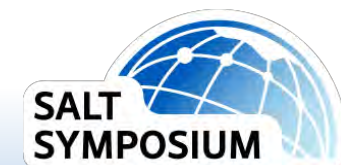


# Chris Passmore

Flodraulics Controls, Ltd.

## Morning Speaker August 2

*Utilizing On-Truck Weather Stations to  
Recommend Application Rates*



# City of Guelph Pilot Study

## Flodraulic Controls

August 2, 2023

UNIVERSITY  
of GUELPH

IMPROVE LIFE.



# Outline

1. Research Objectives
2. Literature Review
3. Pilot Study Preliminary Results
4. Next Steps



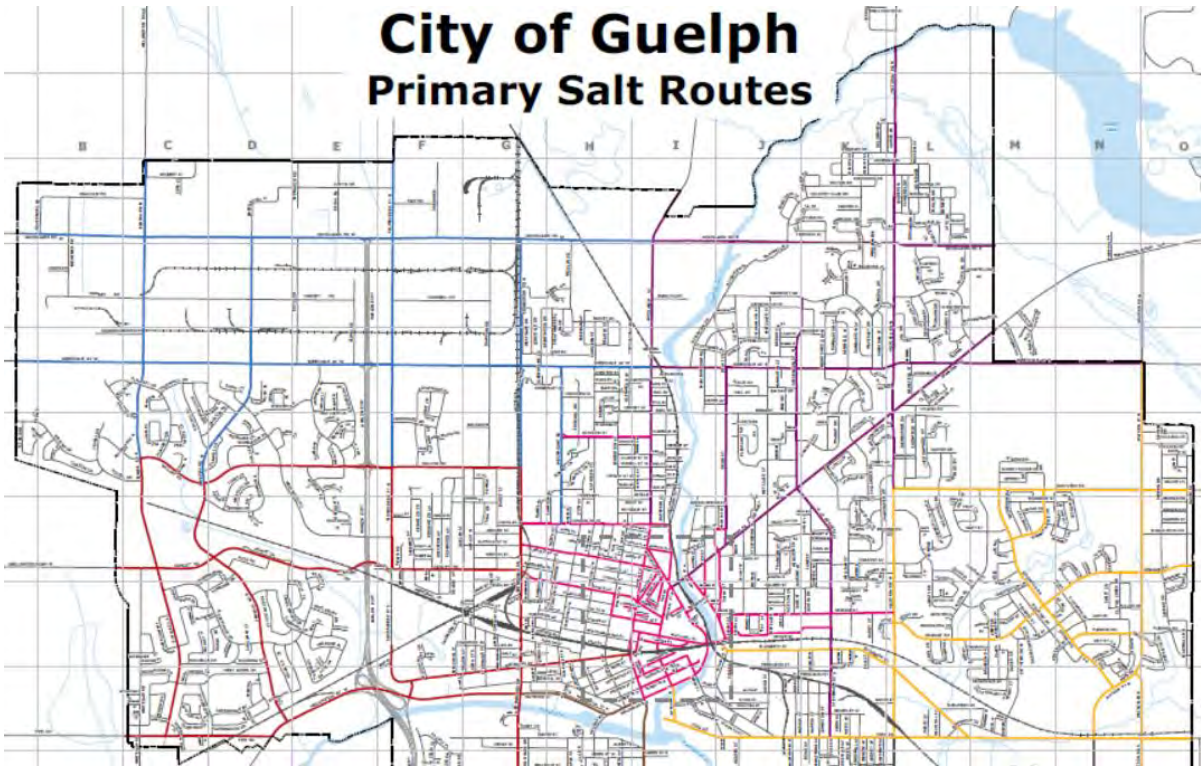
# Objectives of the Pilot Study

This study aim to develop the next generation of smart salt trucks. These trucks will have more advanced control systems for the application of the optimum combination of the brine and rock salt to achieve the desired road safety with less adverse environmental effects on the mapped salt vulnerable areas (***Precision Salt Application***).

