Queensferry Crossing - Ice Accretion Issues

Technical Presentation to MSPs
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Technical Presentation Contents

- History of the design
- Ice accretion at QC – what's actually happening?
- Ice Problems at other bridges
- Timeline at Queensferry Crossing
- Short term Plan
- Medium term Plan
- Future Plans

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History of
the Design
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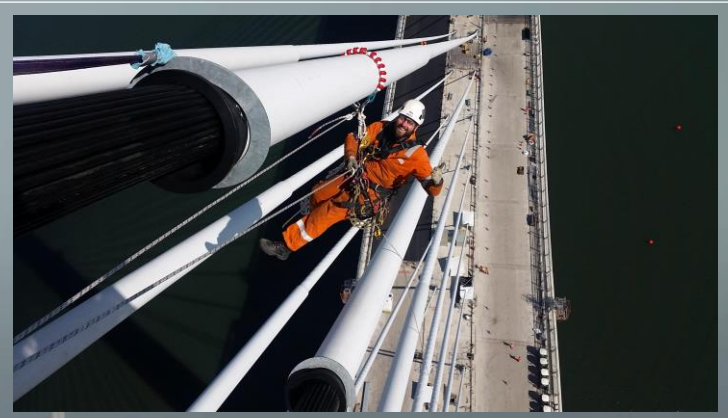
Ice Accretion:

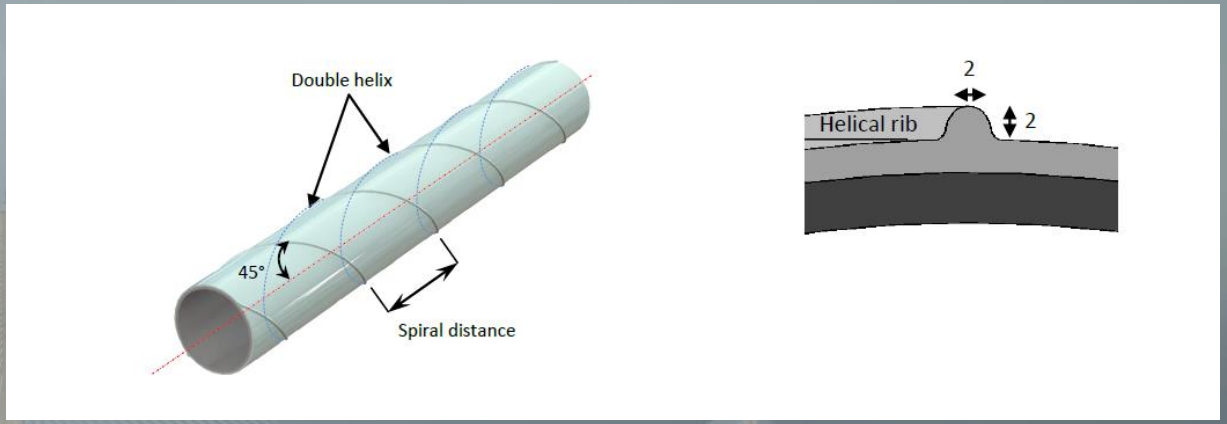
identification and management of the risk during the design process

- Identification of risk:
  - Ice falling on traffic.
  - Impact on dynamic performance.
- Impact on option selection.
- International best practice.
  - Low risk in UK.
  - No solution available that avoided road closure.
- Residual risks highlighted to operator.



Stay Cables

- 205m high towers
- 288 individual stay cables
- Outer diameter: 200mm to 315mm.
- Approx. combined length of cables 75km.
- Approx. combined surface area of cables 60,000m^2.
- Surface of the stay pipe designed to shed water and minimise rain induced oscillations.



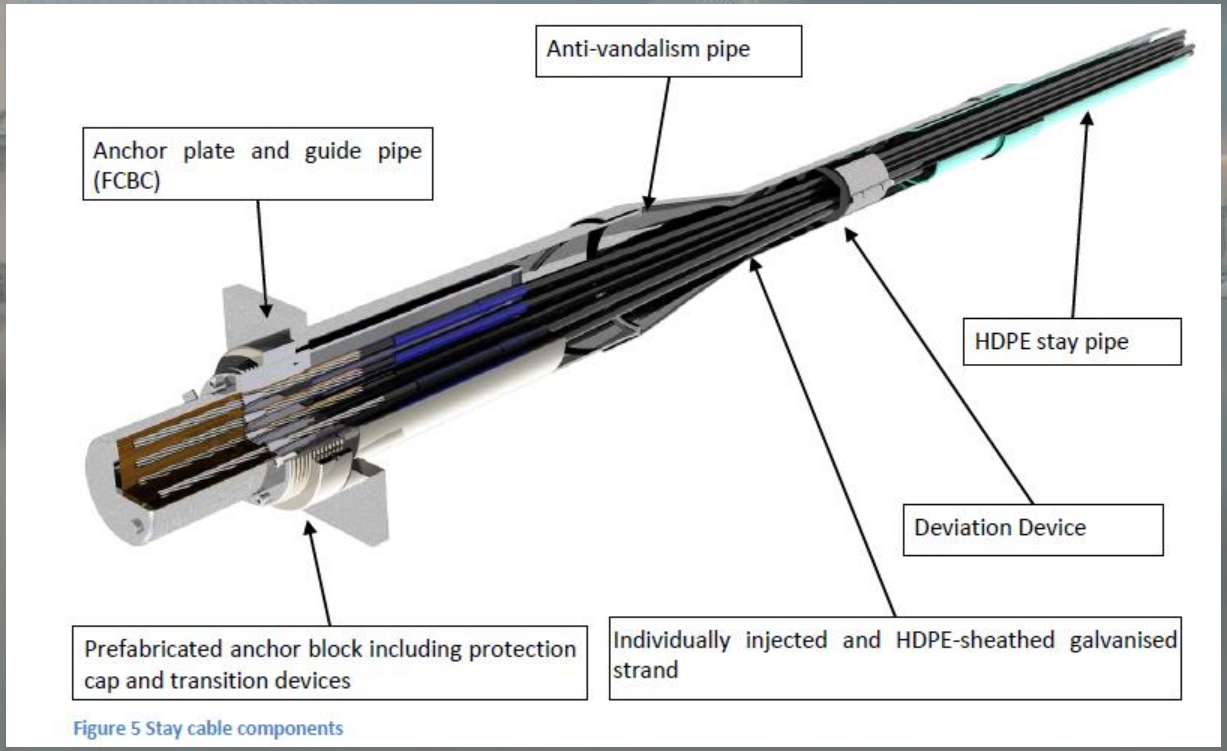


Figure 5 Stay cable components

Ice Accretion at QC – What's Actually Happening?

