# Water-Trak NTL fleet fitment interim report

**AMENDMENT RECORD**

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# Table of Contents






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# 1 INTRODUCTION

## 1.1 Project Summary

Water-Trak Ltd is advancing a system mounted on rolling stock which applies a small amount of water to the rail head in low adhesion conditions. Research has shown that the amount of water on the rail head plays a critical role in adhesion; while a dry rail gives the best braking results and a fully wetted rail still provides good levels of deceleration, a damp, contaminated rail causes very low friction. The Water-Trak system creates "rainy day" conditions on the rail head when low adhesion is detected by adding a controlled quantity of water.

The concept has previously been successfully trialled both on a test track and in mainline passenger service operation using a small number of trains equipped with Water-Trak. The purpose of this project is to fit the technology to an entire fleet of trains, providing the rail industry with operational evidence for the benefits of water addition in mitigating low adhesion and enabling subsequent roll-out of Water-Trak across the GB rail network.

The previous pilot project involved two Northern Class 319/3 trains, equipped with Water-Trak systems, which operated in passenger service throughout autumn 2021 and into early 2022. Two Northern Class 170 train were also equipped with Water-Trak, but due to operational constraints were not available for trial until autumn 2022.

This interim report contains an analysis of the key results obtained from the four Water-Trak equipped trains, operating through autumn 2022, documenting the impact of water addition on a range of relevant train performance parameters. The report also provides a brief update on progress towards fleet fitment of Water-Trak in the remaining Northern Class 170 trains.

# 2 OBJECTIVES

The aim of this project is to demonstrate the impact on autumn performance of a fleet of Water-Trak equipped trains operating in passenger service on the mainline, supporting the business case for subsequent roll-out across the GB rail network. To achieve this outcome, the project must deliver the following:

- An approved Water-Trak Class 170 fleet fitment design.
- A fleet of up to 16 Northern Class 170 trains operating with Water-Trak systems.
- Northern train drivers who are ready to exploit Water-Trak assisted train braking, maximising the opportunity for reduced autumn journey times.
- An analysis of operational data from the Water-Trak equipped fleet of trains.
- An analysis of operational performance data for other Northern trains running on the same lines of route and/or following Water-Trak trains.
- A final report detailing the results of the performance analysis and presenting the business benefits of Water-Trak.



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# 3 DESIGN AND APPROVALS – NEW 170 FLEET DESIGN

## 3.1 Class 170

The starting point for the Class 170 fleet fitment was the system design prepared for operation in the Class 170 trains in autumn 2021. Several detail changes were incorporated in the new fleet fitment design to increase reliability, reduce installation time and manufacturing complexity. The key changes to the design were as follows:

- New water level sensor and baffle enabling more consistent operation.
- Increased tank volume to 125 litres.
- An improved drain plug design providing more robust sealing and fool proof operation.
- Introduction of flexible hosing wherever possible, increasing reliability and reducing the need for on-site pipe forming and brazing.
- Incorporation of a connector to enable easier testing, installation and removal.
- Simplified construction of the tank and associated bracketry, reducing the number of fixings required.
- Industry standard isolation switch.
- Test switch re-located for more convenient depot operation.

### 3.1.1 Overview of installation

The water delivery unit (comprising the water tank, a pneumatic pump with ancillaries and trace heating) was positioned in the centre of the train underframe ahead of the leading bogie – see figure 1. The Water-Trak control unit was mounted inside the electrical cabinet at the rear of the leading carriage and was connected to the WSP rack, Remote Monitoring Device (RMD) and OTMR mounted in the same cabinet. When actuated, water is delivered through flexible high-pressure hose from the water delivery unit to nozzles attached to the lifesavers ahead of the leading axle.

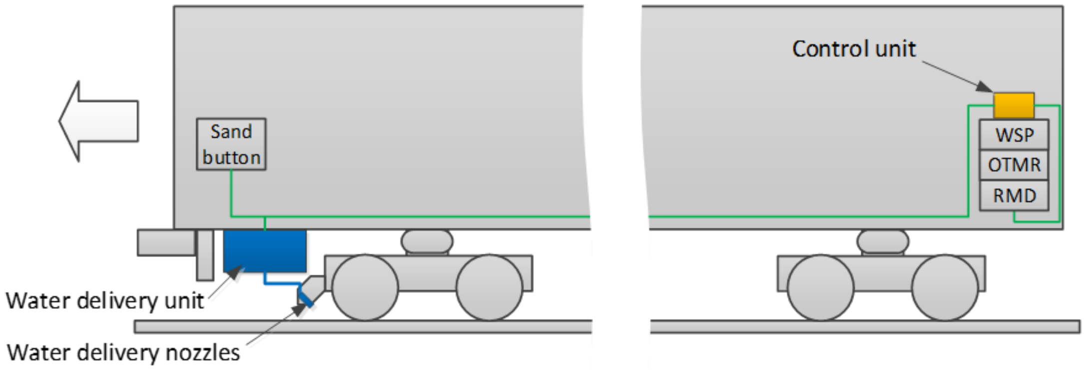


Figure 1: Schematic of the Water-Trak installation in the Class 170 train

Water dispensing can be activated in two ways: when a signal is received from the WSP wheel slide relay or as the result of a manual dispense signal. The manual dispense signal is actuated when the cab sanding button is pressed.



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Figure 2 shows a selection of views of the Water-Trak system installed in a Class 170 train.

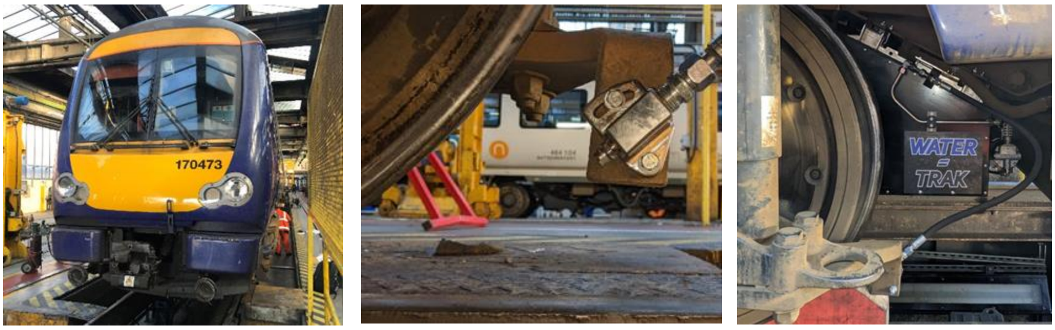


Figure 2: Water-Trak installed in Class 170

### 3.1.2 Approvals

In order to achieve approval for operation of Water-Trak in passenger service in the Class 170, the following documents were completed and signed off:

- Design Attestation AC/0420/22 Issue 01 prepared by Aegis Certification Services Ltd.
- Network Rail summary of compatibility NRSC-0170-102-i Class 170
- Safety Requirements close-out document WTSRS002.3
- Northern SHE validation
- Northern Engineering Change approval



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# 4 DEMONSTRATION PLAN

## 4.1 Evidence required.

The overall aim of the Class 170 fleet fitment is to show that Water-Trak is a proven and practical control measure to address low adhesion conditions.

Proof of the operational effectiveness of Water-Trak will be confirmed through the analysis of:

- The level of braking deceleration delivered related to brake demand for Water-Trak and non-Water-Trak equipped trains.
- Journey time data for Water-Trak trains, following trains (i.e., trains arriving up to 2 hours afterwards) and non-Water-Trak trains.

The practicality and suitability of Water-Trak for use in the rail industry will be demonstrated by assessing the following items:

- Resilience to freezing conditions.
- Water consumption during autumn.
- Depot support requirements.
- Sand usage compared with non-Water-Trak trains.
- Wheel flats compared with non-Water-Trak trains.
- Incidence of track circuit failures during autumn 2023 compared with previous years.
- The overall business case for fitment of Water-Trak.

This interim report details the analysis of the evidence collected to date and highlights areas where further information is still required to meet the final project objective.

## 4.2 Data sources

To support delivery of the evidence detailed above, data has been collected from the following sources:

- On-train telemetry and near-real-time data visualisation from Water-Trak trains
- Autumn adhesion warnings
- Incident data reports from Northern Trains (e.g., Station over-runs, tyre turning)
- Weather data from MetDesk and Rail Weather Monitoring provided for the trial regions.
- Rail Head Treatment Train (RHTT) performance and timetabling
- Driver feedback (e.g., depot whiteboards)
- Depot maintenance records and feedback
- Route information, including gradient data (5 Mile Line Diagrams document)
- Journey time and GPS speed data (Northern Trains Aegis software)
- OTMR data

The data paths for journey time and OTMR information are shown in figure 3.



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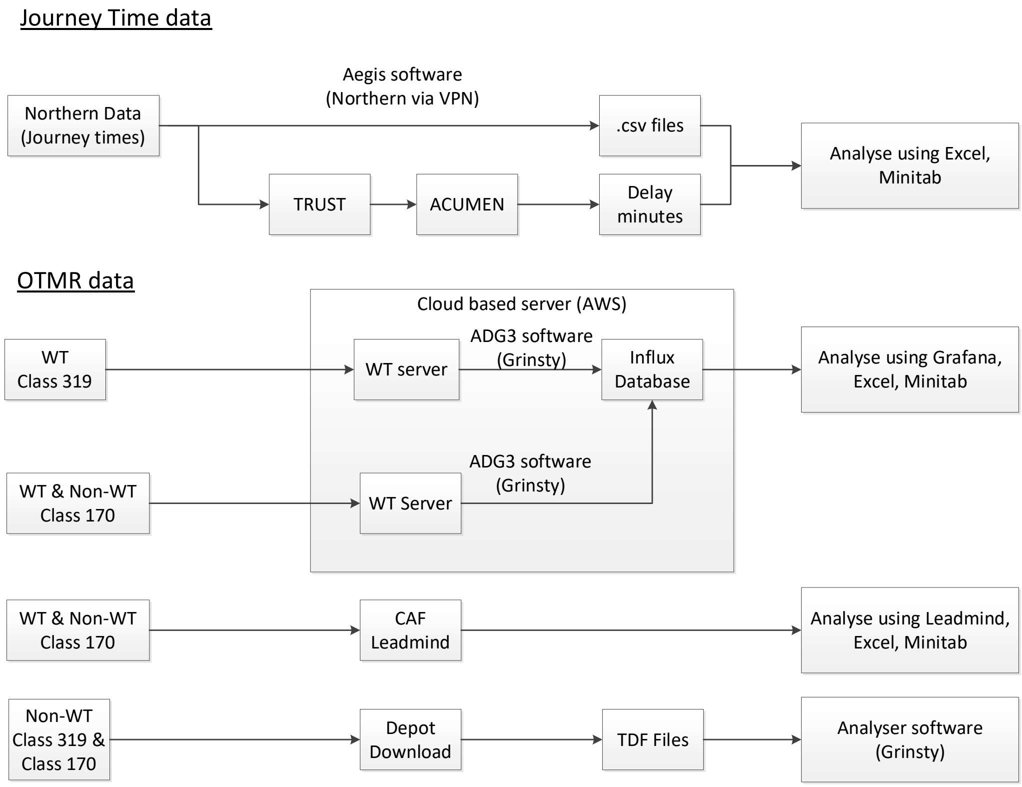


Figure 3: Water-Trak 2022 and 2023 data paths

## 4.3 Analysis

### 4.3.1 Braking improvement.

OTMR data was used to analyse braking deceleration rates during WSP events for both Water-Trak and non-Water-Trak equipped trains. Key OTMR and data logger parameters included brake demand from the driver, brake pressure, WSP activity, water delivery duration and train speed. In some instances, the OTMR train speed was supplemented with GPS train speed data from the Northern Trains Aegis database.