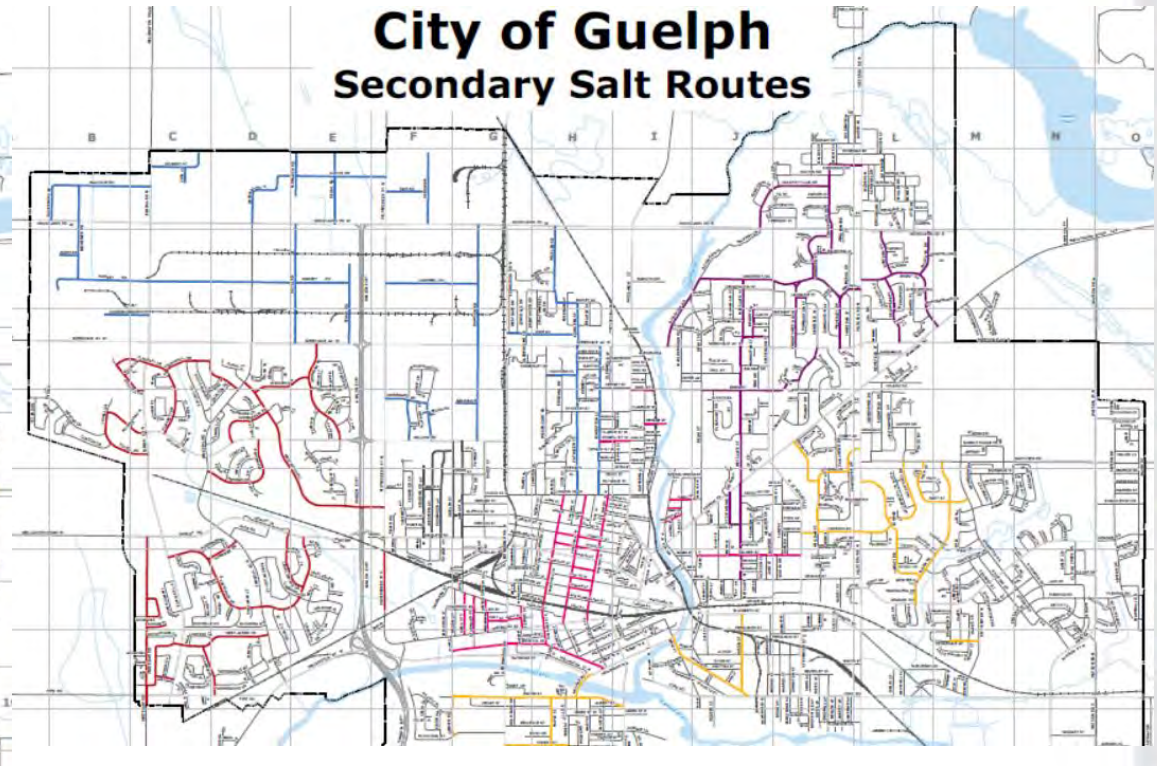


# Case Study Salt Routes

**City of Guelph  
Primary Salt Routes**



**City of Guelph  
Secondary Salt Routes**



Biological



Biomedical



Computer



Systems and Computing



Water Resources



Mechanical



Environmental

# Road Classes & Levels of Service



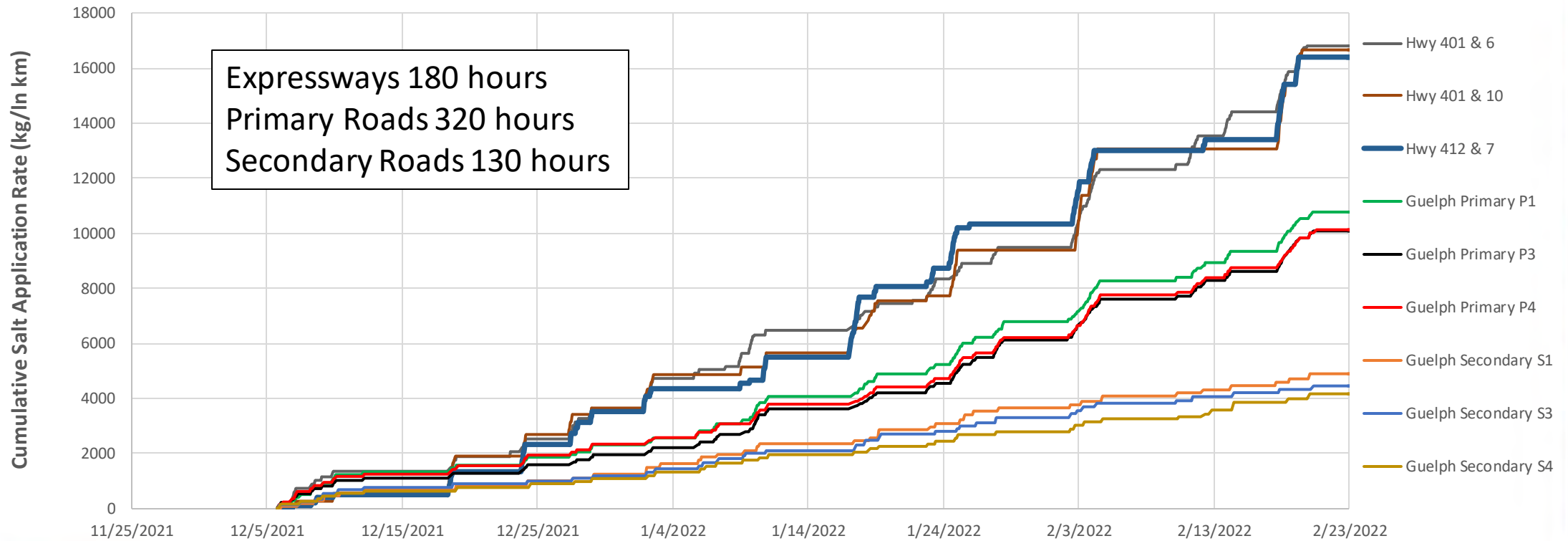
Reference	Road Agencies	Urban - Class of Highway	Traffic Volume (AADT)	Speed Limit (km/hr)
ALBERTA TRANSPORTATION HIGHWAY GEOMETRIC DESIGN GUIDE, 2022	Alberta Ministry of Transportation, Canada	Freeway/Expressway	≥ 10,000	80 – 110
		Arterial Divided	5000 – 30,000	40 – 50
		Arterial Undivided	1000 – 15,000	30
		Collector Undivided	300 – 8000	30
		Local	< 1000	20
- Ontario Regulation #239/02 Minimum Maintenance Standards - City of Toronto, 2013	Ontario Ministry of Transportation, Canada	Freeway/Expressway	> 40,000	80 – 100
		Major Arterial	> 20,000	50 – 60
		Minor Arterial	8,000 – 20,000	40 – 60
		Collector	2,500 – 8,000	40 – 50
- City of Toronto, 2013		Local	< 2,500	40 - 50
TAC, 2009	Japan	8 class from A to E	Class A > 20,000 Class B-G: 20,000 – 1000 Class H < 1000	NA.
FHWA, 2013	United States	Freeway/Expressway	13,000 – 55,000	NA.
		Principal Arterial	7,000 – 27,000	48 – 88.5
		Minor Arterial	3,000 - 14,000	40 – 88.5
		Major Collector Minor	4000 - 6300	40 – 88.5
		Collector	1100 - 4000	40 – 56
		Local	80 - 700	32 - 48

Levels of Service Summary Table

LEVEL OF SERVICE	Level 1A	Level 1B	Level 2	Level 3	Level 4
Type of Road	- All 100 Series - Selected high volume highways	- All Trunks - Selected highways as per AADT limits	- All Routes - Selected highways as per AADT limits	- All Local Paved Roads	- All Gravel Roads
AADT Limits	> 7,500	7,500 - 4,000	4,000 - 1,500	< 1,500	
Primary objective	Essentially Bare Pavement*1	Essentially Bare Pavement*1	Centre Line Bare 2.5m to 5.0m	Centre Line Bare 1.2m to 2.5m	Snow Packed
Time to meet primary objective after end of storm, not exceeding	8 hrs	12 hrs	12 hrs	24 hrs	24 hrs
Salting - Application of salt	Beginning of storm and during as required	Beginning of storm and during as required	Beginning of storm and after	Beginning of storm where required and after	N/A
Max. Application Rate (Rate based on 2-Lane Road)	125 kg/CL km	125 kg/CL km	110 kg/CL km	85 kg/CL km	N/A
Plowing - Begin plowing when snow accumulation - Max allowable accumulation	≤ 25mm ≤ 75mm	≤ 25mm ≤ 100mm	≤ 50mm ≤ 150mm	During storm as required ≤ 200mm	During storm as required ≤ 200mm
Sanding -Application of sand	- Not normally sanded - Sand only during severe cold with slippery conditions	Beginning of storm for environmentally sensitive areas or during severe cold with slippery conditions	Beginning of storm for environmentally sensitive areas or during severe cold with slippery conditions	- Beginning of storm where required and after - For environmentally sensitive areas - Slippery conditions when required	- After storm - For environmentally sensitive areas - Slippery conditions when required
Max. Application Rate (Rate based on 2-Lane Road)	N/A	800 kg/CL km	800 kg/CL km	500 kg/CL km	500 kg/CL km

