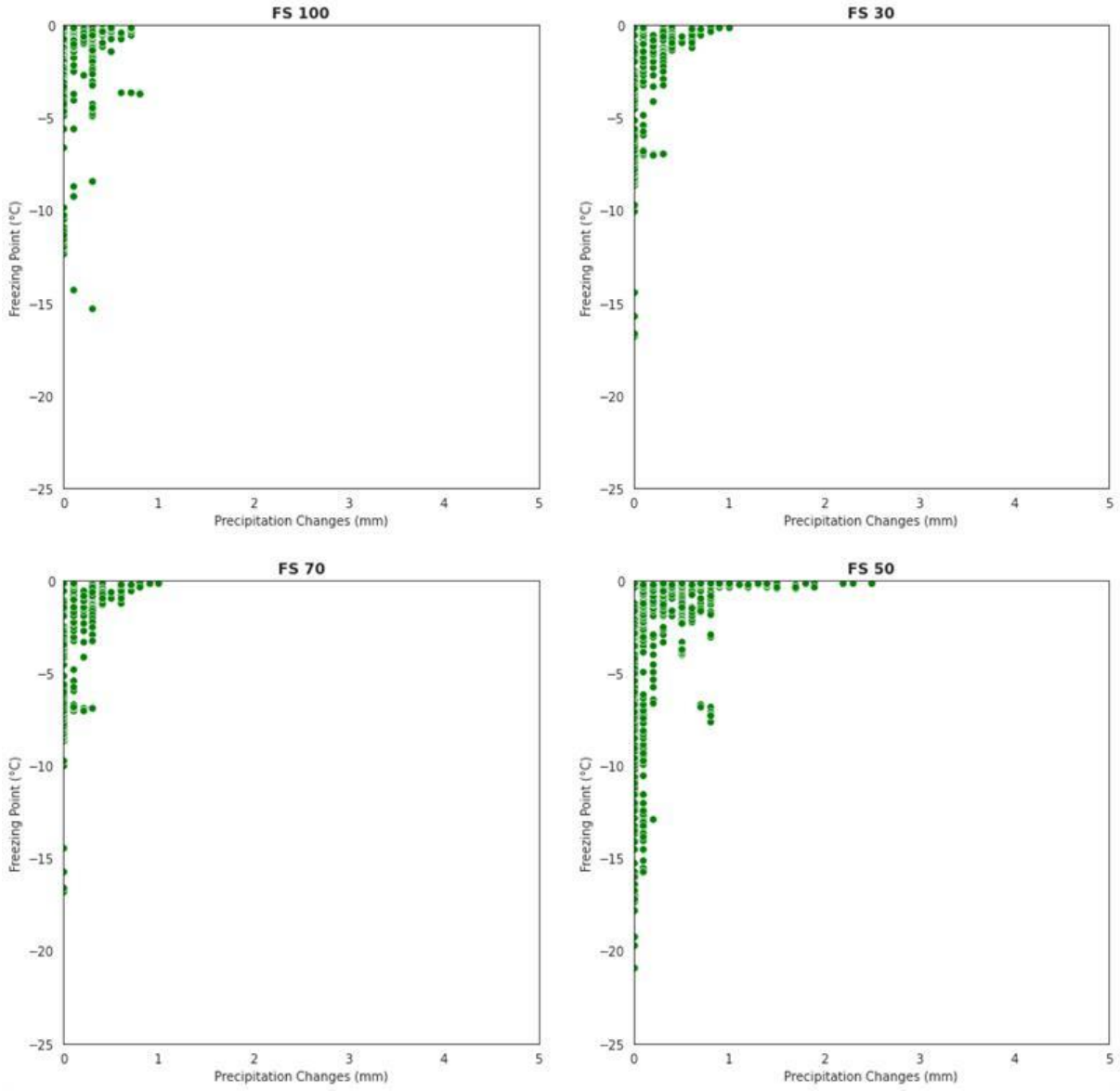

Figure 8: Freezing point change with precipitation amount, 20g/m²

7.3 Residual salt and freezing point longevity

7.3.1 Effect of road wetness

For spreading at 20g/m², Figure 9 summarises the variation in salt amount and Figure 10 the variation in freezing point temperature with time after spreading, showing the comparison between the different treatment methods for different road wetness levels.

With the equivalent spread rate, the data shows very similar response for FS 30 and FS 50, with both methods showing higher residual salt levels and lower freezing points than FS 70 and FS 100 treatments. This difference is more pronounced on the wet roads in comparison to the damp conditions.

Because brine is spread with a maximum of 23% concentration, there is a limit on the amount of salt that can be retained on the road after brine only spreading even with very low losses. In comparison the FS 30 is spreading over 3 times the amount of salt.