### 4.3.2 Journey time impact.

Data from the Northern Trains Aegis database was analysed firstly to quantify the "autumn effect" on journey times and then to evaluate the impact of water addition. The analysis looked at the average and variation in journey times, which have been shown to increase in autumn in previous studies.

### 4.3.3 Following trains impact.

Downloads from the Northern Trains Aegis database provided journey time data for trains of the same Class running up to 2 hours after a Water-Trak equipped train on the same section of track. The following train impact was assessed by studying differences in journey time for Water-Trak and non-Water-Trak trains using Aegis data.



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### 4.3.4 Resilience to freezing conditions.

Weather data was used to identify periods when temperatures were below 0°C. Data logger parameters, in particular water system pressure, were analysed during and after these periods to assess the impact of freezing on the operation of the system. It was also possible to analyse the frequency of operation in low temperature conditions by recording the number of times the system triggered.

### 4.3.5 Driving style.

GPS data were used to analyse the impact of driving style on operation of the Water-Trak system. Key outputs were train speed-time and speed distance traces for selected journey legs and routes.

### 4.3.6 Water consumption

The number of dispenses and individual delivery durations were used to assess the volume of water dispensed per day and per mile of autumn operation.

## 4.4 Operation

### 4.4.1 Train preparation

Pre-autumn checks were carried out on all Water-Trak trains to ensure correct operation of the water delivery systems and other related on-train systems (e.g., sanding systems, WSP). Where necessary, corrective actions were undertaken.

### 4.4.2 Driver requirements

A driver briefing document was updated and distributed to inform the drivers that no additional action is required of the driver when operating trains equipped with the Water-Trak system. The briefing also instructs drivers to follow the current driving policy within Northern which is to apply a constant level of Step 2 braking, avoiding “fanning” of the brakes (i.e. continually cycling the brakes between Steps 1 and 2).

### 4.4.3 Routing

The Class 319 and 170 trains continued to operate normally on their usual routes, in accordance with the standard timetable requirements.

### 4.4.4 Filling and maintenance

Maintenance procedures were reviewed and updated both train classes. The documents detailed the activities needed to support filling, inspection and servicing. In addition, winterisation procedures were re-issued, detailing actions to protect the systems in low temperatures and to mitigate the risk of damage due to freezing.



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# 5 RESULTS

## 5.1 Water-Trak operation

The rail industry recognised autumn period in 2022 was between 1st October and 13th December. The Water-Trak system in 319379 was activated on 12th October 2022 and 319368 was switched-on after some repairs had been completed on 21st October 2022. Both trains operated from the start with water delivery enabled for braking only. The first Class 170 (170473) Water-Trak system was enabled on 2nd November. Activation of the system was once again delayed due to the need for driver approval and the unit returned to Holbeck depot on the 23rd November for a planned passenger information system upgrade, preventing any further autumn operation. A second Class 170 (170454) was activated on 19th November 2022 and continued to operate to the end of autumn. Unfortunately, the data feed from this unit did not include any OTMR-based readings and dispense data was only available for one end of the train.

### 5.1.1 Overall summary.

The total dispensing history for the four trains in 2022 is shown in table 1. Overall, the trains covered over 32,000 miles during the trial and dispensed water 556 times.

| | Dispenses | Volume (litres) | Mileage |
|---|---|---|---|
| 319368 | 96 | 204 | 6,762 |
| 319379 | 186 | 370 | 11,346 |
| 170473 | 89 | 273 | 1,240 |
| 170454 | 185 | 424 | 13,501 |
| Total | 556 | 1272 | 32,849 |

Table 1: Summary of Water-Trak operation during autumn 2022

NB The lack of telemetry on the '50' car end of 170454 means the number of dispenses is an underestimate and might have been as high as 750.

The total volume of water delivered throughout the entire trial was approximately 1,250 litres. This is equivalent to less than 16 minutes of water output for a single Railhead Treatment Train. The higher water usage on the 170s, combined with the lower tank volume in these units, increased the risk of the tank running dry. During the trial, on the 6th November, one of the tanks on 170473 remained empty for over 200 miles. The water usage for the Class 319 trains was considerably lower than that of the 170s. There was an instance of low water level indicated for 319368, car 77473 on the 1st and 2nd of November which could have been due to a fault with the tank level sensor.



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### 5.1.2 Location and density of water dispenses.

Figure 4 shows the location and density of water dispenses in the form of a heat map; red indicates a larger number of dispenses over the autumn trial period. The trace shows the primary areas in the Northwest region (operating Class 319s) where the largest volume of water was dispensed, including Liverpool to Wigan, Liverpool to Newton-Le-Willows and the area around Manchester Airport to Crewe. The map also shows the parts of the Eastern region (operating Class 170s) where most water was used, namely Leeds, Harrogate and York, Hull to Scarborough and Hull to Sheffield.

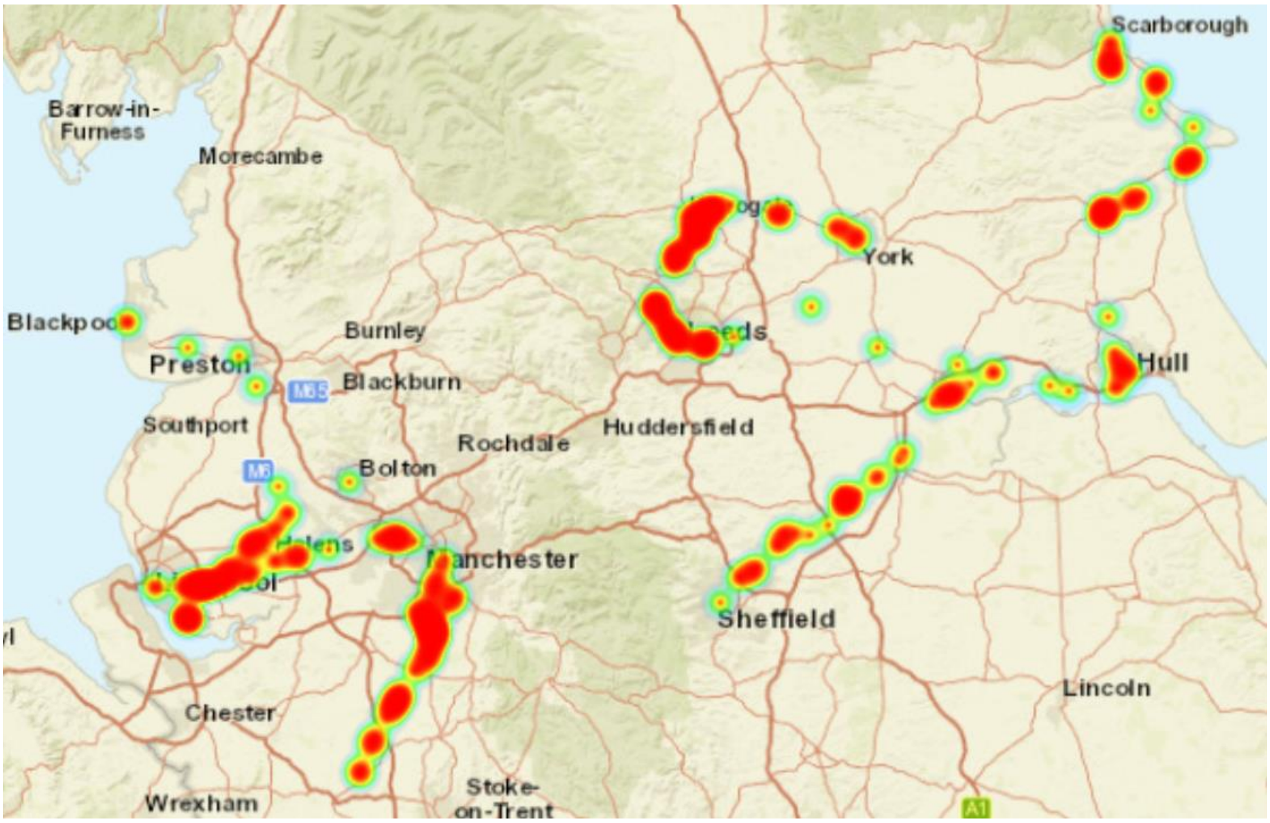


Figure 4: Heat map of water dispense locations

### 5.1.3 Autumn timeline of water usage

Figure 5 and 6 show graphs of the water dispensing frequency ordered by day (figure 5 for Class 319s and figure 6 for Class 170s). The colour bar at the top of each the charts indicates the adhesion predicted for each day in the relevant operating region. Figure 6 illustrates the impact of delayed deployment of 170473 with no dispenses until the 2nd November and the delayed operation of 170454 which didn't start dispensing until the 19th November. As in 2021, the level of adhesion problems varies significantly day-to-day.

