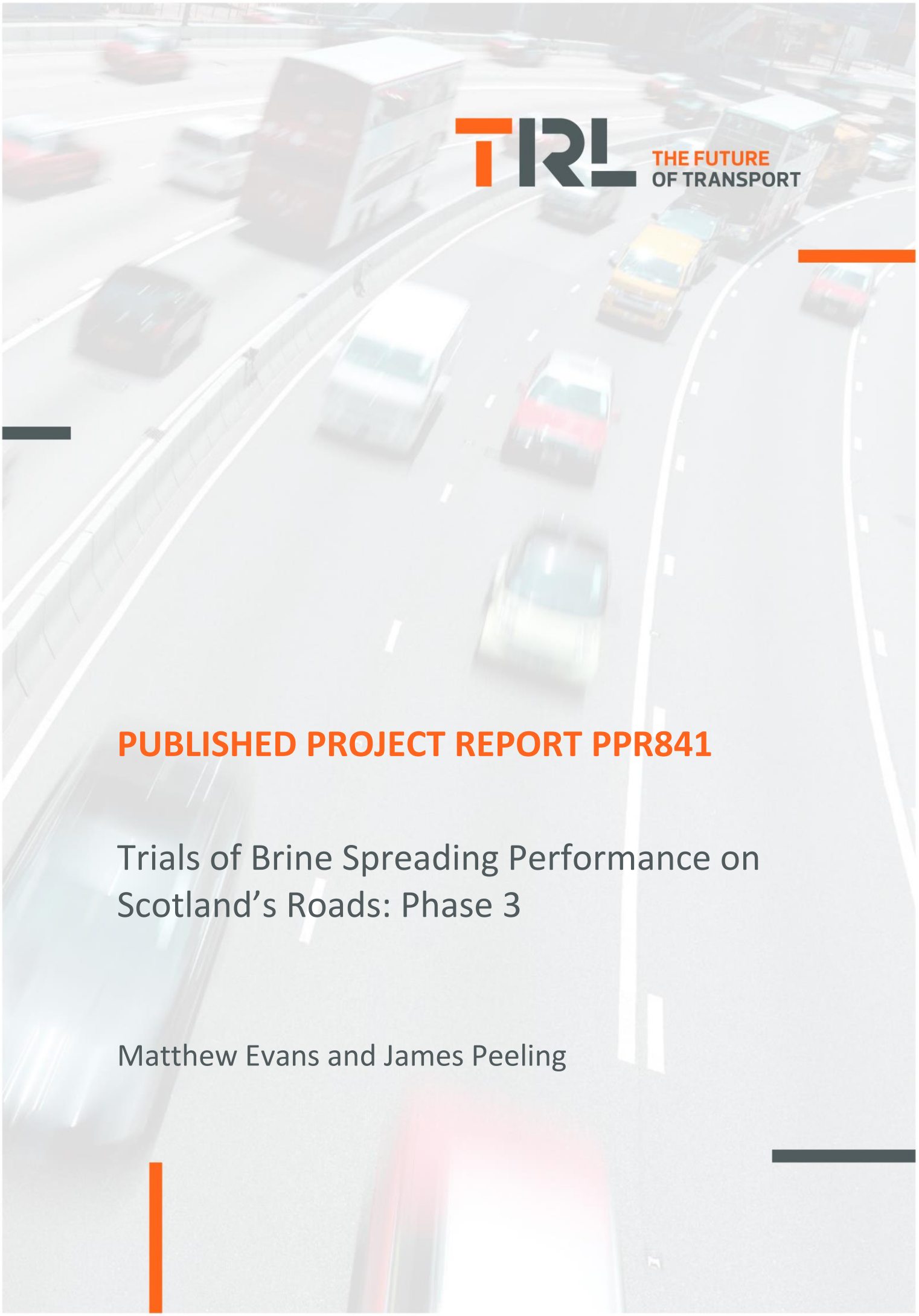

THE FUTURE OF TRANSPORT

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Trials of Brine Spreading Performance on Scotland's Roads: Phase 3

Matthew Evans and James Peeling

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Executive Summary

TRL were commissioned by Transport Scotland to support the development and coordination of a third phase of live brine trials for the 2016/17 winter season; to develop and enhance research into understanding liquid de-icer performance on Scotland's roads.

The first phase of work carried out in 2015 had involved measurements of residual salt carried out immediately before and after spreading brine, and then after various lengths of trafficking time. Indications were that residual salt levels after brine spreading on HRA exhibited greater longevity than after pre-wetted spreading, but the results did not show a significant difference between the percentage salt losses measured for brine and pre-wetted salt on thin surfacing.

A second phase of live trials was carried out during the 2015/16 winter season, with brine spreading carried out as routine treatments across different locations to provide a range of road surfacing types and trial conditions.

For the third phase of trials reported here, further brine spreading was carried out during the 2016/17 winter season including the spreading of brine over the full length of treatment routes. This enabled assessment over a full winter season and experience to be gained spreading in the more varied conditions that occur along longer treatment lengths.

For the first half of the winter season, brine spreading was carried out by the Scottish trunk road Operating Companies BEAR, Amey and Scotland Transerv using the same trial sites and combi spreaders as for the previous season's trials. For the second half of the season, larger capacity liquid only spreaders were used to treat the full length of selected treatment routes on the A9 and A77. Brine spreading on the full routes was carried out using liquid only spreaders with capacity up to 12,000 litres.

When conditions were appropriate brine spreading was carried out over the trial locations as part of routine network treatments, with the road and weather condition continuously and automatically monitored after spreading. When conditions were considered inappropriate for brine, e.g. during snow events, the standard treatment of pre-wetted or dry salt was applied.

Monitoring was principally thought the use of non-invasive road condition sensors to detect the presence of ice or snow on the road and provide 'Grip' readings. These non-invasive sensors use the spectroscopic properties of different states of water to determine the amount of snow, ice or water on the pavement surface and use these values to estimate the effect on the pavement's surface friction (the skid resistance).

The trials demonstrated that brine was an effective treatment for the conditions prevailing during the trial period, and brine spreading was a suitable treatment on the majority of days when spreading occurred on the trial sites.

There were no prolonged or severe periods of snow or low temperatures during the trial period, and conditions were generally considered favourable for brine spreading. A small number of instances of loss of 'Grip' were measured during brief snow events, typically where pre-wetted salt was used on the test sites instead of brine.

From the end January to the end of the winter season routine brine spreading was successfully carried out over two full routes, with 16 treatments on Route 20R11 on the A9 and 15 treatments on Route A20/3 on the A77.

The results have provided an indication of the conditions of road surface wetness and temperature for which brine spreading is effective, and some indication on the limits of effectiveness during precipitation. Based on the conditions under which the brine spreading has been trialled, recommended spread rates have been provided for precautionary treatments before frost and light snow or rain.

1 Background

Trials of brine spreading have been carried out over the previous two winters on the Transport Scotland network. Trials during the 2014/15 winter season were carried out on two trial sites to compare the rate of loss of salt from brine and pre-wetted spreading. Building on these trials, monitoring of routine brine treatments and comparison to equivalent pre-wet treatments was carried out during February, March and April 2016. The principal aim of the work was to assess the effectiveness and longevity of precautionary treatments using sodium chloride brine versus pre-wetted salt for UK climatic conditions and on road surfacing types representative of the wider UK network.

Further trials were recommended over the 2016/17 winter season to enable an assessment to be carried out over a full winter season and to provide operational experience of brine spreading over the full length of selected treatment routes.

2 Introduction

TRL were commissioned by Transport Scotland to support the development and coordination of a third phase of live trials for the 2016/17 winter season; to develop and enhance research into understanding the performance of brine on UK/Scotland's roads.

For the first half of the winter season, brine spreading was carried out by the Operating Companies BEAR, Amey and Scotland Transerv using the same trial sites and combi spreaders as for the previous season's trials.

For the second half of the season, larger capacity liquid only spreaders were used to treat the full length of selected treatment routes on the A9 and A77.

When conditions were appropriate brine spreading was carried out over the trial locations as part of routine network treatments with the road and weather condition continuously and automatically monitored after spreading.

3 Trial Sites

Trials were carried out as part of routine winter treatments across different locations to provide a range of road types and trial conditions.

The trials made use of the existing monitoring sites and equipment installed on the treatment routes for the 2015/16 winter trials.

For the first half of the season, spreading was carried out on the same trial sites as for the 2015/16 trials. Each of these trial sites comprised a short (~1500m) section of a route to be treated with brine, with comparison to spreading with pre-wetted salt on adjacent sections.

For the second half of the winter season, longer trial sites were used on the A9 and A77:

- On the A77, brine spreading was carried out over the full length of route A20/3 with a spreading length of 56.6km. This route included the short trial section for monitoring of the weather and road conditions.

- On the A9, brine spreading was carried out on Route 20R11 between Loaninghead and Dunblane, with a spreading length of 47km. Road and weather data was provided from weather stations located at Balhaldie and Loaninghead.

The A9 and A77 trial sites comprised dual carriageways with average spread widths of 7m, while the A702 is a single carriageway section where brine and pre-wetted spreading was carried out on adjacent sections.

The trial site information is summarised in Table 1 and locations are shown in Figure 2 to Figure 6.

Table 1 – Trial site information

Regional Unit	Route	Surface material	Road type	Spread length (km)	Spreading methods
South West Unit	A77 Dutchhouse Northbound	14mm Thin surfacing	Dual Carriageway (D2AP)	1.5	Comparison of brine and pre-wetted
	A77 Ayr to Kilmarnock	Mixed	Dual Carriageway (D2AP)	56.6	Brine only
North West Unit	A9 Inveralmond	HRA	Dual Carriageway (D2AP)	1.5	Comparison of brine and pre-wetted
	A9 Loaninghead to Dunblane	Mixed	Dual Carriageway (D2AP)	47	Brine only
South East Unit	A702 Boghall	14mm Thin surfacing	Single Carriageway (S2)	1.5	Comparison of brine and pre-wetted

Figure 1. Location of trial sites

Figure 2. A9 Short trial site – Inveralmond.

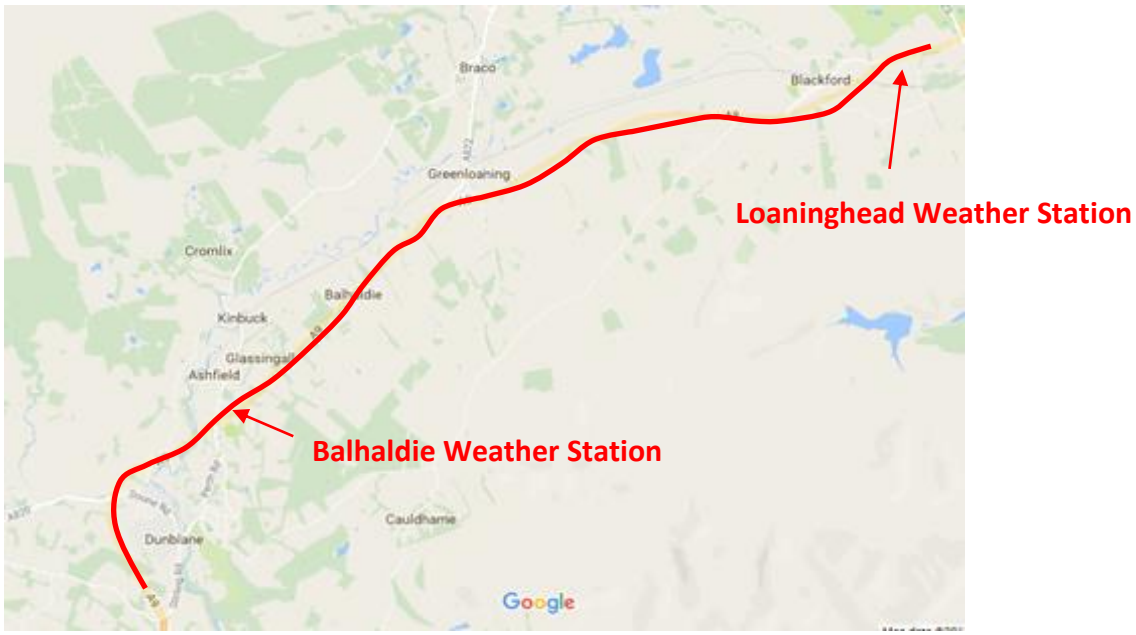

Figure 3. A9 Full route trial site – Loaninghead to near Dunblane

Figure 4. A77 Short trial site – Dutchhouse

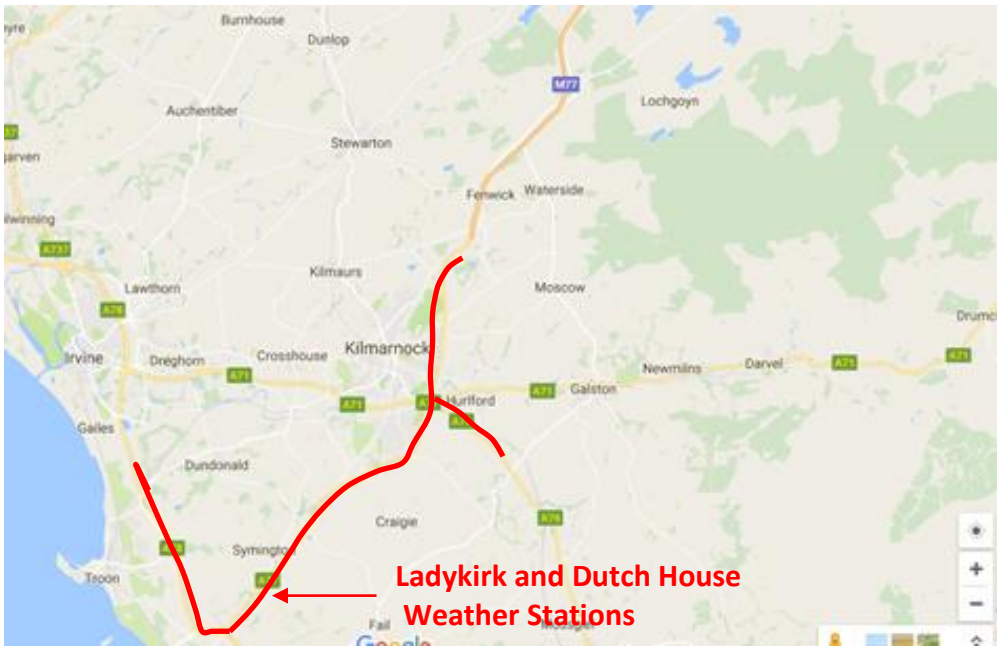

Figure 5. A77 Full route trial site – Ayr to Kilmarnock

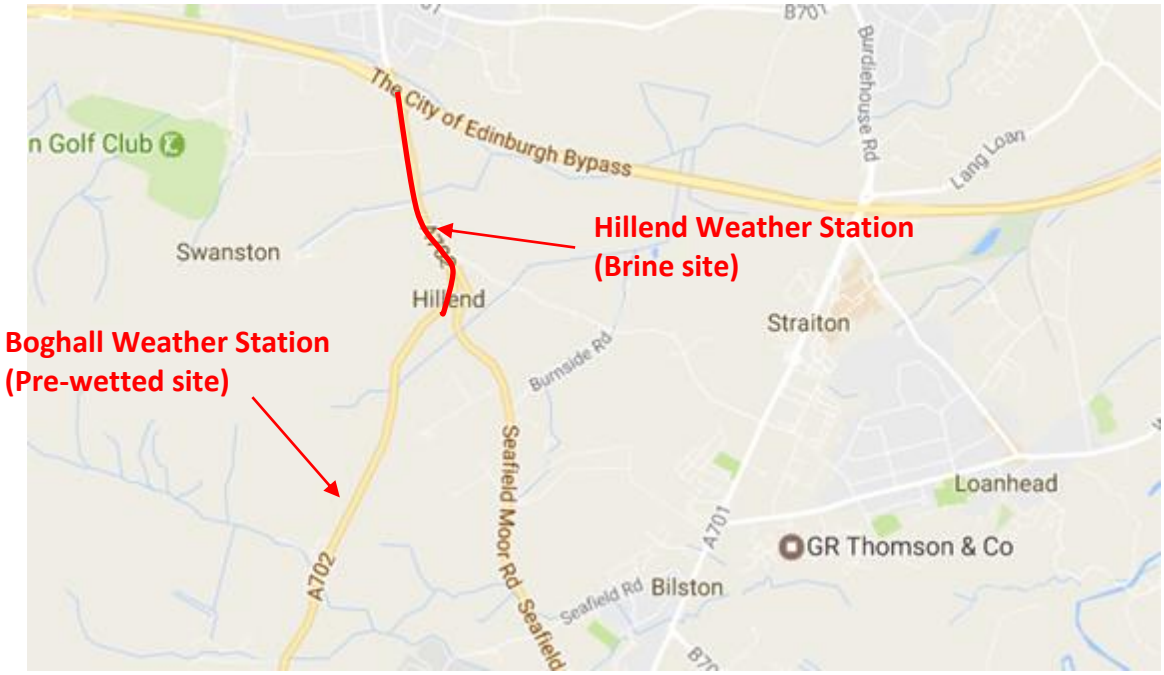

Figure 6. A702 Trial site – Hillend

4 Spreaders and de-icing chemicals

Brine and pre-wetted spreading was carried out on the short trial sites using a combi-spreader from each of the Operating Company's fleets. Before the trials all spreaders were calibrated; this including monitoring the discharge rate and carrying out a visual check of the brine and pre-wetted salt distribution.

Brine spreading on the full routes was carried out using liquid only spreaders:

- For the A9 route: Econ 11,000 litre capacity tanker (Figure 7)
- For the A77 route: Boschung 12,000 litre capacity liquid hopper mounted on a 32 tonne chassis (Figure 8)

For both vehicles, brine was applied through nozzles mounted on a spray bar on the rear of the vehicles.

The brine used for the trials was supplied from a saturator at each of the trial depots with a concentration between 20 and 23%. The pre-wetted salt for each trial comprised 6.3mm dry rock salt and brine in the ratio 70:30 by weight.

Figure 7. Econ tanker used on the A9 (Source: BEAR Scotland)

Figure 8. Boschung liquid hopper used on the A77 (Source: Scotland TranServ)

5 Trial Methodology

Brine spreading was carried out for precautionary treatments before frost or ice, at temperatures above -5°C. When snow was forecast in combination with freezing temperatures, pre-wetted or dry treatments were applied to the trial sites.

For the first half of the winter season, brine spreading was carried out on the shorter trial sections in conjunction with the routine pre-wetted salt treatments on the TS network.

Conventional pre-wetted spreading is currently carried out on the Transport Scotland network in accordance with the standard Treatment Matrix included in Appendix A (Table 7.2.K.2, Schedule 7 Part 2 of the 4G Term Contract).

For each condition in the Matrix where brine spreading was trialled (precautionary treatments above -5°C), the spread rates used were:

- Pre-wetted salt – 10 to 20g/m²
- Brine – 15 to 30ml/m²

For each pre-wetted treatment, a brine treatment was carried out on the adjacent section at the same time (treatment timing on each section as close as operationally practical).

For the second half of the winter season, brine spreading on the A9 and A77 was carried out over full routes using liquid only spreaders.

- A9 – Route 20R11, spreading length 47km
- A77 – Route A20/3, spreading length 56.5km
- A702 – Brine spreading was continued on the short trial section

6 Monitoring of road conditions

Monitoring equipment on each trial site included:

- Non-invasive DSC111 weather sensors to detect the presence of ice or snow on the road and provide 'Grip' readings. The 'Grip' value is an indication of the effect of weather conditions on surface friction (the skid resistance)
- Road weather station including wind speed and embedded DRS 511 sensor (A77 and A9 sites only)

All weather station and patrol data was fed back to the Operating Company control centre. Access to weather station data was made available through the Vaisala RoadDSS system, allowing real time and historical analysis of data for the trial period.

The 'Grip' value was monitored at all times for any drop below 0.6, and the surface state monitored for presence of ice or snow, to show when there was a risk of the road surface become slippery for the driver. Based on experience in use of the sensors internationally, Vaisala has defined a critical 'Grip' value of 0.6 above which it is considered there is adequate friction.

The performance of the Vaisala DSC device has been investigated in a number of studies, both as a fixed monitor and also for vehicle mounted operation. A literature review of

research into these and similar devices' performance and further laboratory testing was carried out by TRL on behalf of Highways England (Sanders and Jeffrey, 2017). The results of this work have provided confidence that such devices can detect the presence of ice or snow contaminants. Based on the laboratory testing, 'Grip' measurements for snow and ice contaminated surfaces were below the threshold value of 0.6, with 'Grip' measurements ranging between 0.1 and 0.6 when snow and ice was present on the tested surfaces.

7 Results

7.1 Overview of weather conditions during trial

Summary tables of average and minimum air temperatures and road surface temperatures, (RST) for each weather station are provided in Appendix B. In general, it was a mild winter with few snow events. November and January were the coldest months – the minimum air temperature recorded was -7.2°C on the A9 in November and the minimum RST recorded was -6.1°C on the A9 in November.

7.2 Frequency of brine treatments

Details of the treatments carried out for each site and selected weather station data are presented in the tables in Appendix C.

Table 2 shows that brine spreading was possible on the majority of nights when treatments were required during the trial period.

Table 2 – Summary of treatments where brine was used

Test site	Trial Period	Days where spreading	No. of brine treatments	% of days where brine spreading used
A9 Inveralmond – Short trial site	1st November to 9th February	58	58	**100**
A9 Loaninghead to Dunblane – Full route	10th February to end of season	17	16	**94**
A77 Dutchhouse – Short trial site	19th November to 25th January	22	19	**86**
A77 Ayr to Kilmarnock – Full route	26th January to end of season	17	15	**88**
A702 Hillend – Short trial site	1st December to end of season	71	51	**70**

7.3 Weather and road conditions during and after spreading

The majority of treatments were carried out at relative humidity values greater than 70%, and more than half were carried out at relative humidity greater than 80%. The road surface was often damp or wet during or after spreading. Table 3 to Table 8 summarise some of the key weather parameters at the time of spreading and at the point of minimum surface temperature after each treatment.

At time of spreading, the key parameters selected included the road surface condition (dry, moist, wet etc) and the relative humidity. At the time of minimum temperature the key parameters selected are the minimum road surface temperature reached after spreading and road surface conditions.

7.3.1 A702

The majority of treatments were carried out at relative humidity values greater than 70%, and more than half were carried out at relative humidity greater than 80%. The road surface was often damp or wet during or after spreading.