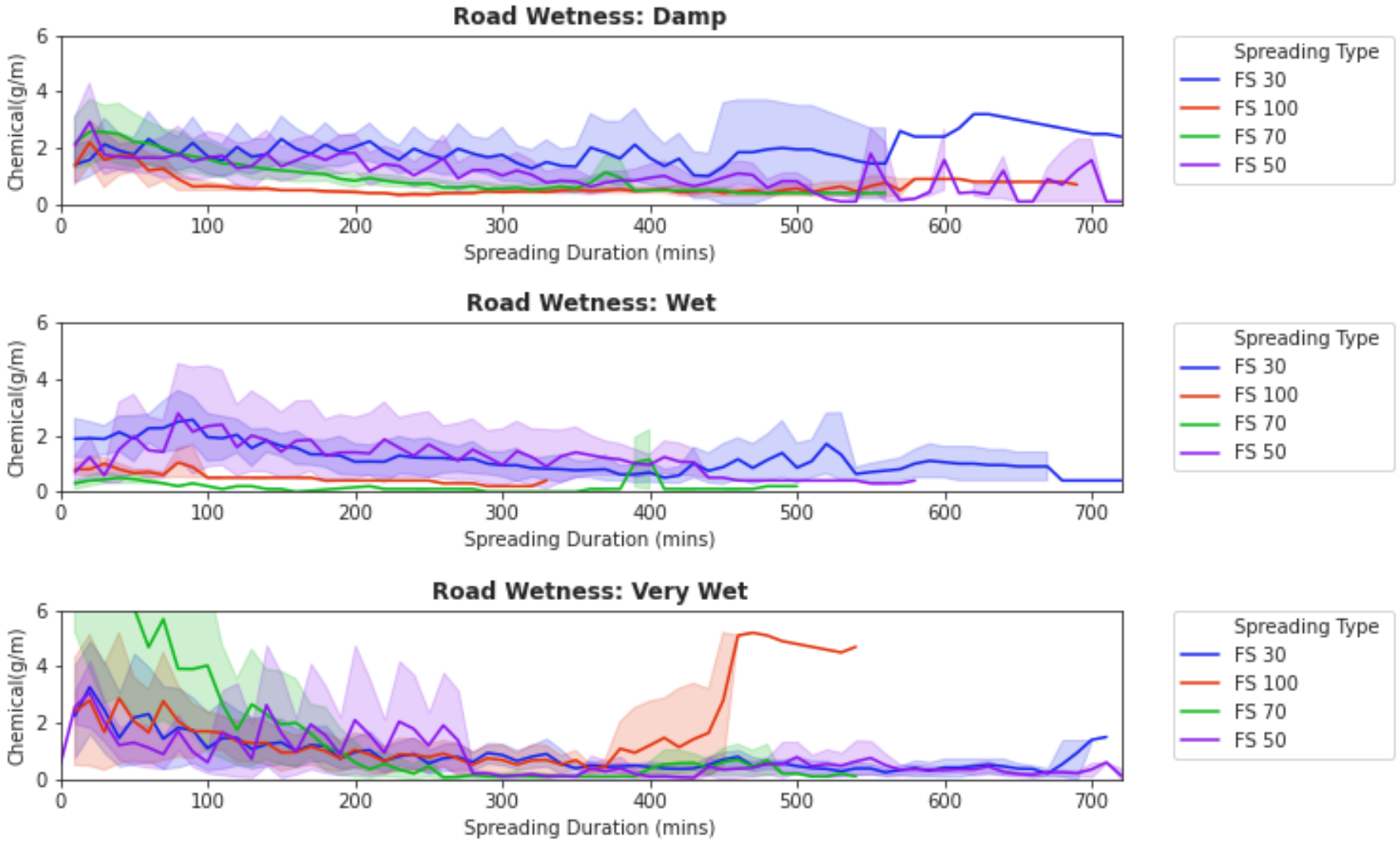

Figure 9: Salt amount variation after spreading

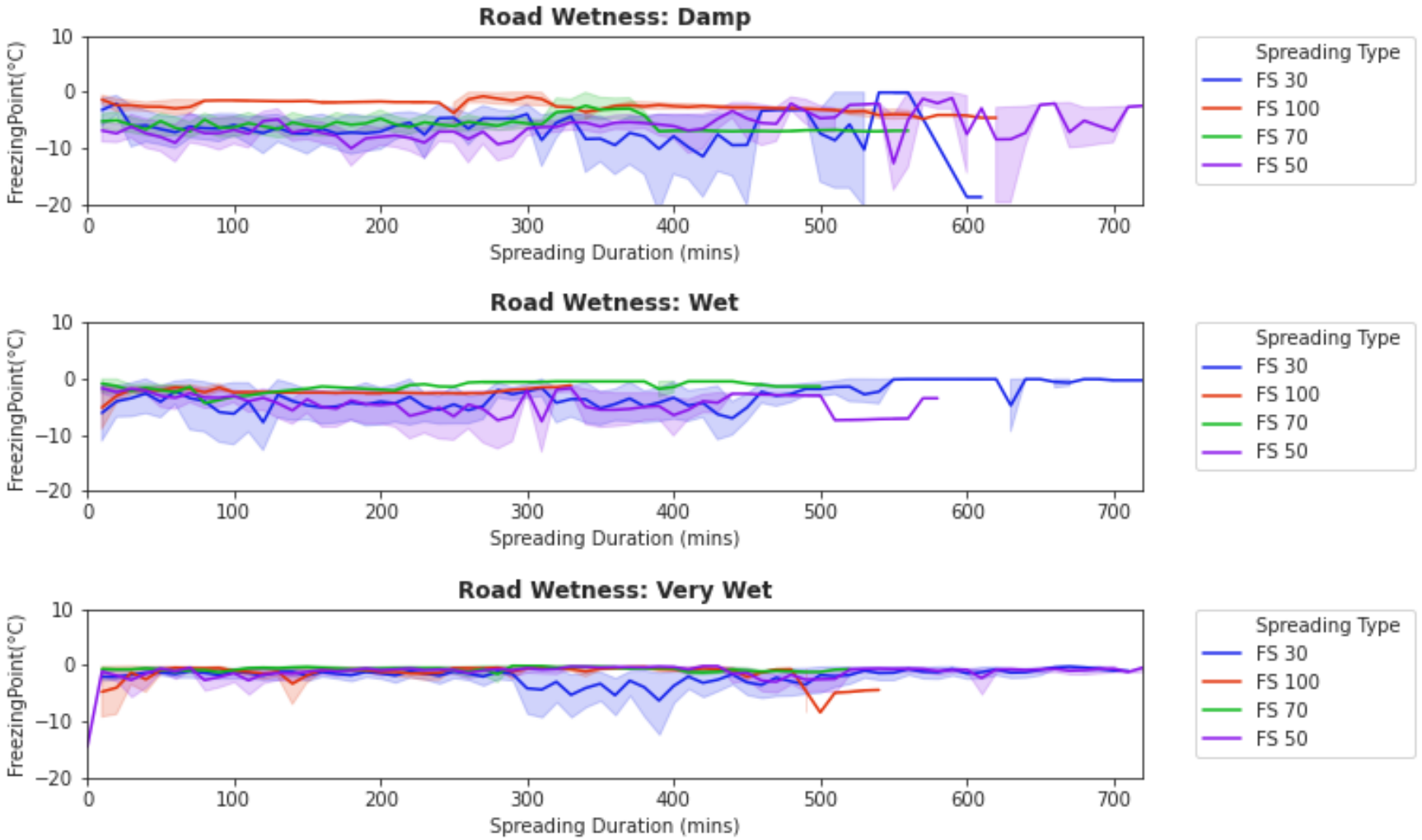

Figure 10: Freezing point variation after spreading

7.3.2 Time of spreading (traffic levels)

Figure 11 summarises the variation in salt amount and Figure 12 the variation in freezing point with time after spreading, showing the comparison between the different treatment methods for the different times of spreading.

The results highlight some effects of time of treatment on the residual salt and freezing point behaviour.

For afternoon treatments, there will be greater trafficking and loss of solid salt immediately after spreading, and as shown in Figure 11 there is a clear decrease in the residual salt levels over the duration of the treatment. The maximum duration before repeating after an afternoon treatment on the A835 is 12 hours if freezing conditions persist, and the results support this decision, with significantly reduced salt and freezing point after this period.

For morning treatments, there will be very low traffic and loss of solid salt. The treatments with higher solid salt share show a much flatter response in the residual salt behaviour with a less pronounced reduction. The sensors are only picking up the amount of salt in solution, and the lower losses of the solid salt allow the salt to dissolve over the treatment period.

In the low traffic morning treatments FS 50 shows the highest initial salt level and freezing point reduction, with FS 30 exhibiting greater salt and lower freezing point after approximately 3 hours and longer.

The freezing point behaviour tends to show a much flatter response as compared to the residual salt. The initial dissolution of salt will decrease the freezing point. This depression appears to be maintained over the duration of the treatment for damp and wet roads. Salt may be lost as solution, resulting in the reduction in salt amount shown by the sensors, however the freezing point of the solution remaining is maintained, except on very wet roads where precipitation or heavy dew formation will dilute and/or wash away the salt solution.