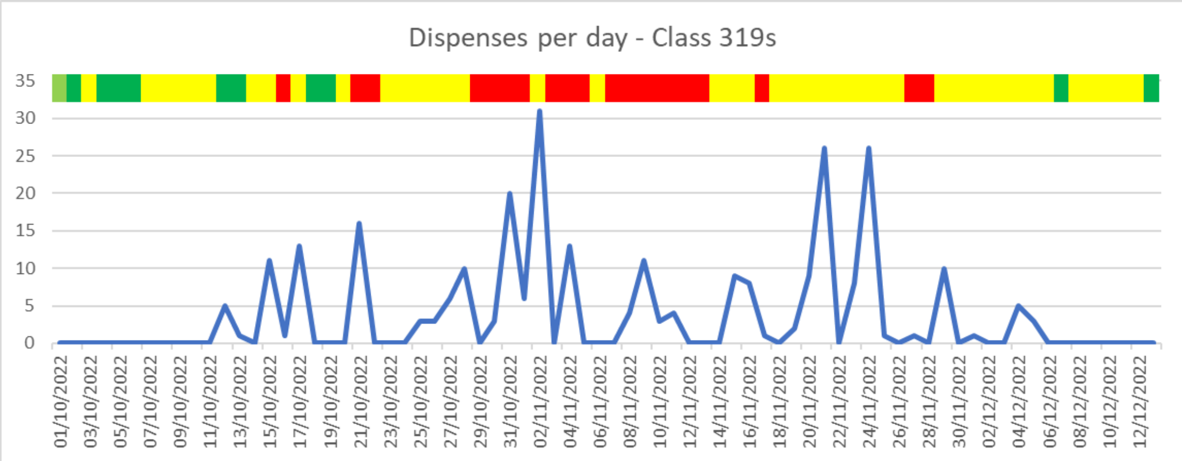


Figure 5: Dispensing frequency for Class 319s through autumn 2022

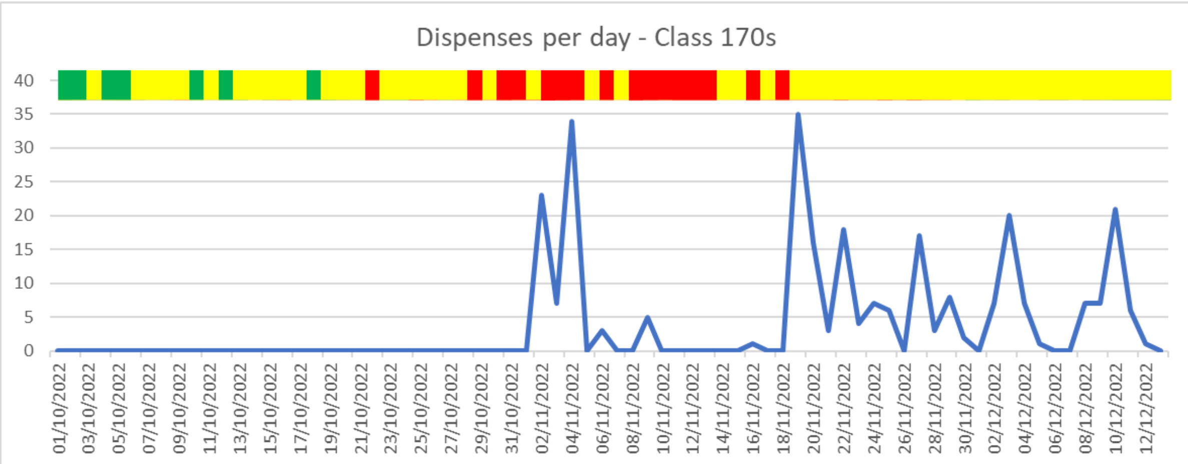


Figure 6: Dispensing frequency for Class 170s through autumn 2022

Although the number of dispenses per day recorded for the two train classes seem to be similar, it should be noted that the mileage covered by the trial Class 319s was significantly higher than that of the Class 170s. Using the results shown in table 1, the dispense rate for 170s was significantly higher at 30* dispenses/1000 miles compared with 8.5 for the Class 319s. The difference seen is due to the increased sensitivity (i.e., triggering at far lower creep levels) of the WSP system in the Class 170 trains.

** This figure has been calculated using an estimate for the missing dispense telemetry on 170454.*



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### 5.1.4 Sand usage

Northern have started to collect data for autumn sand usage across their fleet. Over time this will allow sand usage by unit number, car number and train class to be analysed. An initial analysis of autumn 2022 consumption was conducted which showed a 13% increase in sand usage per mile for the Water-Trak equipped Class 319s compared with the 319 fleet and a 32% reduction in sand usage versus the fleet for the equivalent Class 170s. These results still have a high level of uncertainty but it is hoped that this data source will provide an useful insight into sand usage during autumn 2023.

### 5.1.5 Pre-autumn checks

Following initial Water-Trak fitment, all the trial trains continued to operate in passenger service ahead of autumn 2022 with their systems switched off. Pre-checks were conducted in late September and early October to assess the condition of the installed systems. Here is a brief summary of the findings for each unit:

319368 – blocked nozzles, leaking pressure release valve, detached pipe brackets
319379 – blocked nozzles, leaking drain plug, detached pipe brackets
170473 – damaged water hose and missing nozzle manifold
170454 – partially block nozzles

The systems on all trains were repaired and cleaned ahead of autumn operation. In addition, the following changes were made to the system settings (autumn 2021 figures in brackets).
319368 – Timers set to 20 seconds (30 seconds) and thermostats set to 15°C (5°C)
319379 – Timers set to 20 seconds (30 seconds) and thermostats set to 15°C (5°C)
170454 – Timers set at 15 seconds (20 seconds) and thermostat on 50454 set to 15°C (5°C)
170473 – Timers remained at 20 seconds but thermostat set to 15°C (5°C)



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### 5.1.6 Operation in freezing conditions

Figure 7 shows air temperature readings recorded hourly at Glazebury weather station (Network Rail's Rail Weather Monitoring at www.railweather.co.uk data) between 1st October and December 24th, 2022. During the trial period, freezing conditions were encountered on ten days from 9th to the 18th of December. The lowest autumn temperatures were recorded during this period.

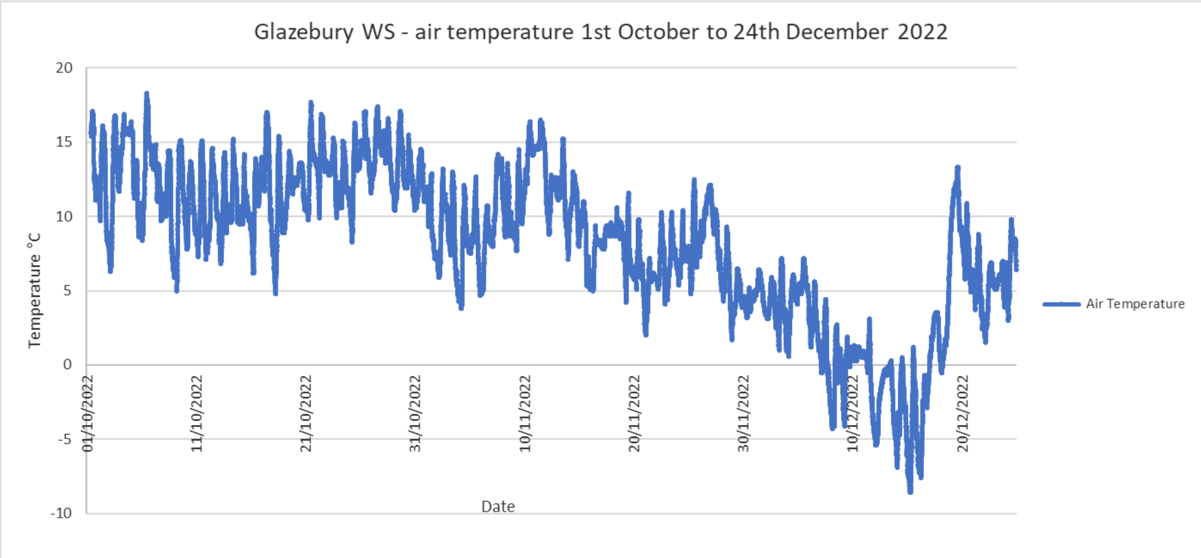


Figure 7: Air temperature readings at Glazebury Weather Station, autumn 2022

The lowest temperature recorded was -8.6°C on the night of the 15th of December. The prolonged period of sub-zero temperatures led to water delivery elements of the Water-Trak systems on the Class 319 trains freezing as seen in 2021. Subsequent inspection showed that the water systems on both 319s had suffered freezing damage.

Figure 8 shows evidence of damage to the pump inlet strainer and the pump pressure switch on 319368. Similar damage was also reported for 319379 indicating a vulnerability in this system design. No reports of damage have been received for Class 170s, where a more robust design has been employed.

Figure 8: Frost damaged pump inlet strainer (L) and pump pressure switch (R).



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## 5.2 Impact of water addition on braking

### 5.2.1 Analysis method

The braking deceleration rates achieved during WSP events were analysed for both Water-Trak and non-Water-Trak equipped trains. Deceleration rates (in units of %g) were quantified for all step 2 braking manoeuvres which lasted for 5 seconds or more. GPS data for the train was used to help quantify decelerations in manoeuvres where the OTMR speed trace was not suitable (e.g. during wheel-slide). Local track gradient data was used, when available, to correct any deceleration results which took place on upgrades or downgrades.

Figure 9 provides more detail of how data from the Grafana analysis dashboard was used to calculate train deceleration. Firstly, timings for WSP triggered water deployment were identified. Valid braking manoeuvres were those where at least 5 seconds of step 2 braking occurred (where brake pressure is over 2). The time period from the start of water addition to the end of step 2 braking was recorded and the speed reduction noted. Deceleration values were calculated by dividing the speed reduction by the braking time period.

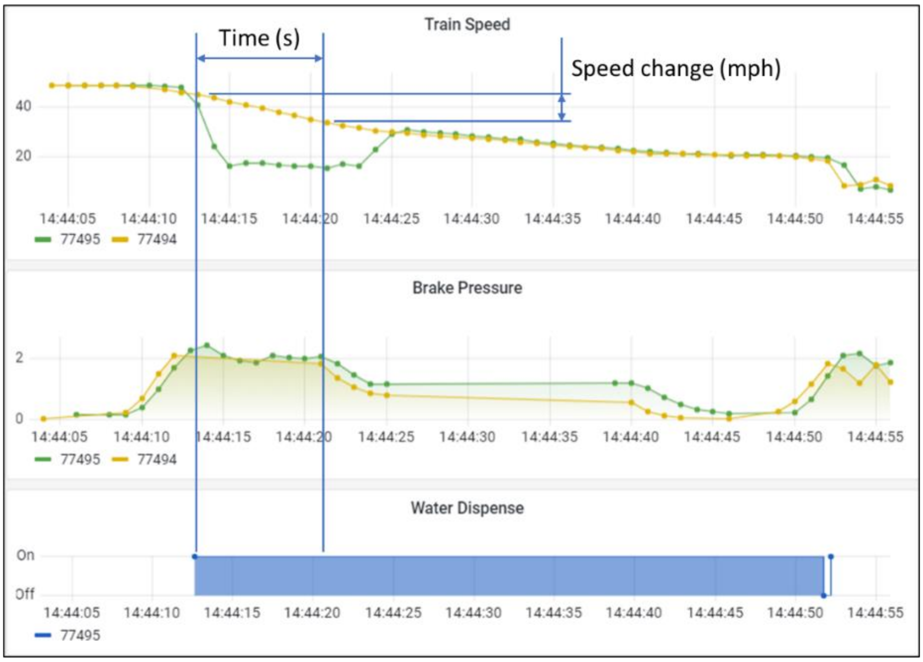


Figure 9: Annotated Grafana speed, brake pressure and water dispense trace

During analysis, it was noted that many slides occurred in step 1 braking on the Class 170s; it was decided that step 1 deceleration should also be analysed for these trains – see section 5.2.3.