Table 3 – Minimum surface temperature after spreading at A702 site

Road surface state at time of spreading	Road surface state at time of minimum temperature	Minimum temperature (°C)	
		30ml/m²	15ml/m²
Wet	Wet	-2.9	-2.7
Wet	Moist	-3.5	-0.5
Moist	Moist	-3.5	-1.2
Dry	Dry	-1.2	0.1
Moist	Wet	-0.7	-
Dry	Moist	-1.2	0
Dry	Wet	-1.1	-

Table 4 – Conditions at time of spreading at A702 site

Relative Humidity (%)	Number of treatments for each condition			
	Road surface state			
	Dry	Moist	Wet	Slushy
50 to less than 60	-	-	-	-
60 to less than 70	6	-	-	-
70 to less than 80	6	5	7	-
Higher than or equal to 80	9	5	13	-

7.3.2 A77

The majority of treatments were carried out at relative humidity values greater than 80%. The road surface was often damp or wet during or after spreading.

Table 5 – Minimum surface temperature after spreading at A77 site (Combined for the short and full length route)

Road surface state at time of spreading	Road surface state at time of minimum temperature	Minimum temperature (°C)
		20ml/m²
Wet	Wet	0.6
Wet	Moist	-2
Moist	Moist	-3.7
Dry	Dry	-3.1
Moist	Wet	0.9
Dry	Moist	-3.5
Dry	Wet	-1.8

Table 6 – Conditions at time of spreading at A77 site (Combined for the short and full length route)

Relative Humidity (%)	Number of treatments for each condition			
	Road surface state			
	Dry	Moist	Wet	Slushy
50 to less than 60	1	-	-	-
60 to less than 70	9	1	-	-
70 to less than 80	4	4	-	-
Higher than or equal to 80	3	19	5	-

7.3.3 A9

The majority of treatments were carried out at relative humidity values greater than 80% on wet or moist road surfaces.

Table 7 – Minimum surface temperature after spreading at A9 sites (Combined for the short and full length route)

Road surface state at time of spreading	Road surface state at time of minimum temperature	Minimum temperature (°C)
		30ml/m²
Wet	Wet	-6.5
Wet	Moist	-1.9
Moist	Moist	-1.7
Dry	Dry	-
Moist	Wet	-0.9
Dry	Moist	1.3
Dry	Wet	-3.7

Table 8 – Conditions at time of spreading at A9 sites (Combined for the short and full length route)

Relative Humidity (%)	Number of treatments for each condition			
	Road surface state			
	Dry	Moist	Wet	Slushy
50 to less than 60	1	-	-	-
60 to less than 70	4	-	3	-
70 to less than 80	5	2	7	-
Higher than or equal to 80	2	7	50	-

7.4 Monitoring of 'Grip' and surface state

The level of 'Grip' was reported monthly during the trial period and graphs are presented in Sections 7.4.1 to 7.4.3 for each site. For each figure, a timeline showing the minimum surface temperature on each day was indicated by the following:

- Temperature below 0°C = blue
- Temperature above 0°C = green
- Snow = yellow

For each day on the timeline, treatments were presented by either brine (B), or pre-wetted (P).

Key:

	RST at or above 0°C
	RST below 0°C
	Snow

B	Brine treatment
P	Pre-wetted treatment
-	No Action

Based on experience in use of the sensors internationally, Vaisala has defined a critical 'Grip' value of 0.6 above which it is considered there is adequate friction. In addition to monitoring of the 'Grip', the sensors also continuously monitor the surface state.

During the trials there were a number of snow (where brine was not used) and heavy rainfall events resulting in 'Grip' values below 0.6. Instances of 'Grip' below 0.6 and/or where instances of ice, slush or snow were reported after brine spreading are summarised in Section 7.5.

There was generally confidence in the accuracy of the 'Grip' measurements reported by the sensors during the trial period. As noted in Section 7.4.1, some spurious 'Grip' readings

below 0.6 were reported on the A702 pre-wetted trial section, which were not related to the road conditions i.e. occurring during dry conditions when temperatures above freezing. These were predominantly during the final period of the trial, in conditions where winter treatments were not being carried out, and it is not considered these impacted on the validity of the trial results. The device was otherwise appearing to function correctly during this period, demonstrating expected responses to wet road surfaces after rainfall. Likely causes of such readings can include interference or blocking of sensor signals from vehicles parked under the sensors, contamination of the lenses or a temporary change in the road surface being monitored e.g. mud or dirt on the road surface.

7.4.1 A702 grip levels

The lowest 'Grip' reading in December (Figure 9) was 0.2, which was reported by the sensor monitoring the control section where salt was spread. This event did not correlate with any treatments and the RST was above 0°C. The only occasion where the sensor monitoring the spread of brine dropped below 'acceptable' levels was on the 26th of December with a reading of 0.37. This was at the same time as a pre-wet treatment where there was snow. The 'Grip' for both sensors shows some variation between the 21st and 24th of December where brine treatments were used. The 'Grip' fell below 0.6 for the sensor monitoring brine on two occasions during this time period, during snow events where road surface temperatures were above freezing.

For January (Figure 10) there were two 'Grip' readings below 'acceptable' levels, which were both recorded on the sensor monitoring salt spreading. The first of these was on the 9th of January with a reading of 0.09. The RST was at or above 0°C and the reading was recorded before a series of days where pre-wet treatments were used for snow conditions. The 'Grip' also falls to 0.41 on the 19th of January when the RST is above 0°C and was not treated.

The lowest 'Grip' reading in February (Figure 11) was reported at 0.31 on the sensor monitoring brine spreading on the 10th of January. This was at a time when pre-wet treatments were being used due to snow.

In March and April (Figure 13) a number of spurious 'Grip' readings below 0.5 were reported on the sensor for salt spreading which were not related to the road conditions.

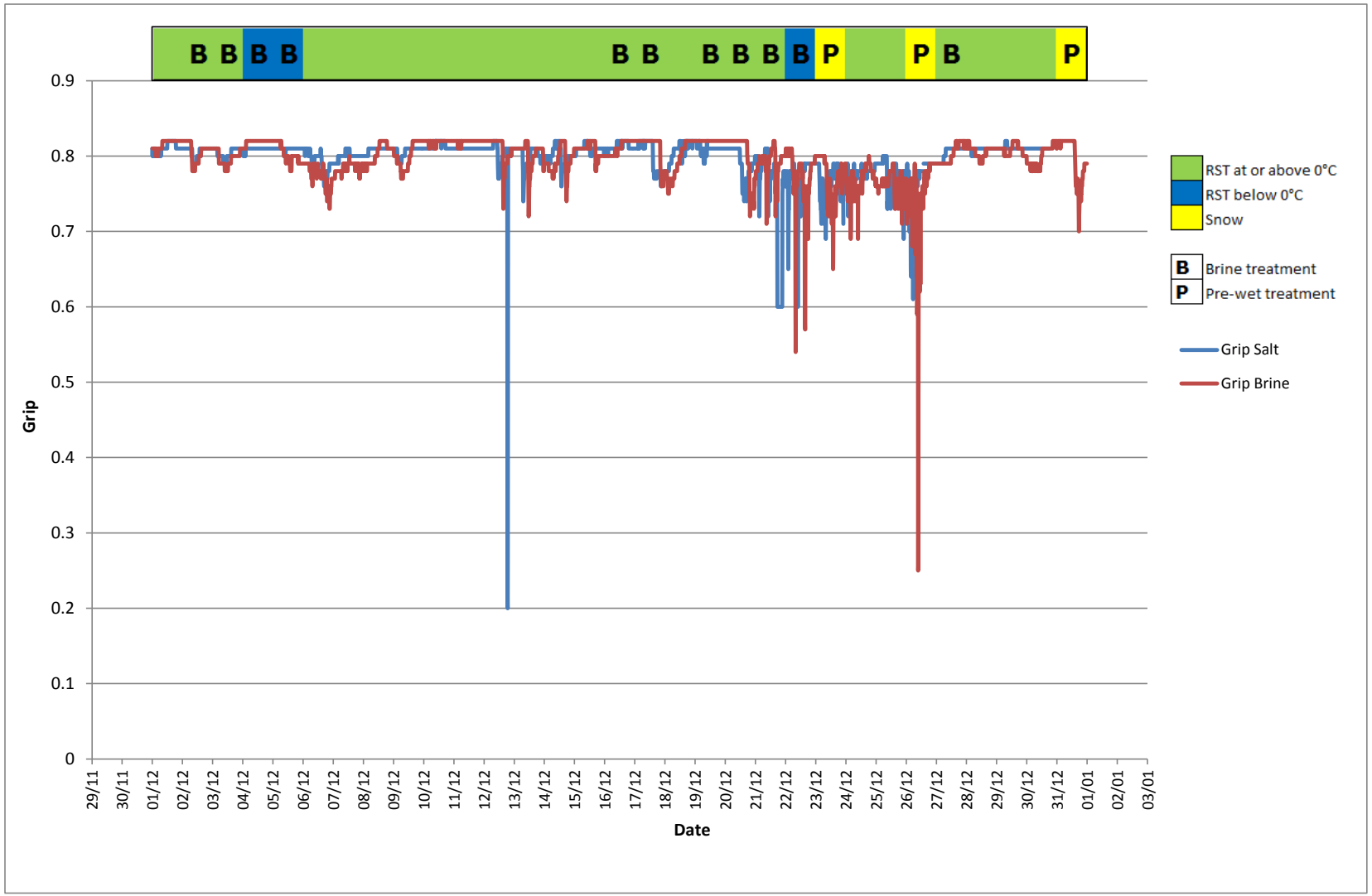

Figure 9 – Level of 'Grip' reported on the A702 site during December 2016

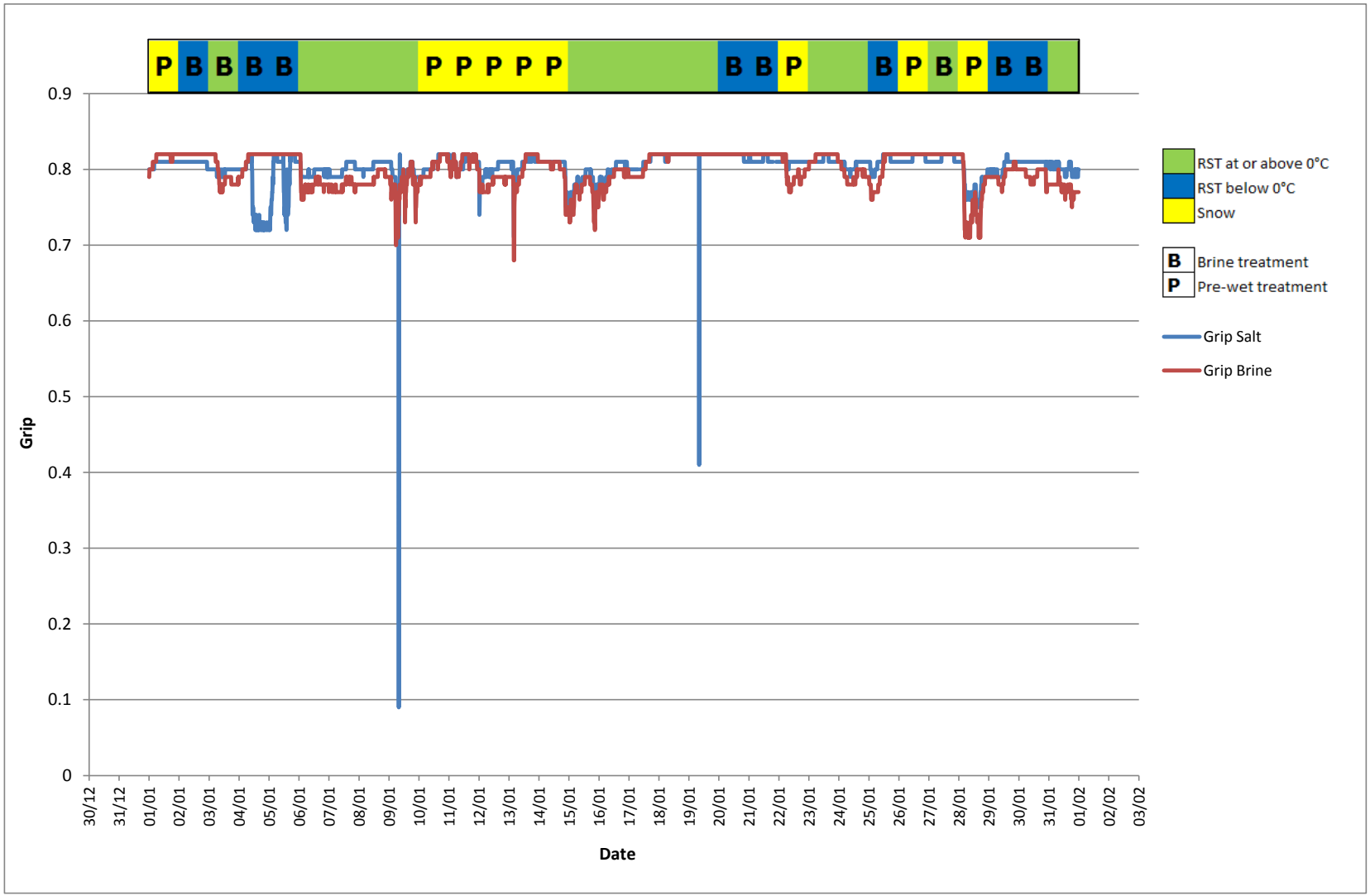

Figure 10 – Level of 'Grip' reported on the A702 site during January 2017

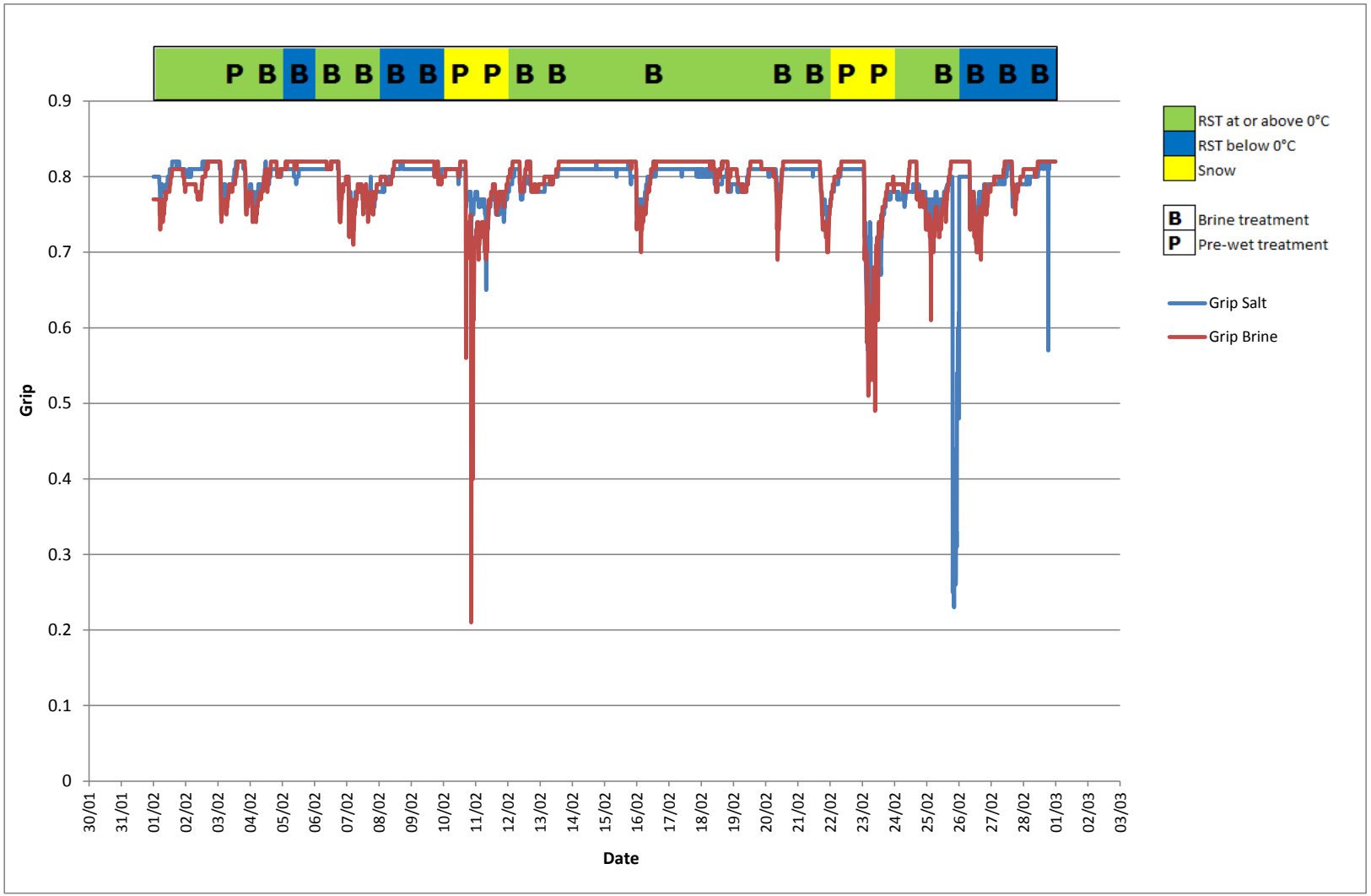

Figure 11 – Level of 'Grip' reported on the A702 site during February 2017

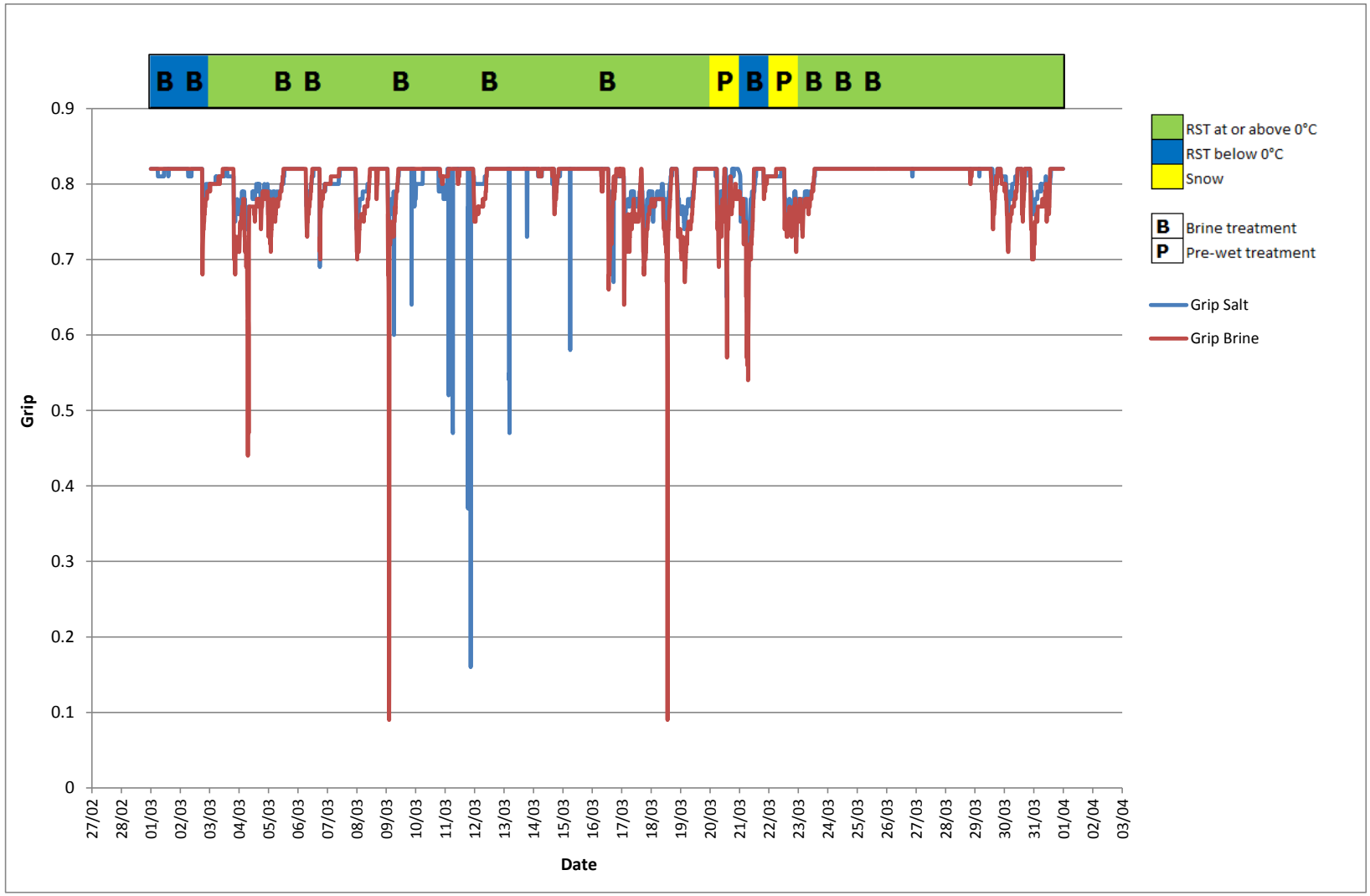

Figure 12 – Level of 'Grip' reported on the A702 during March 2017

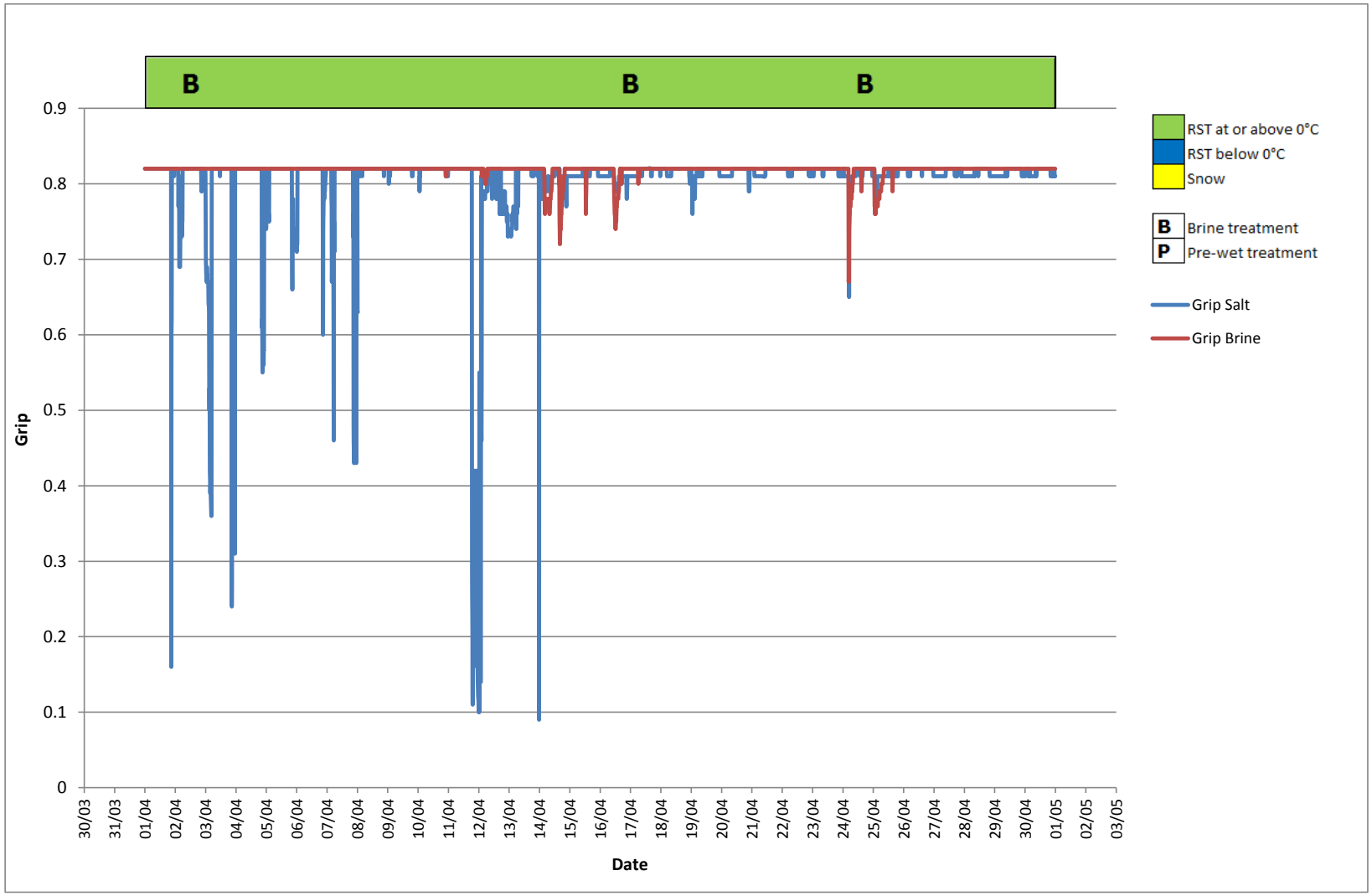

Figure 13 –Level of 'Grip' reported on the A702 during April 2017

7.4.2 A77 Grip Levels

The 'Grip' readings for November and December (Figure 14 and Figure 15) do not drop below 'acceptable' levels for either sensor during the trial period, which began on the 18th of November The lowest reported value was 0.62 on the 26th of December for the sensor monitoring brine spreading. This did not correlate with any treatments and RSTs were at or above 0°C.