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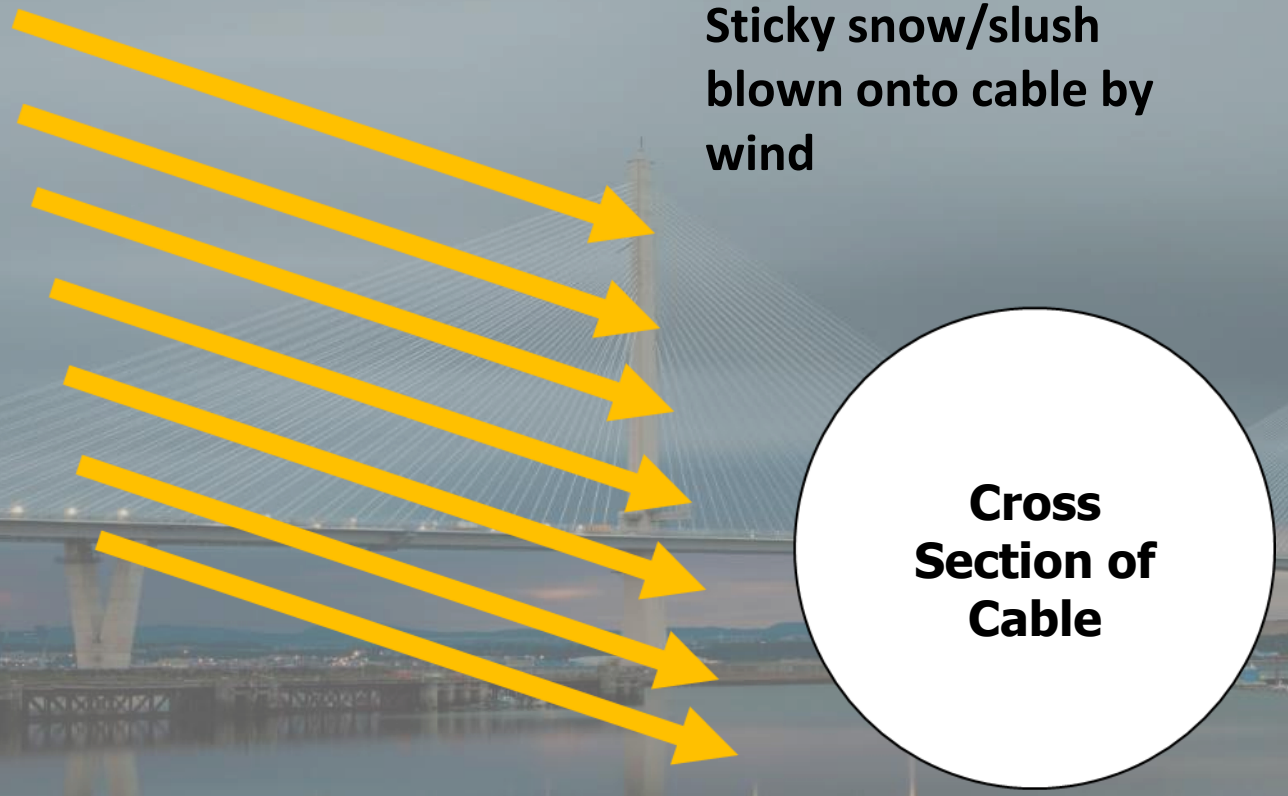
Ice Accretion at QC – What's Actually Happening