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### 5.2.2 Effect of water addition on Class 319 braking

Figure 10 shows the individual value deceleration results for all step 2 WSP braking manoeuvres recorded during autumn 2022. The control data was derived from OTMR downloads from Class 319 trains together with data for one of the two Water-Trak trains running prior to their systems being switched on. 143 samples have been recorded for Water-Trak while there were 93 Control samples and 32 samples for good adhesion.

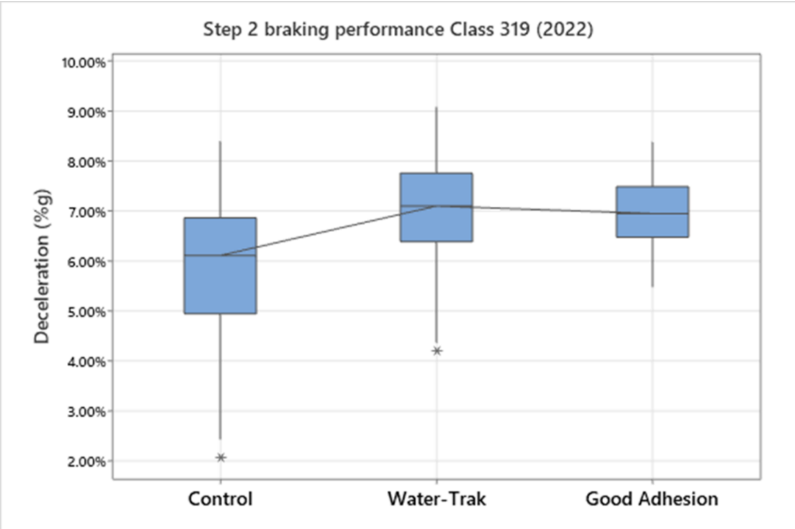


Figure 10: Deceleration rates for Water-Trak trains compared with braking for Control trains and in good adhesion conditions.

The graph shows that the median deceleration for the Water-Trak trains increases by 1%g (from 6.1%g to 7.1%g) and returning to good adhesion levels. More importantly, the variation in deceleration appears to be smaller for Water-Trak than the Control, although not quite as low as for good adhesion conditions. The lowest deceleration values for Water-Trak were 4.2%g, whereas decelerations as low as 2%g were recorded for the Control.

Figure 11 compares the Class 319 step braking results recorded in 2021 and 2022.

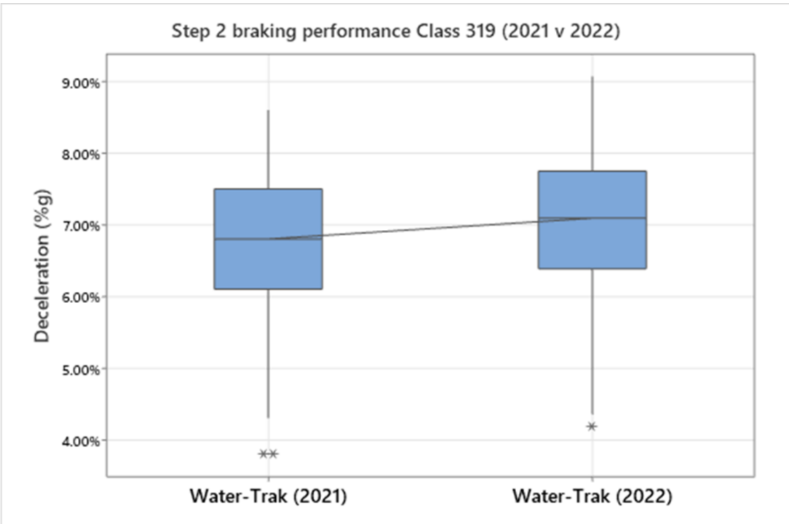


Figure 11: Comparison of step 2 Class 319 braking results for 2021 and 2022



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This data shows a small but statistically significant improvement for 2022 step 2 braking performance. This change in performance could be due to a number of factors, singly or in combination: resolution of WSP and sanding faults present in 2021 on both Water-Trak trains, increased water delivery temperature and milder autumn conditions in 2022.

Using combined data from 2021 and 2022, with a total of 378 Water-Trak samples and 234 control samples, figure 12 compares step 2 braking results for Water-Trak over two autumns.

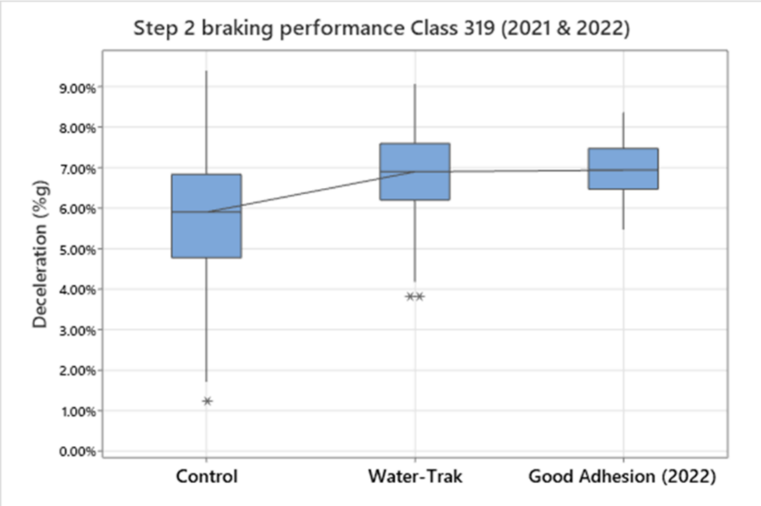


Figure 12: Comparison of Water-Trak, control and reference good adhesion data for both autumns



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Figure 13 shows a two-sample t-test comparing mean decelerations for Water-Trak trains and the Control using combined data from 2021 and 2022. The analysis indicates that there is a statistically significant increase in mean deceleration (with at least 99.9% confidence).

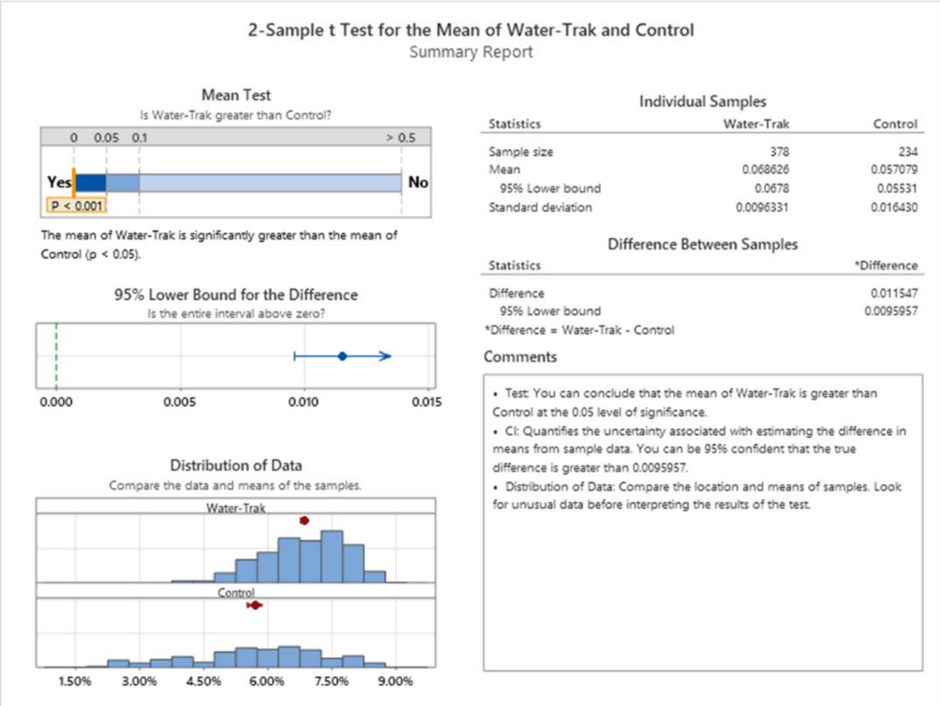


Figure 13: 2 sample t-test comparing means of Water-Trak and Control decelerations for both autumns.



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Figure 14 shows the results of a two-sample standard deviation test comparing the variation in the Water-Trak decelerations with the control. The conclusion from this analysis is that the variation in Water-Trak deceleration is significantly lower than that of the control (again with at least 99.9% confidence).

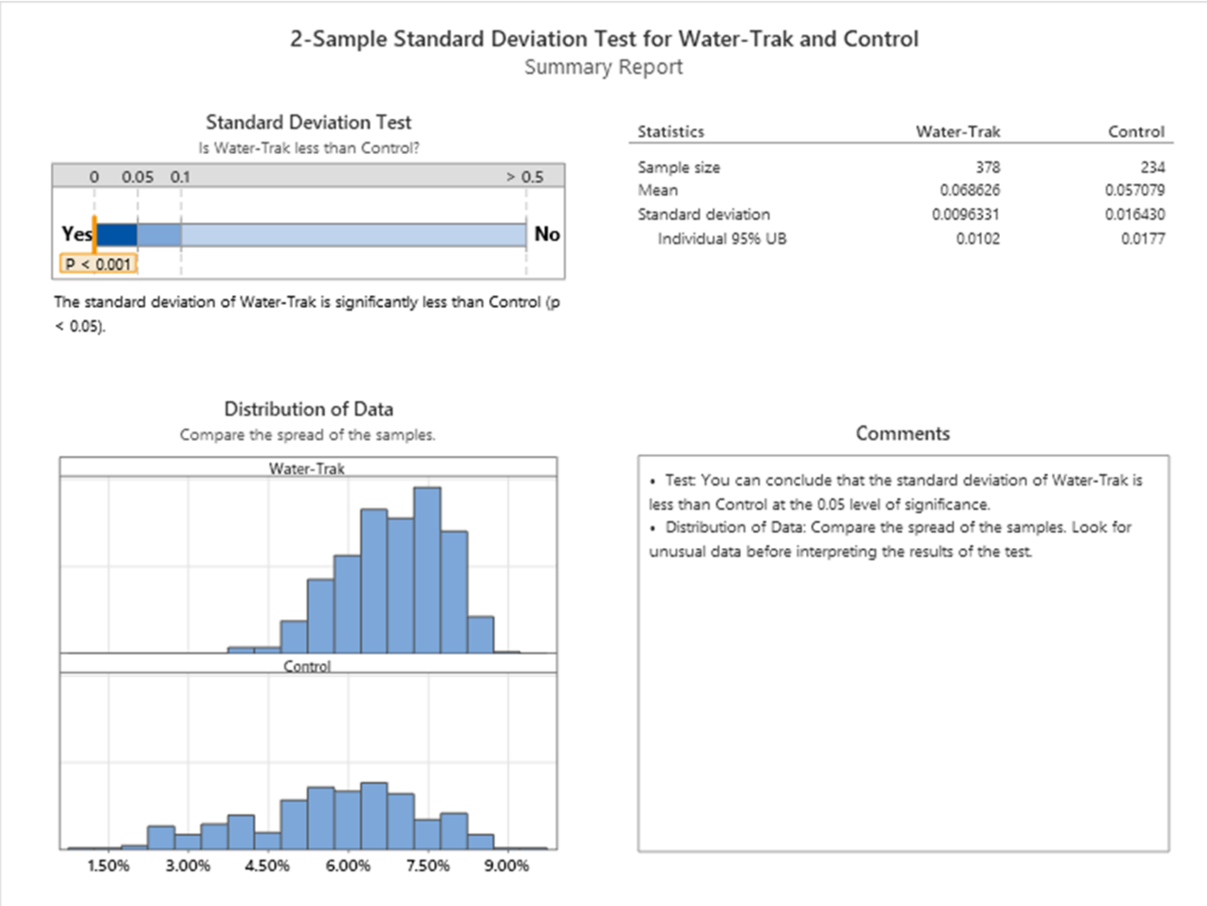


Figure 14: Two-sample standard deviation test comparing Water-Trak and Control decelerations.