A 'Grip' reading of 0.28 was reported on the 12th of January (Figure 16) by the sensor monitoring salt spreading. This correlated with a pre-wet treatment and snow conditions.

The 'Grip' readings for February (Figure 17) did not drop below 'acceptable levels' with the lowest reading of 0.67 for the sensor monitoring brine spreading on the 7th of February.

The 'Grip' readings for March (Figure 18) did not drop below 'acceptable' levels with the lowest reading of 0.65 for both sensors monitoring salt spreading and brine spreading on the 14th of March and 15th of March respectively.

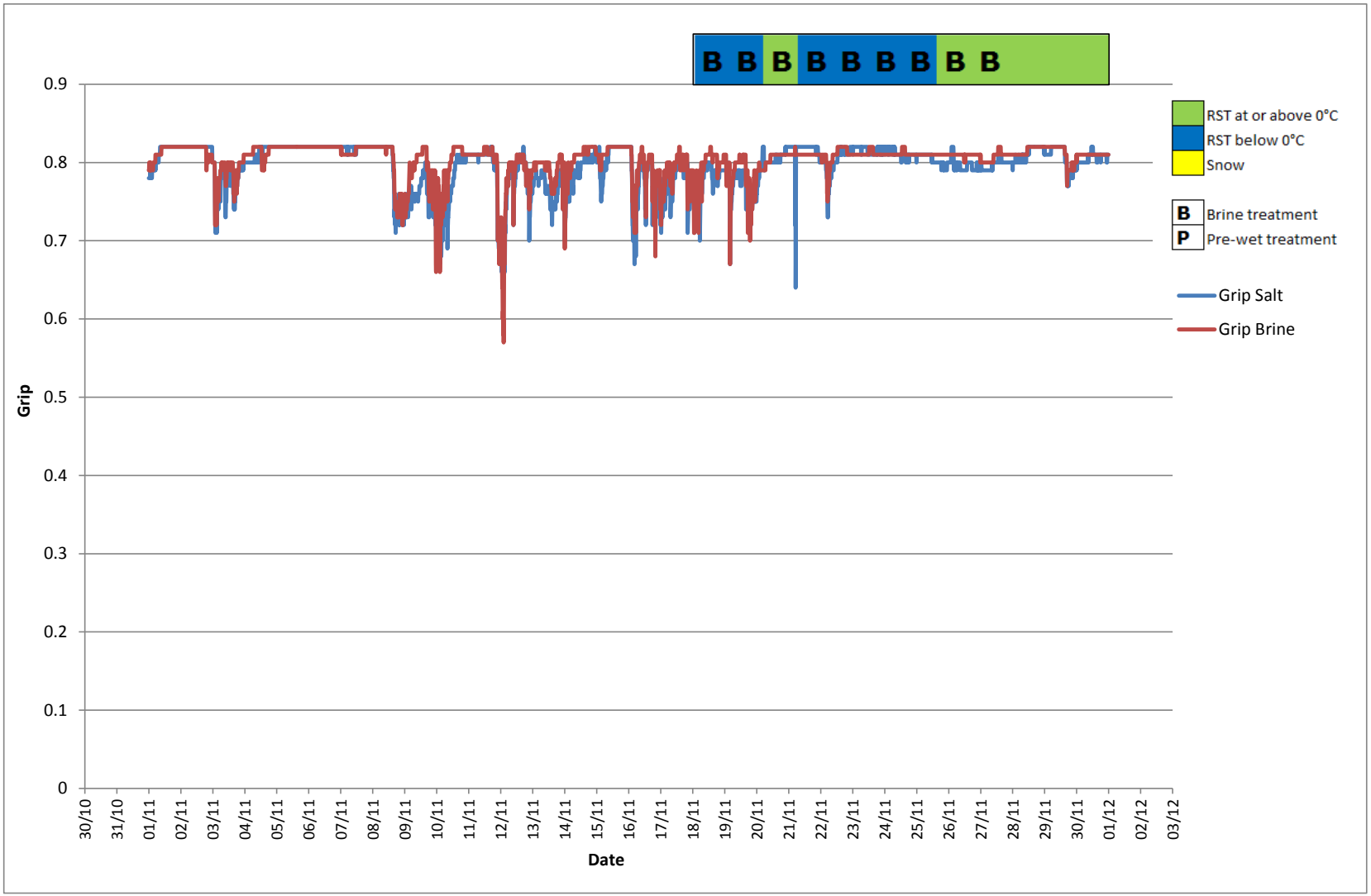

Figure 14 – Level of 'Grip' reported on the A77 during November 2016 (Note – Brine treatments did not commence until the 18th of November)

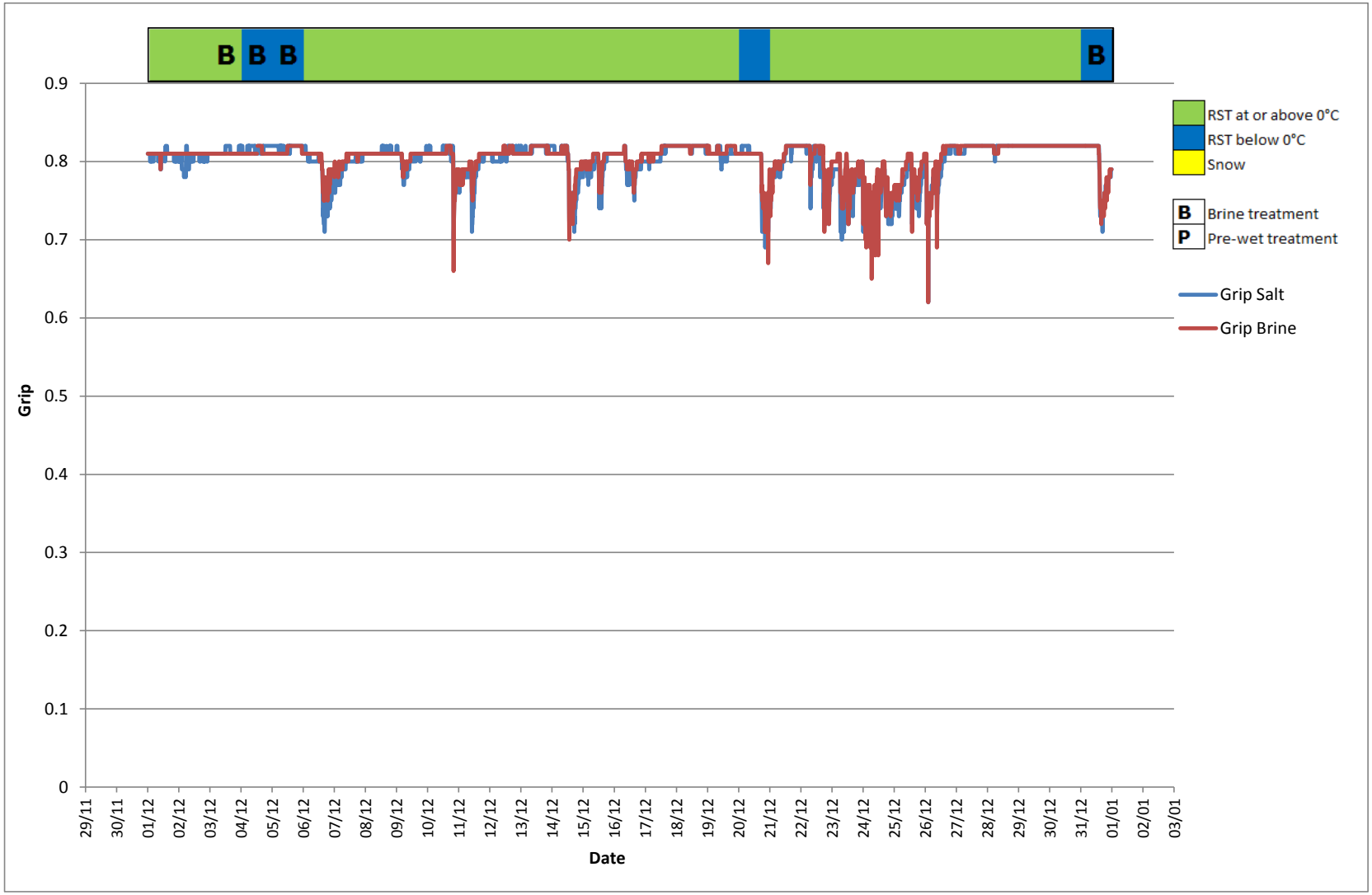

Figure 15 – Level of 'Grip' reported on the A77 during December 2016

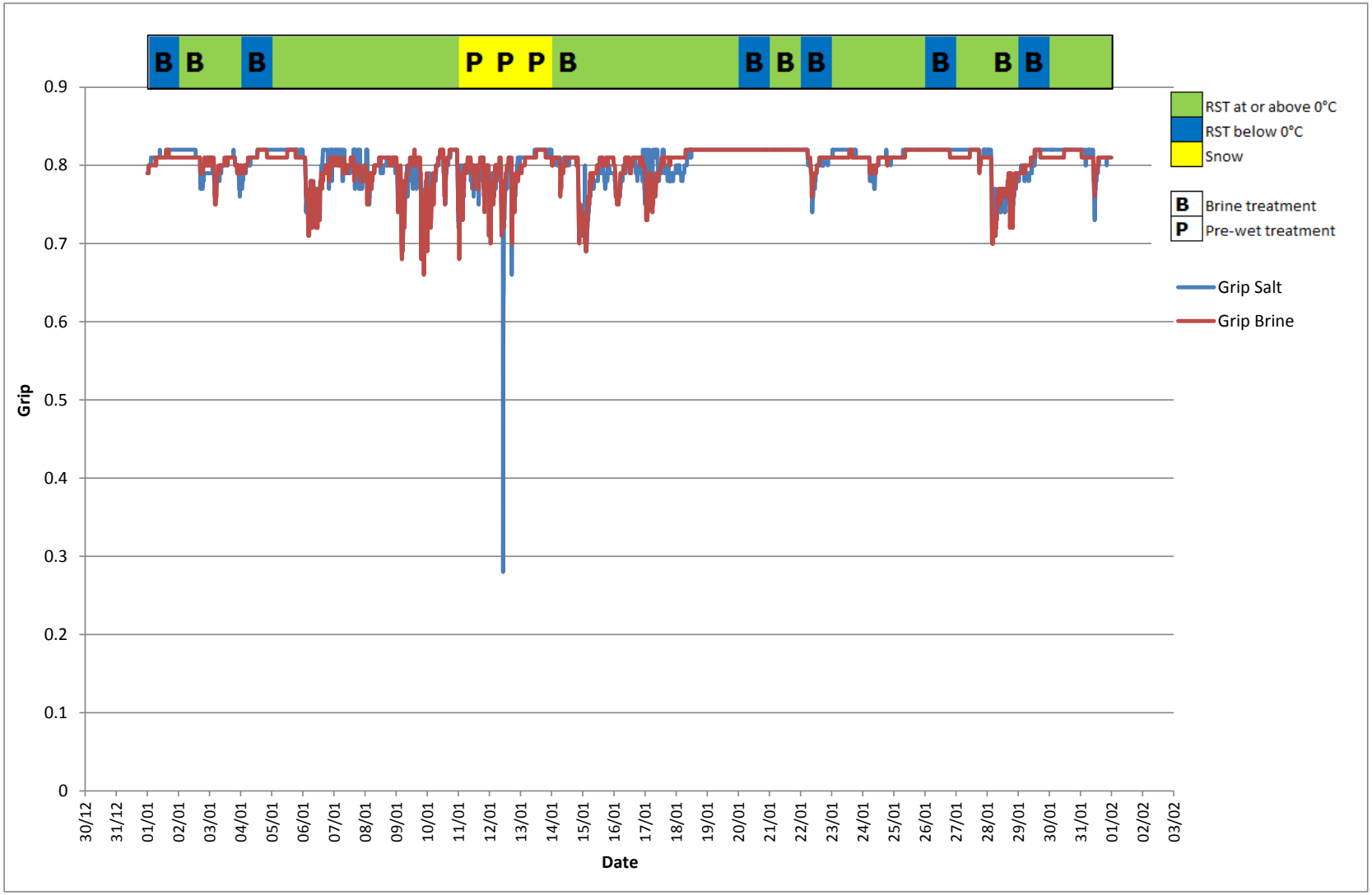

Figure 16 – Level of 'Grip' reported on the A77 during January 2017

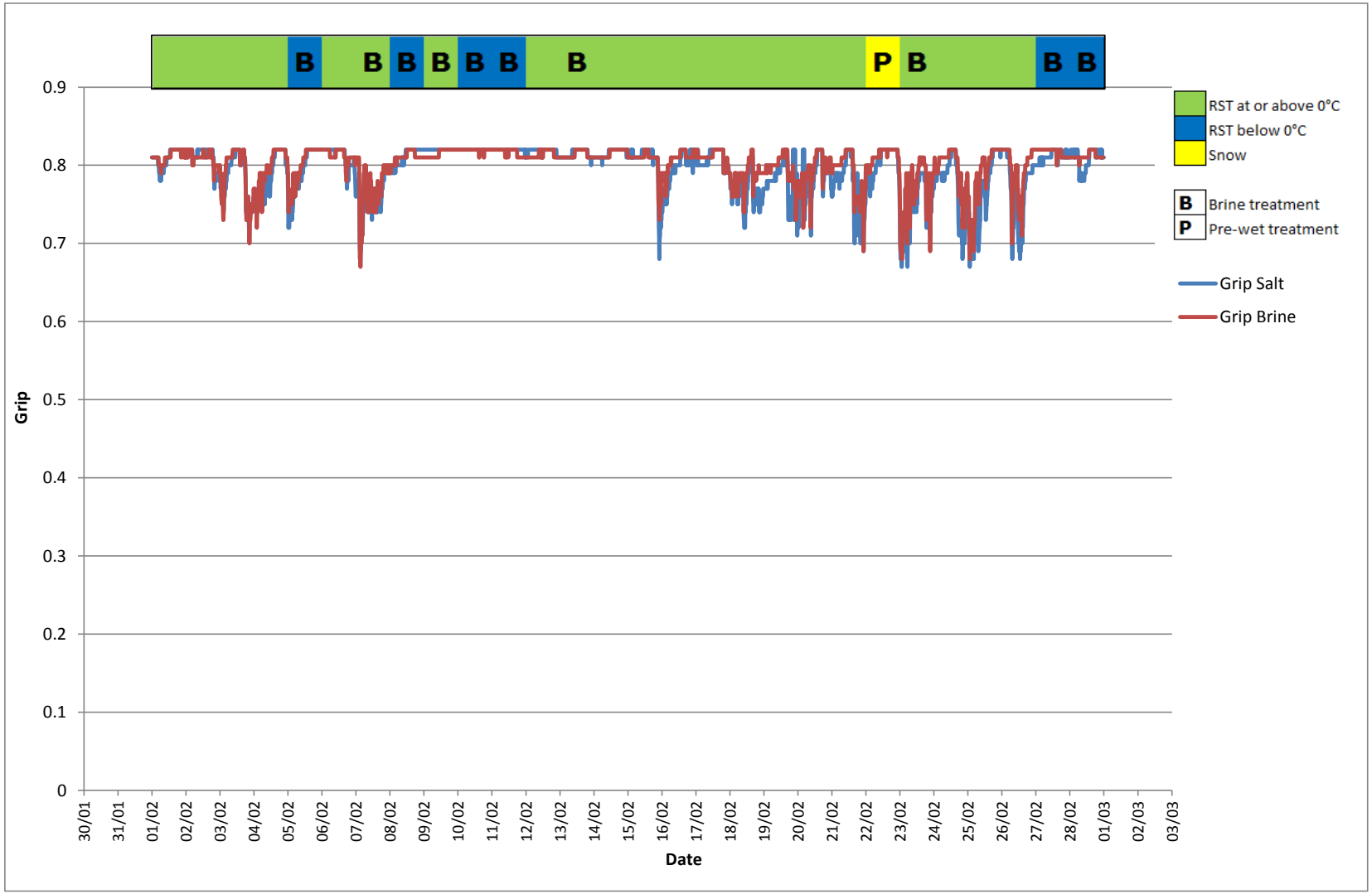

Figure 17 – Level of 'Grip' reported on the A77 during February 2017

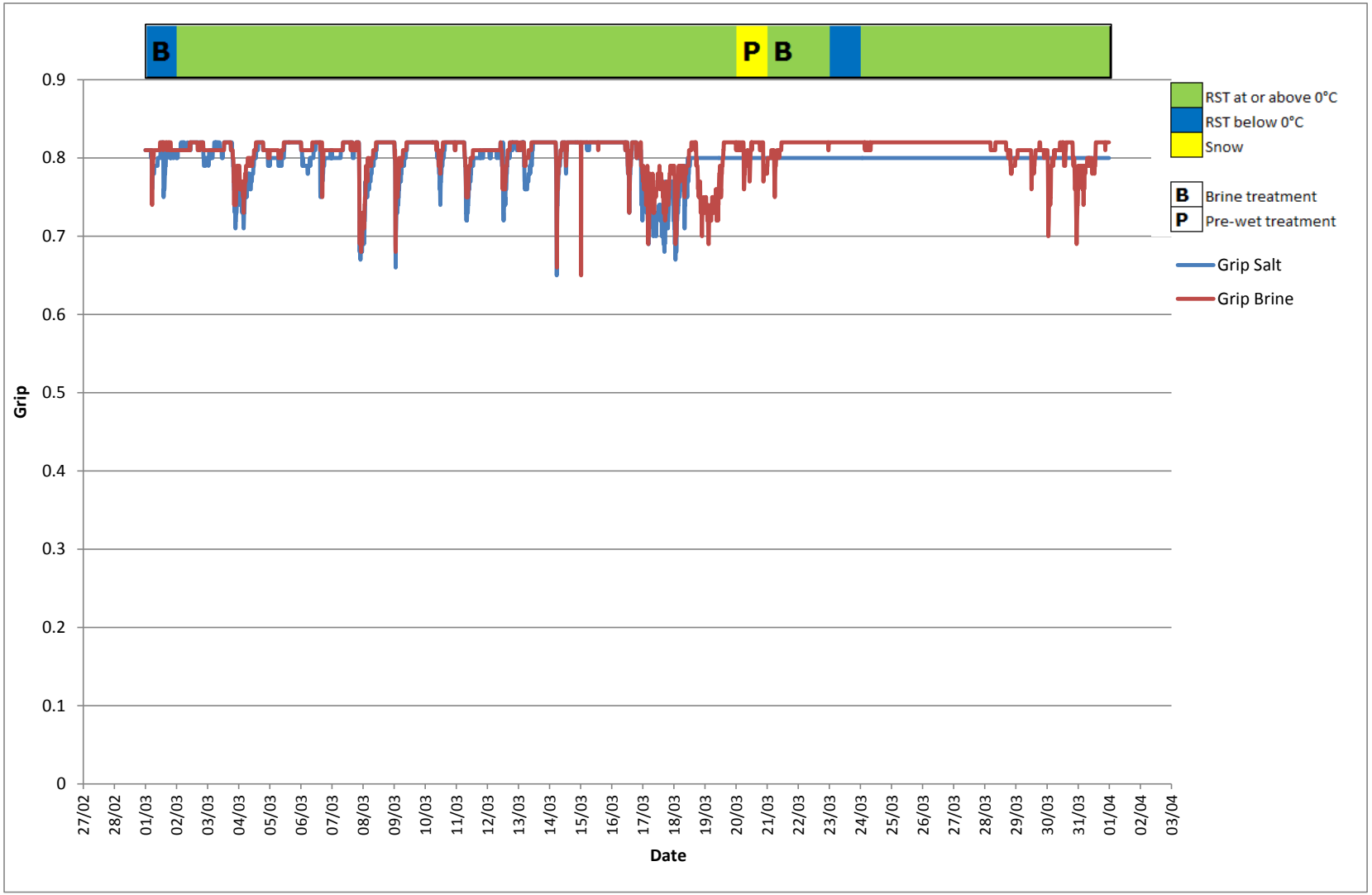

Figure 18 – Level of 'Grip' reported on the A77 during March 2017

7.4.3 A9 Grip Levels

A9 Perth (Inveralmond)

The 'Grip' readings for November and December (Figure 19 and Figure 20) did not drop below 'acceptable' levels with the lowest reading of 0.63 for the sensor monitoring brine spreading on the 26th of December. This correlated with a brine treatment when RSTs were at or above 0°C.

A 'Grip' reading of 0.37 was recorded on the 13th of January (Figure 21) by the sensor monitoring brine spreading. This correlated with a brine treatment with RSTs below 0°C.

The 'Grip' readings for February (Figure 22) did not drop below 'acceptable' levels with the 'Grip' barely dropping below 0.7 at the same time as when brine treatments were implemented.