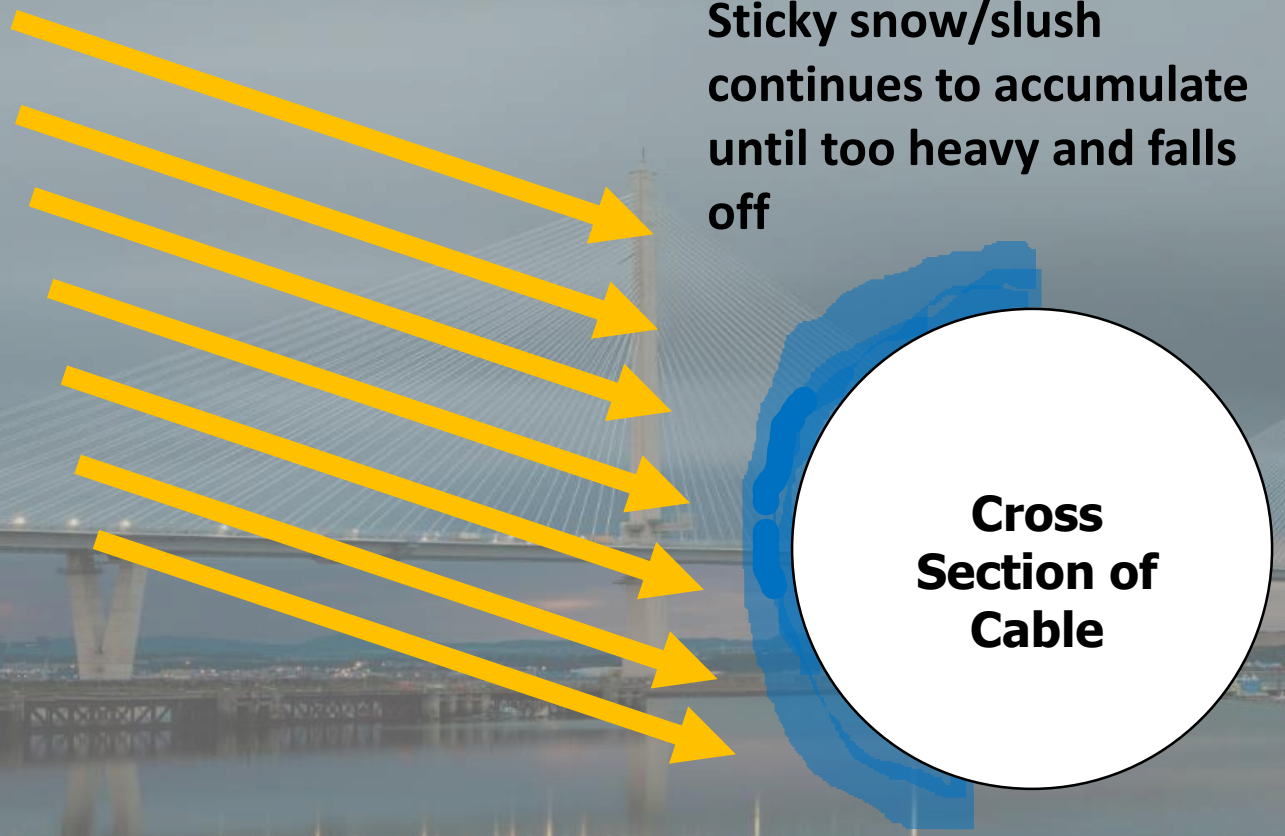


Ice Accretion at QC – What's Actually Happening

Sticky snow/slush sticks to face of cable, and begins to accumulate

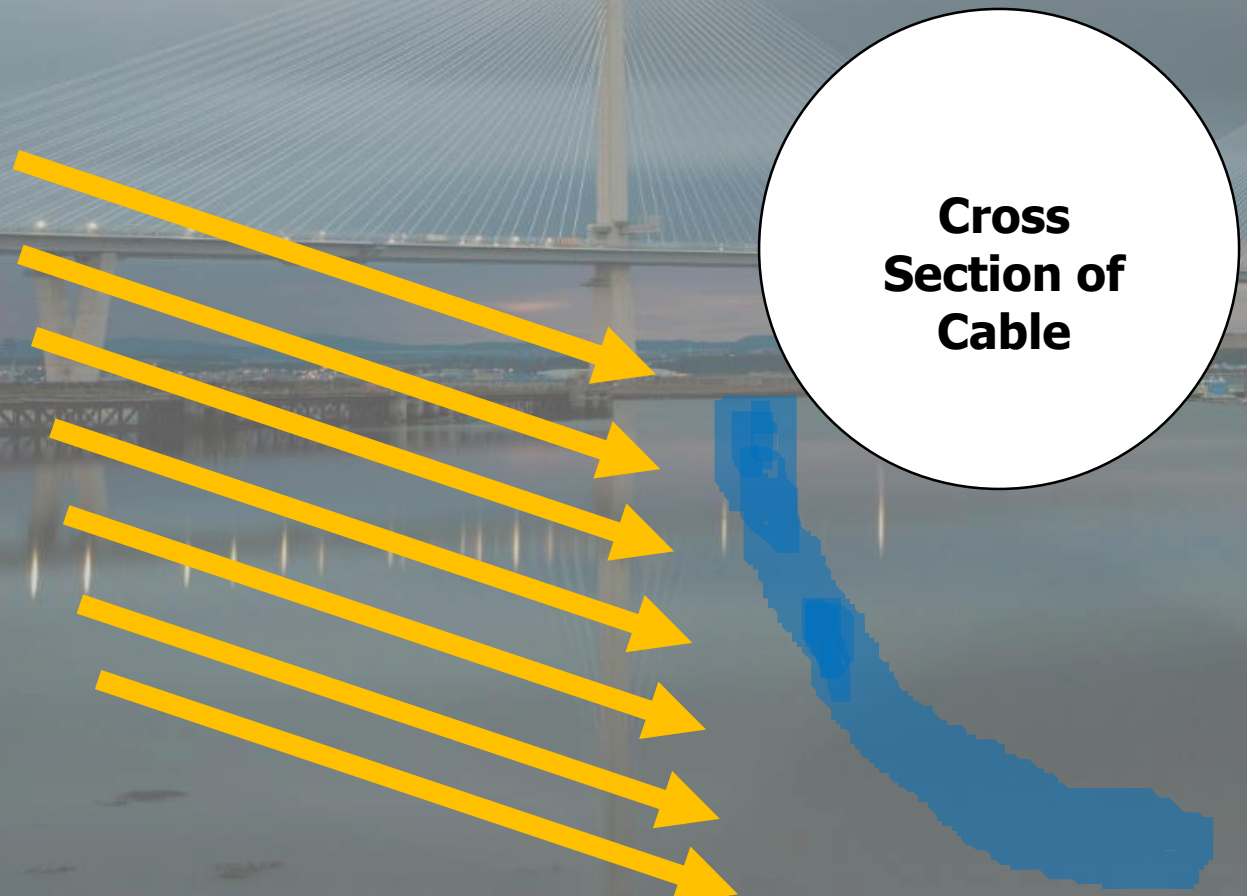
Cross Section of Cable

Ice Accretion at QC – What's Actually Happening



Ice Accretion at QC – What's Actually Happening

15 Minute Cycle from Accretion to Falling



Loose chunks of frozen snow/slush immediately picked up by the wind and carried onto carriageway below (or into sea)

Ice Accretion at QC – Apparent Key Parameters

Key Parameters Observed as Affecting Ice Accretion For use in Operational Decision Matrix
Wind speed and direction
Air temperature
Dew point temperature
Relative Humidity
Surface temperature (cables or towers)

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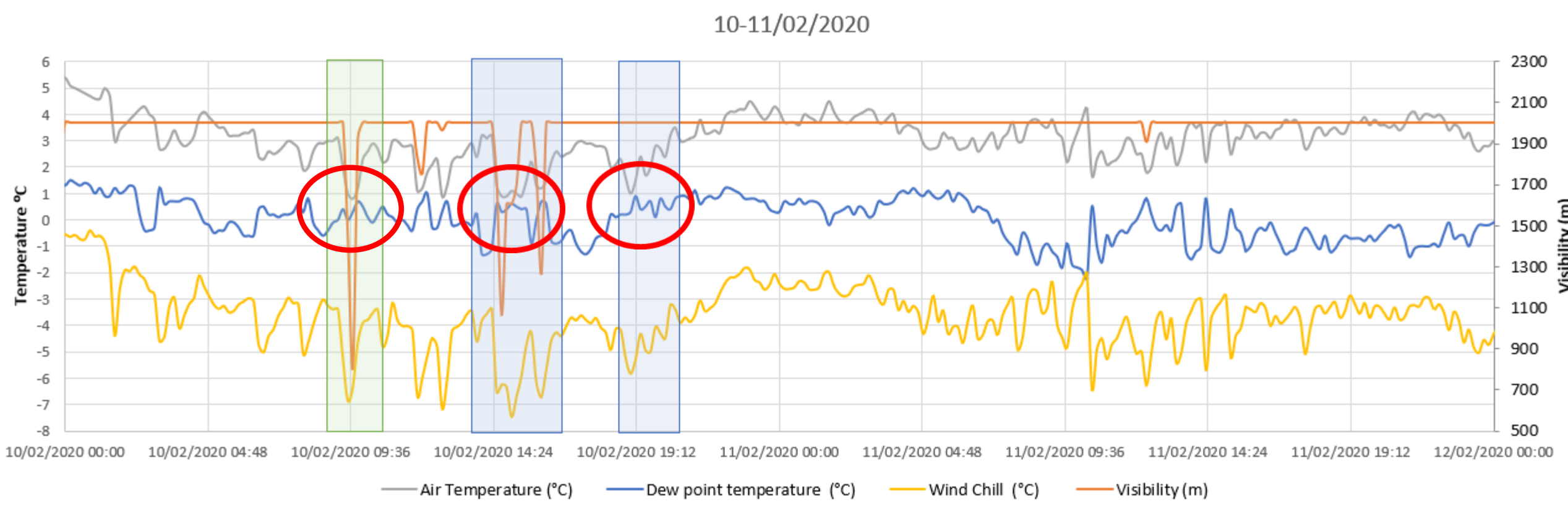
Ice Accretion at QC – What's Actually Happening

- Blue shaded area two recorded incidences of ice accumulating and falling on Monday 10th
- Green shaded area, similar conditions, snowing heavily, but no recorded incidence of ice on Monday 10th
- Air temperature and dew point temperature converge between 0.5 and 1°C
- 11/02/2020 no recorded ice accretion – similar convergence not present