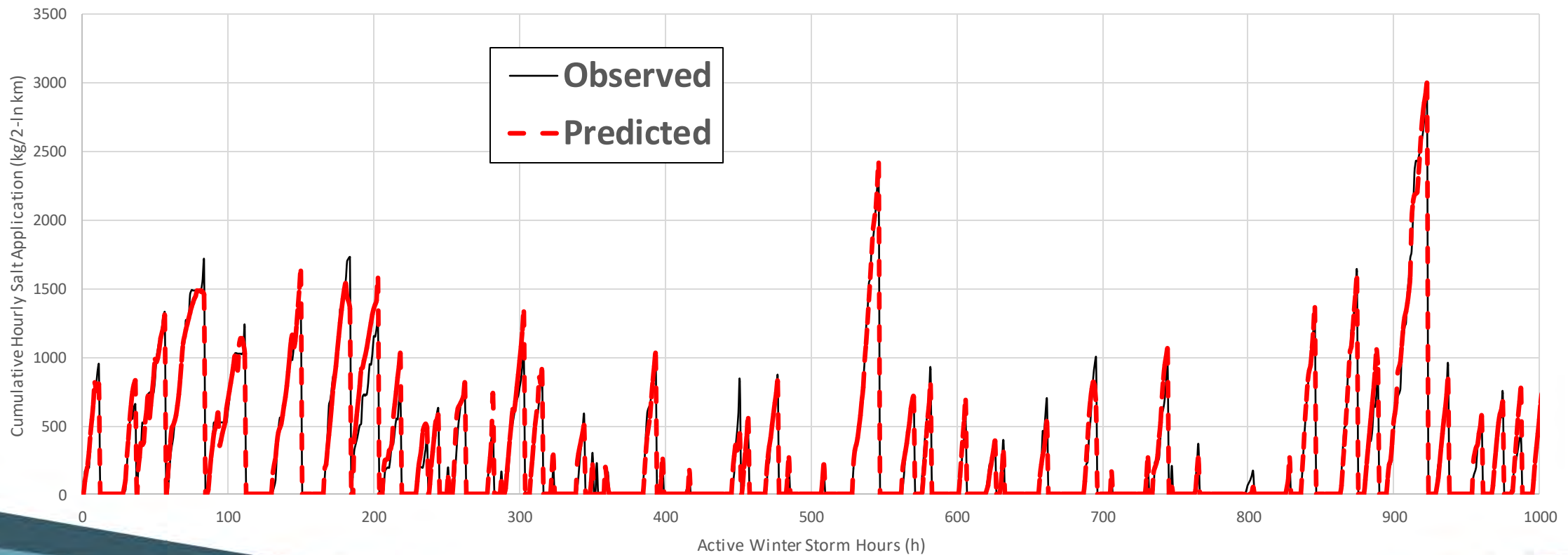


# Cumulative Road Salt Application



# The ML Model Performance (MTO Highways)

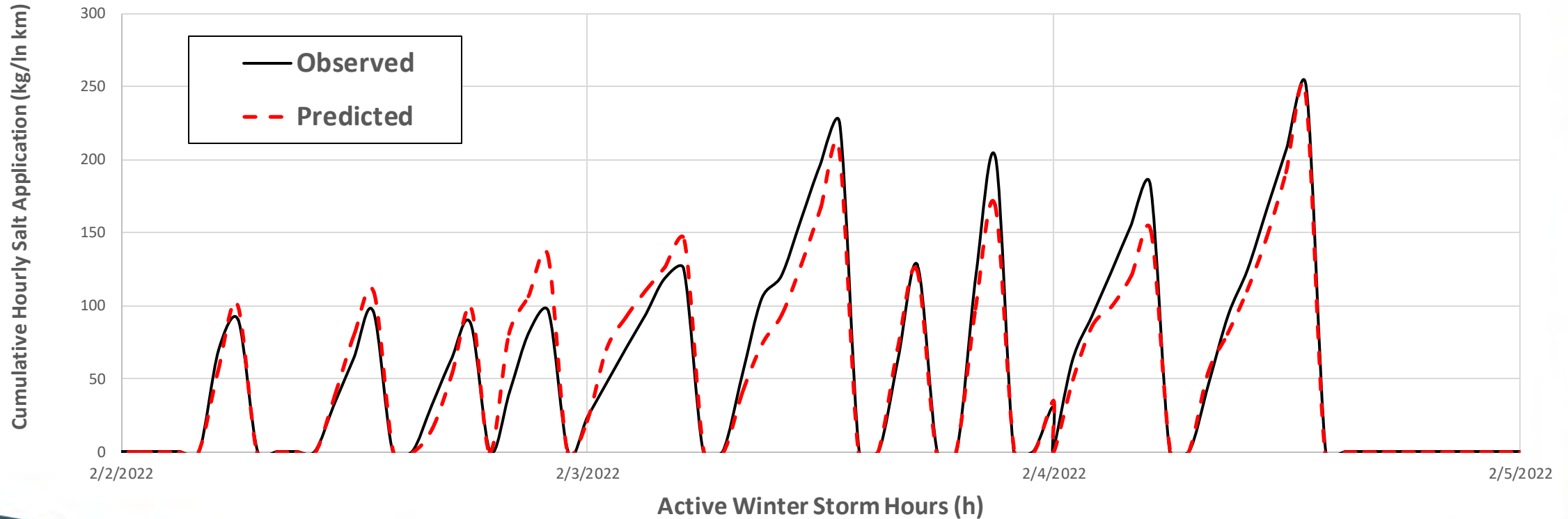
Cumulative Hourly Salt Application (kg/2-ln km)





# The ML Model Performance (City of Guelph)

City of Guelph Primary Route Cumulative Hourly Salt Application (kg/ln km)