For the full route trial site, low 'Grip' down to 0.36 was measured on the morning of the 23rd February, during a snow event and when pre-wetted salt had been spread on the trial site.

A9 Balhaldie

There was one 'Grip' event in February (Figure 23) below 'acceptable' levels at 0.36 on the 23rd of February, which correlated with a pre-wet treatment for snow. The 'Grip' readings for March and April (Figure 24 and Figure 25) did not drop below 'acceptable' levels.

The Loaninghead station is not equipped with a sensor to enable reporting of 'Grip' data.

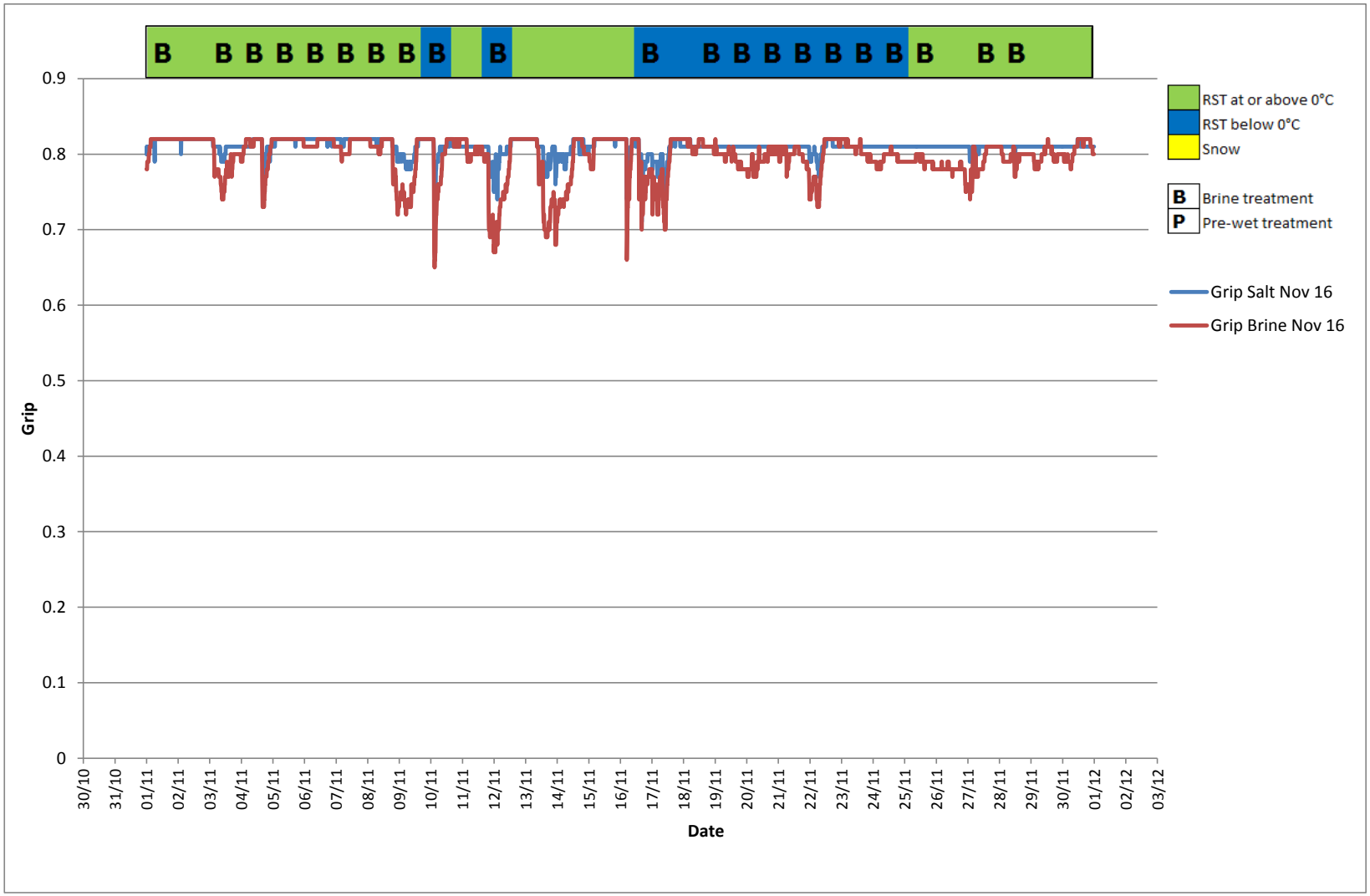

Figure 19 – Level of 'Grip' reported on the A9 Inveralmond in November 2016

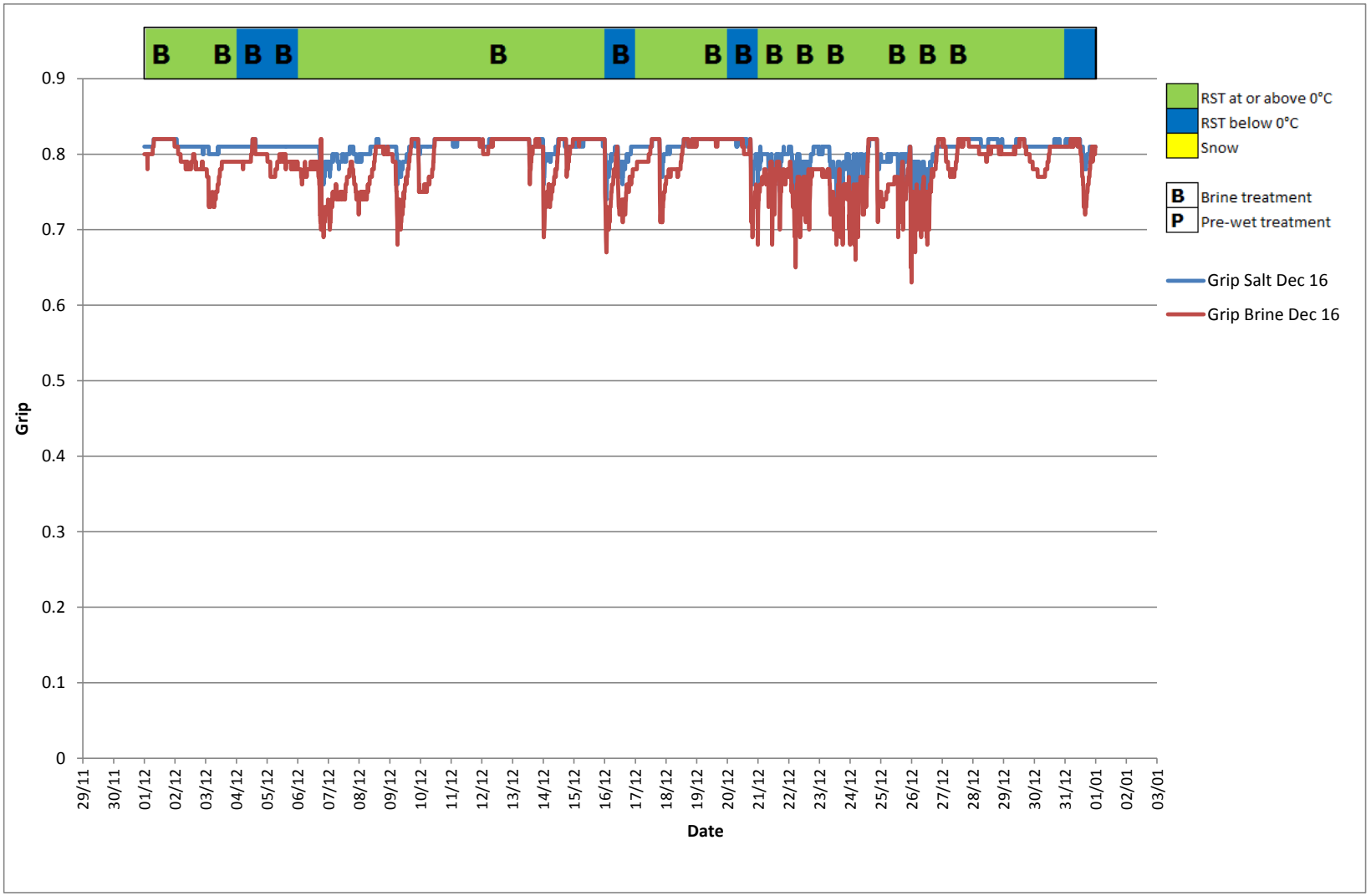

Figure 20 – Level of 'Grip' reported on the A9 Inveralmond in December 2016

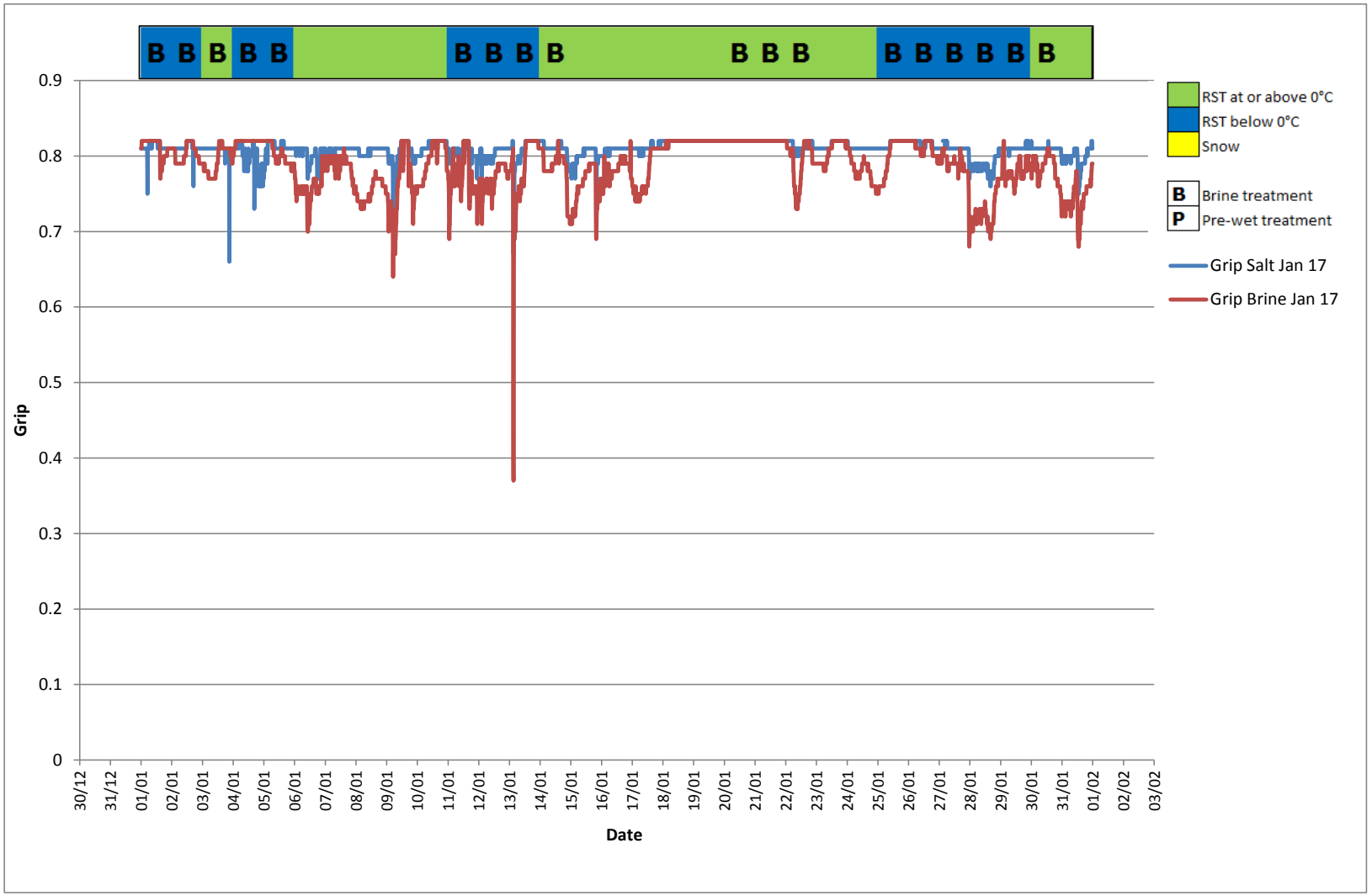

Figure 21 – Level of 'Grip reported on the A9 Inveralmond in January 2017

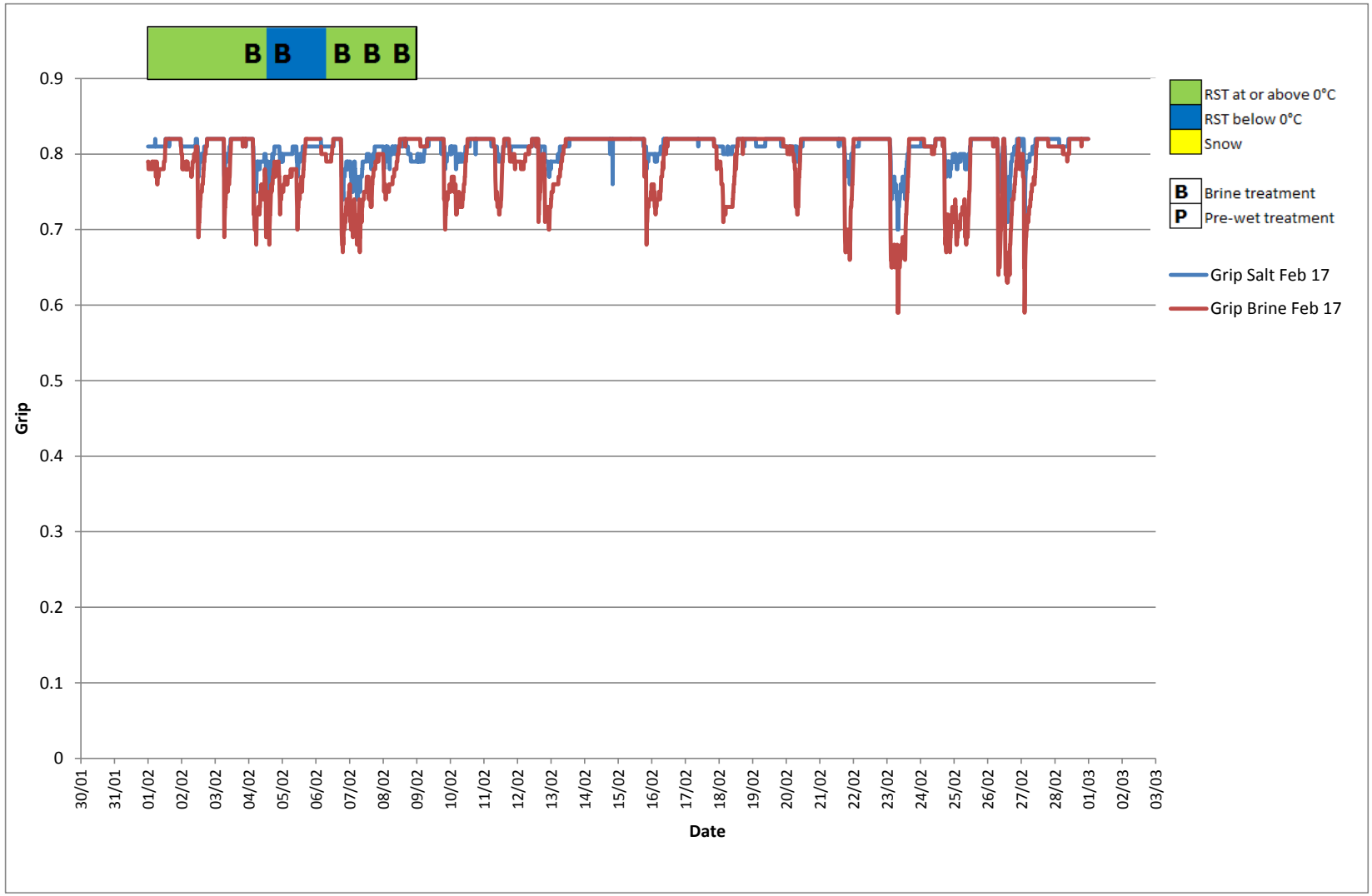

Figure 22 – Level of 'Grip' reported on the A9 Inveralmond in February 2017

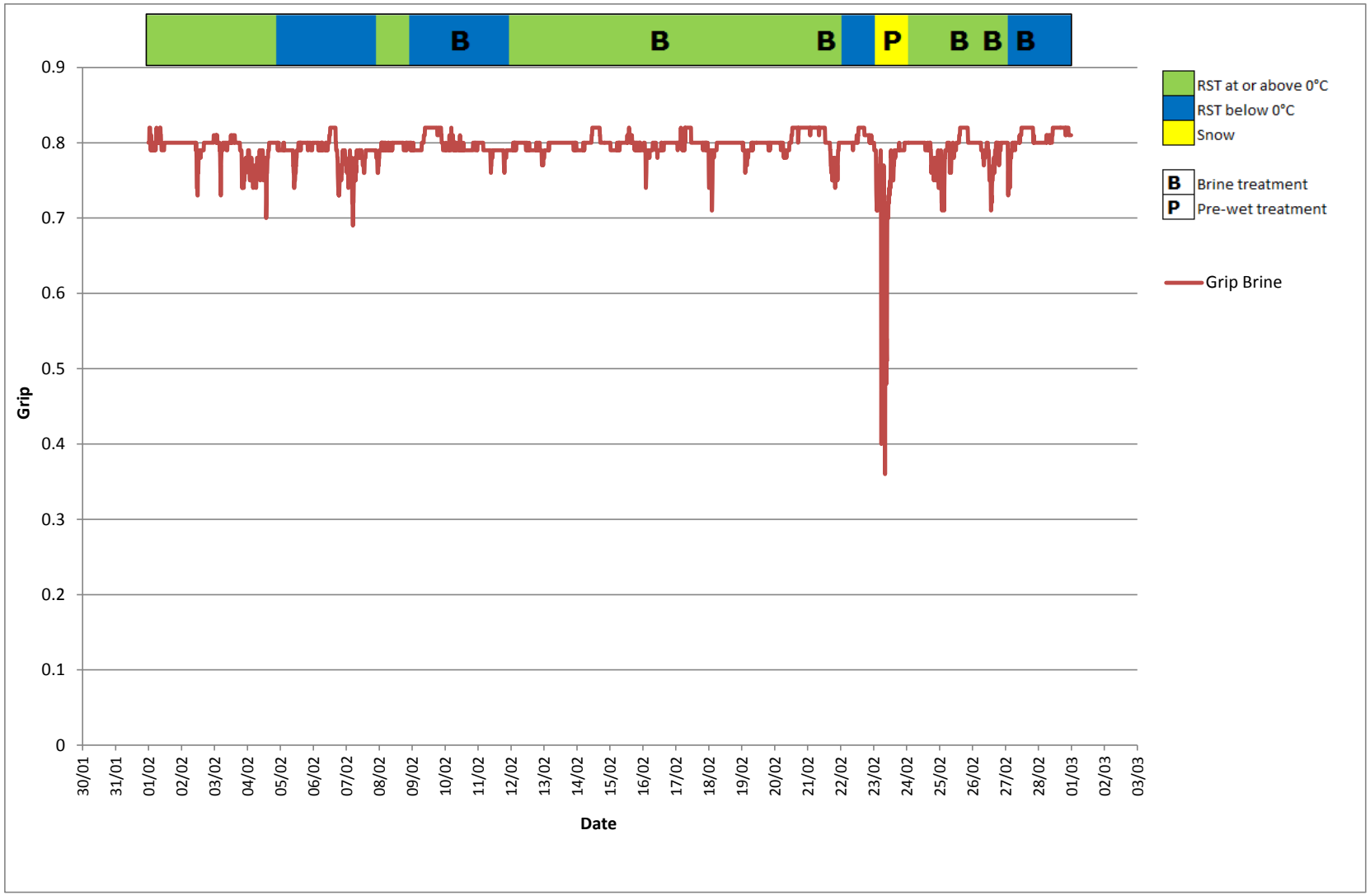

Figure 23 – Level of 'Grip' on the A9 Balhaldie in February 2017

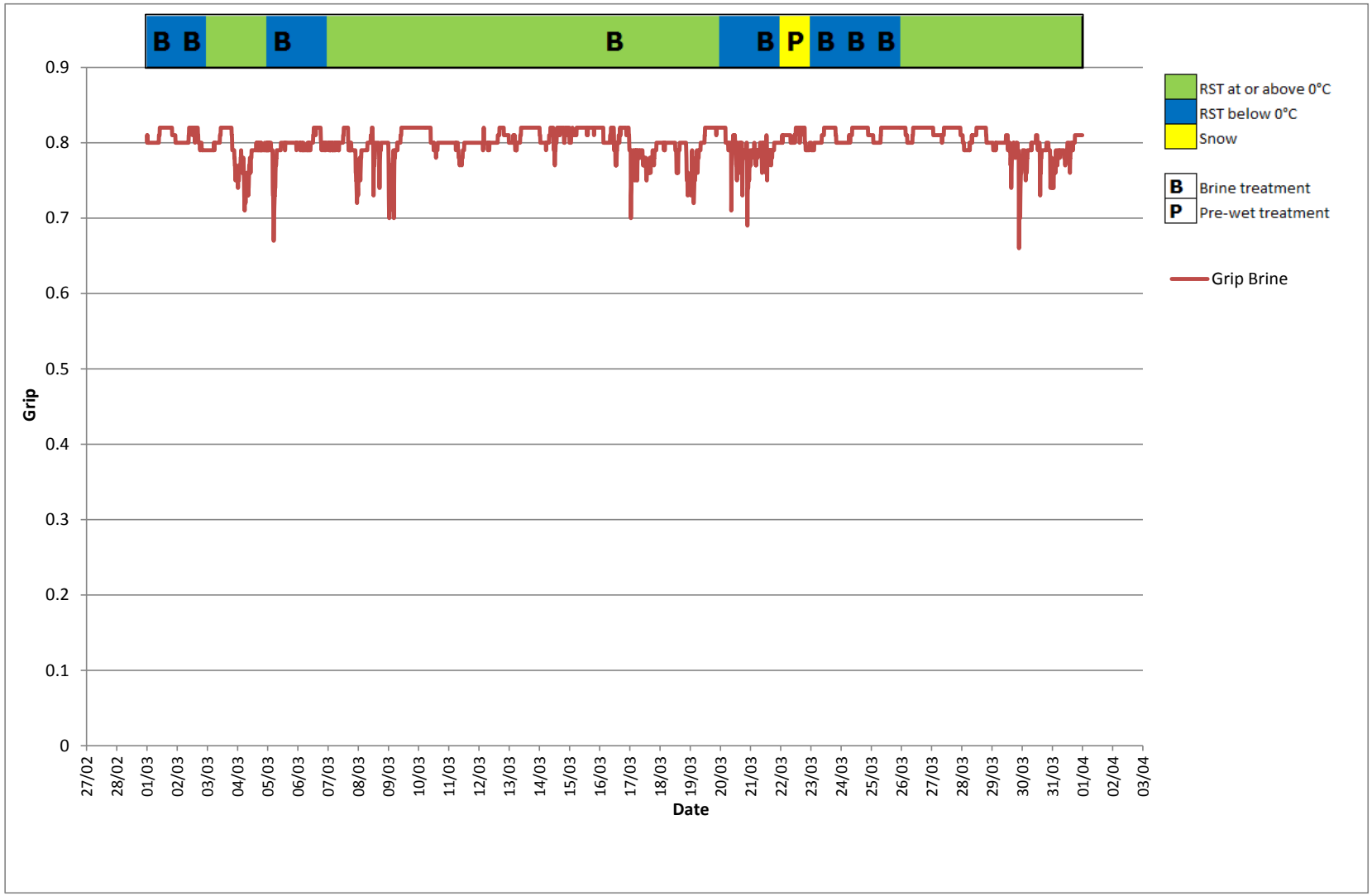

Figure 24 – Level of 'Grip' on the A9 Balhaldie in March 2017

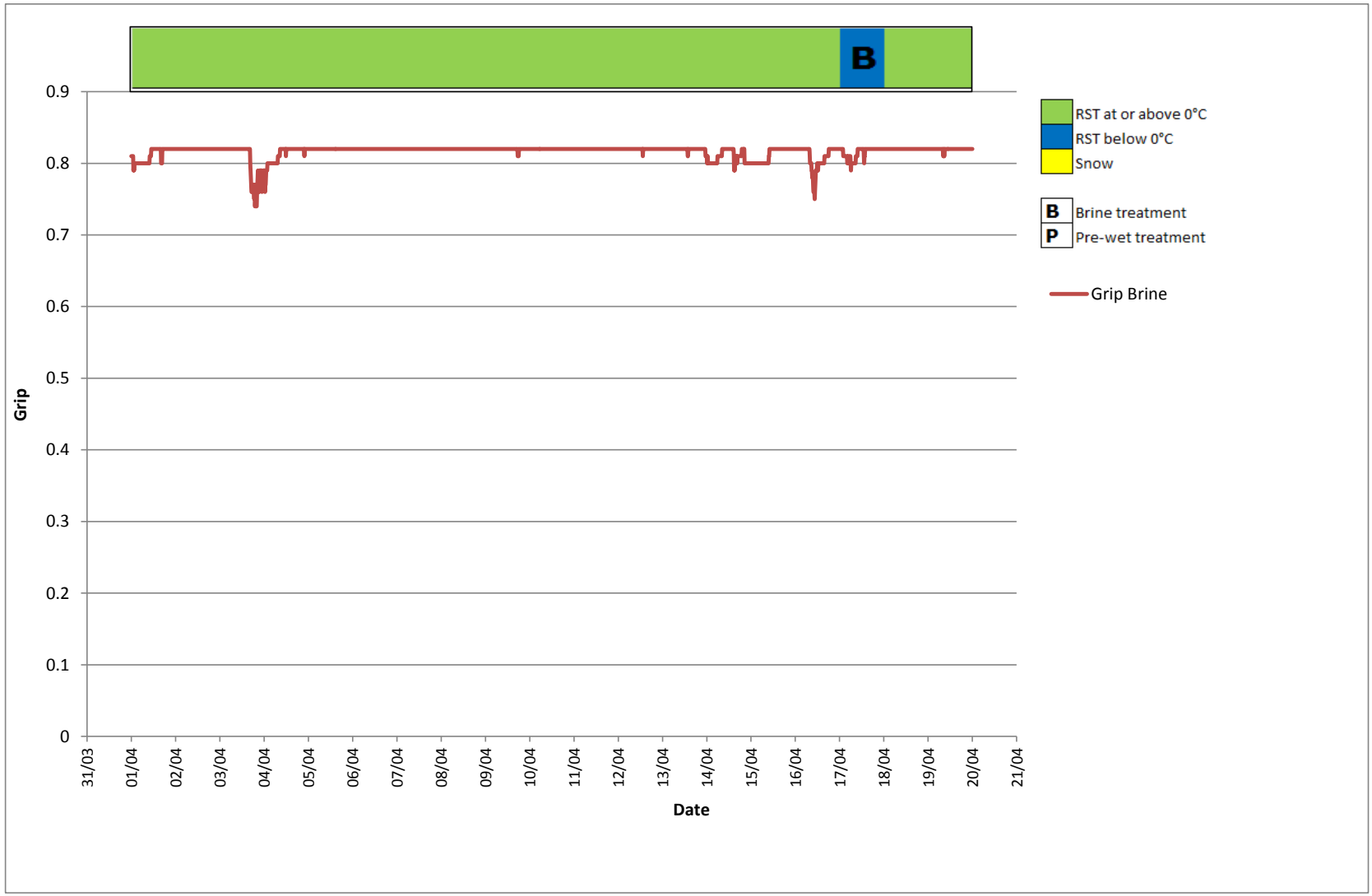

Figure 25 – Level of 'Grip on the A9 Balhaldie in April 2017

7.5 Results summary

Table 9 summarises the minimum surface temperatures reached after spreading for precautionary treatments carried out across all the trial sites. Monitoring of the road conditions after brine spreading, using remote surface state sensors, embedded road sensors and from patrols has indicated that the spread rates have provided an effective treatment for these conditions.

Table 9. Minimum temperature after spreading

Road surface state at time of spreading	Minimum temperature		
	30ml/m²	20ml/m²	15ml/m²
Dry	-2.9	-3.5	0.1
Moist	-6.5	-3.7	-1.2
Wet	-4.7	-2	-2.7

To provide evidence for the resilience of brine treatments to precipitation, weather station and road condition data were analysed for the events where precipitation had occurred after spreading and for near or sub-zero road surface temperatures.

Table 10 summarises the key parameters assessed for these events, including the total amount of precipitation (from rain or snow), water film thickness on the road surface and minimum road surface temperatures (details of events are provided in Appendix D).

The data has demonstrated that where snowfall occurred this was typically in conjunction with road surface temperatures greater than -2°C and often above freezing.

Two events were identified where snow or ice was detected after snow or rainfall in freezing conditions:

- A brief recording of a slushy state (A9, 29th January) after brine spreading on a very wet road after rainfall (water film thickness greater than 0.2mm). There was no associated loss of 'Grip' because of the small amounts of ice detected.
- Recording of a snowy state (A9, 13th January) for approx. 20 minutes during a short duration snowfall on a freezing road surface. The loss of 'Grip' was for both brine and pre-wetted salt trial sections. The snowfall resulted in a water film thickness greater than 0.4mm.

Table 10. Summary of conditions where precipitation occurred after spreading for sub-zero road surface temperatures

Location and date	Road surface state at time of spreading (Water layer thickness, mm)	Brine spread rate (ml/m²)	Total precipitation after spreading (mm)	Minimum temperature (°C)	Performance assessment
A702, 9th February	Dry	30	0.3	-0.3	No issues
A702, 2nd March	Dry	30	1.7	-1.1	No issues
A77, 27th February	Moist (<0.01)	30	0.2	-2.6	No issues
A9, 11th January	Moist (0.03)	30	1.8	-0.6	No issues
A9, 12th January	Wet (0.12)	30	0.5	-0.8	No issues
A9, 29th January	Very wet (0.41)	30	2	-2.2	Slushy and icy surface state reported on the brine treated section, no loss of 'Grip'
A9, 13th January	Wet (0.12)	30	0.5	-1.4	Loss of 'Grip' and snowy surface state reported on both brine and pre-wetted sections

8 Conclusions and recommendations

Brine has provided an effective treatment for the conditions prevailing during the trial period, and brine spreading was a suitable treatment on the majority of days when spreading occurred on the trial sites.

There were no prolonged or severe periods of snow or low temperatures during the trial period, and conditions were generally considered favourable for brine spreading. A small number of instances of loss of 'Grip' were measured during brief snow events, typically where pre-wetted salt was used on the test sites instead of brine.

From the end of January to the end of the winter season, routine brine spreading was successfully carried out over two full routes, with 16 treatments on Route 20R11 on the A9 and 15 treatments on Route A20/3 on the A77.

The results have provided an indication of the conditions of road surface wetness and temperature for which brine spreading is effective, and some indication on the limits of effectiveness during precipitation.

Based on the conditions under which the brine spreading has been trialled, recommended spread rates are provided in Table 11 and Table 12 for precautionary treatments before frost and light snow or rain. The dry and damp road surface definitions are as provided in the NWSRG Spread Rates guidance, with the descriptions provided in Table 13.

It is considered there is scope for reduction in the rates that are recommended and the use of brine for a wider range of conditions, for example before and during more significant snow events, if the effectiveness can be demonstrated operationally on the network. However safety is paramount and any further reduction or changes in practice must be effectively managed in order to mitigate the risks.

Further trials are recommended over the 2017/18 winter season, to include brine spreading to be carried out before and during snow events and in temperatures below -5°C. The trials will further develop the understanding of liquid performance in the full range of conditions experienced on the Scotland network and will support the development of operational guidance for liquid spreading.

Table 11. Recommended precautionary brine spread rates (temperature bands as specified in current 4G contract requirements)

Road Surface Temperature (RST) when frost/ice is predicted	Recommended Spread Rates – Brine Spreading (ml/m²)	
	Dry/Damp Road	Wet Road
RST lower than or equal to plus 1°C but higher than minus 2°C	10	20
RST lower than or equal to minus 2°C but higher than minus 5°C	25	30

Light snow showers forecast <10mm (1mm water)[1]	30	-
Light rain showers forecast <1mm[1]	30	-

Note 1: Brine treatments before snow or light rain only when spreading on dry/damp road surface and minimum RST >-2°C

Table 12. Recommended precautionary brine spread rates (1°C temperature bands)

Road Surface Temperature (RST) when frost/ice is predicted	Recommended Spread Rates – Brine Spreading (ml/m²)	
	Dry/Damp Road	Wet Road
RST lower than or equal to minus 1°C but higher than minus 2°C	10	20
RST lower than or equal to minus 2°C but higher than minus 3°C	15	25
RST lower than or equal to minus 3°C but higher than minus 4°C	20	25
RST lower than or equal to minus 4°C but higher than minus 5°C	25	30
RST lower than or equal to minus 5°C but higher than minus 6°C	30	-
Light snow showers forecast <10mm (1mm water)[1]	30	-
Light rain showers forecast <1mm[1]	30	-

Note 1: Brine treatments before snow or light rain only when spreading on dry/damp road surface and minimum RST >-2°C

Table 13. Road surface wetness definitions

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/m^2)
Wet Road	A road on which traffic produces 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	**UNTREATABLE*** 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)

9 Acknowledgements

The work described in this report was carried out in the Infrastructure division of the Transport Research Laboratory.

The assistance of the following was much appreciated: Nicholas Russell of Amey; Bob Ogg of BEAR Scotland; Andy Fraser and Andrew Adam of Scotland TranServ; Brian Davis of Vaisala and Martin Thomson of Transport Scotland.