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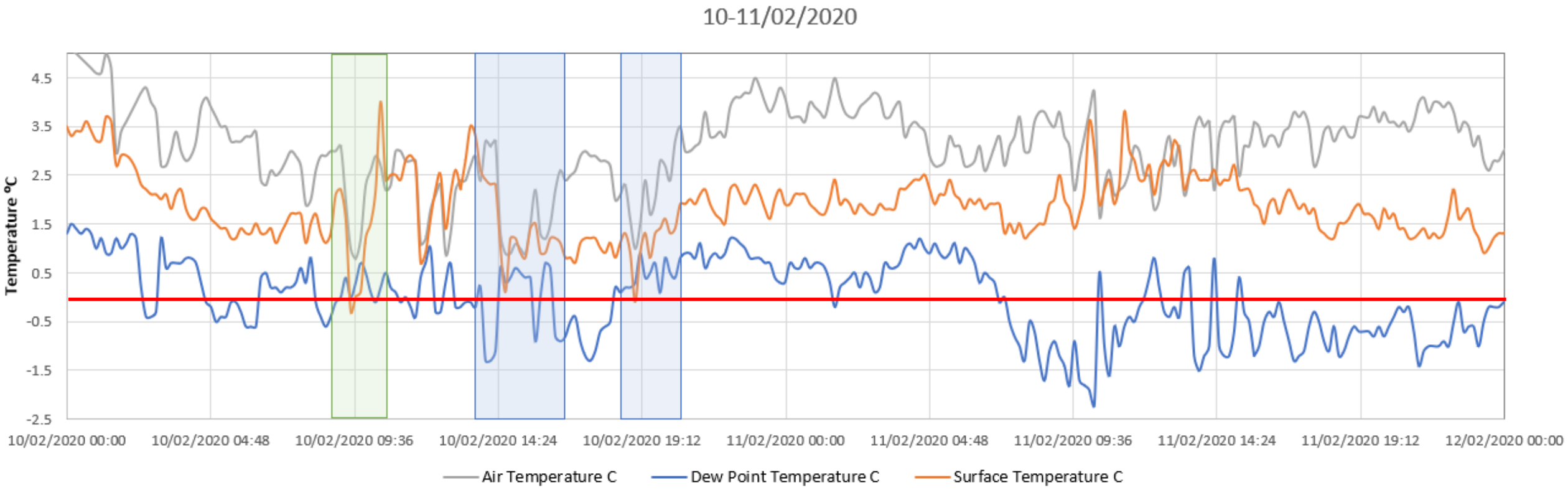
Ice Accretion at QC – What's Actually Happening

- 11/02/2020 - Air temperature and Road surface temperature remained higher than Monday



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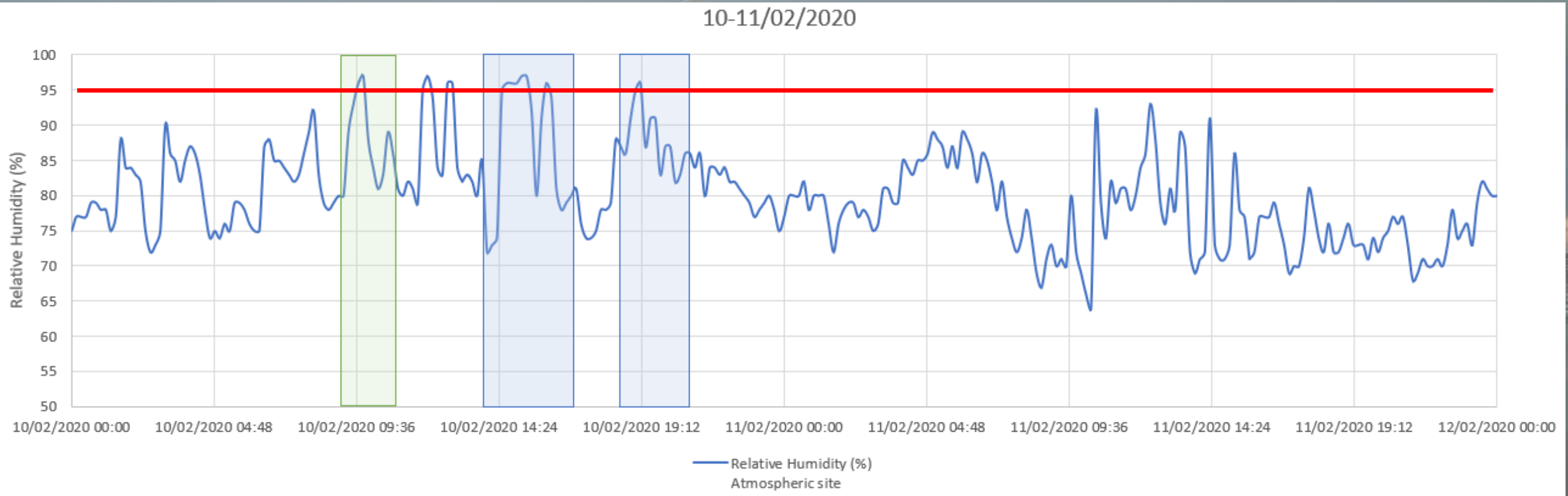
Ice Accretion at QC – What's Actually Happening

- Relative humidity reached 95% on 10/02/2020 but didn't reach 95% on the 11/02/2020



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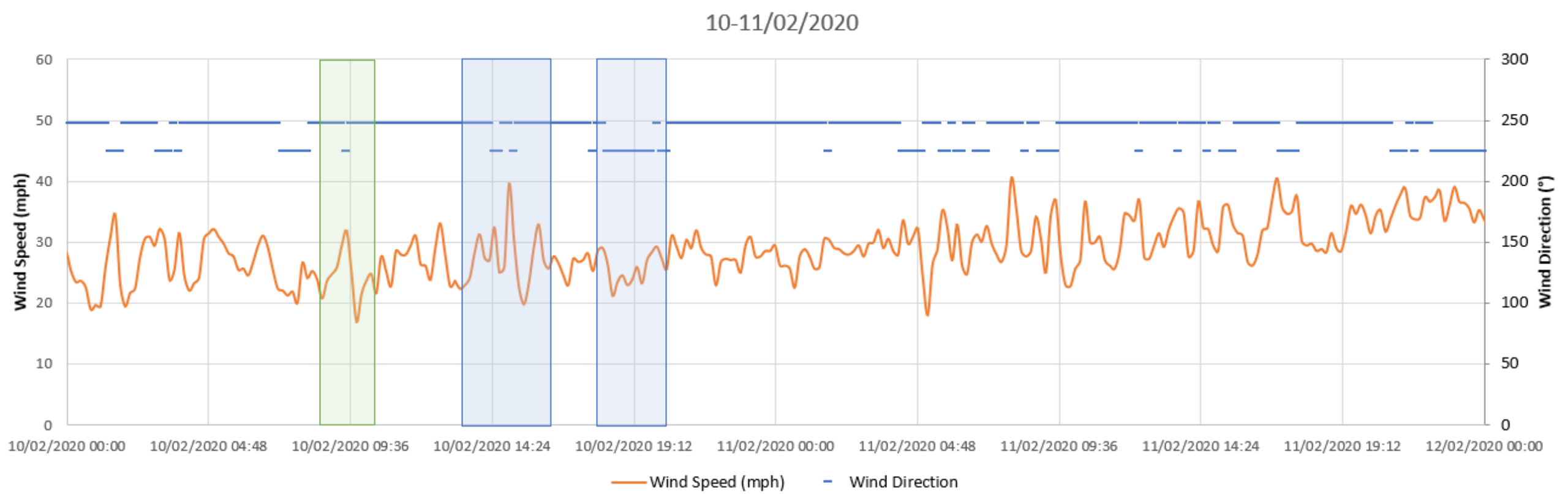
Ice Accretion at QC – What's Actually Happening