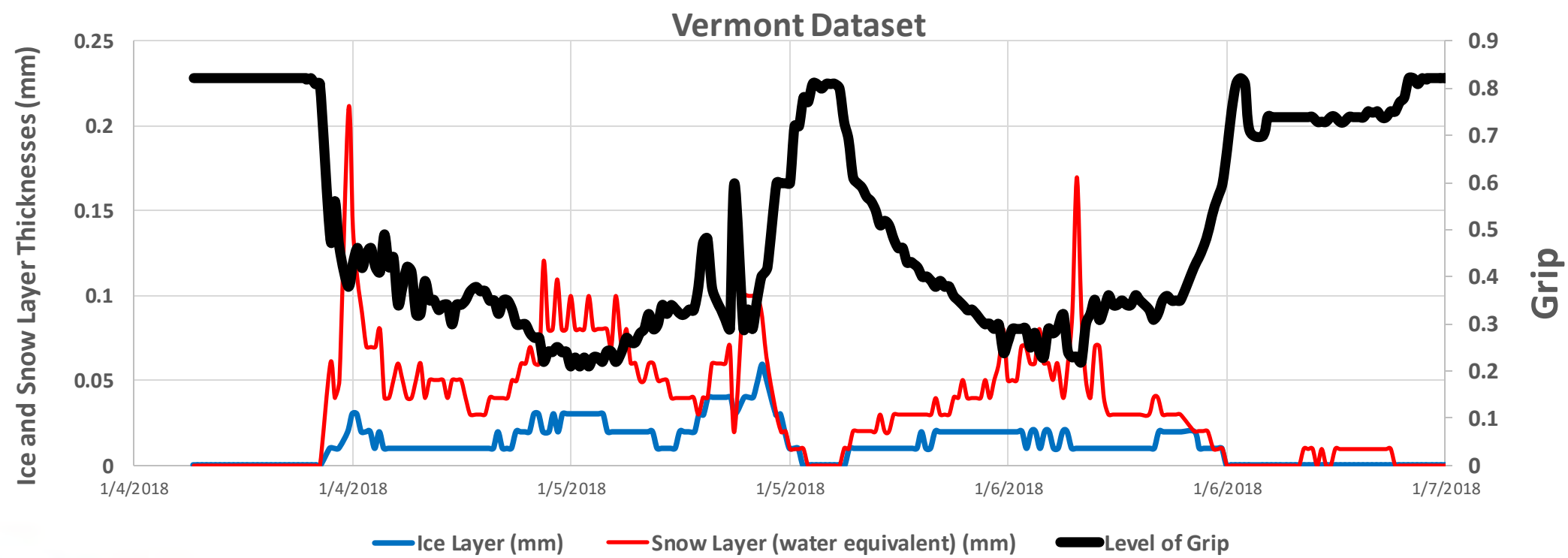
# The Effect if Ice & Snow Layer on Grip

		Snow Layer Thickness (mm)																															
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	
Ice Layer Thickness (mm)	0	82%	53%	49%	42%	34%	31%	24%	23%	21%	18%	18%	19%	19%	18%	19%	15%	16%	18%	16%	15%	16%	15%	16%	17%	17%	15%	17%	15%	13%	12%	11%	
	0.1	62%	57%	43%	33%	30%	32%	33%	31%	35%	36%	36%	40%	40%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%								
	0.2	50%	43%	33%	27%	28%	29%	30%	29%	31%	37%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%											
	0.3	53%	31%	28%	20%	20%	20%	23%	20%	15%	10%	10%	10%	10%	10%	10%	10%	10%															
	0.4	50%	25%	18%	13%	15%	17%	15%	15%	12%	10%	10%	10%	10%	10%	10%	10%																
	0.5	47%	27%	18%	17%	14%	12%	13%	14%	10%	10%	10%	10%	10%	10%	10%																	
	0.6	44%	25%	20%	17%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%																		
	0.7	42%	19%	18%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%																			
	0.8	42%	14%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%																				
	0.9	49%	20%	10%	10%	10%	10%	10%	10%	10%	10%	10%																					
	1	51%	15%	10%	10%	10%	10%	10%	10%	10%	10%																						
	1.1	44%	10%	10%	10%	10%	10%	10%	10%																								
	1.2	41%	10%	10%	10%	10%	10%	10%																									
	1.3	36%	10%	10%	10%	10%	10%																										
	1.4	31%	10%	10%	10%	10%																											
	1.5	27%	10%	10%	10%																												
	1.6	23%	14%	10%	10%																												
	1.7	21%	10%	10%																													
	1.8	19%	10%	10%																													
	1.9	18%	10%	10%																													
	2	17%	10%																														
	2.1	15%	10%																														
	2.2	12%	10%																														
	2.3	10%	10%																														
	2.4	10%	10%																														
	2.5	10%	10%																														
	2.6	10%	10%																														
	2.7	10%																															
	2.8	10%																															
	2.9	10%																															
	3	10%																															

**Vaisala Algorithm Calculated Grip**  
 409,363 calculated values from Vermont RWIS



# The Effect of Ice & Snow Layer on Grip



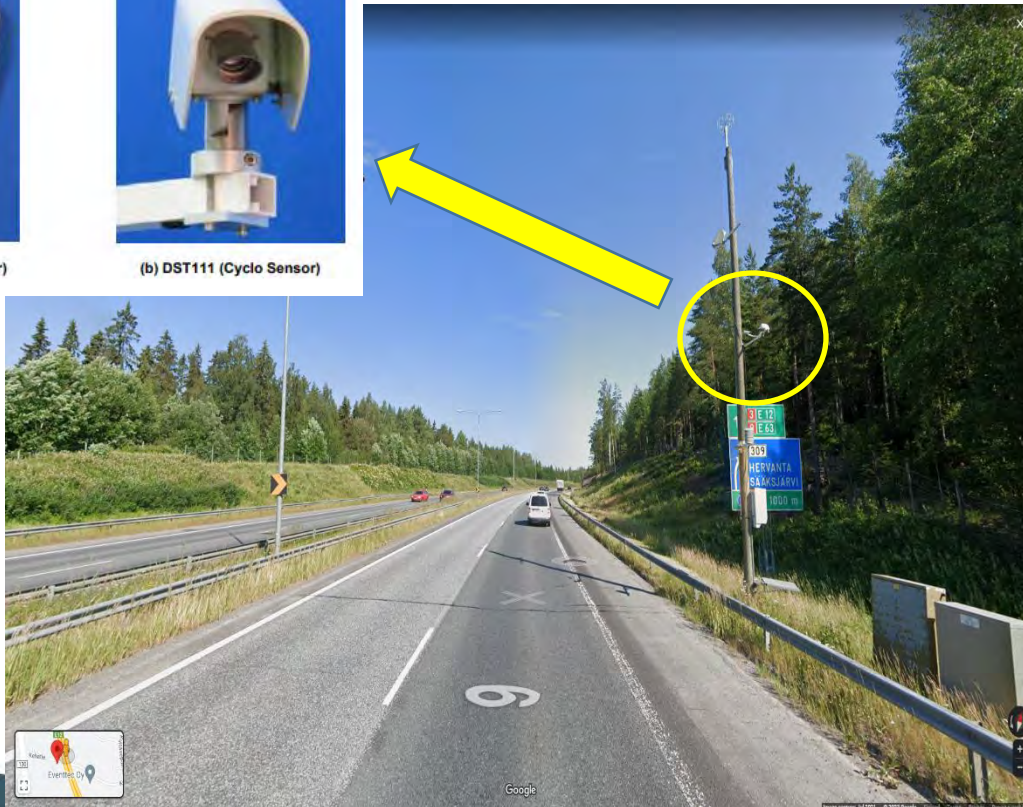
# RWIS (Finland - 2023)