References

Sanders P and Jeffrey R (2017). *Assessment of technologies for the inference of road surface skid resistance.* Client Project Report CPR2395. TRL Ltd.

Appendix A Transport Scotland Pre-wetted Treatment Matrix

Table 7.2.K.2 – Spreading Rates for Precautionary Treatments Matrix

Spreading Rates for Precautionary Treatments Matrix			
	Road Surface Condition	Frost Susceptible/surface water run-off area (grammes/square metre)	Road Surface Wet (grammes/square metre)
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 to 20*	*10 to 20*
C.	RST lower than or equal to minus 2°C but higher than minus 5°C	*10 to 20*	*10 to 20*
D.	RST lower than or equal to minus 5°C	*20*	*20*
E.	RST lower than or equal to plus 1°C but higher than minus 2°C following rain	*20*	*30*
F.	RST lower than or equal to minus 2°C but higher than minus 5°C following rain	*30*	*40*
G.	RST lower than or equal to minus 5°C following rain (see note B)	*40*	*40*
H.	Hoar Frost	*20*	*20*
I.	Freezing Fog	*10*	*20*
J.	Freezing Rain	*40 (See Table 7.2.K.1)*	*40 (See Table 7.2.K.1)*
K.	Snow Accumulations up to 30mm	*30*	*40*
L.	Snow Accumulations over 30mm	*40*	*40*
M.	Hard Packed Snow/Ice	*See Table 7.2.K.4*	*See Table 7.2.K.4*
Note A. "RST" means road surface temperature. Note B. Refer also to paragraph 5.4 of this Part.			

Appendix B Average and minimum air temperatures and RSTs for weather stations

The red font denotes the lowest monthly average air temperature recorded over the season.

Table 14 – Average air temperature for weather stations by month

Weather Station	Average air temperature (°C) by month					
	Nov	Dec	Jan	Feb	Mar	Apr
A702 Boghall (Salt)	4.1	6.3	4.2	4.6	6.6	-
A702 Hillend (Brine)	4.6	6.8	4.7	5.0	6.8	-
A77 Ladykirk (Salt)	5.0	7.3	5.3	5.5	7.2	-
A77 Dutch House (Brine)	5.2	7.8	5.7	5.9	7.4	-
A9 Inveralmond (Salt)	3.7	6.6	4.2	5.5	6.8	-
A9 Inveralmond Brine Trial (Brine)	3.5	6.3	4.0	5.3	6.6	-
A9 Balhaldie (Brine	-	-	-	4.7	5.9	7.6
A9 Loaning Head (Brine)	-	-	-	4.3	5.6	7.3
Average	**4.4**	**6.9**	**4.7**	**5.1**	**6.6**	**7.5**

Table 15 – Minimum air temperatures for weather stations by month

Weather Station	Minimum air temperature (°C) by month					
	Nov	Dec	Jan	Feb	Mar	Apr
A702 Boghall (Salt)	-7.5	-2.7	-3.6	-1.6	-1.8	-
A702 Hillend (Brine)	-6.1	-2.5	-3.1	-0.5	-0.5	-
A77 Ladykirk (Salt)	-3.1	-0.4	-2.1	-2.6	-0.3	-
A77 Dutch House (Brine)	-3.4	-0.6	-3.1	-2.5	-1.5	-
A9 Inveralmond (Salt)	-7.1	-4.6	-5.7	-3.1	-2.6	-
A9 Inveralmond Brine Trial (Brine)	-7.2	-4.3	-6.1	-3.3	-2.8	-
A9 Balhaldie (Brine	-	-	-	-3.8	-4.5	-3.8
A9 Loaning Head (Brine)	-	-	-	-4.2	-4.3	-5

Table 16 – Average road surface temperature (RST) for weather stations by month

Weather Station	Average RST (°C) by month					
	Nov	Dec	Jan	Feb	Mar	Apr
A702 Boghall (Salt)	3.5	5.0	3.3	4.4	7.6	-
A702 Hillend (Brine)	3.4	4.8	3.0	4.0	6.8	-
A77 Ladykirk (Salt)	4.7	6.7	4.8	5.4	8.4	-
A77 Dutch House (Brine)	4.8	6.8	5.0	5.8	8.8	-
A9 Inveralmond (Salt)	3.3	5.5	3.5	5.1	7.3	-
A9 Inveralmond Brine Trial (Brine)	3.6	5.6	3.5	5.2	7.3	-
A9 Balhaldie (Brine	-	-	-	4.6	6.8	11.0
A9 Loaning Head (Brine)	-	-	-	4.2	6.6	11.3
Average	**3.9**	**5.7**	**3.8**	**4.9**	**7.4**	**11.1**

Table 17 – Minimum road surface temperatures (RSTs) for weather stations by month

Weather Station	Minimum RST (°C) by month					
	Nov	Dec	Jan	Feb	Mar	Apr
A702 Boghall (Salt)	-5.8	-4.3	-4.1	-2.7	-2.1	-
A702 Hillend (Brine)	-3.8	-3.5	-3.9	-2	-1.1	-
A77 Ladykirk (Salt)	-3	-1.4	-2.7	-2.4	-0.2	-
A77 Dutch House (Brine)	-3.7	-1.9	-3.5	-3.1	-1	-
A9 Inveralmond (Salt)	-6.1	-3.2	-3.7	-2.3	-1.6	-
A9 Inveralmond Brine Trial (Brine)	-5.5	-3.1	-4.2	-2.7	-1.8	-
A9 Balhaldie (Brine	-	-	-	-3.5	-3.4	-0.9
A9 Loaning Head (Brine)	-	-	-	-4.1	-4.1	-2.1

Appendix C Summary of treatments and sensor data

A702

		Treatment 1				Treatment 2							
Date	Type of Treatment	Time	Spread rate (ml/m^2)	Surface state 3	RH (%)	Time	Spread rate (ml/m^2)	Surface state 3	Surface T (°C)	RH (%)	Lowest Temp (°C)	Time of lowest Temp	Surface state 3
02/12/2016	Salt	03:00	10	Moist	89						1.5	07:20	Moist
02/12/2016	Brine	03:00	15	Wet	90						1.7	06:30	Wet
03/12/2016	Salt	19:00	20	Moist	82	03:00	10	Moist	2.5	78	-0.9	08:00	Moist
03/12/2016	Brine	19:00	30	Wet	83	03:00	15	Wet	2.4	74	-0.5	08:30	Moist
04/12/2016	Salt	14:30	20	Moist	73	03:00	10	Moist	-3.4	86	-4.1	04:40	Moist
04/12/2016	Brine	14:30	30	Moist	75	03:00	15	Wet	-2.4	93	-3.5	01:40	Moist
05/12/2016	Salt	14:00	20	Moist	77	03:00	10	Moist	-2.8	92	-4.3	02:00	Moist
05/12/2016	Brine	14:00	30	Wet	88	03:00	15	Wet	-2.3	93	-2.9	01:30	Wet
16/12/2016	Salt	22:00	20	Dry	87						0.7	04:00	Moist
16/12/2016	Brine	22:00	30	Moist	76						2.2	06:30	Moist
17/12/2016	Salt	15:00	10	Dry	76						4.5	17:40	Dry
17/12/2016	Brine	15:00	15	Dry	75						4.2	19:10	Dry
19/12/2016	Salt	15:00	20	Dry	86	03:00	10	Moist	0.3	87	-0.7	02:50	Moist
19/12/2016	Brine	15:00	30	Dry	85	03:00	15	Dry	0.6	83	0.1	04:30	Dry
20/12/2016	Salt	01:00	20	Wet	84						1.4	04:10	Wet
20/12/2016	Brine	01:00	30	Wet	84						1	06:00	Wet
21/12/2016	Salt	15:00	20	Moist	77						0.1	23:40	Icy
21/12/2016	Brine	15:00	30	Moist	74						0.1	23:40	Wet

		Treatment 1				Treatment 2							
Date	Type of Treatment	Time	Spread rate (ml/m^2)	Surface state 3	RH (%)	Time	Spread rate (ml/m^2)	Surface state 3	Surface T (°C)	RH (%)	Lowest Temp (°C)	Time of lowest Temp	Surface state 3
22/12/2016	Salt	14:00	20	Wet	89						-1.5	15:20	Wet
22/12/2016	Brine	14:00	30	Wet	87						-2.1	15:20	Wet
23/12/2016	Salt	20:00	20	Wet	72	03:00	20	Wet	1.8	80	0.6	05:00	Wet
25/12/2016	Salt	02:00	40	Wet	86						0.1	03:50	Wet
26/12/2016	Salt	12:00	LP	Wet	86	18:00	20	Wet	2.8	85	0.8	23:20	Wet
27/12/2016	Salt	15:00	20	Moist	74						0.8	21:50	Moist
27/12/2016	Brine	15:00	30	Wet	74						0.8	20:40	Wet
31/12/2016	Salt	01:00	20	Moist	81						-0.9	08:40	Moist
01/01/2017	Salt	15:00	20	Moist	74	03:00	10	Moist	-2.2	71	-3.1	05:40	Moist
02/01/2017	Salt	15:00	20	Moist	80						-0.4	19:10	Moist
02/01/2017	Brine	15:00	30	Dry	77						-0.3	19:10	Moist
03/01/2017	Salt	03:00	10	Moist	74						0.2	06:30	Moist
03/01/2017	Brine	03:00	15	Wet	80						0	09:00	Moist
04/01/2017	Salt	15:00	20	Dry	56	03:00	10	Dry	-1.2	76	-3.1	06:10	Dry
04/01/2017	Brine	15:00	30	Dry	60	03:00	15	Dry	-1.2	77	0	09:00	Moist
05/01/2017	Salt	15:00	20	Dry	70						0.1	16:00	Dry
05/01/2017	Brine	15:00	30	Dry	72						-0.9	16:10	Dry
10/01/2017	Salt	03:00	20	Moist	66						2.7	06:50	Moist
11/01/2017	Salt	14:00	40	Dry	63	02:00	40	Wet	-0.7	88	-3.1	23:10	Moist
12/01/2017	Salt	14:00	40	Moist	74	02:00	20	Wet	-2.7	72	-3.6	00:40	Moist
13/01/2017	Salt	15:00	20	Dry	78	02:00	20	Moist	-2.9	87	-3.5	06:50	Moist

		Treatment 1				Treatment 2							
Date	Type of Treatment	Time	Spread rate (ml/m^2)	Surface state 3	RH (%)	Time	Spread rate (ml/m^2)	Surface state 3	Surface T (°C)	RH (%)	Lowest Temp (°C)	Time of lowest Temp	Surface state 3
14/01/2017	Salt	15:00	40	Moist	76	02:00	20	Wet	2.4	92	-0.8	18:00	Moist
20/01/2017	Salt	22:00	20	Moist	92						-1.9	07:40	Moist
20/01/2017	Brine	22:00	30	Dry	92						-1.2	09:20	Moist
21/01/2017	Salt	15:00	20	Dry	82	03:00	10	Moist	1	96	-0.5	23:00	Moist
21/01/2017	Brine	15:00	30	Moist	87	03:00	15	Wet	1.1	96	-0.2	21:50	Moist
22/01/2017	Salt	13:00	20	Moist	90	15:00	20	Moist	3.7	89	-0.1	06:30	Moist
25/01/2017	Salt	03:00	20	Moist	93						-2.7	04:40	Moist
25/01/2017	Brine	03:00	30	Moist	87						-2.1	04:50	Moist
26/01/2017	Salt	15:00	20	Dry	61	03:00	20	Moist	-3.1	68	-3.7	05:20	Moist
27/01/2017	Salt	14:00	20	Dry	64	02:00	20	Moist	2.3	81	1.8	03:20	Moist
27/01/2017	Brine	14:00	30	Dry	64	02:00	30	Moist	1.8	77	1.1	03:20	Wet
28/01/2017	Salt	14:00	40	Wet	96	02:00	20	Moist	-0.6	95	-2.2	06:10	Moist
29/01/2017	Salt	15:00	20	Dry	82	03:00	20	Moist	-4	95	-4.1	05:10	Moist
29/01/2017	Brine	15:00	30	Wet	82	03:00	30	Wet	-2.5	94	-3.5	04:20	Wet
30/01/2017	Salt	15:00	20	Moist	93						2.5	19:40	Moist
30/01/2017	Brine	15:00	30	Wet	77						1.4	18:00	Wet
03/02/2017	Salt	03:00	20	Wet	97						2.5	07:20	Wet
04/02/2017	Salt	15:00	20	Moist	95	03:00	10	Moist	0.5	91	-0.1	06:10	Moist
04/02/2017	Brine	15:00	30	Wet	71	03:00	15	Wet	0.7	82	0.1	01:30	Wet
05/02/2017	Salt	15:00	20	Moist	100	03:00	20	Moist	-2	93	-2.7	05:00	Moist
05/02/2017	Brine	15:00	30	Moist	78	03:00	15	Moist	-0.9	83	-1.2	05:00	Moist