- Wind speed high but consistent



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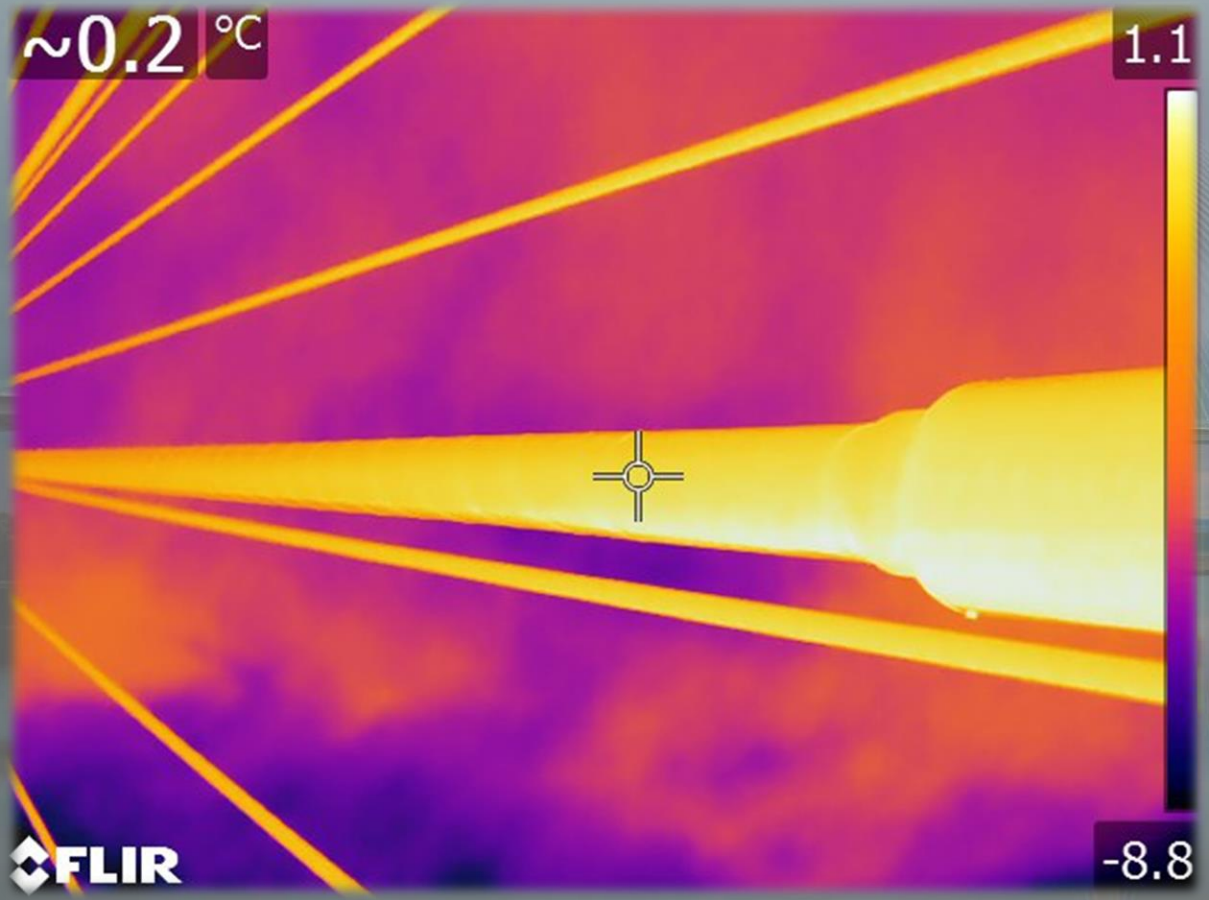
Ice Accretion at QC – What's Actually Happening

- Surface Temperatures Measured by Thermal Imaging Camera



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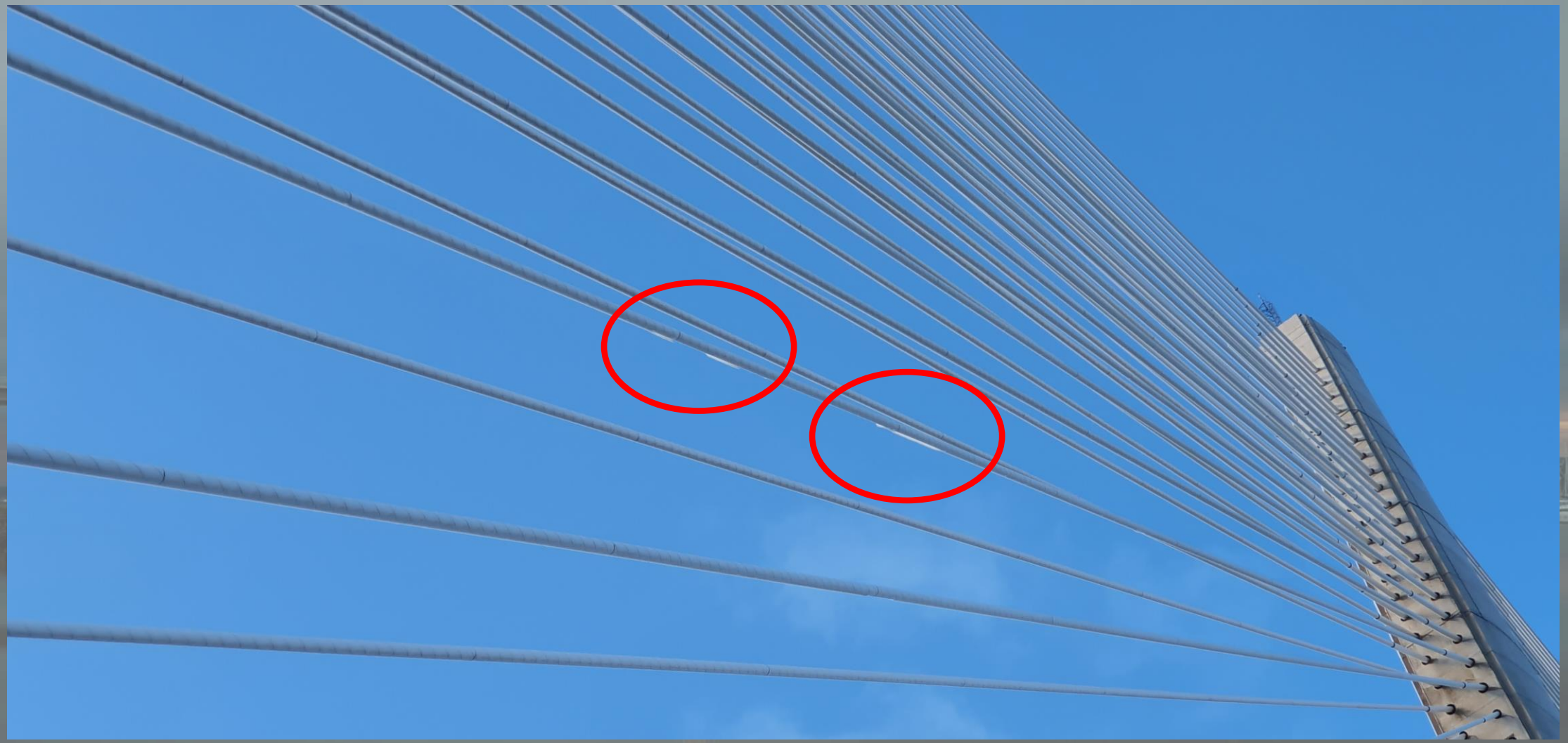