Overall, this analysis shows that Water-Trak equipped trains have significantly better braking (higher step 2 deceleration with reduced variation) when compared with the control. These results, recorded during passenger service operation through two autumns, conclusively prove the benefits delivered by equipping Class 319 trains operating in the Northwest region with Water-Trak.



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### 5.2.3 Effect of water addition on Class 170 braking

Following agreement to activate Water-Trak in Class 170 trains on the 2nd November, the system on 170473 was activated on the 2nd of November. Figure 15 shows step 2 braking decelerations with WSP present recorded over the days leading up to and beyond the switch-on.

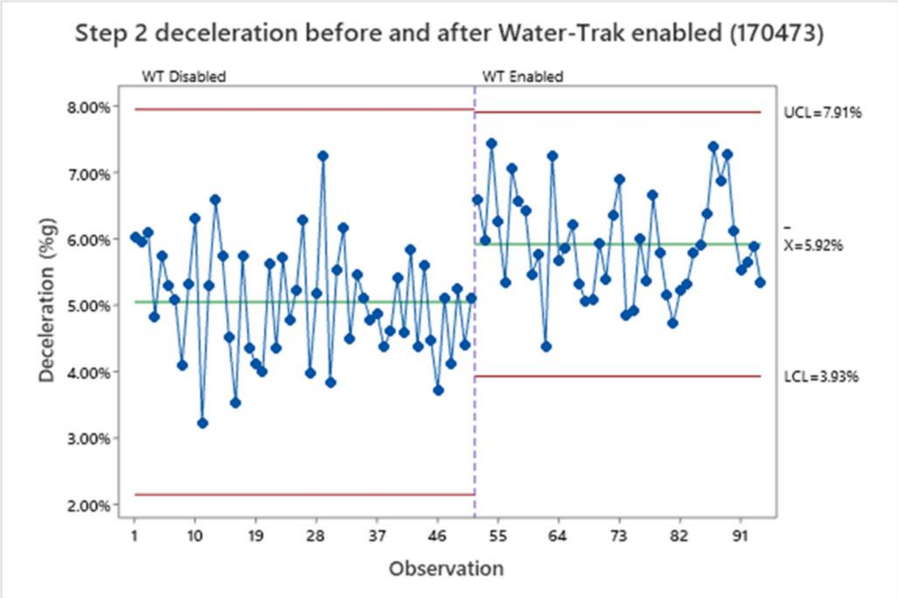


Figure 15: Time series of step 2 Water-Trak decelerations.

As with the Class 319 braking data, there was a significant uplift in deceleration when Water-Trak was enabled (0.9%g, from 5.05%g to 5.92%g). The variation in deceleration (illustrated by the red upper and lower control limit lines) also reduced greatly when Water-Trak was switched on. In contrast, deceleration data for the rest of the Class 170 fleet over the same time period showed a reduction in deceleration – see figure 16.

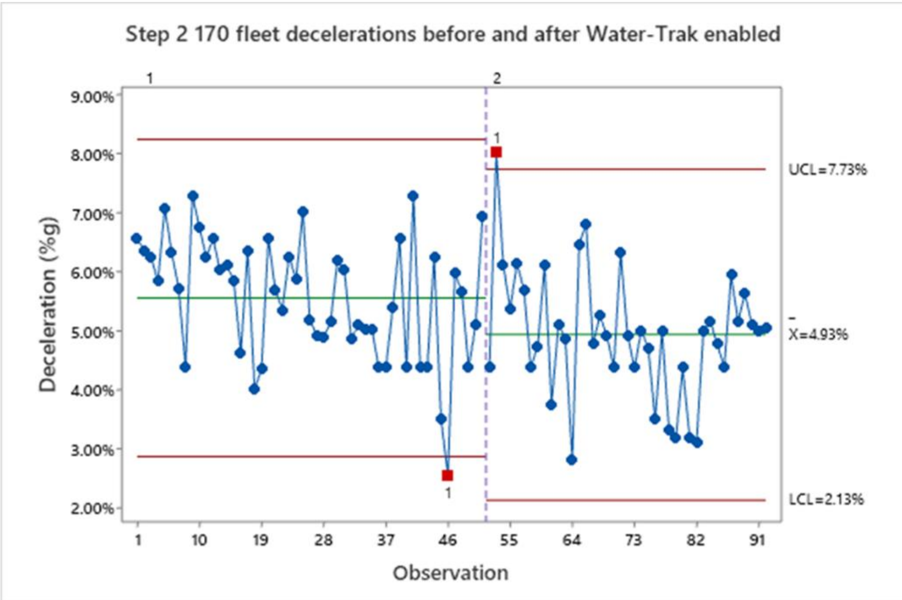


Figure 16: Control time series of step 2 170 fleet decelerations.

Figure 17 shows the individual value deceleration results for step 2 WSP braking manoeuvres uploaded from 170473 during autumn 2022. The control data was derived from OTMR downloads from Class 170 trains. Good adhesion data was generated by analysing the braking performance of 170473 (without WSP triggering) during summer.

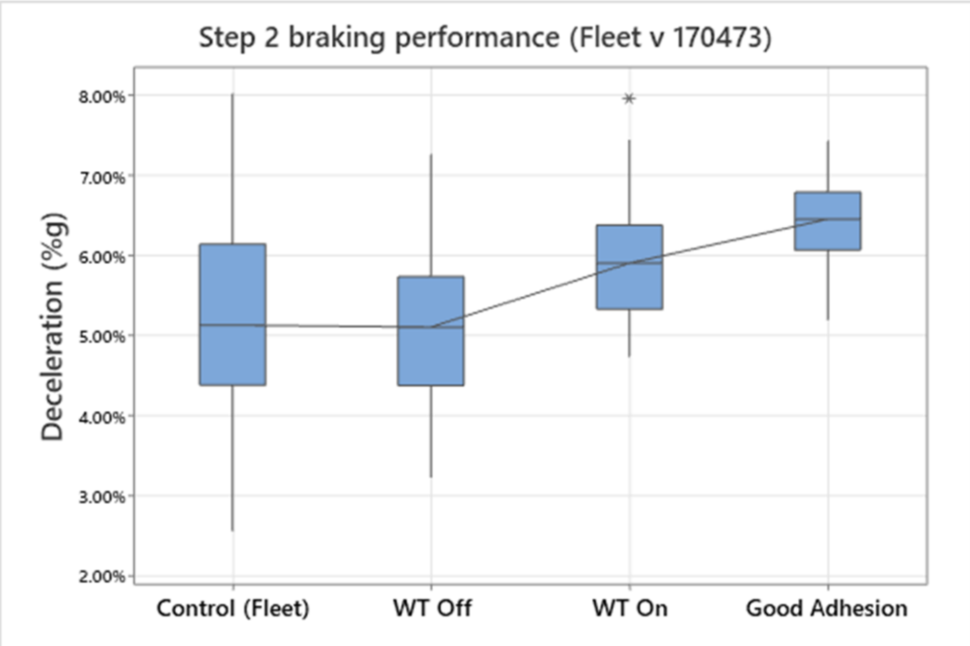


Figure 17: Comparison of step 2 braking between control and 170473

The graph shows that there is an insignificant difference in braking performance between the Class 170 fleet and 170473 with Water-Trak disabled. When Water-Trak was enabled in 170473, the same uplift in deceleration shown in figure 15 is evident once again, with decelerations approaching the level possible in good adhesion conditions and none of the very low decelerations seen for the fleet.

A further observation can be made when comparing the autumn control data with good adhesion data collected earlier in the year – a drop in median deceleration from 6.45%g to 5.12%g or 1.33%g is evident. This compares unfavourably with the reduction in deceleration for the Class 319 of 0.9%g from a higher good adhesion deceleration of 7%g and indicates that Class 170s may be more sensitive to autumn conditions than Class 319s.



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Figure 18 shows a two-sample t-test comparing mean decelerations for Water-Trak enabled and a Control using combined fleet and Water-Trak off data. The analysis indicates that there is a statistically significant increase in mean deceleration (with at least 99.9% confidence).