		Treatment 1				Treatment 2							
Date	Type of Treatment	Time	Spread rate (ml/m^2)	Surface state 3	RH (%)	Time	Spread rate (ml/m^2)	Surface state 3	Surface T (°C)	RH (%)	Lowest Temp (°C)	Time of lowest Temp	Surface state 3
06/02/2017	Salt	03:00	20	Wet	91						1.7	22:20	Wet
06/02/2017	Brine	03:00	30	Moist	83						1.8	07:10	Wet
07/02/2017	Salt	03:00	20	Wet	100						2.1	03:30	Wet
07/02/2017	Brine	03:00	15	Wet	95						2.2	06:00	Wet
08/02/2017	Salt	15:00	20	Dry	100	02:00	20	Dry	0.9	100	-0.6	22:40	Dry
08/02/2017	Brine	15:00	30	Dry	82	02:00	15	Dry	0.6	86	-0.9	23:00	Dry
09/02/2017	Salt	15:00	20	Dry	100	03:00	20	Moist	0.4	90	0	02:50	Moist
09/02/2017	Brine	15:00	30	Dry	73	03:00	30	Wet	0	88	-0.3	02:40	Wet
10/02/2017	Salt	14:00	20	Dry	100	02:00	20	Wet	0	88	-0.5	02:10	Wet
11/02/2017	Salt	14:00	20	Wet	100	03:00	20	Moist	0.3	100	0	02:30	Moist
12/02/2017	Salt	14:00	20	Moist	77						0.7	16:50	Moist
12/02/2017	Brine	14:00	30	Wet	74						0.8	16:50	Wet
13/02/2017	Salt	19:00	20	Dry	100						2.3	03:20	Moist
13/02/2017	Brine	19:00	30	Moist	86						1.8	07:50	Moist
16/02/2017	Salt	20:00	10	Dry	85						0.7	06:10	Moist
16/02/2017	Brine	20:00	15	Moist	82						1.8	02:50	Wet
20/02/2017	Salt	03:00	10	Dry	81						3	06:10	Dry
20/02/2017	Brine	03:00	15	Dry	80						3.3	06:30	Dry
21/02/2017	Salt	03:00	10	Wet	75						1.8	05:40	Moist
21/02/2017	Brine	03:00	15	Wet	74						2.4	06:30	Wet
22/02/2017	Salt	23:00	40	Dry	85						-0.4	04:00	Wet

		Treatment 1				Treatment 2							
Date	Type of Treatment	Time	Spread rate (ml/m^2)	Surface state 3	RH (%)	Time	Spread rate (ml/m^2)	Surface state 3	Surface T (°C)	RH (%)	Lowest Temp (°C)	Time of lowest Temp	Surface state 3
23/02/2017	Salt	14:00	40	Wet	93	03:00	20	Wet	-1.3	86	-1.9	06:50	Wet
25/02/2017	Salt	00:00	10	Icy	83						2	04:50	Moist
25/02/2017	Brine	00:00	15	Dry	81						2.2	03:10	Dry
26/02/2017	Salt	22:00	20	Wet	76						0.3	02:20	Moist
26/02/2017	Brine	22:00	30	Wet	79						1.3	02:20	Wet
27/02/2017	Salt	19:00	20	Wet	92						-2.3	06:40	Moist
27/02/2017	Brine	19:00	30	Wet	92						-1.2	07:20	Wet
28/02/2017	Salt	15:00	20	Dry	53	03:00	20	Dry	-1.4	84	-1.9	05:20	Dry
28/02/2017	Brine	15:00	30	Dry	64	03:00	30	Dry	-0.1	76	-0.4	04:40	Moist
01/03/2017	Salt	15:00	20	Dry	63	03:00	10	Dry	-1.7	81	-2.1	04:10	Dry
01/03/2017	Brine	15:00	30	Dry	66	03:00	15	Moist	-0.5	76	-0.7	04:20	Moist
02/03/2017	Salt	15:00	20	Dry	70						-1	05:10	Moist
02/03/2017	Brine	15:00	30	Dry	74						-1.1	05:30	Wet
05/03/2017	Salt	21:00	10	Dry	89						1.7	21:00	Dry
05/03/2017	Brine	21:00	15	Dry	88						1.7	21:20	Dry
06/03/2017	Salt	21:00	20	Wet	86						-0.1	06:10	Moist
06/03/2017	Brine	21:00	30	Wet	85						0.6	06:10	Wet
09/03/2017	Salt	21:00	10	Dry	78						3.9	05:40	Dry
09/03/2017	Brine	21:00	15	Dry	75						2.5	01:20	Dry
12/03/2017	Salt	00:00	10	Dry	82						3.3	02:40	Dry
12/03/2017	Brine	00:00	15	Dry	81						3.8	01:10	Dry

		Treatment 1				Treatment 2							
Date	Type of Treatment	Time	Spread rate (ml/m^2)	Surface state 3	RH (%)	Time	Spread rate (ml/m^2)	Surface state 3	Surface T (°C)	RH (%)	Lowest Temp (°C)	Time of lowest Temp	Surface state 3
16/03/2017	Salt	15:00	20	Wet	80						1.9	23:50	Moist
16/03/2017	Brine	15:00	30	Wet	85						2	22:40	Wet
20/03/2017	Salt	21:00	20	Dry	81						-0.4	07:00	Slushy
21/03/2017	Salt	19:00	20	Dry	80	03:00	20	Moist	-1.5	81	-1.5	03:00	Moist
21/03/2017	Brine	19:00	30	Moist	75	03:00	30	Wet	-0.3	78	-0.9	03:40	Wet
22/03/2017	Salt	20:00	20	Wet	90						2.9	20:00	Wet
23/03/2017	Salt	21:00	20	Dry	77						-0.8	06:20	Dry
23/03/2017	Brine	21:00	30	Dry	81						0.1	06:00	Dry
24/03/2017	Salt	22:00	10	Dry	63						0.9	05:50	Dry
24/03/2017	Brine	22:00	15	Dry	65						1.4	05:20	Dry
25/03/2017	Salt	03:00	10	Dry	67						1.9	06:90	Dry
25/03/2017	Brine	03:00	15	Dry	61						2.9	07:40	Dry
01/04/2017	Salt	03:00	10	Dry	81						4.2	06:30	Dry
01/04/2017	Brine	03:00	15	Dry	78						4.6	07:00	Dry
17/04/2017	Salt	22:00	20	Dry	62						-0.5	05:50	Moist
17/04/2017	Brine	22:00	30	Dry	55						0.4	06:00	Dry
24/04/2017	Salt	00:00	20	Moist	75						1.2	01:10	Wet
24/04/2017	Brine	00:00	30	Dry	73						2.1	05:50	Wet
25/04/2017	Salt	20:00	20	Dry	55						0.2	04:10	Moist
25/04/2017	Brine	20:00	30	Dry	56						0.8	03:50	Dry

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		Treatment 1					Treatment 2									
Date	Type of Treatment	Time	Spread rate	Surface state 1	Surface state 3	RH (%)	Time	Spread rate	Surface state 1	Surface state 3	Surface Temp	RH (%)	Lowest Temp	Time of lowest Temp	Surface state 1	Surface state 3
19/11/2016	Salt	15:30	20	Moist	Wet	95	04:00	20	Trace	Wet	-1.1	99	-1.8	08:00	Wtrtd	Wet
19/11/2016	Brine	15:30	20	Trace	Moist	91	04:00	20	Trace	Wet	-1.3	95	-2	08:20	Trace	Moist
20/11/2016	Salt	14:00	20	Trace	Wet	94	03:00	20	Trace	Moist	0	99	-2.4	07:10	Trace	Wet
20/11/2016	Brine	14:00	20	Trace	Moist	93	03:00	20	Trace	Moist	0.4	98	-2.4	08:10	Trace	Moist
21/11/2016	Salt	13:00	20	Trace	Wet	90							0.9	15:40	Trace	Moist
21/11/2016	Brine	13:00	20	Trace	Moist	89							1.4	16:30	Trace	Moist
22/11/2016	Salt	15:00	20	Wet	Wet	69	05:00	20	Trace	Wet	-2.3	91	-2.4	04:50	Trace	Wet
22/11/2016	Brine	15:00	20	Trace	Dry	64	05:00	20	Trace	Moist	-2.6	93	-2.7	04:50	Trace	Moist
23/11/2016	Salt	14:00	20	Moist	Wet	78							-3.1	03:00	Moist	Wet
23/11/2016	Brine	14:00	20	Dry	Dry	75							-3.5	04:00	Trace	Moist
24/11/2016	Salt	20:00	20	Trace	Wet	90							-3.1	05:20	Moist	Wet
24/11/2016	Brine	20:00	20	Trace	Moist	91							-3.7	05:30	Trace	Moist
25/11/2016	Salt	14:00	20	Moist	Wet	90							-0.7	05:20	Moist	Wet
25/11/2016	Brine	14:00	20	Trace	Moist	87							-1.3	01:40	Wtrtd	Moist
26/11/2016	Salt	03:00	20	Trace	Wet	93							4.7	03:50	Trace	Wet
26/11/2016	Brine	03:00	20	Wtrtd	Moist	91							4.7	04:00	Trace	Moist
27/11/2016	Salt	20:00	20	Moist	Wet	92							2.9	04:20	Trace	Wet
27/11/2016	Brine	20:00	20	Trace	Moist	92							3	04:20	Trace	Moist
03/12/2016	Salt	22:00	20	Trace	Wet	90							0.6	00:10	Trace	Wet
03/12/2016	Brine	22:00	20	Trace	Moist	85							0.5	00:00	Trace	Moist
04/12/2016	Salt	14:00	20	Dry	Wet	77	04:00	20	Trace	Wet	-1.9	88	-1.9	03:30	Trace	Wet
04/12/2016	Brine	14:00	20	Dry	Dry	71	04:00	20	Trace	Moist	-1.8	87	-1.9	03:30	Trace	Moist

		Treatment 1					Treatment 2									
Date	Type of Treatment	Time	Spread rate	Surface state 1	Surface state 3	RH (%)	Time	Spread rate	Surface state 1	Surface state 3	Surface Temp	RH (%)	Lowest Temp	Time of lowest Temp	Surface state 1	Surface state 3
05/12/2016	Salt	14:00	20	Moist	Wet	75							-0.8	01:20	Trace	Wet
05/12/2016	Brine	14:00	20	Moist	Dry	69							-0.7	01:10	Trace	Moist
31/12/2016	Salt	03:00	20	Moist	Wet	89							-1.4	08:40	Trace	Wet
31/12/2016	Brine	03:00	20	Moist	Moist	86							-1.1	08:50	Trace	Moist
01/01/2017	Salt	16:00	20	Trace	Wet	71							-3.4	06:10	Trace	Moist
01/01/2017	Brine	16:00	20	Trace	Dry	68							-3.4	06:00	Trace	Moist
02/01/2017	Salt	14:00	20	Trace	Wet	79							3.1	18:00	Moist	Wet
02/01/2017	Brine	14:00	20	Trace	Moist	75							3.9	16:10	Trace	Moist
04/01/2017	Salt	14:00	20	Wet	Moist	70	04:00	20	Trace	Dry	-3.7	84	-3.8	04:20	Trace	Dry
04/01/2017	Brine	14:00	20	Moist	Dry	66	04:00	20	Trace	Moist	-3.4	83	-3.5	03:10	Trace	Moist
11/01/2017	Salt	23:00	40	Trace	Wet	70							0.3	05:10	Trace	Wet
11/01/2017	Brine	23:00	20	Trace	Moist	66							0.9	05:00	Wtrtd	Wet
12/01/2017	Salt	14:00	40	Trace	Wet	83	04:00	20	Trace	Wet	0.4	81	-0.4	06:30	Trace	Wet
12/01/2017	Brine	14:00	-	Trace	Moist	81	04:00	20	Trace	Moist	0.8	78	0.3	06:20	Trace	Moist
13/01/2017	Salt	14:00	40	Moist	Moist	66	03:00	20	Trace	Wet	-0.1	80	-0.1	02:30	Trace	Wet
13/01/2017	Brine	14:00	20	Dry	Dry	64	03:00	20	Trace	Moist	0.4	76	0.3	02:30	Trace	Moist
20/01/2017	Salt	23:00	20	Moist	Dry	93							-0.8	03:50	Wtrtd	Moist
20/01/2017	Brine	23:00	20	Moist	Dry	92							-0.7	04:00	Trace	Dry
21/01/2017	Salt	14:00	10	Dry	Dry	66							2	20:10	Moist	Dry
21/01/2017	Brine	14:00	20	Dry	Dry	58							2.2	20:10	Moist	Dry
22/01/2017	Salt	19:00	20	Trace	Wet	95							-2.3	04:40	Moist	Wet
22/01/2017	Brine	19:00	20	Trace	Moist	91							-1.9	04:20	Trace	Moist
26/01/2017	Salt	15:00	20	Dry	Dry	72							-2.8	01:30	Trace	Dry

		Treatment 1					Treatment 2									
Date	Type of Treatment	Time	Spread rate	Surface state 1	Surface state 3	RH (%)	Time	Spread rate	Surface state 1	Surface state 3	Surface Temp	RH (%)	Lowest Temp	Time of lowest Temp	Surface state 1	Surface state 3
26/01/2017	Brine	15:00	20	Dry	Dry	69							-2.6	02:50	Trace	Moist
28/01/2017	Salt	22:00	20	Moist	Wet	86							0.2	02:20	Wtrtd	Wet
28/01/2017	Brine	22:00	20	Trace	Wet	87							0.6	02:20	Wtrtd	Wet
29/01/2017	Salt	17:00	20	Moist	Moist	84							-1.5	04:00	Moist	Moist
29/01/2017	Brine	17:00	20	Trace	Dry	85							-0.8	05:00	Trace	Moist
05/02/2017	Salt	19:00	20	Moist	Dry	91							-1.2	04:30	Moist	Moist
05/02/2017	Brine	19:00	20	Moist	Dry	86							-0.4	03:40	Trace	Dry
07/02/2017	Salt	20:00	20	Moist	Wet	85							1.3	01:00	Trace	Wet
07/02/2017	Brine	20:00	20	Trace	Wet	83							1.3	01:30	Trace	Moist
08/02/2017	Salt	18:00	20	Moist	Moist	91	04:00	20	Moist	Dry	-2.2	90	-2.4	04:40	Moist	Moist
08/02/2017	Brine	18:00	20	Trace	Moist	85	04:00	30	Trace	Moist	-1.4	81	-1.7	04:50	Trace	Moist
09/02/2017	Salt	15:00	20	Dry	Dry	71	00:00	20	Moist	Moist	1.8	80	1.1	04:00	Moist	Moist
09/02/2017	Brine	15:00	20	Moist	Dry	66	00:00	30	Moist	Dry	2.1	78	1.5	03:10	Moist	Dry
10/02/2017	Salt	15:00	20	Dry	Dry	73							-3.3	01:40	Moist	Wet
10/02/2017	Brine	15:00	20	Dry	Dry	71							-3.1	02:10	Trace	Dry
11/02/2017	Salt	22:00	20	Trace	Moist	85							-0.4	03:00	Trace	Wet
11/02/2017	Brine	22:00	20	Trace	Moist	83							-0.1	03:00	Trace	Moist
13/02/2017	Salt	01:00	20	Trace	Wet	84							-0.1	04:20	Wtrtd	Wet
13/02/2017	Brine	01:00	20	Trace	Moist	83							0.5	04:40	Trace	Moist
22/02/2017	Salt	04:00	40	Wet	Wet	97							2.5	09:20	Wtrtd	Wet
22/02/2017	Brine	04:00	-	Wtrtd	Wet	91							3.1	09:00	Wtrtd	Wet
23/02/2017	Salt	23:00	20	Moist	Wet	86							1	05:10	Trace	Wet
23/02/2017	Brine	23:00	20	Trace	Wet	81							1.8	05:00	Trace	Moist

		Treatment 1					Treatment 2									
Date	Type of Treatment	Time	Spread rate	Surface state 1	Surface state 3	RH (%)	Time	Spread rate	Surface state 1	Surface state 3	Surface Temp	RH (%)	Lowest Temp	Time of lowest Temp	Surface state 1	Surface state 3
27/02/2017	Salt	18:00	20	Moist	Wet	89							-2.7	04:10	Moist	Wet
27/02/2017	Brine	18:00	20	Trace	Moist	87							-2.6	04:10	Trace	Moist
28/02/2017	Salt	15:00	20	Dry	Dry	70	05:00	20	Wtrtd	Wet	1.6	92	-0.3	01:10	Trace	Wet
28/02/2017	Brine	15:00	20	Moist	Dry	65	05:00	30	Wtrtd	Wet	1.1	93	-0.7	00:20	Trace	Moist
01/03/2017	Salt	18:00	20	Moist	Wet	76							-0.9	03:30	Trace	Wet
01/03/2017	Brine	18:00	20	Moist	Dry	78							-0.9	03:00	Trace	Moist
20/03/2017	Salt	01:00	40	Moist	Wet	79							0.7	05:30	Wtrtd	Wet
20/03/2017	Brine	01:00	-	Trace	Moist	77							1.5	05:30	Trace	Wet
21/03/2017	Salt	20:00	20	Dry	Wet	68							0.1	03:30	Trace	Wet
21/03/2017	Brine	20:00	20	Moist	Dry	69							0.9	00:50	Trace	Dry

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		Treatment 1					Treatment 2								
Date	Type of Treatment	Time	Spread rate	Surface state 1	Surface state 3	RH (%)	Time	Spread rate	Surface state 1	Surface state 3	Surface T	RH (%)	Lowest Temp	Time of lowest Temp	Surface state 3
01/11/2016	Salt	22:00	20	Dry	Dry	72							3.7	05:10	Moist
01/11/2016	Brine	22:00	30	Dry	Dry	73							3.1	05:30	Moist
03/11/2016	Salt	04:55	20	Moist	Moist	92							2.1	05:40	Moist
03/11/2016	Brine	04:55	30	Trace	Wet	90							1.6	06:10	Wet
04/11/2016	Salt	02:00	20	Moist	Dry	71							1.9	04:50	Moist
04/11/2016	Brine	02:00	30	Trace	Dry	72							1.3	06:20	Moist
05/11/2016	Salt	22:00	20	Moist	Dry	71							1.3	02:30	Dry
05/11/2016	Brine	22:00	30	Trace	Moist	70							0.9	02:50	Wet
06/11/2016	Salt	19:00	20	Moist	Dry	77							0.7	02:30	Dry
06/11/2016	Brine	19:00	30	Moist	Dry	76							0.1	01:10	Wet
07/11/2016	Salt	15:00	20	Moist	Dry	63	03:00	20	Moist	Dry	3.9	89	3.9	02:20	Dry
07/11/2016	Brine	15:00	30	Moist	Dry	60	03:00	30	Moist	Wet	3.8	89	3.8	1:40	Wet
08/11/2016	Salt	02:00	20	Wet	Moist	96							3.4	05:50	Wet
08/11/2016	Brine	02:00	30	Wet	Wet	95							3.2	06:30	Wet
09/11/2016	Salt	03:30	20	Wet	Wet	96							1.8	07:10	Moist
09/11/2016	Brine	03:30	30	Wet	Wet	97							1.3	07:00	Wet
10/11/2016	Salt	15:00	20	Moist	Dry	70	03:00	20	Trace	Moist	-1.5	96	-1.9	05:00	Moist
10/11/2016	Brine	15:00	30	Dry	Dry	71	03:00	30	Trace	Wet	-2.2	97	-2.7	05:10	Wet
12/11/2016	Salt	23:00	20	Moist	Dry	97							0.2	02:40	Dry
12/11/2016	Brine	23:00	30	Trace	Moist	96							-0.5	02:30	Moist
17/11/2016	Salt	19:00	20	Dry	Dry	95	03:00	20	Trace	Moist	0.4	98	-0.6	02:00	Moist
17/11/2016	Brine	19:00	30	Trace	Dry	95	03:00	30	Trace	Wet	0.2	97	-0.9	02:00	Wet
19/11/2016	Salt	15:00	20	Trace	Moist	88	03:00	20	Trace	Moist	-2.2	97	-2.2	03:00	Moist
19/11/2016	Brine	15:00	30	Trace	Wet	93	03:00	30	Trace	Wet	-2.6	97	-2.8	03:10	Wet
20/11/2016	Salt	15:00	20	Trace	Moist	95	03:00	20	Trace	Moist	-1.1	97	-3.8	07:20	Moist