(a) DSC111 (Spectro sensor)



(b) DST111 (Cyclo Sensor)



## Marjo Hippi

PhD, Senior Research Scientist at Finnish Meteorological Institute  
Helsinki Metropolitan Area

### Pedestrian slipping injuries due to weather

- Pavement Surface Temp [C]
- Air Temperature [C]
- Precipitation intensity [mm/h]
- The amount of salt [g/m<sup>2</sup>]
- **Friction (Grip)**
- **Ice Layer Thickness (mm)**
- **Snow Layer Thickness (mm)**
- **Water Layer Thickness (mm)**



Biological



Biomedical



Computer



Systems and Computing



Water Resources



Mechanical



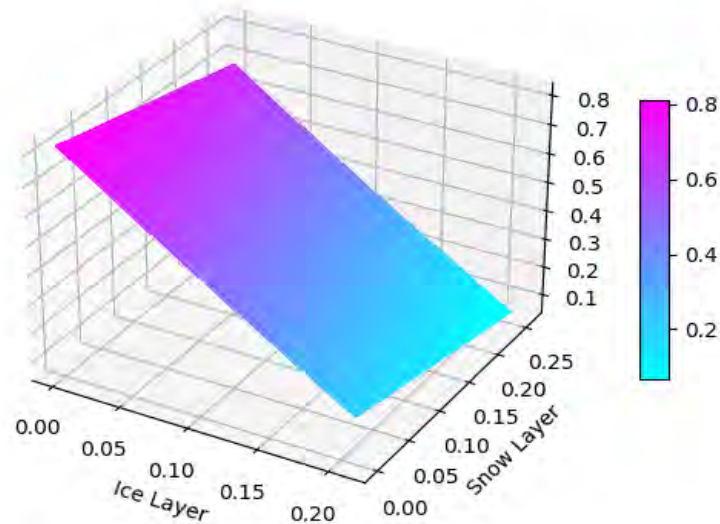
Environmental

# Effect of Snow and Ice Layer Thicknesses on Grip

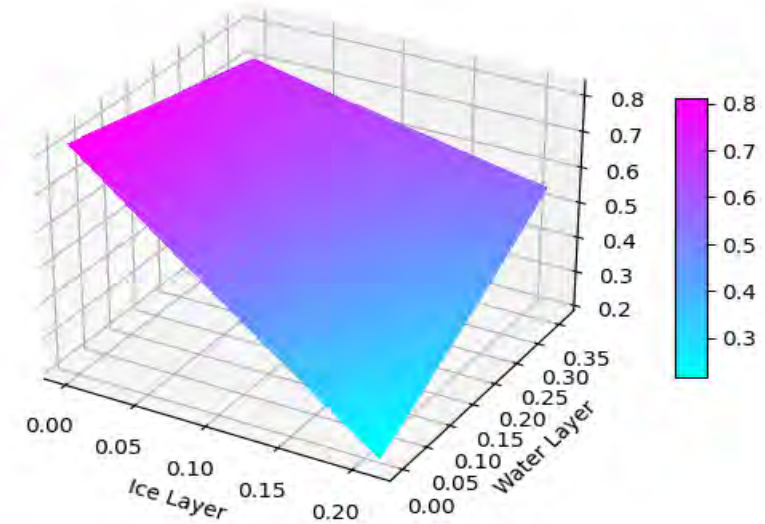
$$\text{Grip} = [W^2 + 6W + 0.634I - 3.13]I + [3W - 0.565]S - [I^2 + 0.305]W + 0.827$$

$W = \text{Water Layer}, S = \text{Snow Layer}, I = \text{Ice layer}$

Grip as a function of Ice Layer(mm) & Snow Layer (mm)



Grip as a function of Ice Layer(mm) & Water Layer (mm)



# Vaisala MD30 – Japan Airport, 2018

One comparison in Japan:

(Vaisala MD30)



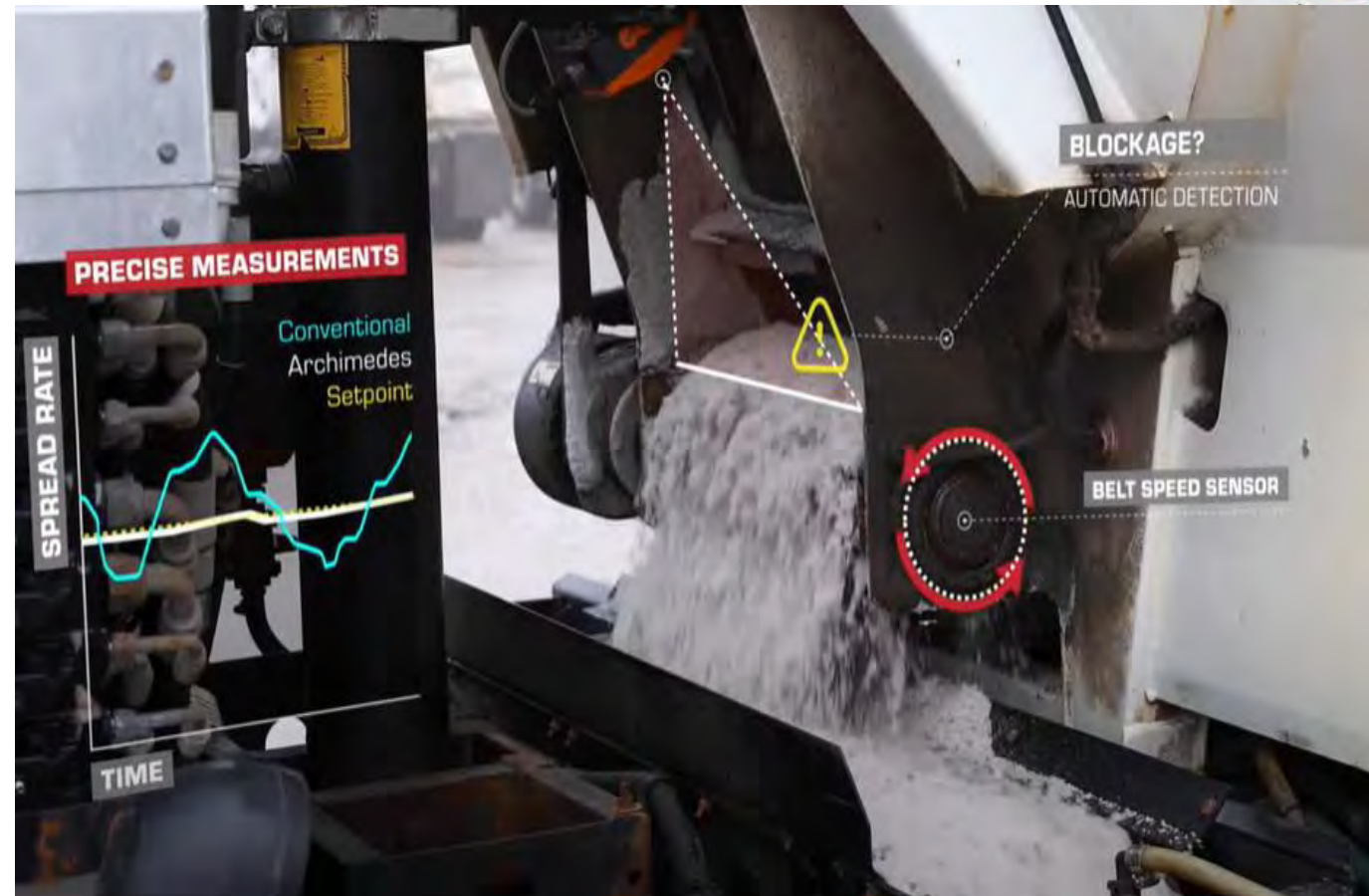
Summary of Japan test:

Condition	MD30	Friction (u)	
		New friction meter in MD30 car	Old separate friction truck
Used friction scale	0.09-0.82	0.01-1.40	0.01-1.40
2mm water	0.45	1.00	0.89
1mm snow (water equivalent)	0.38	0.25	0.50
0.5mm ice	0.10	0.40	0.20
Dry / 0.1mm of snow (w.e.)	0.80	1.05	0.81



# Closed-Loop Control

- The control system measures, adapts and records salt payout in real-time
- Other approaches are only as accurate as the last calibration and lack proof of application



# Archimedes System

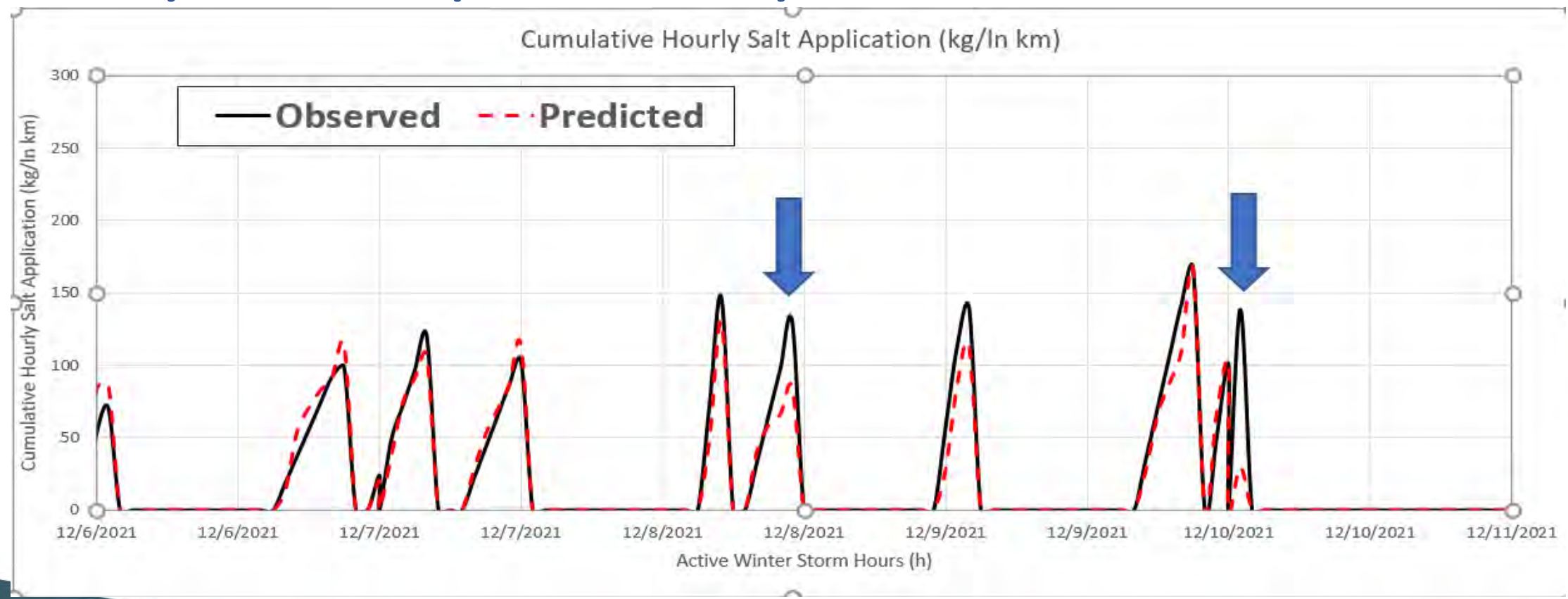
Salt Route P7		Truck#21304 with Archimedes		SAR
Start	End	lane km	ton	(kg/ln km)
1/12/2023 23:20	1/13/2023 2:38	108.2	8.52	79
1/13/2023 3:37	1/13/2023 6:11	87.8	6.97	79
1/13/2023 7:21	1/13/2023 10:17	63.2	5.02	79
1/24/2023 4:07	1/24/2023 6:06	69.6	6.35	91
1/25/2023 8:15	1/25/2023 8:21	0.4	0	0
1/25/2023 12:24	1/25/2023 14:47	56	5.31	95
1/25/2023 19:53	1/25/2023 22:27	58.5	4.3	74
1/26/2023 8:04	1/26/2023 10:58	59.5	5.55	93
1/26/2023 12:35	1/26/2023 19:00	37.1	3.42	92
1/26/2023 19:44	1/26/2023 22:21	70.9	6.22	88
1/26/2023 23:21	1/27/2023 2:13	68.4	5.34	78
1/27/2023 3:42	1/27/2023 5:56	40.6	3.58	88
				<b>937</b>