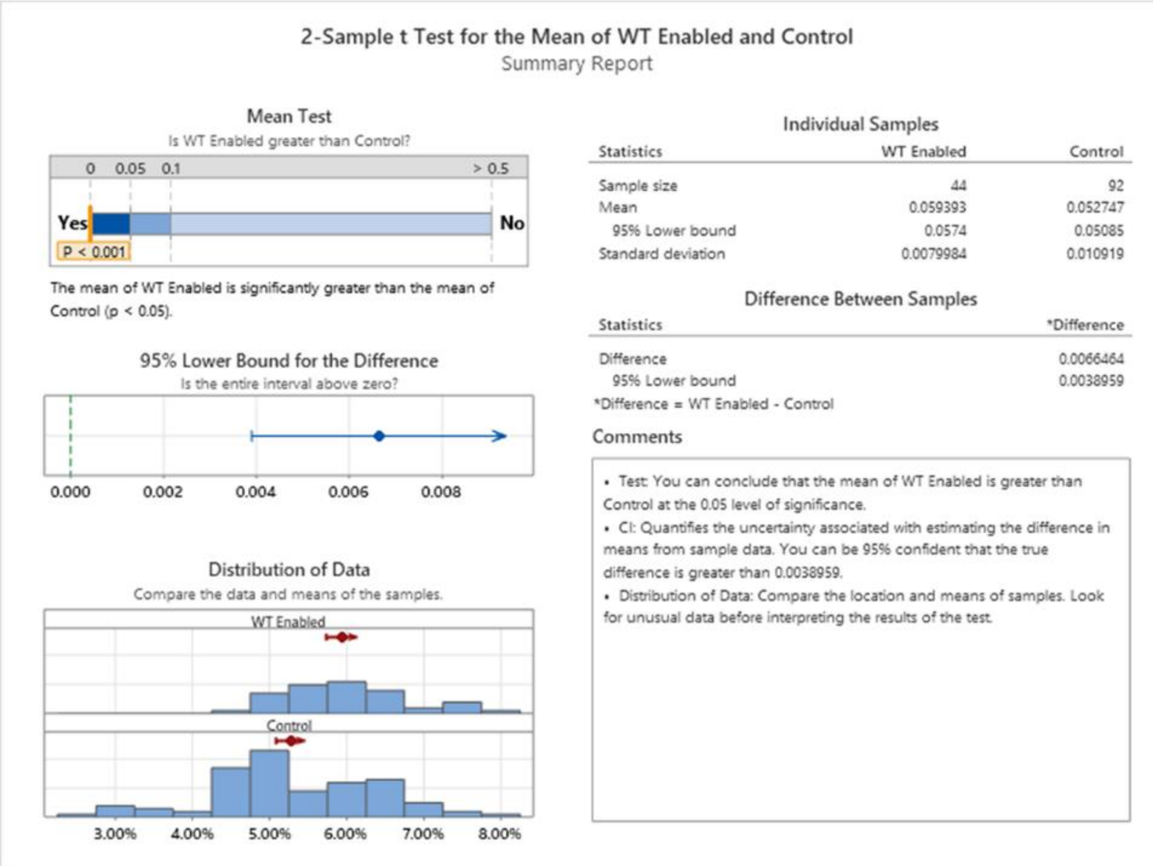


Figure 18: 2-sample t-test comparing mean deceleration of Water-Trak against Control.



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Figure 19 shows the results of a two-sample standard deviation test comparing the variation in the Water-Trak decelerations with the control. The conclusion from this analysis is that the variation in Water-Trak deceleration is significantly lower than that of the control (with at least 98.8% confidence).

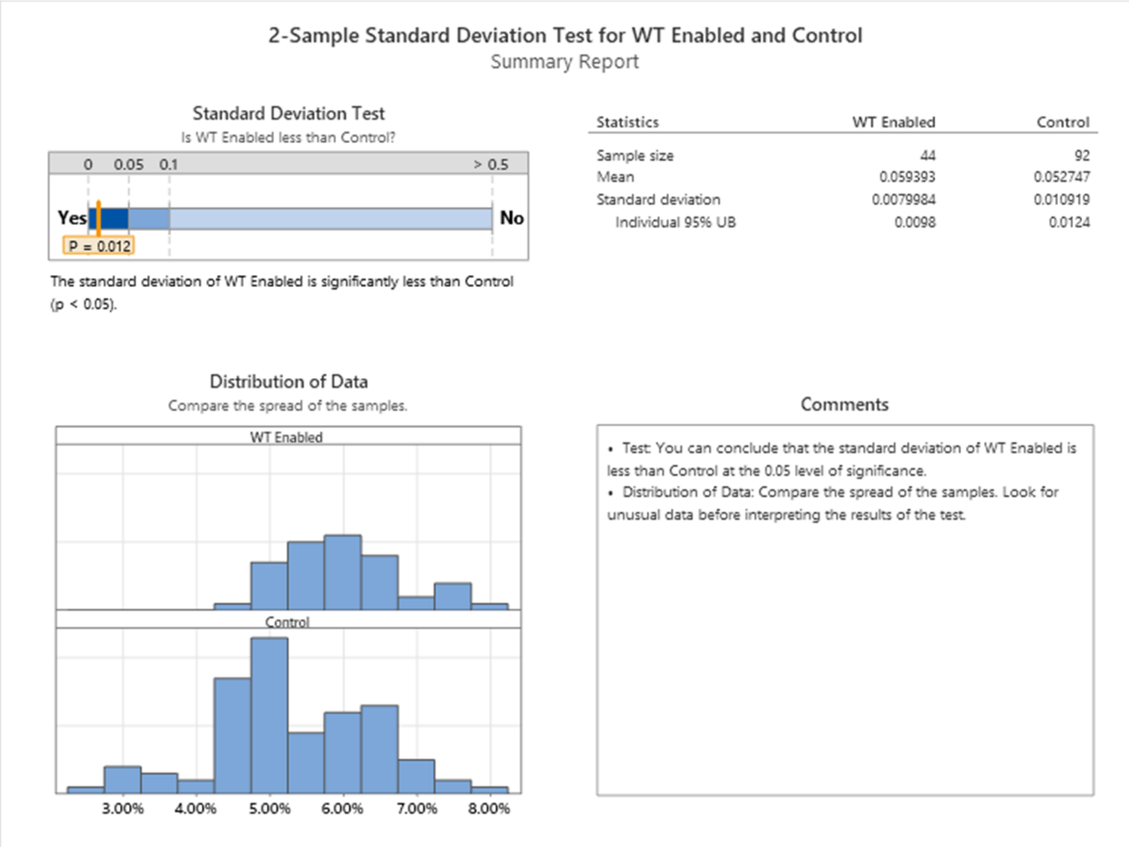


Figure 19: 2-sample standard deviation test comparing Water-Trak with Control

As with the Class 319s, this analysis shows that Water-Trak equipped Class 170s have significantly better braking (higher step 2 deceleration with reduced variation) when compared with the Control.

During autumn it was also noted that Class 170 trains often encountered significant WSP activity even when braking in step 1. Although sanding is not currently enabled for step 1 braking in Class 170s, water delivery is still operational and it was decided that it could be useful to analyse step 1 braking performance.



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Figure 20 shows the individual value deceleration results for step 1 WSP braking manoeuvres uploaded from 170473 during autumn 2022. The control data was derived from OTMR downloads from Class 170 trains and good adhesion data was derived from 170473 braking manoeuvres without WSP during summer.

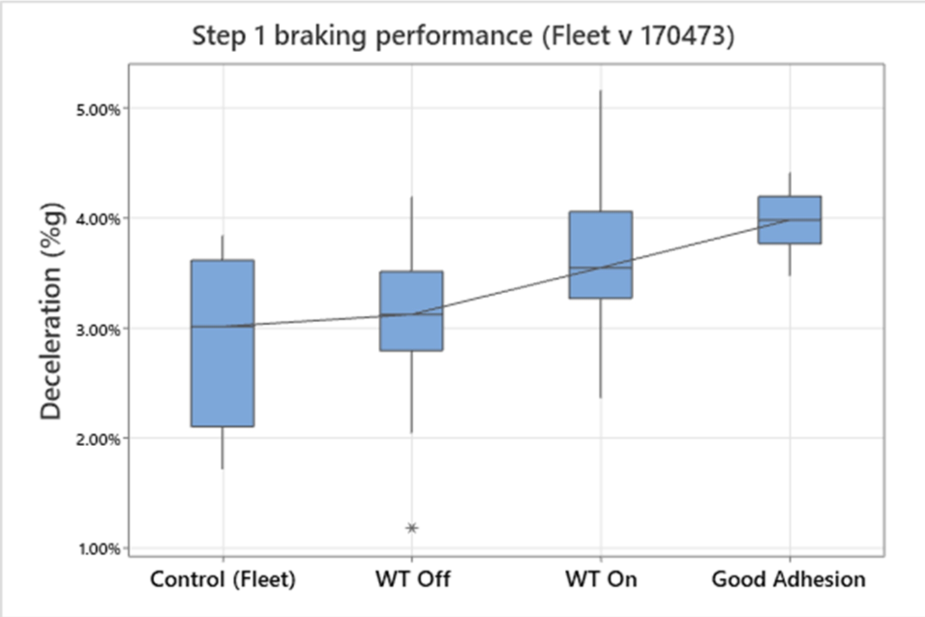


Figure 20: Comparison of 170 fleet and 170743 with Water-Trak off, on and operating in summer.

The graph shows that Water-trak improved step 1 braking deceleration by 0.5%g (from approximately 3%g to 3.5%g). This would equate to a reduction in step 1 stopping distance from 50mph of more than 120 metres. This improvement is delivered without any sand being dispensed.

When comparing the autumn control data with good adhesion data collected earlier in the year a drop in median step 1 deceleration from 4%g or 3%g can be seen. This is an even larger percentage reduction in deceleration than seen in step 2 for Class 170s. This large drop in performance during autumn may be the result of a more sensitive WSP combining with a lack of sanding in step 1.



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Figure 21 shows a two-sample t-test comparing mean step 1 decelerations for Water-Trak enabled and a Control using combined fleet and Water-Trak off data. The analysis indicates that there is a statistically significant increase in mean deceleration (with at least 99.7% confidence).

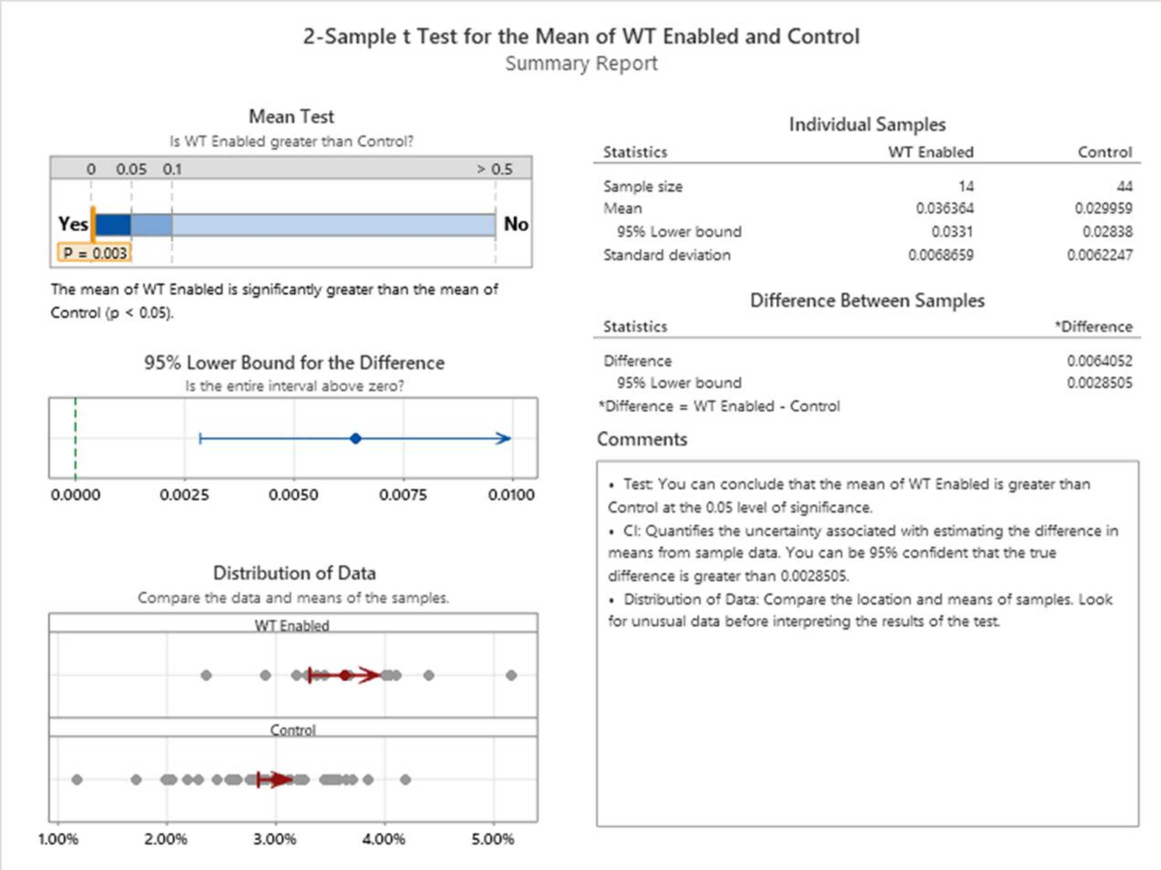


Figure 21: 2 sample t-test comparing Water-Trak step 1 braking with a Control.