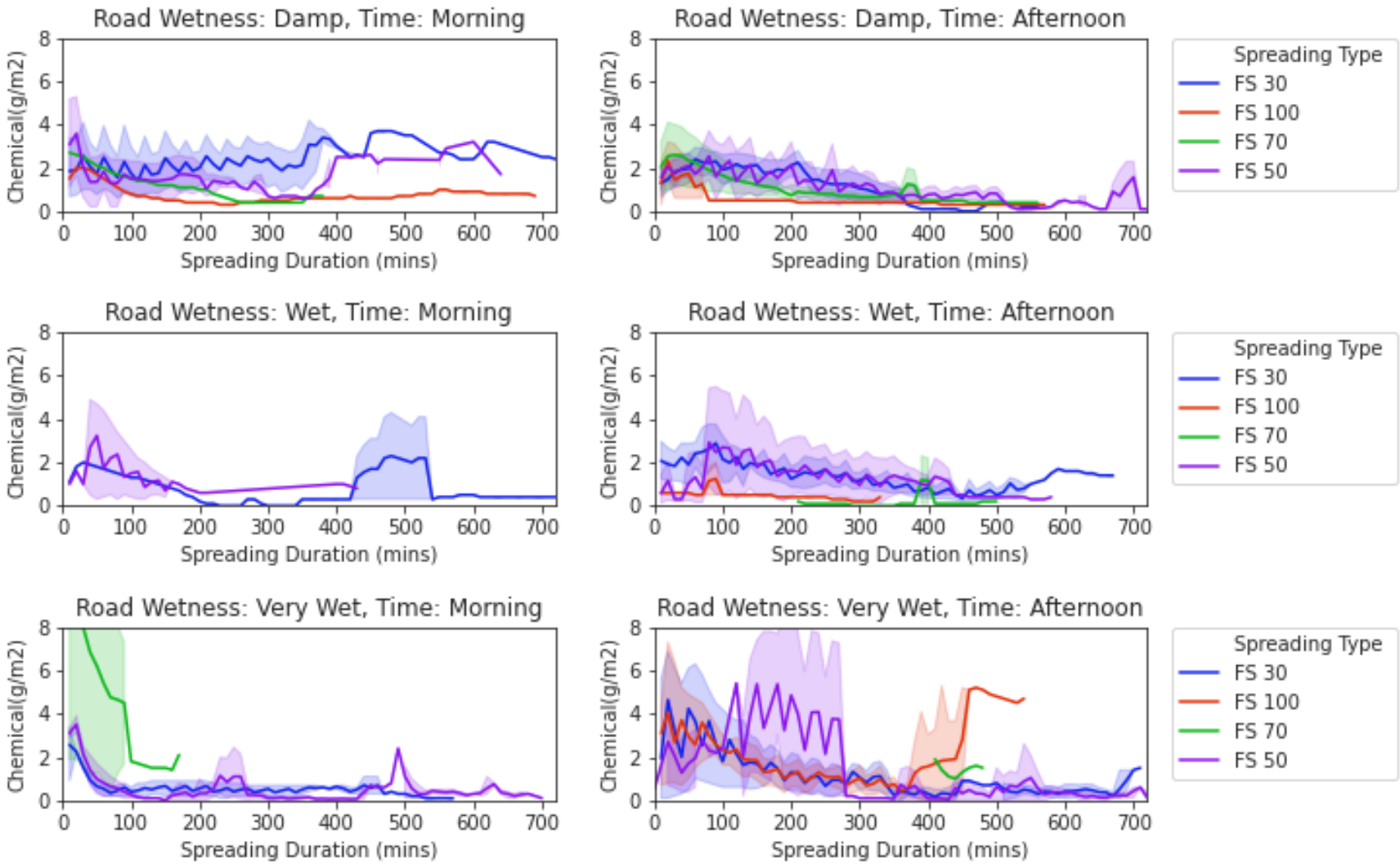

Figure 11: Salt amount variation after spreading

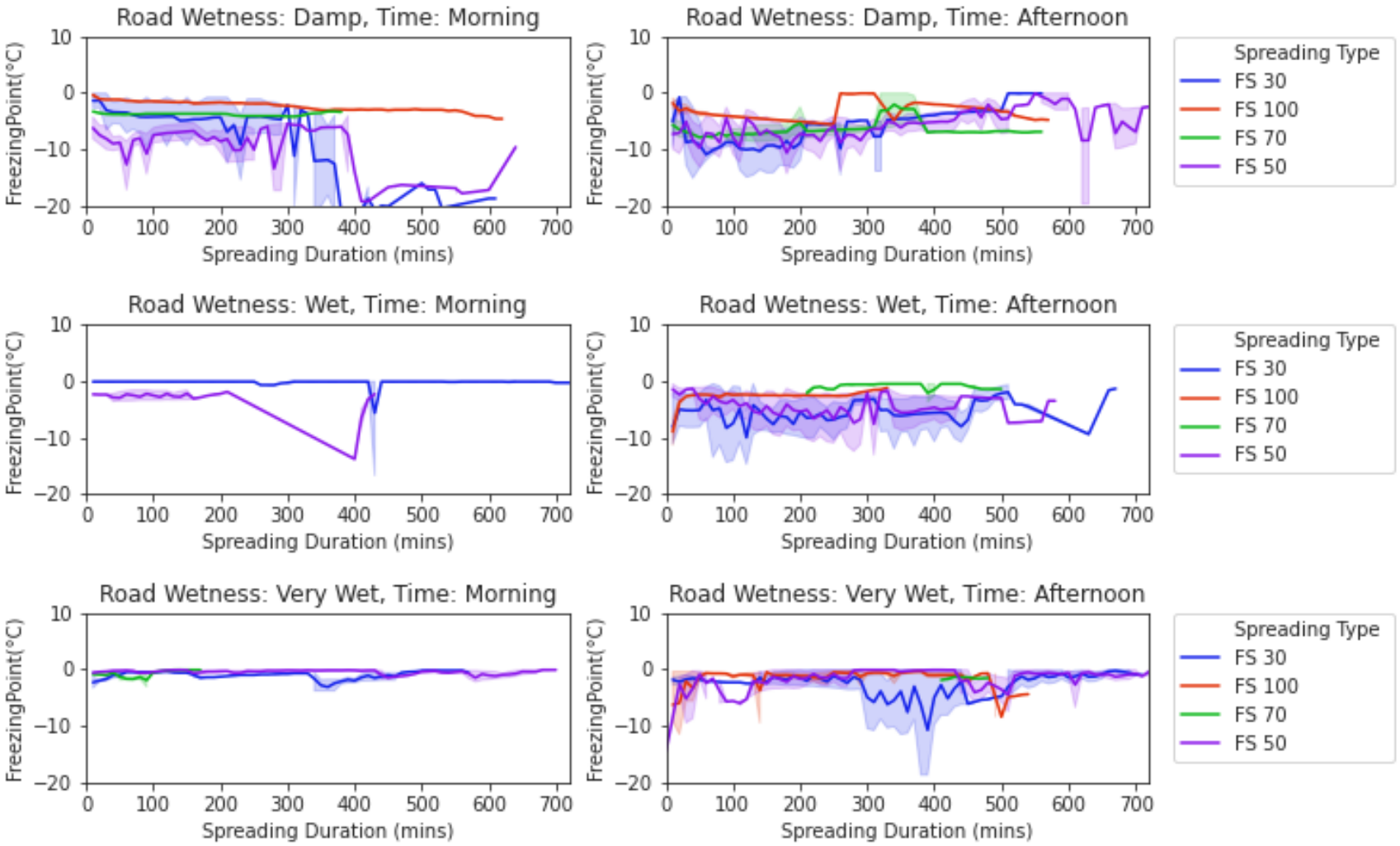

Figure 12: Freezing point variation after spreading

8 Treatment method suitability for different conditions

8.1 Basis for the performance of different treatment methods

The effectiveness of a treatment will depend on two key factors:

1. How much salt remains on the road surface after spreading
2. How much of this salt has dissolved to form a salt solution

Table 5 provides a summary of the relative advantages and disadvantages of spreading a solid and liquid de-icer.

Table 5: Advantages and disadvantages of solid and liquid de-icer

De-icer component	Pros	Cons
Solid salt	If retained on road surface, can provide larger amounts of chemical on road surface (>10g/m^2 of sodium chloride) More resilience to dilution and wash off Larger particles dissolve slowly to provide long lasting treatment (if retained on road surface and sufficient humidity (greater than 75-80%) and surface moisture. Large particles less affected by wind.	More susceptible to loss from vehicle and wind effects – more pronounced on heavier trafficked roads and drier road surfaces Harder to treat full width without overspreading (particle bounce) Time required to dissolve and become effective
Brine	Less loss from trafficking - in particular for heavier traffic conditions. Can more precisely treat full carriageway width without overspreading to verges Effective immediately without time required for dissolving of salt - particularly for low traffic situations.	Dilution on very wet roads/snow – shorter acting treatments Limit on amount of chemical that can be applied, even with lower losses (<10g/m^2 of sodium chloride) More affected by wind during spreading

8.2 Overall assessment of performance

It is clear that no single treatment method is the most effective solution across all of the winter conditions experienced. The spreading of solid and liquid de-icers, and the combination of solid and liquids either through pre-wetting of salt or from simultaneous spreading of liquid only and solid salt treatments, offer different advantages and disadvantages affecting the suitability of the treatments for different road conditions.