Salt Route P6		Truck#20314 without Archimedes		SAR
Start	End	lane km	ton	(kg/ln km)
1/12/2023 20:06	1/12/2023 22:57	79.1	6.51	82
1/12/2023 23:27	1/13/2023 2:41	79.4	6.73	85
1/13/2023 1:40	1/13/2023 3:47	78.3	6.83	87
1/24/2023 4:20	1/24/2023 5:45	48.9	5.62	115
1/25/2023 8:07	1/25/2023 11:29	65.9	5.89	89
1/25/2023 13:11	1/25/2023 14:29	43	5.09	118
1/25/2023 19:49	1/25/2023 22:34	60.9	5.58	92
1/26/2023 8:13	1/26/2023 11:17	64.9	6.62	102
1/26/2023 12:44	1/26/2023 19:00	33.1	3.21	97
1/26/2023 19:44	1/26/2023 22:09	42.5	4.16	98
1/26/2023 23:49	1/27/2023 2:53	67.4	6.4	95
1/27/2023 3:52	1/27/2023 5:53	39.9	4.07	102
				<b>1162</b>



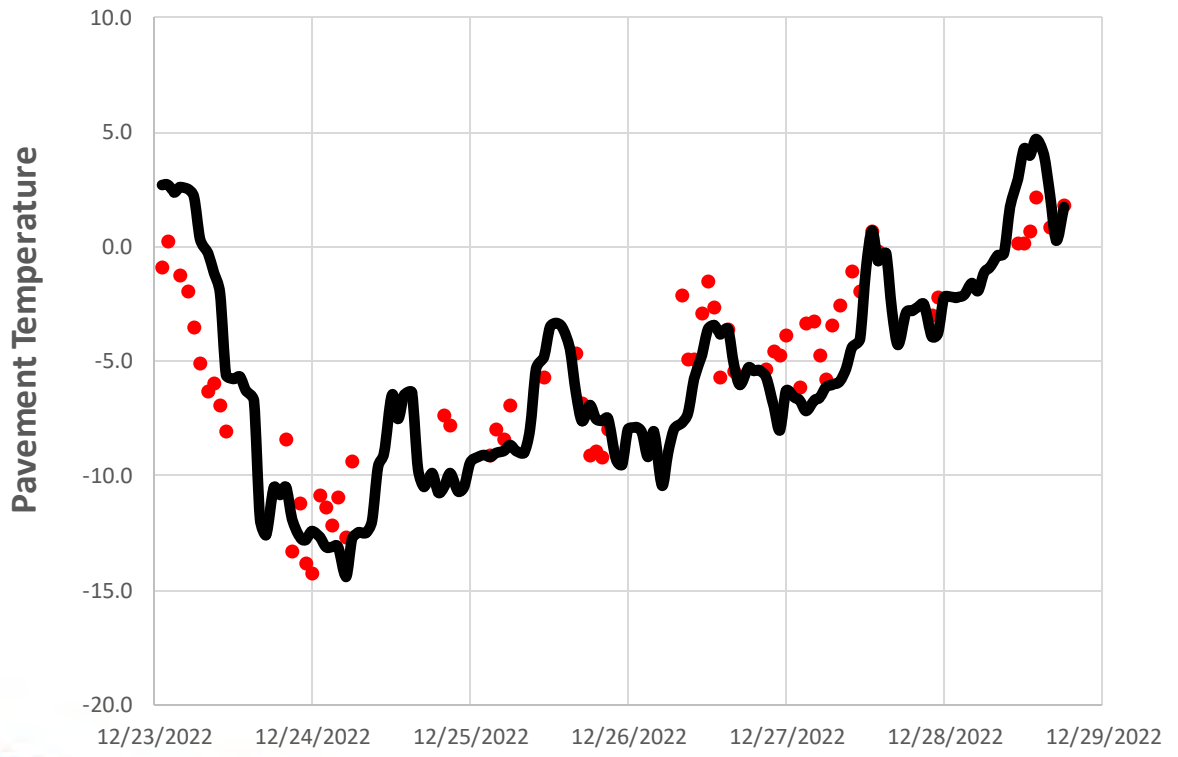


# City of Guelph Primary Routes



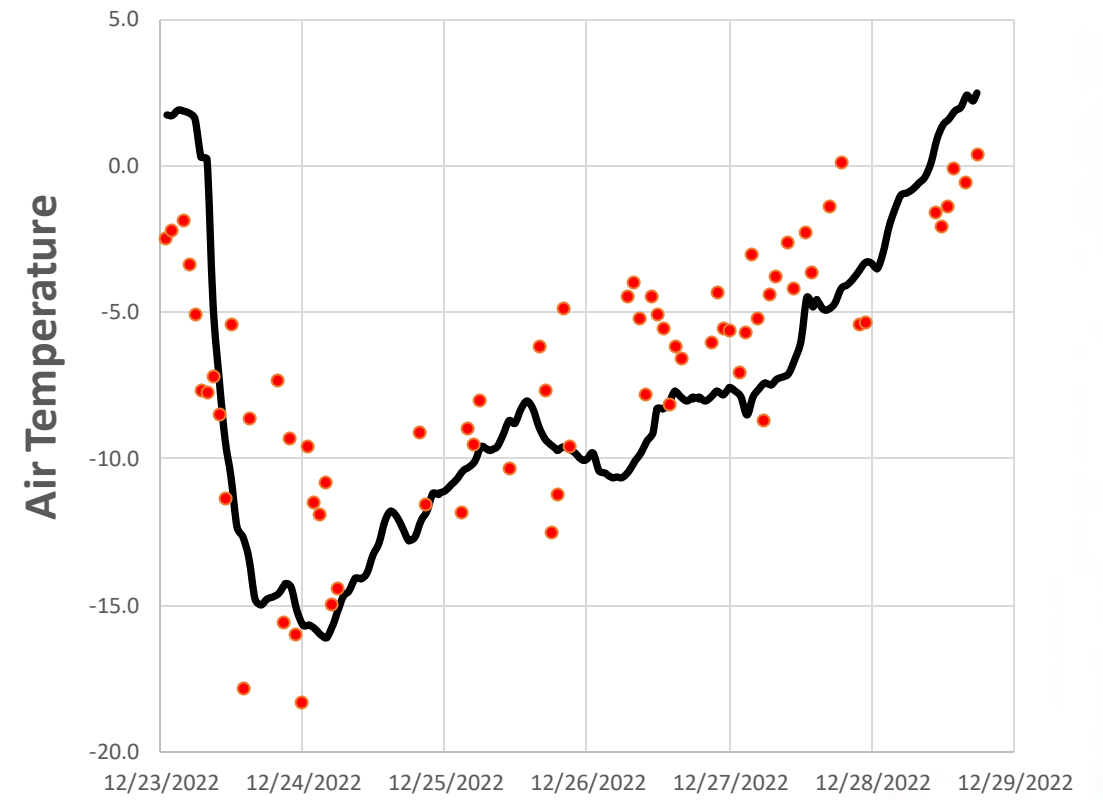
# Pavement Temp (C)