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Ice Accretion at QC – What's Actually Happening

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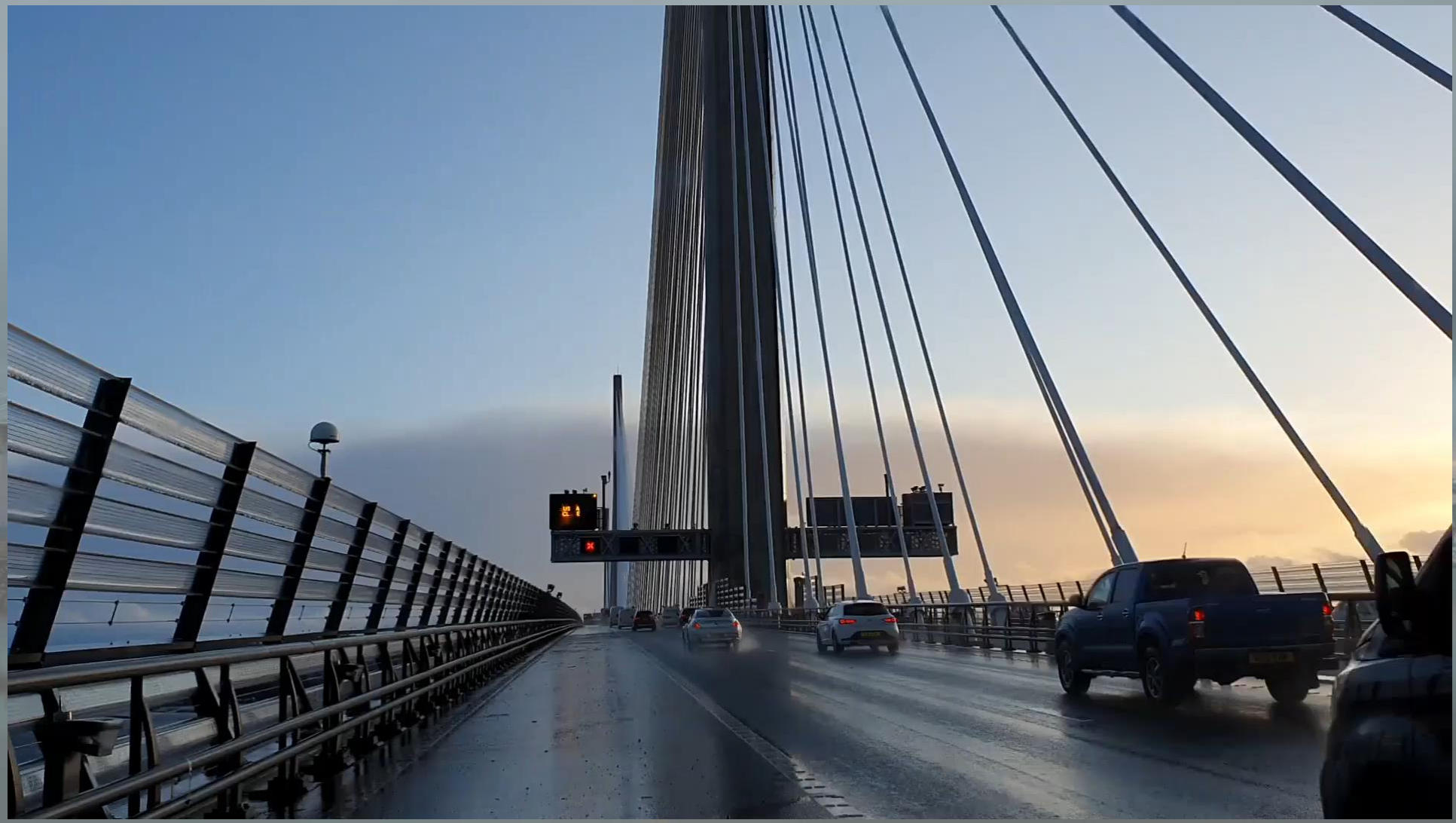

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Ice Accretion at QC – What's Actually Happening

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Ice Accretion at QC – What's Actually Happening

- Ice also accumulates and falls from concrete tower faces and grooves

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Ice Problems
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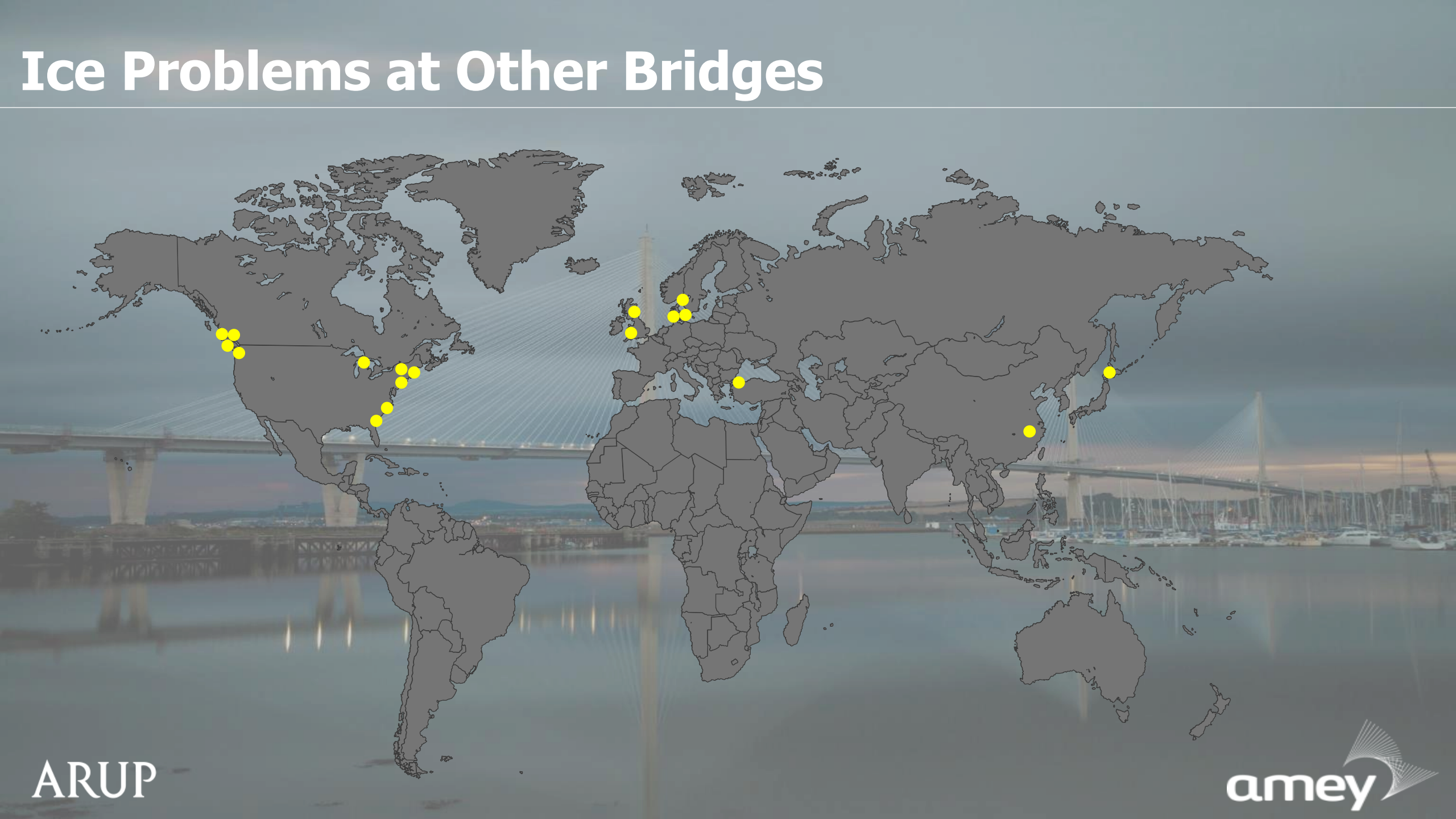
Ice Problems at Other Bridges