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## 5.3 Effect of water addition on traction

### 5.3.1 Traction analysis method

The decision was taken not to enable traction water addition for autumn 2022. It was still considered to be important to find out if Water-Trak might positively or negatively affect traction. To understand the impact of Water-Trak, acceleration rates for departures immediately after a Water-Trak dispense were analysed for Water-Trak equipped Class 319 trains. In the case of Water-Trak data, the acceleration achieved (in units of $m/s^2$) was quantified for all power notch 4 applications of over 10 seconds sub-divided into 10 second segments. This data was compared with 2021 control data, 2021 Water-Trak data with dispensing and against a good adhesion reference.

### 5.3.2 Comparison of traction data

Figure 23 shows a regression analysis using acceleration results for Water-Trak (with and without water), Control trains and a good adhesion reference. Switching off water delivery has resulted in a reduction in autumn acceleration similar to that experienced by non-Water-Trak trains. The analysis suggests that operating Water-Trak for braking alone does not have a negative effect on traction and once again highlights the potential benefit of using Water-Trak for traction.

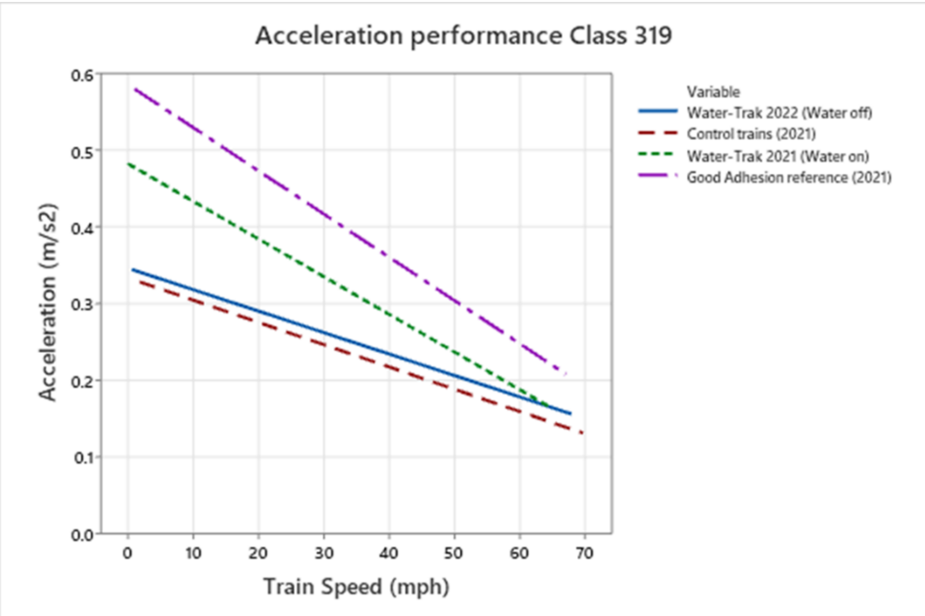


Figure 23: acceleration values for 2022 Water-Trak (water off) vs 2021 results

## 5.4 Impact on journey times

Journey time data is available on the Northern Aegis database and has been used to analyse comparative train performance for Water-Trak trains, Water-Trak following trains and other trains operating on the same sections.



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### 5.4.1 Autumn effect on journey times – Class 319s

Analysis has been conducted on journey time for individual legs on the line of route running from Huyton to Bryn. A comparison was made between Class 319 journey times in Summer and Autumn. Table 2 shows the outputs of this analysis.

| | Huyton-Prescott | Prescott-Eccleston Park | Eccleston Park – Thatto Heath | Thatto Heath-St Helens Central | St Helens Central-Garswood | Garswood-Bryn |
|---|---|---|---|---|---|---|
| Summer Median | 202 secs | 131 secs | 131 secs | 173 secs | 367 secs | 148 secs |
| Autumn Median | 208 secs | 140 secs | 147 secs | 178 secs | 376 secs | 157 secs |
| **% change 2022** (% change 2021) | **+3%** (+1.7%) | **+6.9%** (+5.4%) | **+12.2%** (+7.6%) | **+2.9%** (+2.3%) | **+2.5%** (+1.1%) | **+6.1%** (+3.4%) |
| Summer variation (IQR) | 11 secs | 13 secs | 11 secs | 11 secs | 21 secs | 10 secs |
| Autumn variation (IQR) | 13 secs | 12 secs | 18 secs | 13 secs | 25 secs | 14 secs |
| **% change 2022** (% change 2021) | **+16%** (+8.3%) | **-7.7%** (+18.2%) | **+63.6%** (+63.6%) | **+18.2%** (+40%) | **+16.7%** (+14.3%) | **+40%** (+40%) |

Table 2: Summary of journey times between Huyton and Bryn, percentage change summer vs autumn 2022 (2021 in brackets).

The results in table 2 demonstrate that the impact of autumn is not uniform and they also show that it varies from year to year. It appears that the autumn impact on this route in 2022 (a journey time increase of 9 seconds per leg) is greater than for 2021 (5.5 seconds per leg).

The change in average for the journey legs shown in table 2 between summer and autumn are statistically significant (greater than 95% confidence), however, the level of variation inherent in journey times makes it hard to draw statistically significant conclusions when focusing only on the Water-Trak trains. This is a key consideration when reviewing the following section as Water-Trak journey times are compared with the overall Class 319 fleet.

### 5.4.2 Comparison of Water-Trak vs the fleet – Class 319s

For autumn 2022 in the North-western region, journey time data was collected and analysed for three lines of route – Liverpool Lime Street to Bryn, Newton-Le-Willows to Huyton and Crewe to Wilmslow. Figure 26 shows the stations on the Liverpool Lime Street to Bryn route.

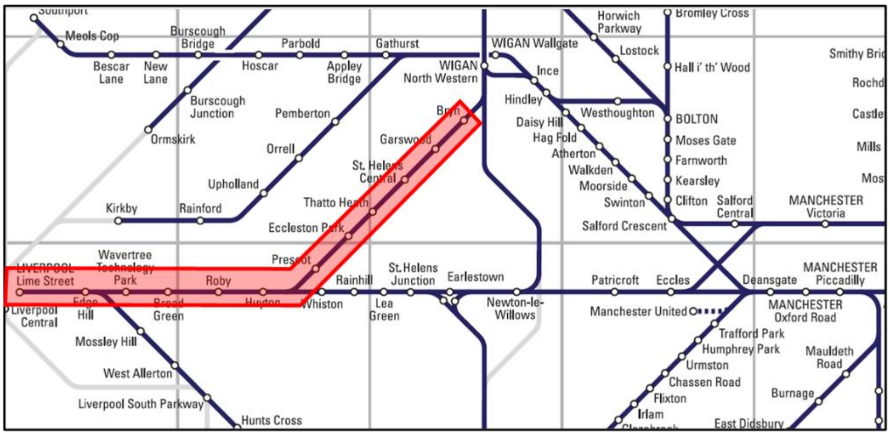


Figure 26: Liverpool Lime Street to Bryn.



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Table 3 shows the journey time differences over the 11 legs of the Liverpool Lime Street to Bryn route. It details the impact of autumn on journey times in terms of seconds lost per leg and the Water-Trak journey time saving. The following train is defined as the first 319 train running within two hours after a Water-Trak train.

| Start | Finish | Autumn impact (secs per leg) | Water-Trak change (secs per leg) | Following train change (secs per leg) |
|---|---|---|---|---|
| Liverpool Lime Street | Bryn | 6.5 | -1.5 | -1.2 |
| Bryn | Liverpool Lime Street | 7.5 | -3.0 | -1.6 |
| | **Average** | **7.0** | **-2.3** | **-1.4** |

Table 3: Comparison of 2022 autumn impact, Water-Trak and following train time savings for the Liverpool Lime Street to Bryn route.

The autumn impact for 2022 for the Liverpool Lime Street to Bryn route is of a similar order to that recorded in table 2 for the shorter section between Huyton and Bryn. In this case, Water-Trak gave an overall journey time saving of 2.3 seconds per leg while the following train also showed a saving of 1.4 seconds per leg.

Figure 27 shows the route between Huyton and Newton-Le-Willows which comprises six journey legs.

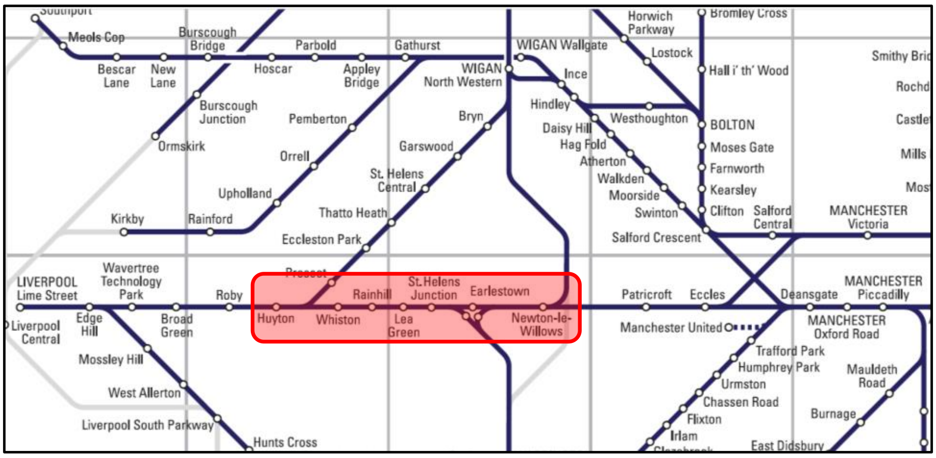


Figure 27: Huyton to Newton-Le-Willows

Table 4 shows the journey time differences for the Huyton to Newton-Le-Willows route. Once again it details the impact of autumn on journey times and shows the journey time savings per leg for Water-Trak and following trains.

| Start | Finish | Autumn impact (secs per leg) | Water-Trak change (secs per leg) | Following train change (secs per leg) |
|---|---|---|---|---|
| Newton-Le-Willows | Huyton | 9.9 | -2.7 | -0.3 |
| Huyton | Newton-Le-Willows | 7.8 | -1.5 | -1.2 |
| | **Average** | **8.8** | **-2.1** | **-0.8** |

Table 4: Comparison of 2022 autumn impact, Water-Trak and following train time savings for the Huyton to Newton-Le-Willows route.