With regard to the pros and cons of solid and liquid treatments, higher brine share treatments which involve the simultaneous spreading of solid salt (pre-wetted from a spinner) and a liquid only treatment (applied directly to the road surface from a spray bar) can offer the benefits of both approaches while mitigating against the disadvantages of any one approach in isolation.

The road surface wetness is a key factor influencing the effectiveness of treatments. For dry, damp and wet roads i.e. water thickness less than 0.1mm for the duration of the treatment, the amount of salt that can be spread by FS100 provides effective treatments to -5^{o}C on wet roads, and much lower on dry and damp roads. FS 70 provides effective treatments down to around -7^{o}C on wet roads.

FS50 provides very similar performance to FS30 while spreading around 20% less salt and effectiveness to around -15^{o}C on wet roads.

As shown from the plots of freezing point in Figure 5 and Figure 7, above a water thickness of approximately 0.5mm, and precipitation amounts more than 2mm, all treatment methods show very limited freezing point temperature suppression of the road surface. Comparison of the FS50 and FS30 performance with FS70 and brine only shows some advantage for high solid salt share treatments over the higher liquid share treatments in the conditions leading up this range.

Based on the analysis, the key parameters that have an impact on treatment effectiveness have been identified and limiting values for the effectiveness of treatments assessed. A summary is presented in Table 6.

Table 6: Key parameters and limiting values for precautionary treatments

Condition	Treatment method performance
Damp Roads or wet roads	For FS30 and FS50 pre-wetted salt, minimum freezing point -20°C on damp roads (<0.05mm) and -15°C on wet roads (<0.1mm). For the FS70 pre-wetted salt, minimum freezing point -10°C on damp roads and -7°C on wet roads. For FS100, minimum freezing point -7°C on damp roads and -5°C on wet roads. In normal traffic (e.g. afternoon) 12 hours confirmed to be suitable maximum treatment effectiveness time
Very wet roads and precipitation	As road wetness increases, all treatment types show reduced freezing points of the road surface moisture, tending towards very low suppression at around Limits for effectiveness for FS50 and FS30: (for RST to -5°C): • 0.2mm water thickness • 0.5mm of precipitation (water equivalent) Limits for effectiveness for FS70: (for RST to -2°C): • 0.2mm water thickness • 0.5mm of precipitation (water equivalent) Limits for effectiveness for FS100 (for RST to -2°C): • 0.2mm water thickness • 0.2mm of precipitation (water equivalent)

Very light traffic after spreading – RST to -7°C	In the low traffic morning treatments FS 50 shows the highest initial salt level and freezing point reduction, with FS 30 exhibiting greater salt and lower freezing point after approximately 3 hours and longer.
High Wind Averaging over 20mph when spreading	All treatment methods show effect and must be carefully monitored
Hoar Frost and Freezing Fog	FS 50 effective for treatment of frost or thin ice (than 0.1mm) in early morning very low traffic
De-bonding Layer Before Snow	FS 50 and 70 effective. FS70 for temperatures >-5°C FS100 marginal temperatures >-1°C

References

Evans M (2019). Trials of Brine Spreading Performance on Scotland's Roads: 2018-19, *Published Project Report PPR927*, Wokingham, Berkshire: Transport Research Laboratory (TRL).

NWSRG (2019a). Spread rates for Precautionary Salting.

NWSRG (2019b). Treatments for Snow and Ice.

Appendix A Summary of spreading events for 2019/20

Date	Location	Time and type of Treatment	Minimum surface temp (°C)	Maximum layer thickness (mm)	Precipitation before event	Ice reports			FPT>RST (Active sensor)	Grip	General description
						Patrol public police	Embedded sensor	Non – invasive sensor			
12/11	Aultguish	Standard pre-wetted 16.40 20g/ m²	-2.9°C at onset of ice at 00:10	0.01mm at time of treatment 0.04 mm maximum after treatment before ice	0.1mm rain after treatment before ice		Icy		From 00:50 to 01:10 Patrol treatment	0.80	RST less than dew point from 16.30 High humidity around 100%
14/11	Aultguish	15.30 20g/m²	-1.9°C at onset of ice at 00:30	0.12mm at time of treatment 0.22 mm maximum after treatment before ice	0.6mm rain after treatment before ice		Wtrd	Slushy/Icy	From 18:00 to 18:25 20:30 to 01:00 (Time of follow up treatment)		Max wind speed <10mph at time of spreading Slushy road reported from 23:40 until 00:40 (One ice report 00:30, Grip = 0.6) – before follow up treatment at 00:50
17/11	Aultguish	15:40 20g/m²	-4.5°C at 23:40	0.07mm at time of treatment	0.1mm from light		Icy 00:30 to 00:50	Snowy/Slush 00:20 to 01:20	21:10 to 00:30		Light snow between 00:00 and 02:0