● Calibrated MD30      — RWIS-WR4 Guelph



# Air Temp (C)

— ECCC (station GUELPH TURFGRASS)      ● Calibrated MD30

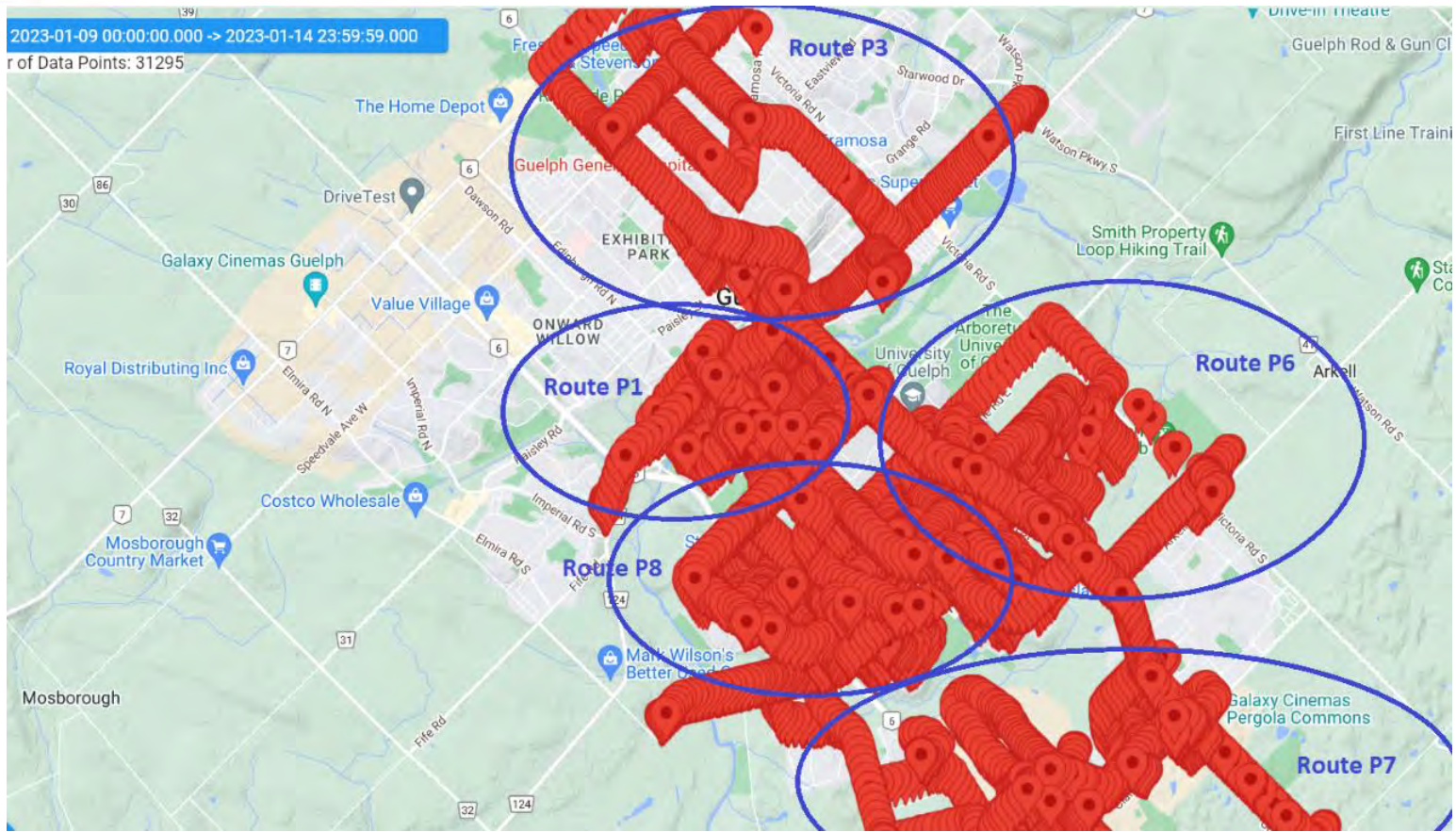


# DLA & Salt Automated Switching

- User Friendly Web Platform to manage fleet and reporting
- Dynamically select application method and prescription on any road or specific location
- Raise or lower prescribed application based on storm severity across all road classes with one click
- **Switch between aggregate and liquid applications at any time based on GPS locations**
- Easy access to Reporting Data

The screenshot displays a web-based interface for managing fleet and reporting. It features a map with roads labeled Wellington Rd 39, Marden Rd, Conservation Rd, and Anservation Rd. A 'Salt Sensitive Area' is highlighted in green. Two panels show application rates for Level 1, 2, and 3 for Granular and Liquid applications. The left panel shows rates of 60, 80, and 120 Kg/Km for Granular and 0, 20, and 20 L/Km for Liquid. The right panel shows rates of 0, 15, and 0 Kg/Km for Granular and 20, 15, and 20 L/Km for Liquid. A red sidebar on the left contains various icons for navigation and settings.





# Next Steps

- Recommended salt application rates on screen.
- Adding to the fleet of smart salt trucks.
- Base stations for reference data.
- Mapping micro-climate and micro topography accident risk map for each route.
- Mapping salt vulnerable areas to adjusting speed limits within each route.
- Optimizing DLA and Rock Salt application for specific winter events.
- Grip testing to learn ice/snow/water layer thicknesses effect on road surface conditions.
- Add additional real-time winter climate monitoring stations.



# Next Steps

**ROAD SPEED FAULT**  
Speed sensor fault

**SALT**  
kg/km

**250**  
RECOMMENDED

**300** ACTUAL

**300** SETPOINT

**ROAD SPEED**  
60  
km/h

**ROAD TEMP**  
-5  
°C

**AMBIENT TEMP**  
-15  
°C

**ROAD CONDITION**  
SNOW 2.2mm  
CAUTION ADVISED

USER | HOME | CALIBRATION | SETTINGS | HELP

- Biological
- Biomedical
- Computer
- Systems and Computing
- Water Resources
- Mechanical
- Environmental