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The autumn impact for this route is slightly higher than for the Liverpool Lime Street to Bryn line but the Water-Trak journey time saving is similar. The saving for following trains is somewhat lower.

Figure 28 shows the route between Crewe and Wilmslow which comprises six journey legs.

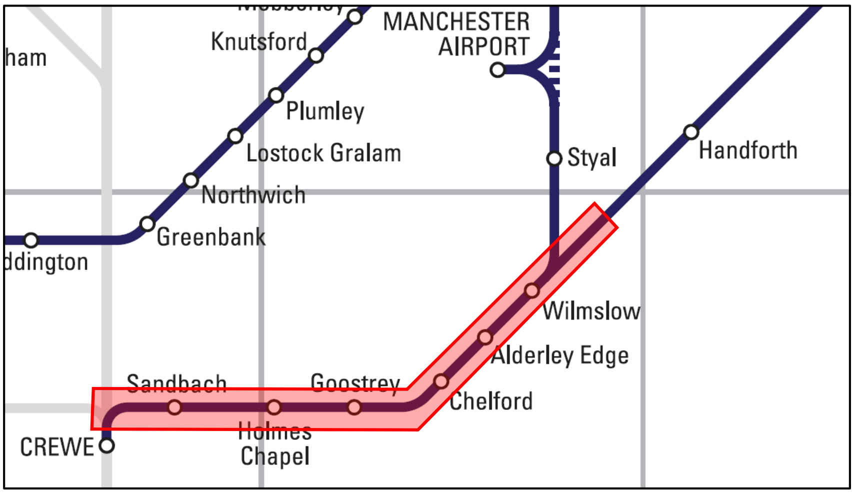


Figure 28: Route between Crewe and Wilmslow

Table 5 shows the journey time differences for the Crewe Wilmslow route.

| Start | Finish | Autumn impact (secs per leg) | Water-Trak change (secs per leg) | Following train change (secs per leg) |
|---|---|---|---|---|
| Crewe | Wilmslow | 9.6 | 2.9 | 0.8 |
| Wilmslow | Crewe | 8.3 | 8.3 | -3.3 |
| | **Average** | **9.0** | **5.6** | **-1.3** |

Table 5: Comparison of 2022 autumn impact, Water-Trak and following train time differences.

The autumn impact for this route is similar to that for the Huyton to Newton-Le-Willows line but in this case, Water-Trak journey time actually take longer. There is still a small following train time saving.

The analysis conducted so far shows that while there is an apparent journey time saving for Water-Trak on some routes, in other cases the journey time for Water-Trak increases. The reasons for these differences are not yet understood and further work is required to uncover the root causes:

- Engagement with drivers from the Liverpool and Manchester Piccadilly depots to understand how their driving confidence is affected by various factors around autumn including Water-Trak operation.
- Analysis of speed-time and speed-distance traces for the fleet vs. Water-Trak to understand where time is being gained or lost.
- Regression analysis to uncover the key factors behind the effect of Water-Trak on journey time.
- Time-based analysis to characterise any learning curve associated with use of Water-Trak.



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### 5.4.3 Comparison of Water-Trak vs the fleet – Class 170s

An initial analysis has been conducted on journey time for individual legs on the line of route running from Hornbeam to Poppleton. A comparison was made between Class 170 journey times in Summer and Autumn. Table 6 shows the outputs of this analysis.

| | Hornbeam - Harrogate | Harrogate - Starbeck | Starbeck – Knaresborough | Knaresborough - Cattal | Cattal - Hammerton | Hammerton - Poppleton |
|---|---|---|---|---|---|---|
| Summer Median | 145 secs | 244 secs | 199 secs | 469 secs | 180 secs | 448 secs |
| Autumn Median | 149 secs | 252 secs | 208 secs | 474 secs | 185 secs | 453 secs |
| **% change 2022** (% change 2021) | **+2.7%** (-1.3%) | **+3.3%** (+1.6%) | **+4.5%** (+0%) | **+1.1%** (+0.6%) | **+2.8%** (+3.3%) | **+1.1%** (+0.2%) |
| Summer variation (IQR) | 13 secs | 22 secs | 14 secs | 16 secs | 24 secs | 18 secs |
| Autumn variation (IQR) | 16 secs | 26 secs | 22 secs | 21 secs | 25 secs | 23 secs |
| **% change 2022** (% change 2021) | **+23.0%** (+11.1%) | **+18.2%** (+45.0%) | **+57.1%** (+81.8%) | **+31.2%** (+29.4%) | **+0.4%** (+50.0%) | **+27.7%** (+38.9%) |

Table 6: Summary of journey times between Hornbeam and Poppleton, percentage change summer vs autumn 2022 (2021 in brackets).

The results in table 6 demonstrate that the impact of autumn is not uniform across journey legs and varies significantly from year to year. It appears that the autumn impact on this route in 2022 (a journey time increase of 6 seconds per leg) is far greater than for 2021 (one seconds per leg). Although there is a smaller summer-autumn difference in median journey times, there is still a marked increase in variation of autumn journey time compared with summer.

While some journey times with Water-Trak were shorter, there were also several journeys which took longer. The small number of Class 170 Water-Trak journeys conducted in 2022 means it is hard to draw any meaningful conclusions from this data. Leading up to and during autumn 2023, further activities are planned to provide a clearer picture of journey time improvements due to fitment of Water-Trak across the fleet:

- Building drivers' awareness of and confidence in Water-Trak to ensure that they can exploit the benefits of improved water-assisted braking during autumn operation.
- Collection of Class 170 journey time data from previous autumns to establish a robust benchmark of historical autumn performance.

## 5.5 Punctuality

Whilst the journey time analysis in section 5.4 suggest that Water-Trak may provide benefits in delay reduction for train operating companies, it also raised the possibility that reduced journey time variation could lead to an enhanced passenger experience through improved punctuality. To explore the impact of Water-Trak, it was decided to create a model of a line of route, based on real journey time data which could be used to simulate multiple journeys between Bryn and Liverpool Lime Street.



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### 5.5.1 Analysis method

The analysis used the journey time data for the non-Water-Trak Class 319 fleet (operating both in summer and in autumn), the autumn Water-Trak trains and the following trains. This data was collected for each journey leg running between Bryn and Liverpool Lime Street. Each set of data was characterised using Weibull curve fitting, and 10,000 data points were generated for each journey leg using the resulting distributions. The journey timings over the entire route were calculated by adding this data together and the resulting information was used to provide an indication the punctuality of the different trains. Figure 29 shows the metrics resulting from this modelling. The figures used are percentage "On Time" (trains arriving within 1 minute of timetabled arrival time for journeys over single and combined legs) and percentage T-3 minutes (those trains arriving within 3 minutes of timetabled arrival time). The graph shows that both punctuality metrics improve not only for Water-Trak trains, but also for the trains following Water-Trak.

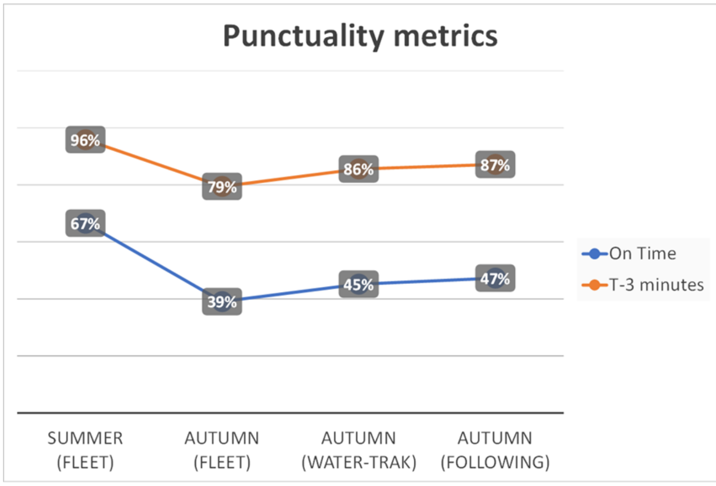


Figure 29: Punctuality metrics comparison

# 6 SUMMARY

## 6.1 Conclusions

- There is now conclusive proof that Water-Trak consistently improves braking in all brake steps across two train classes, two regions and through two autumns.
- Analysis of the traction data so far has shown no negative impact due to Water-Trak operating during braking.
- There is evidence of shorter journey times on some lines of route for Water-Trak trains and following trains.
- Water-Trak and following trains appear to have a lower level of journey time variation, leading to an initial indication of improved punctuality.
- Although they survived Storm Arwen in autumn 2021, the Class 319 Water-Trak systems have suffered damage due to freezing during autumn 2022. The Class 170 Water-Trak systems appeared to have survived similar conditions.
- In contrast to 2021, the autumn 2022 results showed no significant difference between braking performance of 319368 and 319379. This may have been due to improved operation of the sanding systems on 319379.
- Unlike 2021, there was no significant air temperature effect seen in 2022 braking performance.

## 6.2 Next steps

- Complete Water-Trak fitment to the Northern Class 170 fleet. Fleet fitment will build driver confidence and enable the effect of multiple deployments of water on the same lines of route to be assessed.
- Engage with Northern drivers ahead of autumn 2023. Driving style is likely to be a key enabler for improved journey times and reduced delays.
- Specify reduced water dispense times to reduce the risk of the Class 170 systems running out of water.
- Consider reintroducing water addition for traction in combination with reduced dispense time on the two Water-Trak-equipped Class 319s.
- Consider incorporating some simple modifications to protect the vulnerable elements of the Class 319 water system from freezing or ensure parts are available for repair of any damage.
- Recruit a Northern analyst to provide independent verification of the operational benefits of Water-Trak.
- Ensure telemetry is available from the Northern Class 170 fleet ahead of autumn 2023.



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