			-3.3 at 00:40 (ice reported)	0.54mm at time of ice report	snow after treatment before ice					<0.6 between 00:20 and 00:50	Max wind speed <5mph
18/11	Aultguish	02:00 20g/m²	-4.2°C at 03:30 -6.7°C at 08:00	0.17mm at time of treatment 0.19mm at 02:10	<0.1mm light snow				03:30 to 06:50 Patrol treatment at 06:36		Intermittent light snow
11/12	Aultguish	14.00 20g/m² Standard pre-wetted	-0.4°C at 23.30	0.18 mm at time of treatment (14.45) 2.57mm at 01:50	2.3mm precipitation to 23.30				FP=-0.1 at 17:35 01:50 to 02:30		
12/12	Aultguish	02.30 20g/m² Standard pre-wetted	-0.9°C at 02.30 -0.5°C at 06.00	0.5 mm at time of treatment 0.82mm at 04:50	0.7mm before 06:00			Slushy 05:40 to 06:30	06:00 to 06:40	>0.7	Intermittent light snow
13/12	Aultguish	19.40 10g/m²	-1.4°C at 04.40	0.04 mm at time of treatment 0.08mm at 23.00	0.1mm				04:30 to 05:00		Intermittent light rain
15/12	Aultguish	15.46 20g/m² Standard pre-wetted	-3.5°C at 21:30	0.09mm at time of treatment 0.19mm at 16:10	0.3mm before 21:30			Icy 21:30 to 02:30	21:30 to 02:20 (time of follow up treatment)	<0.6 from 22:30 to 02:20	Light snow at time of treatment

08/01	Aultguish	15:40 20g/m² Follow up treatment at 22.50	-1.9°C at onset of ice	0.06mm at time of treatment 0.18mm maximum after treatment before ice	0.4mm rain after treatment before ice		Icy 21:20 to 23:00	Icy 21:50 to 23:00	19:55 to 23:10	<0.6 23:30 to 03:00 (Time of follow up treatment)	Average wind speed 24mph at time of treatment (Gust to 37mph)
11/1	Aultguish	19:40 20g/m²	-0.7°C at 00:00	0.06mm at time of treatment	0.3mm light rain				00:00 to 01:30		Intermittent light rain Max wind speed 21.3mph at time of treatment, average speed 13.6mph
11/1	Brahan	19.00 20g/m²	-1.3°C at onset of ice	0.17mm at time of treatment 1.04mm maximum after treatment before ice	4.9mm rain after treatment before ice reported at 00:50		Icy	-			Medium/heavy rain after treatment before freezing conditions
12/1	Aultguish	15:30 20g/m²	-0.9°C at 19:10 -0.3°C at 23:40	0.09mm at time of treatment 0.46mm at 17:50	0.3mm light rain/snow to 18:10 0.5mm light rain/snow to 23:30				18:10 to 21:35 23:30 to 00:30 (Time of patrol treatment)		Intermittent light rain/snow. Max wind speed 18.6mph at time of treatment, average speed 13.9 mph

									FP = 0 at 18:10		
13/1	Aultguish	23:30 30g/m² Standard pre-wetted salt	-0.2°C at 02:30	0.09mm at time of treatment 0.13mm at 02:30	0.4mm light rain/snow to 02:30				02:35 to 03:20		Max wind speed 32mph at time of treatment, average speed 21 mph
17/1	Aultguish	18:47 30g/m² Standard pre-wetted salt	-0.4°C at 23:30	0.03mm at time of treatment 0.16mm at 02:30	0.4mm light rain before 23:30				23:30 to 00:30		Intermittent light rain Max wind speed 21mph at time of treatment, average speed 14.3 mph
27/1	Aultguish	15:57 30g/m² Standard pre-wetted salt	-1.9°C at 18:40	0.11mm at time of treatment 0.27mm at 17:00	0.2mm before 18:40				18:40 to 20:40		Intermittent snow during and after treatment
2/2	Aultguish	14:40 20g/m²	-0.3°C at 16:25 -0.2°C at 19:50	0.26mm at time of treatment 0.57mm at 16:25	0.4mm rain and snow before 16:25 0.5mm rain and snow before 19:50				16:25 to 17:40 19:50 to 21:50		Light rain/snow during and after treatment