		Treatment 1					Treatment 2								
Date	Type of Treatment	Time	Spread rate	Surface state 1	Surface state 3	RH (%)	Time	Spread rate	Surface state 1	Surface state 3	Surface T	RH (%)	Lowest Temp	Time of lowest Temp	Surface state 3
20/11/2016	Brine	15:00	30	Trace	Wet	95	03:00	30	Trace	Wet	-1.3	96	-4.7	08:00	Wet
21/11/2016	Salt	15:00	20	Trace	Moist	97							-0.9	16:00	Moist
21/11/2016	Brine	15:00	30	Trace	Wet	97							-0.7	15:40	Wet
22/11/2016	Salt	15:00	20	Moist	Dry	67	03:00	20	Trace	Moist	-2.3	95	-2.7	04:50	Moist
22/11/2016	Brine	15:00	30	Dry	Dry	67	03:00	30	Trace	Wet	-2.7	95	-3.3	05:20	Wet
23/11/2016	Salt	15:00	20	Trace	Moist	73	03:00	20	Trace	Moist	-4.6	94	-4.9	04:50	Moist
23/11/2016	Brine	15:00	30	Trace	Wet	77	03:00	30	Trace	Wet	-5.1	95	-5.5	05:10	Wet
24/11/2016	Salt	15:00	20	Trace	Moist	76							-6	04:20	Moist
24/11/2016	Brine	15:00	30	Trace	Wet	86							-6.5	06:00	Wet
25/11/2016	Salt	15:00	20	Trace	Moist	77							-3.2	04:20	Moist
25/11/2016	Brine	15:00	30	Trace	Wet	88							-3.6	03:10	Wet
26/11/2016	Salt	03:00	20	Wet	Moist	98							0.3	08:50	Moist
26/11/2016	Brine	03:00	30	Wtrtd	Wet	98							0	08:50	Wet
28/11/2016	Salt	15:00	20	Moist	Moist	89	03:00	20	Moist	Moist	2.6	96	2.4	23:20	Moist
28/11/2016	Brine	15:00	30	Wet	Wet	90	03:00	30	Trace	Wet	2.2	97	1.9	00:40	Wet
29/11/2016	Salt	19:00	20	Moist	Moist	86							1.1	03:00	Moist
29/11/2016	Brine	19:00	30	Wet	Wet	84							0.5	03:00	Wet
01/12/2016	Salt	19:00	20	Dry	Dry	71							2.4	06:10	Moist
01/12/2016	Brine	19:00	30	Dry	Dry	62							1.9	05:50	Wet
03/12/2016	Salt	03:00	20	Moist	Moist	96							2.5	09:10	Moist
03/12/2016	Brine	03:00	30	Trace	Wet	97							2.2	10:20	Wet
04/12/2016	Salt	15:00	20	Moist	Dry	74	03:00	20	Trace	Moist	-2.7	96	-3.2	07:10	Moist
04/12/2016	Brine	15:00	30	Trace	Wet	80	03:00	30	Trace	Wet	-3.4	96	-4	07:10	Wet
05/12/2016	Salt	15:00	20	Trace	Moist	92	03:00	20	Trace	Moist	-1	96	-1.8	00:20	Moist
05/12/2016	Brine	15:00	30	Wtrtd	Wet	93	03:00	30	Wtrtd	Wet	-1.6	96	-2.6	00:30	Wet
12/12/2016	Salt	03:30	20	Dry	Dry	97							2.2	06:40	Dry

		Treatment 1					Treatment 2								
Date	Type of Treatment	Time	Spread rate	Surface state 1	Surface state 3	RH (%)	Time	Spread rate	Surface state 1	Surface state 3	Surface T	RH (%)	Lowest Temp	Time of lowest Temp	Surface state 3
12/12/2016	Brine	03:30	30	Trace	Moist	97							1.7	06:10	Moist
16/12/2016	Salt	21:00	20	Moist	Moist	94							0.7	04:30	Moist
16/12/2016	Brine	21:00	30	Moist	Wet	91							-0.1	03:50	Wet
19/12/2016	Salt	15:00	20	Dry	Dry	91	03:00	20	Trace	Dry	-0.7	97	-0.9	04:00	Dry
19/12/2016	Brine	15:00	30	Moist	Wet	91	03:00	30	Trace	Moist	-1.5	97	-1.7	03:50	Moist
20/12/2016	Salt	03:00	20	Trace	Dry	97							-0.9	04:00	Dry
20/12/2016	Brine	03:00	30	Trace	Moist	97							-1.7	03:50	Moist
21/12/2016	Salt	15:00	20	Wet	Moist	90							1.6	22:10	Moist
21/12/2016	Brine	15:00	30	Trace	Wet	88							1.4	22:10	Wet
22/12/2016	Salt	19:00	20	Moist	Moist	88							1	00:00	Moist
22/12/2016	Brine	19:00	30	Trace	Wet	87							0.5	09:00	Wet
23/12/2016	Salt	07:15	20	Wet	Wet	89							1.4	04:50	Wet
23/12/2016	Brine	07:15	30	Wtrtd	Wet	84							0.9	05:00	Wet
25/12/2016	Salt	03:00	20	Moist	Wet	92							0.2	07:30	Wet
25/12/2016	Brine	03:00	30	Wtrtd	Wet	91							0.1	07:30	Wet
26/12/2016	Salt	17:00	20	Wet	Moist	86	03:00	20	Wet	Moist	2.1	80	1.8	22:50	Moist
26/12/2016	Brine	17:00	30	Trace	Wet	81	03:00	30	Wtrtd	Wet	1.7	82	1.7	23:40	Wet
27/12/2016	Salt	15:00	20	Moist	Dry	71	03:00	20	Moist	Dry	4.7	76	2.2	19:10	Dry
27/12/2016	Brine	15:00	30	Moist	Wet	72	03:00	30	Trace	Wet	4.5	76	2.1	19:20	Wet
01/01/2017	Salt	15:00	20	Wet	Moist	79	03:00	20	Trace	Moist	-1.2	80	-1.5	05:00	Moist
01/01/2017	Brine	15:00	30	Wet	Wet	80	03:00	30	Trace	Wet	-1.7	78	-2.3	05:00	Wet
02/01/2017	Salt	17:00	20	Moist	Moist	80							0.1	22:40	Moist
02/01/2017	Brine	17:00	30	Moist	Wet	78							-0.5	22:30	Wet
03/01/2017	Salt	23:00	20	Moist	Moist	66							2.7	04:20	Moist
03/01/2017	Brine	23:00	30	Moist	Wet	65							2.5	04:10	Moist
04/01/2017	Salt	15:00	20	Dry	Dry	55	03:00	20	Moist	Dry	0.3	81	-2.2	08:40	Moist

		Treatment 1					Treatment 2								
Date	Type of Treatment	Time	Spread rate	Surface state 1	Surface state 3	RH (%)	Time	Spread rate	Surface state 1	Surface state 3	Surface T	RH (%)	Lowest Temp	Time of lowest Temp	Surface state 3
04/01/2017	Brine	15:00	30	Dry	Dry	55	03:00	30	Trace	Dry	-0.3	82	-2.9	08:00	Wet
05/01/2017	Salt	15:00	20	Moist	Dry	79							-0.4	17:30	Moist
05/01/2017	Brine	15:00	30	Trace	Wet	81							-0.4	17:30	Wet
11/01/2017	Salt	15:00	20	Moist	Dry	75	02:00	20	Trace	Moist	-0.2	88	-0.9	05:40	Moist
11/01/2017	Brine	15:00	30	Moist	Moist	75	02:00	30	Wtrtd	Wet	-0.6	88	-1.8	05:40	Wet
12/01/2017	Salt	15:00	20	Moist	Moist	82							-2.3	23:40	Moist
12/01/2017	Brine	15:00	30	Trace	Wet	85							-2.8	00:00	Wet
13/01/2017	Salt	15:00	20	Trace	Dry	65	03:00	20	Trace	Moist	-2.5	81	-3.7	08:20	Moist
13/01/2017	Brine	15:00	30	Moist	Dry	65	03:00	30	Trace	Wet	-2.9	79	-4.6	08:50	Wet
14/01/2017	Salt	15:00	20	Moist	Dry	61							1.1	18:20	Moist
14/01/2017	Brine	15:00	30	Wtrtd	Wet	64							1	18:20	Wet
20/01/2017	Salt	02:00	20	Dry	Dry	90							3.6	06:00	Dry
20/01/2017	Brine	02:00	30	Trace	Moist	91							3.2	07:00	Moist
21/01/2017	Salt	17:00	20	Dry	Dry	90							2.2	02:50	Dry
21/01/2017	Brine	17:00	30	Moist	Moist	89							1.9	02:30	Wet
22/01/2017	Salt	21:00	20	Moist	Moist	92							2.9	22:20	Moist
22/01/2017	Brine	21:00	30	Trace	Wet	93							2.4	04:30	Wet
25/01/2017	Salt	03:00	20	Moist	Dry	71							0.8	07:40	Dry
25/01/2017	Brine	03:00	30	Trace	Wet	74							-0.5	08:00	Wet
26/01/2017	Salt	15:00	20	Dry	Dry	74	03:00	20	Trace	Dry	-2	97	-2.6	01.10	Moist
26/01/2017	Brine	15:00	30	Moist	Dry	77	03:00	30	Trace	Wet	-2.8	96	-3.7	01:20	Wet
27/01/2017	Salt	15:00	20	Trace	Moist	90	02:00	20	Moist	Wet	0.7	97	-0.6	17:30	Moist
27/01/2017	Brine	15:00	30	Trace	Wet	94	02:00	30	Wtrtd	Wet	0.6	97	-0.8	17:40	Wet
28/01/2017	Salt	17:00	20	Wet	Wet	98	03:00	20	Trace	Moist	-1.7	97	-2.8	07:40	Moist
28/01/2017	Brine	17:00	30	Wtrtd	Wet	97	03:00	30	Trace	Wet	-2.2	94	-3.9	07:00	Wet
29/01/2017	Salt	16:00	20	Moist	Moist	86	03:00	20	Trace	Dry	-0.7	98	-1.3	04:10	Moist
29/01/2017	Brine	16:00	30	Trace	Wet	90	03:00	30	Wtrtd	Wet	-0.9	98	-1.5	04:20	Wet

		Treatment 1					Treatment 2								
Date	**Type of Treatment**	**Time**	**Spread rate**	**Surface state 1**	**Surface state 3**	**RH (%)**	**Time**	**Spread rate**	**Surface state 1**	**Surface state 3**	**Surface T**	**RH (%)**	**Lowest Temp**	**Time of lowest Temp**	**Surface state 3**
30/01/2017	Salt	18:45	20	Trace	Moist	96							2	20:00	Moist
30/01/2017	Brine	18:45	30	Wtrtd	Wet	97							1.6	20:00	Wet
04/02/2017	Salt	19:00	20	Moist	Moist	76	03:00	20	Moist	Moist	1.6	94	0.9	07:50	Moist
04/02/2017	Brine	19:00	30	Trace	Wet	79	03:00	30	Wtrtd	Wet	0.9	95	0.2	07:50	Wet
05/02/2017	Salt	16:00	20	Moist	Wet	87	03:00	20	Trace	-	0.4	98	-0.8	01:10	Moist
05/02/2017	Brine	16:00	30	Moist	Wet	87	03:00	30	Trace	Moist	-0.2	98	-1.9	01:10	Moist
07/02/2017	Salt	15:00	20	Moist	Wet	96	02:00	20	Wet	Moist	0.8	98	0.8	02:00	Moist
07/02/2017	Brine	15:00	30	Wtrtd	Wet	94	02:00	30	Wtrtd	Wet	0.4	98	0.4	02:00	Wet
08/02/2017	Salt	16:00	20	Moist	Dry	81	03:00	20	Moist	Moist	2.8	78	2.5	04:50	Moist
08/02/2017	Brine	16:00	30	Moist	Wet	84	03:00	30	Trace	Wet	2.2	80	2	04:40	Wet
09/02/2017	Salt	19:00	20	Moist	Dry	85							-0.7	03:50	Moist
09/02/2017	Brine	19:00	30	Wet	Moist	84							0.6	06:30	Wet

A9 Balhaldie

		Treatment 1					Treatment 2								
Date	Type of Treatment	Time	Spread rate	Surface state 1	Surface state 3	RH (%)	Time	Spread rate	Surface state 1	Surface state 3	Surface Temp	RH (%)	Lowest Temp	Time of lowest Temp	Surface state 3
10/02/2017	Brine	15:00	30	Wet	-	80							-2.5	22:30	Wet
16/02/2017	Brine	03:45	30	Wet	-	96							1.6	04:30	Wet
21/02/2017	Brine	03:00	30	Wet	-	84							1.8	05:30	Wet
25/02/2017	Brine	00:00	30	Wet	-	89							3.8	00:20	Wet
26/02/2017	Brine	00:55	30	Wet	-	81							0.1	03:00	Wet
27/02/2017	Brine	19:00	30	Wet	-	86							-0.1	22:50	Wet
01/03/2017	Brine	19:00	30	Moist	-	73							-0.8	23:40	Wet
02/03/2017	Brine	19:00	30	Wet	-	87							1.9	23:40	Wet
05/03/2017	Brine	22:00	30	Wet	-	96	00:00	30	Wet	-	-0.2	97	-0.3	23:40	Wet
16/03/2017	Brine	00:00	30	Wet	-	88							2.4	02:20	Wet
21/03/2017	Brine	19:00	30	Wet	-	90							23:40	-1.8	Wet
22/03/2017	Salt	XX:XX													
23/03/2017	Brine	19:00	30	Moist	-	78							23:50	0.2	Wet
24/03/2017	Brine	01:00	30	Wet	-	89							05:30	-0.9	Wet
25/03/2017	Brine	04:00	30	Wet	-	87							05:10	-0.4	Wet
17/04/2017	Brine	00:00	30	Moist	-	74							06:10	-0.9-	Moist

A9 Loaning Head

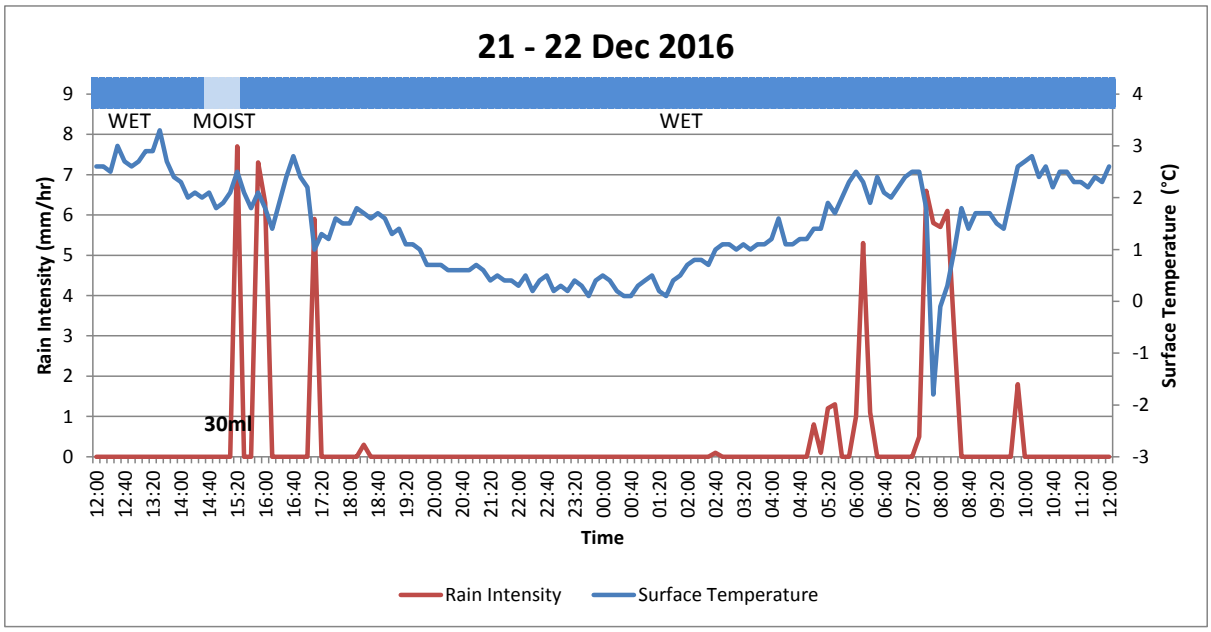
		Treatment 1					Treatment 2								
Date	Type of Treatment	Time	Spread rate	Surface state 1	Surface state 3	RH (%)	Time	Spread rate	Surface state 1	Surface state 3	Surface T	RH (%)	Lowest Temp	Time of lowest Temp	Surface state 3
10/02/2017	Brine	15:00	30	Moist	-	87							-1.9	23:10	Trace
16/02/2017	Brine	03:45	30	Wtrtd	-	100							-0.1	04:40	Trace
21/02/2017	Brine	03:00	30	Trace	-	81							1	04:00	Trace
25/02/2017	Brine	00:00	30	Moist	-	93							3	01:00	Trace
26/02/2017	Brine	00:55	30	Moist	-	83							-0.1	02:10	Wtrtd
27/02/2017	Brine	19:00	30	Moist	-	90							-2.2	23:40	Trace
01/03/2017	Brine	19:00	30	Dry	-	82							-2.3	23:40	Trace
02/03/2017	Brine	19:00	30	Trace	-	92							-0.2	23:30	Trace
05/03/2017	Brine	22:00	30	Dry	-	100	00:00	30	Trace	-	-0.4	100	-0.7	00:20	Trace
16/03/2017	Brine	00:00	30	Wtrtd	-	94							1.7	01:30	Wtrtd
21/03/2017	Brine	19:00	30	Trace	-	90							-2.7	23:50	Trace
22/03/2017	Salt	XX:XX													
23/03/2017	Brine	19:00	30	Moist	-	80							1.5	23:50	Trace
24/03/2017	Brine	01:00	30	Moist	-	91							0	04:40	Trace
25/03/2017	Brine	04:00	30	Dry	-	88							0.5	05:40	Dry
17/04/2017	Brine	00:00	30	Dry	-	77							-2.1	05:50	Dry

Appendix D Precipitation events

D.1 A702 Events

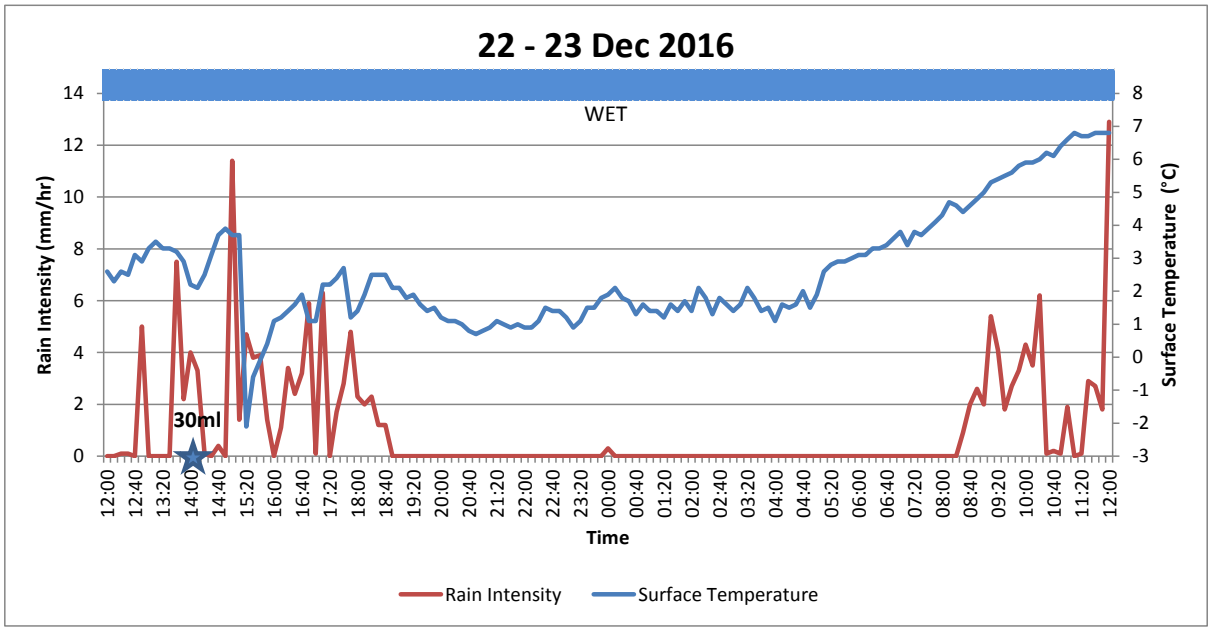
D.1.1 21st December

Time	Event, 21st December
15:00	Spreading 30ml brine (Moist road surface, 0.03mm water layer)
15:20 - 18:00	15:20 to 18:00 intermittent snowfall, 9.6mm total precipitation



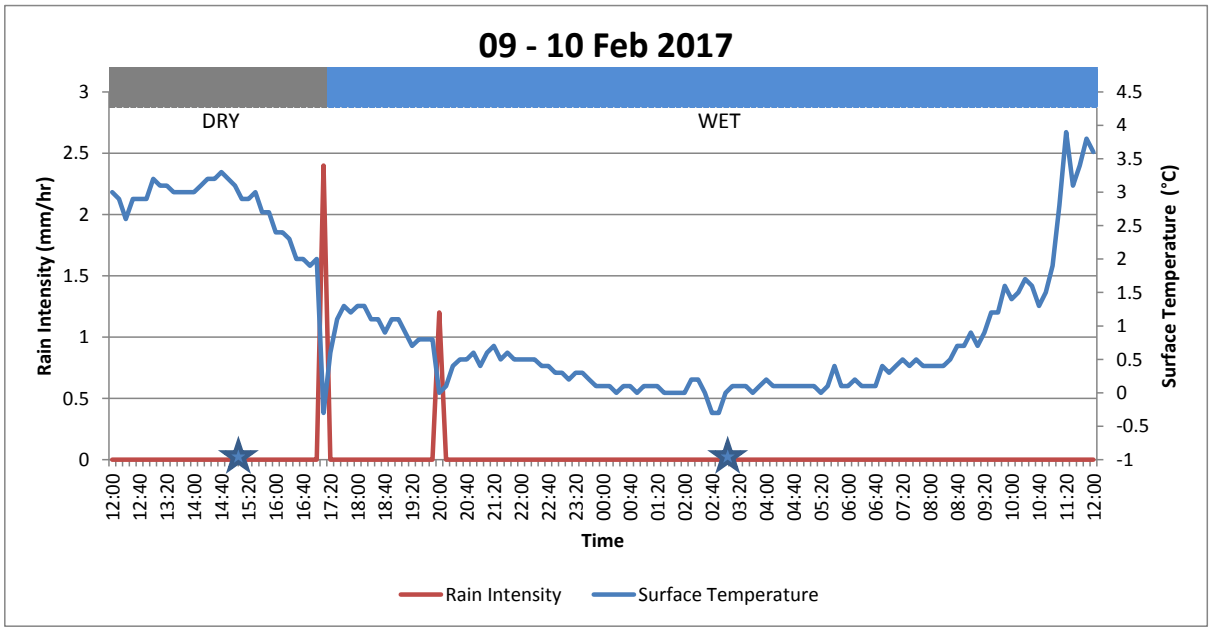
D.1.2 22nd December

Time	Event, 22nd December
14:00	Spreading 30ml brine (Wet road surface, 0.2 to 0.3mm water layer)
14:00 - 18:40	Light to medium snowfall, total precipitation 14mm