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Ice Problems at Other Bridges

Bridge		Frequency of Ice Problems	Operator Response	Mitigation Strategy
Great Belt, Denmark		Closed 6 times since 2006. Closure duration 2-21 hours (average 7 hours)	Close bridge and wait for ice to fall or melt	Prediction algorithm based on weather forecast
Oresund, Denmark /Sweden		Closed 5 times since 2007. Closure duration 2-7 hours	Close bridge and wait for ice to fall or melt	Prediction algorithm based on weather forecast Various prevention and removal methods tried
Uddevalla, Sweden		Closed at least 12 times since opening in 2000.	Close bridge and wait for ice to fall or melt	Prediction algorithm based on weather forecast
Port Mann, Canada		Significant problem ongoing. Multiple incidents of damage to vehicles are commonplace. Most recent 10 January 2020.	Collar system for mechanical removal whilst bridge closed. Requires rope access technicians to operate	Reliance on collar system and prediction system. This is not preventing damage
Prince of Wales, UK		2 Incidents in 2009. Damage to vehicles and bridge closed	Close bridge and wait for ice to fall or melt	Augment monitoring system to help forewarn

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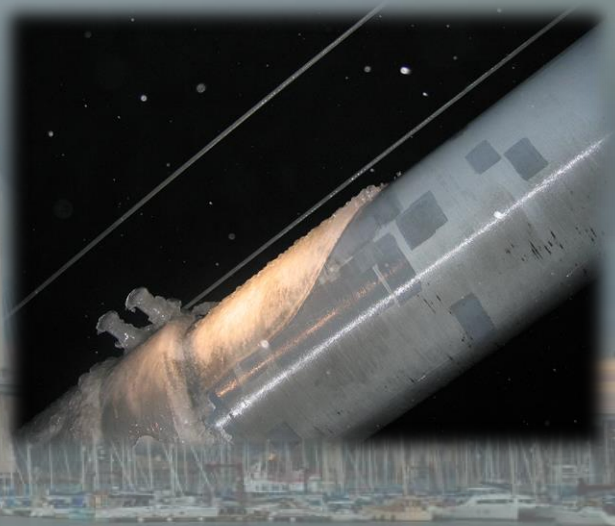
Ice Problems at Other Bridges

- Oresund & Storebaelt Crossings – Examples of Ice Accretion - This is typical of other bridges
- Queensferry Crossing issues thus far are very different to this



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Ice Problems at Other Bridges – Lessons

- Good experience of the issue in worldwide bridge community (ICSBOA) and willingness to share and assist
- Common practice to use predictive algorithms and sensors – these warn but do not prevent
- No entirely successful solution found for prevention or removal
- Common practice to close the bridge until ice has dissipated or risk reduced
- Visual patrols and inspections considered more effective than other methods tried

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Timeline at
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Timeline at Queensferry Crossing

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Short Term
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Short Term Plan (now until end of winter 2019/20)

Implement 5 Point Plan following receipt of forecast information with "wintry showers/Sleet/Snow/wet snow" in the forecaster text:

1. Enhanced Patrols (24/7 during weather conditions potentially conducive to ice formation)
2. Heightened focus on prevailing weather conditions (24/7 during weather conditions potentially conducive to ice formation)
3. Increased Data Gathering & intelligence from site observations (defining the trigger points / decision matrix) and continue work to identify viable mitigation options
4. Pre-mobilised / pre-positioned Traffic Management
5. Enhanced stakeholder comms – Rail, Bus, Local Authority

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Medium Term Plan (Winter 2020/2021)

Short Term Plan Activities Continue plus the following additional activities:

6. Use of FRB as emergency diversion route (implications for public transport corridor, network improvements to links, traffic modelling, major works completion, etc)
7. Data from sensors (including new ice and precipitation sensors and any others needed) used to assist in early detection and provide automated alerts in conjunction with forecast
8. Further refinement / definition of decision matrix as data set expands
9. Continue to develop viable mitigation options and initiate R&D activity with specialist testing organisation to appraise options / full scale testing (also consideration of load effect, dynamic effect, local & global action etc on bridge)

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Future
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Future Plans (Winter 2021 onwards)

Medium Term Plan Activities Continue plus the following additional activities:

10. Implementation of appropriate viable mitigation solution based on outcome from Research & Development Activities

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Thank you
Any Questions?
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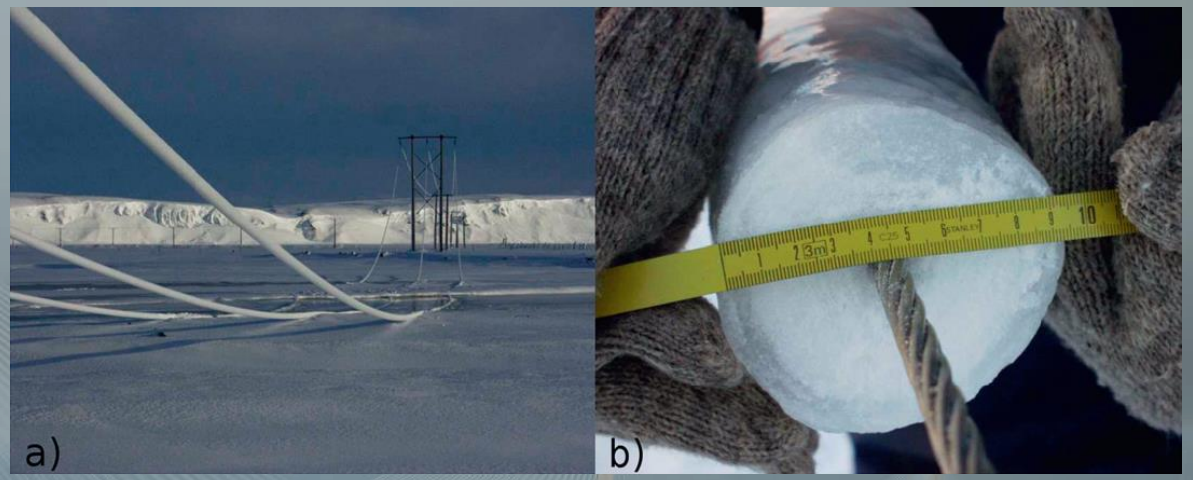
Ice Accretion Theory – icing mechanisms

- Ice formation mechanisms are either "in-cloud" or "precipitation"
- Aviation industry primarily concerned with “in-cloud” icing.
- Precipitation icing due to wet snow is primary risk for structural icing in UK

Wet snow icing on power cables.



Ground level in-cloud icing – very rare.

Freezing rain

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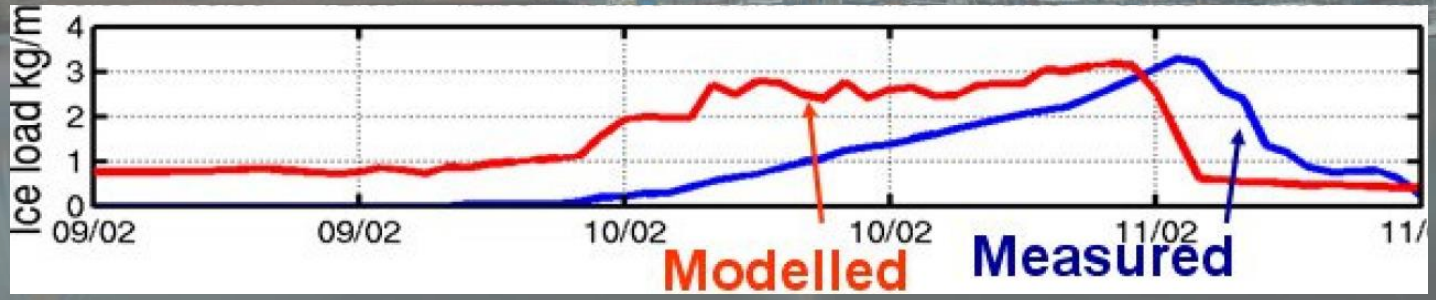
Ice Accretion Theory – ice accretion models

- Predictive models developed through COST Action 727
- Simple calculation method but relies on meteorological parameters that are hard to measure/forecast
- Wet snow accretion is high risk when temperatures are just above freezing and snow is around 75% ice

Table 1: Conditions associated with precipitation ice accretion (adapted from ISO 12494)

Type of ice	Dry bulb air temperature (°C)		Water content in air	Typical storm duration
	min	max		
Wet snow	0	3	Partially melted snow (approx. 75-95% ice)	hours
Glaze	-10	0	Freezing rain or drizzle	hours
Rime	-20	0	Low lying cloud with supercooled droplets	days



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Ice Accretion Theory – forecasting

- Input from US National Centre for Atmospheric Research on COST Action 727 - encouraging results with next generation precipitation model
- No Met Office models provide this information
- Equivalent data may be available from European Centre for Medium Range Weather Forecasting (based in UK).

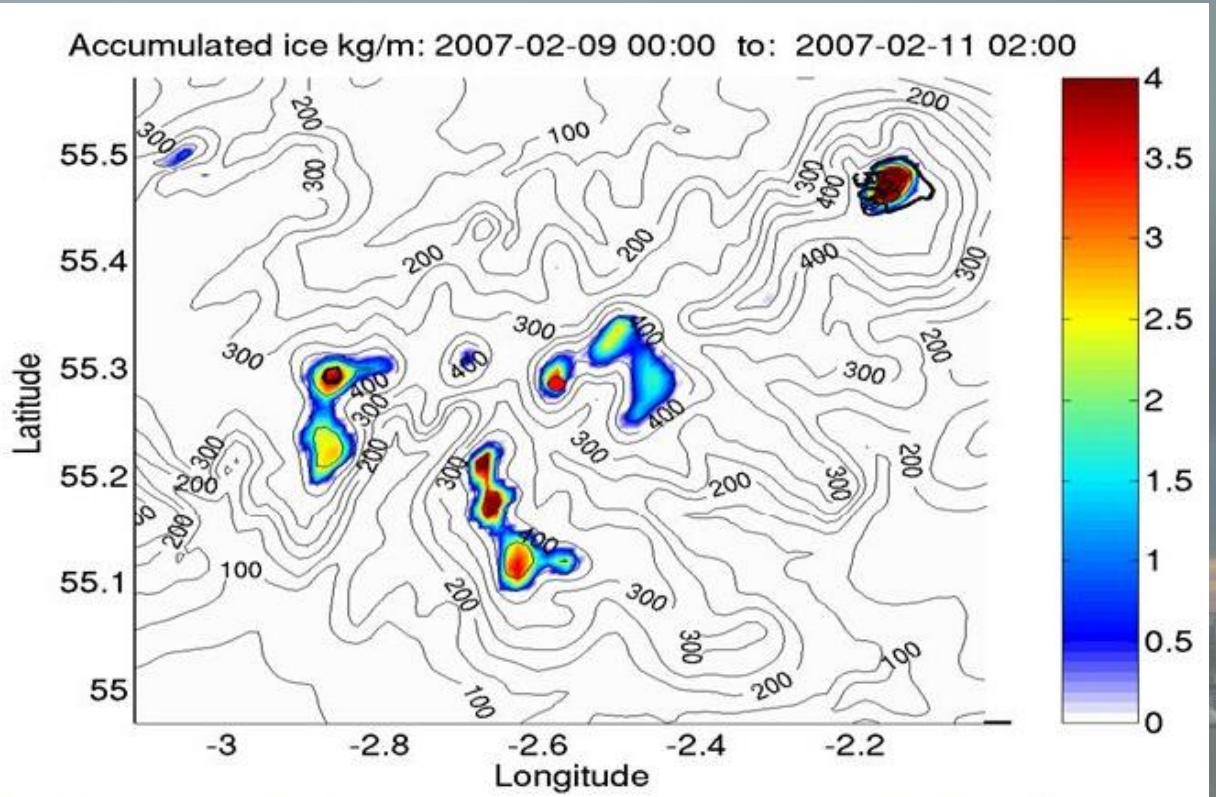

Fig. 3 Accumulated ice load data according to geographical location. Area shown is Scottish Borders with Deadwater Fell at 55.3 Latitude and -2.6 Longitude.

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