12/2	Aultguish	15:40 30g/m² Standard pre-wetted salt	-0.8°C at 17:40	0.07mm at time of treatment 0.52mm at 17:50	0.5mm before 17:40			Slushy 19:10 to 20:30	17:40 to 20:40	>0.7	Intermittent snow during and after treatment Max wind speed 23.3mph at time of treatment, average speed 15 mph
13/2	Aultguish	03:34 20g/m² Standard pre-wetted salt	-7.1°C at time of treatment -7.3°C at 04:50	0.05mm at time of treatment 0.04mm at time of treatment					00:00 to 05:00		
14/2	Aultguish	16.40 20g/m²	-2°C at onset of ice 01:50	0.50mm at time of treatment 0.58mm maximum after treatment before ice	1.5mm rain after treatment before ice reported at 00:50		Icy	Moist	00:30 to 03:00 (Time of patrol treatment)		Light rain during and after treatment before freezing conditions Max wind speed 30mph at time of treatment
15/2	Aultguish	20:50 10g/m²		0.1mm at time of treatment					Example of low response (wind?) RST >0		Max wind speed 24.2mph at time of treatment, average speed 15.4 mph
15/2	Aultguish	03:38 30g/m²	-0.2°C at 05:50	0.36mm at time of treatment	0.5mm after treatment			Slushy 05:50 to 08:10	05:50 to 08:00		

		Standard pre-wetted salt		1.59mm at 05:00	before 05:50						
23/2	Aultguish	15:30 20g/m² Standard pre-wetted salt	-1.3°C at 19:20	0.04mm at time of treatment 0.1mm at 15:50	0.2mm rain after treatment before 19:20		Icy 20:50 to 21:20		19:20 to 23.25 (Time of follow up treatment)		Intermittent rain during and after treatment Max wind speed 23.3mph at time of treatment, average speed 15 mph
03/03	Aultguish	17.30 20g/m²	-1.5°C at onset of ice at 22.00	0.28mm at time of treatment 0.37mm max after treatment before ice	0.6mm rain after treatment before ice reported at 22.00		Trace	Icy 22:00 to 00:00	21:00 to 00:20		Continuous light snow/rain after treatment before freezing conditions Max wind speed 13mph at time of spreading Follow up treatment at 23.50 immediately restores Grip and wet road state (ice layer was <0.1mm)
14/03	Aultguish	23.20 20g/m²	-0.2°C at 02:50	0.12mm at time of treatment 0.72mm at 01:40	1.3mm rain after treatment before 02:50				02:50 to 04:00		Light rain during treatment Spells of medium intensity rain before freezing conditions

18/03	Aultguish	22.00 20g/m²	-0.4 at 03:20	0.05mm at time of treatment 0.23mm at 02:00	0.5mm rain after treatment before 03:20		Icy 04:20 to 04:30		03:20 to 04:40		Intermittent light rain after treatment Max wind speed 22mph at time of treatment, average speed 15 mph

14/11 Aultguish	Road conditions at time of treatment: 	Road conditions at 20:00: 

	Road conditions at 00:30:  	
17/11 Aultguish	Road conditions at time of treatment:	Road conditions at 00:00:

	 Road conditions at 00:10: 	 Road conditions at 00:20: 
8/01 Aultguish	Road conditions at time of treatment:	Road conditions at 22:50:

		
11/1 Brahan	Road conditions at time of treatment: 	Road conditions at 00:50: 

Trials of higher brine share pre-wetted treatments

Sensor measurements and records of road conditions were used to assess the conditions under which effective treatments were carried out using pre-wetted salt with a 50:50 ratio of dry salt:brine and to provide a comparison with standard pre-wetted treatments. The measurements indicated that comparable freezing point temperatures were achieved by the FS 30 and FS 50 pre-wetted salt, with a minimum freezing point around -20^{o}C achieved on damp roads (<0.05mm) and -15^{o}C on wet roads (<0.1mm). The amount of salt that can be spread by FS100 provides effective treatments to -5^{o}C on wet roads, and much lower on dry and damp roads. FS 70 provides effective treatments down to around -7^{o}C on wet roads. As road wetness increases, all treatment types show reduced freezing points of the road surface moisture, tending towards very low suppression at around 0.5mm water thickness and 2mm of precipitation (water equivalent). For all treatment methods, the freezing point behaviour tends to show a much flatter response as compared to the residual salt. The initial dissolution of salt will decrease the freezing point. This depression appears to be maintained over the duration of the treatment for damp and wet roads. Salt may be lost as solution, resulting in the reduction in salt amount shown by the sensors, however the freezing point of the solution remaining is maintained, except on very wet roads where precipitation or heavy dew formation will dilute and/or wash away the salt solution.

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