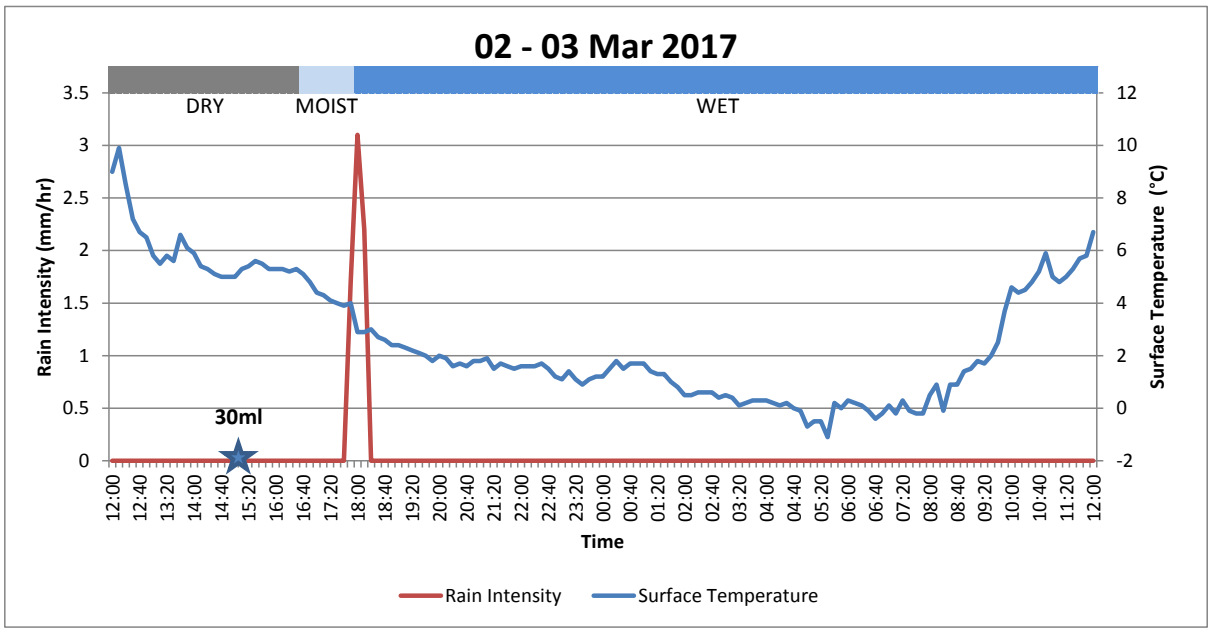
D.1.3 9th February

Time	Event, 9th February
15:00	Spreading 30ml (Dry road surface, humidity 73%)
17:00 - 20:00	Two light snow showers, total precipitation 0.3mm
02:40	Road surface temperature drops below freezing, minimum -0.3°C
03:00	Spreading 30ml brine (Wet road surface, 0.06mm water layer)



D.1.4 2nd March

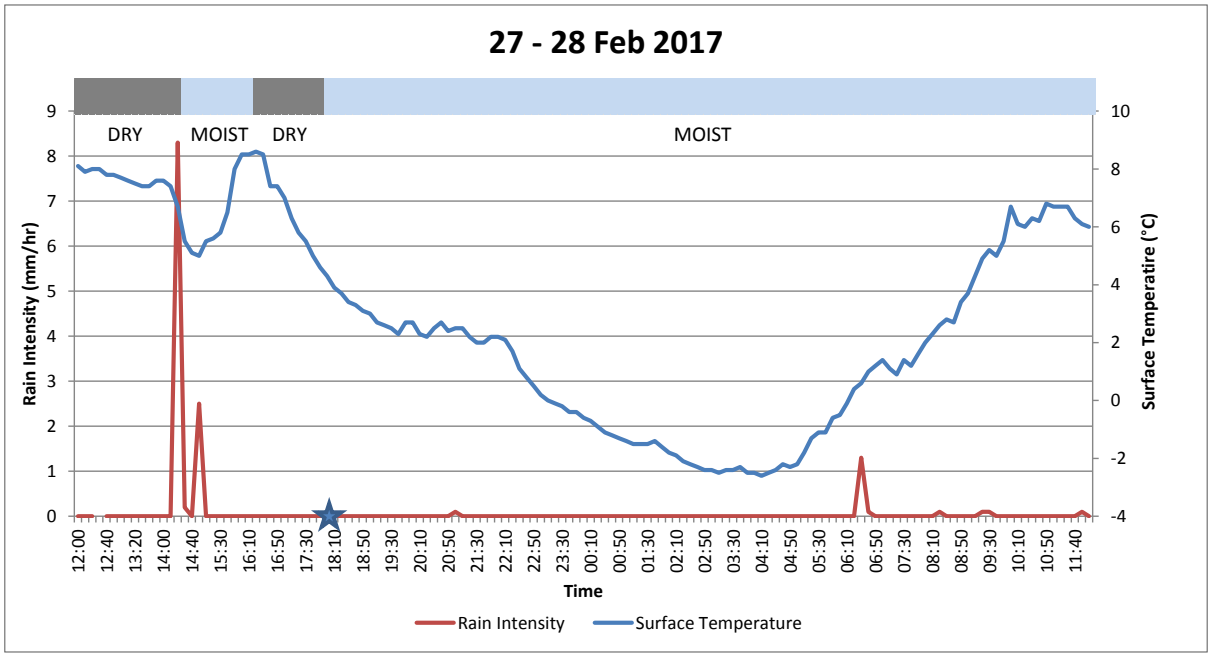
Time	Event, 2nd March
15:00	Spreading 30ml (Dry road surface, humidity 74%)
17:50 - 18:10	Light top medium snowfall, total precipitation 1.7mm
04:50	Road surface temperature drops below freezing
05:30	Minimum road surface temperature -1.1C



D.2 A77 Events

D.2.1 27th February

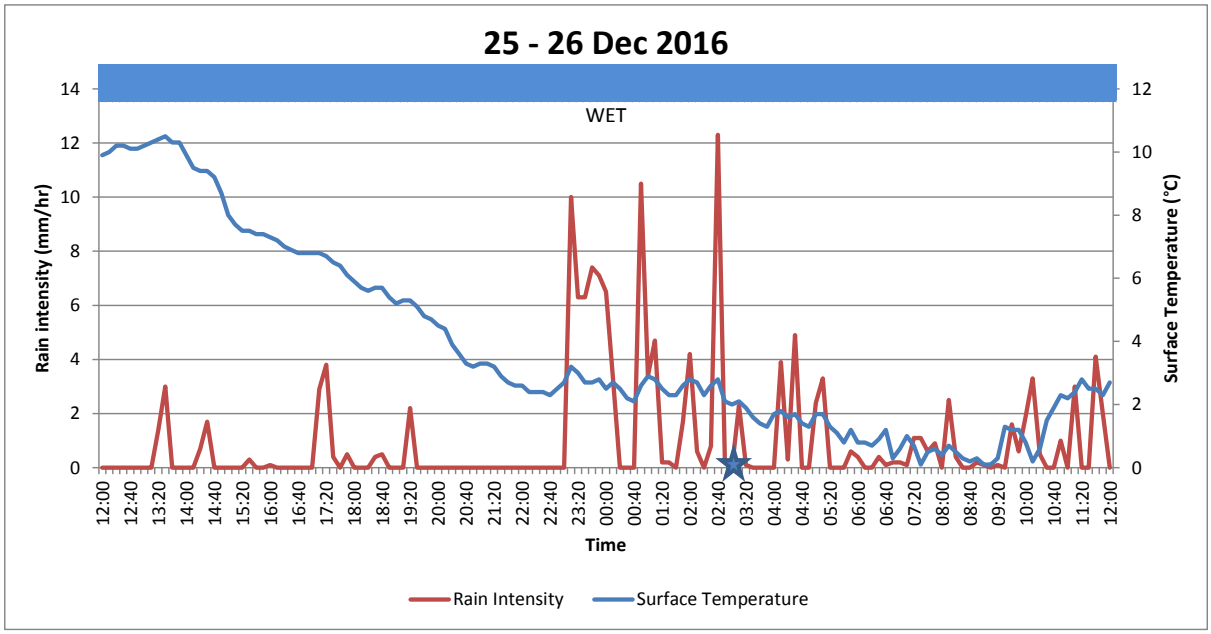
Time	Event, 27th February
18:00	Spreading 20ml (Moist road surface, humidity 87%)
21:00 – 21:10	Light snowfall, total precipitation 0.2mm
06:30 to 06:50	Light snowfall, total precipitation 0.5mm, RST 0.6°C and rising



D.3 A9 Events

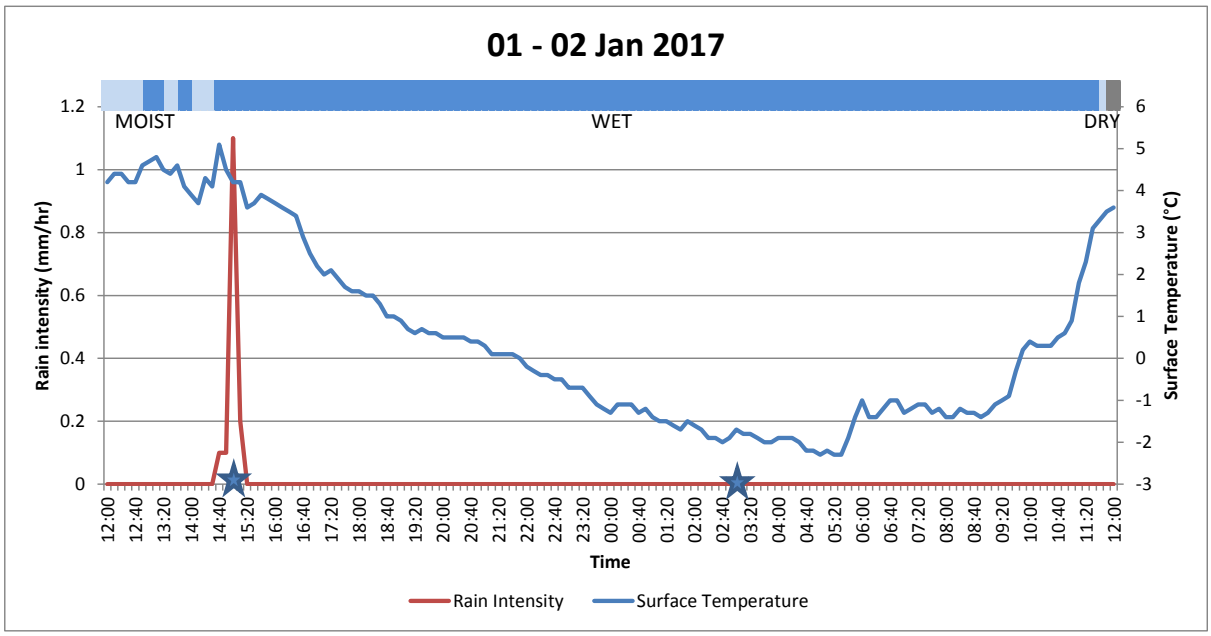
D.3.1 25th December

Time	Event, 25th December
03:00	Spreading 30ml (Wet road surface, 0.3mm water layer)
03:00 -	Light to medium rainfall
07:30	Minimum RST -0.1°C



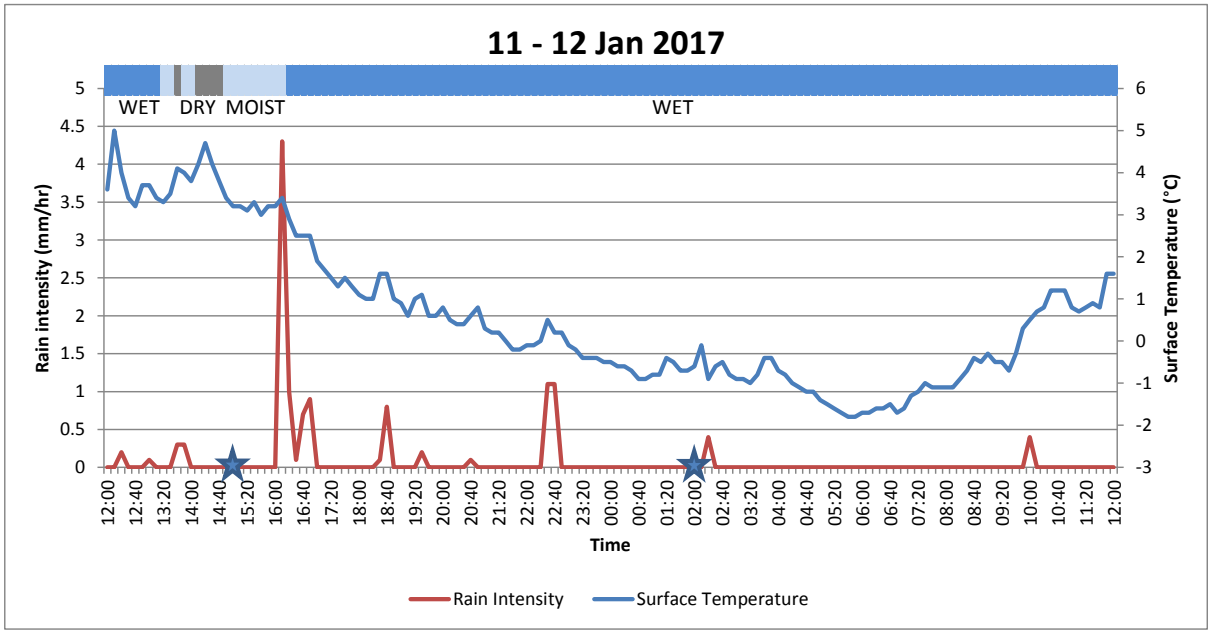
D.3.2 1st January

Time	Event, 1st January
15:00	Spreading 30ml brine (Wet road surface, 0.15mm water layer)
03:00 -	Minimum RST -2.3°C (Wet road surface, 0.1mm water layer)



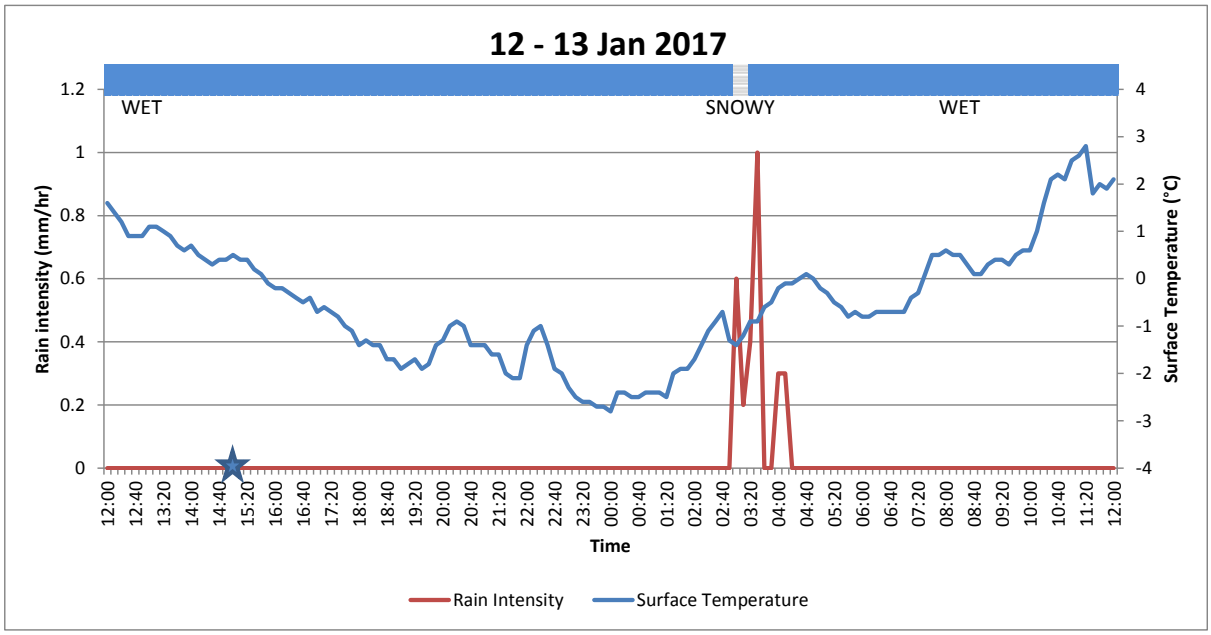
D.3.3 11th January

Time	Event, 11th January
15:00	Spreading 30ml brine (Moist road surface, 0.03mm water layer)
16:00 to 23:00	Intermittent light rainfall, total precipitation 1.8mm
02:00	Spreading 30ml brine (Wet road surface, 0.2mm water layer, RST -0.6°C)
02:20-02:30	Light snow shower, total precipitation 0.1mm
05:40	Min RST -1.8°C



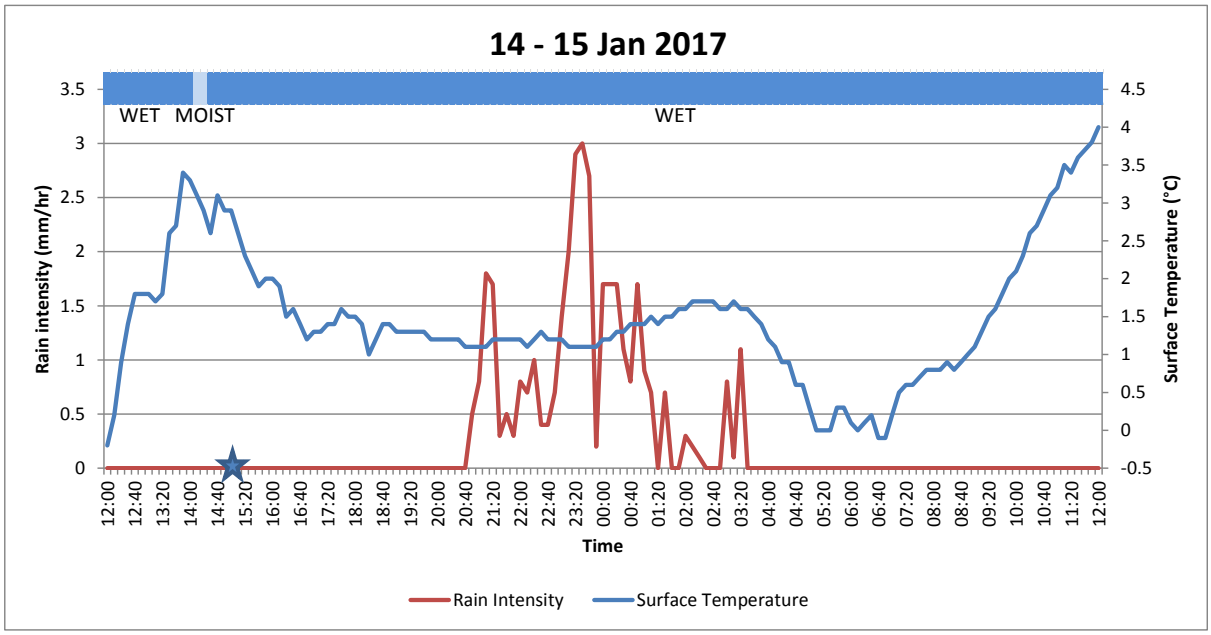
D.3.4 12th January

Time	Event, 12th January
15:00	Spreading 30ml brine (Wet road surface, 0.12mm water layer)
03:00 to 04:40	Light snowfall, total precipitation 0.5mm
05:40	Min RST after rainfall -0.8C



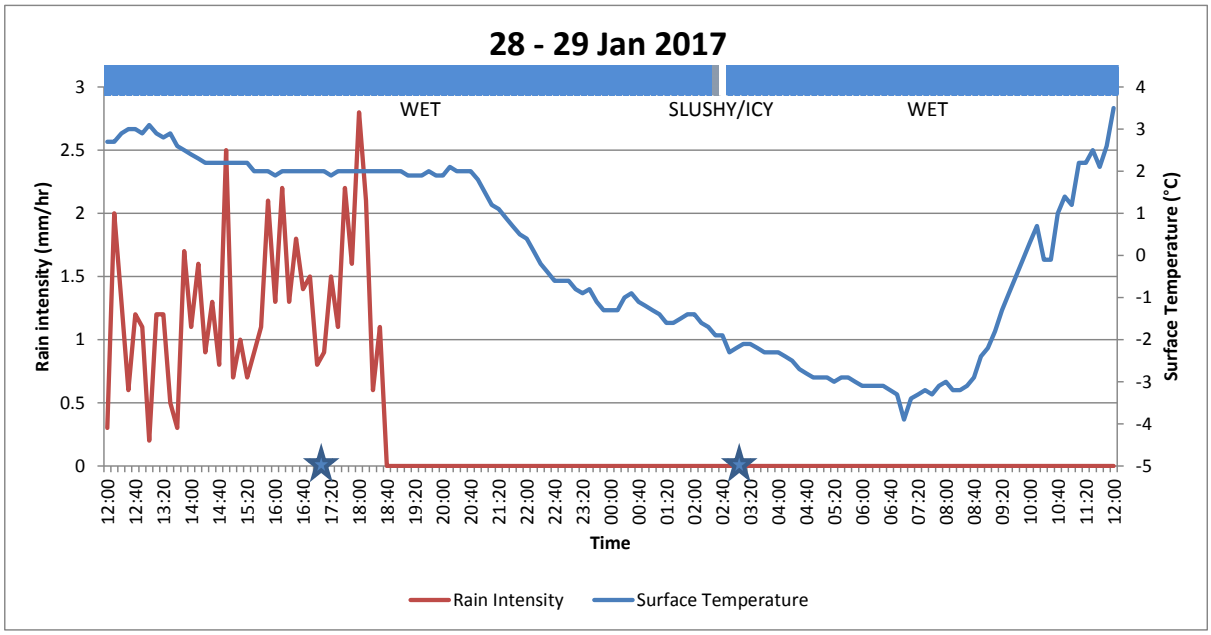
D.3.5 14th January

Time	Event, 14th January
15:00	Spreading 30ml brine (Wet road surface, 0.08mm water layer)
20:30 to 03:20	Light to medium rainfall, total precipitation 6.5mm
06:40	Min RST after rainfall -0.1C



D.3.6 28th January

Time	Event, 28th January
17:00	Spreading 30ml brine (Wet road surface, 0.41mm water layer)
17:00 to 18:30	Light rainfall 2mm
03:00	Spreading 30ml brine (Wet road surface, 0.16mm water layer, RST -2.2C)
07:00	Min RST after rainfall -3.9C



Trials of Brine Spreading Performance on Scotland's Roads: Phase 3

TRL were commissioned by Transport Scotland to support the development and coordination of a third phase of live brine trials for the 2016/17 winter season; to develop and enhance research into understanding liquid de-icer performance on Scotland's roads. Brine spreading was carried out during the 2016/17 winter season including the spreading of brine over the full length of treatment routes. This enabled assessment over a full winter season and experience to be gained spreading in the more varied conditions that occur along longer treatment lengths.

The trials demonstrated that brine was an effective treatment for the conditions prevailing during the trial period, and brine spreading was a suitable treatment on the majority of days when spreading occurred on the trial sites.

The results have provided an indication of the conditions of road surface wetness and temperature for which brine spreading is effective, and some indication on the limits of effectiveness during precipitation. Based on the conditions under which the brine spreading has been trialled, recommended spread rates have been provided for precautionary treatments before frost and light snow or rain.

Other titles from this subject area

PPR757	Trials of the longevity of brine and pre-wetted salt winter service treatments on typical UK road surfacings. 2015
PPR795	Trials of the longevity of brine and pre-wetted salt winter service treatments on typical UK road surfacings: Phase 2. 2016

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