NL WATER RESOURCES MANAGEMENT DIVISION

WSP 2024 HURRICANE SEASON FLOOD ALERT SYSTEM

END-OF-SEASON REPORT

2024-06-01 TO 2024-12-31

FEBRUARY 03, 2025

CONFIDENTIAL

TABLE OF CONTENTS

LIST OF FIGURES

IMPORTANT NOTICE

This report was prepared exclusively for Water Resources Management Division Department of Environment and Climate Change by WSP Canada Inc. The quality of information, conclusions and estimates contained herein is consistent with the level of effort involved in WSP's services and based on: i) information available at the time of preparation, ii) data supplied by outside sources and iii) the assumptions, conditions and qualifications set forth in this report. This report is intended to be used by Water Resources Management Division Department of Environment and Climate Change only, subject to the terms and conditions of its contract with WSP. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

1 FLOOD ALERTS SUMMARY

The WSP Hurricane Season Flood Alert System (HSFAS) Product is the combination of professionally trained meteorologists applying their full knowledge of atmospheric science to Newfoundland and Labrador's weather patterns and combining these patterns with existing trends, known observations, and weather prediction models. Examining maximum precipitation predictions from many different dynamic models, allows forecasters to produce a better forecast of the maximum precipitation potential, based on the strength of different models in handling the atmospheric physics of differing weather patterns.

From June 2024 to December 2024, 77 sites were alerted in total. 20 of the sites had a 12-h and a 24-h alert issued during the same forecast. In the below table, each column is highlighted in the worst alert category exceeded. If both 12-h and 24-h limits were exceeded, we used the 12-h colour. Nine of the sites were alerted for exceeded 100-year 12-h limits. Four of the sites were alerted for exceeded 100-year 24-h limits.

Table 1 Summary of Flood Alerts

	Site location	Issue Date	12-hourly Precipitation Forecast (mm)	24-hourly Precipitation Forecast (mm)
1	Whitbourne	06-30-2024	89.6	122.4
2	Heart's Delight-Islington	06-30-2024	85.0	110.7
3	Winterton	06-30-2024	85.2	110.7
4	Bay Roberts	06-30-2024	75.9	104.3
5	Whitbourne	06-30-2024	89.6	122.4
6	Heart's Delight-Islington	06-30-2024	85.0	110.7
7	Winterton	06-30-2024	85.2	110.7
8	Bay Roberts	06-30-2024	75.9	101.3
9	Ferryland	07-01-2024	78.8	111.1
10	Bay Roberts	07-01-2024	63.6	106.1
11	Churchill Falls	07-13-2024	74.7	75.7
12	Churchill Falls	07-13-2024	45.9	46.3
13	Cox's Cove	07-30-2024	95.4	103.6
14	Battle Harbour (Battle Harbour Lor)	07-30-2024	53.8	55.2
15	Cox's Cove	07-30-2024	95.4	103.8
16	Mary's Harbour	07-30-2024	57.7	62.2
17	Battle Harbour (Battle Harbour Lor	07-30-2024	58.8	60.0
18	Parsons Pond	07-31-2024	83.4	87.2
19	Daniel's Harbour	07-31-2024	83.4	87.2
20	Parsons Pond	07-31-2024	83.4	87.2
21	Daniel's Harbour	07-31-2024	83.4	87.2
22	St. Anthony	07-31-2024	60.4	83.3
23	Parsons Pond	08-01-2024	74.3	84.4
24	Daniel's Harbour	08-01-2024	74.3	84.4
25	Cox's Cove	08-08-2024	54.4	80.6
26	Cox's Cove	08-09-2024	54.2	67.2
27	Nain	10-09-2024	45.3	71.2
28	Hopedale	10-09-2024	55.1	67.2
29	Nain	10-09-2024	49.3	77.9
30	Hopedale	10-09-2024	55.1	73.8

	Site location	Issue Date	12-hourly Precipitation Forecast (mm)	24-hourly Precipitation Forecast (mm)
31	Happy Valley-Goose Bay	10-09-2024	44.8	68.1
32	Nain	10-10-2024	39.6	66.8
33	Hopedale	10-10-2024	51.2	61.4
34	Nain	10-10-2024	41.2	64.9
35	Hopedale	10-10-2024	52.6	57.6
36	Hopedale	10-11-2024	54.9	58.2
37	St. Lawrence	10-23-2024	108.9	130.5
38	Rushoon	10-23-2024	104.3	132.9
39	Appleton, Glenwood	10-23-2024	69.0	88.4
40	Bay Roberts	10-23-2024	71.3	114.9
41	Brigus	10-23-2024	71.3	114.9
42	Portugal Cove-St Philip's	10-23-2024	72.2	111.5
43	Petty Harbour, St. John's (Goulds)	10-23-2024	79.4	111.5
44	Ferryland	10-23-2024	87.4	120.9
45	La Scie	10-23-2024	68.0	80.7
46	Rushoon	10-24-2024	98.8	128.4
47	Hickman's Harbour	10-24-2024	83.1	110.7
48	Heart's Delight-Islington	10-24-2024	93.6	122.0
49	Winterton	10-24-2024	96.0	124.5
50	Bay Roberts	10-24-2024	77.3	92.3
51	Rushoon	10-24-2024	102.6	136.4
52	Clarenville	10-24-2024	84.9	111.1
53	Hickman's Harbour	10-24-2024	85.3	113.6
54	Mary's Harbour	11-19-2024	46.7	79.7
55	Battle Harbour (Battle Harbour Lor)	11-19-2024	49.3	77.6
56	Mary's Harbour	11-19-2024	46.5	70.7
57	Channel-Port aux Basques (Port Aux Basques)	12-03-2024	104.4	112.0
58	Isle aux Morts	12-03-2024	104.4	112.0
59	Burnt Islands	12-03-2024	105.8	114.3
60	Rose Blanche	12-03-2024	105.8	114.3
61	Burgeo	12-03-2024	95.2	104.2
62	Isle aux Morts	12-03-2024	90.9	98.6
63	Channel-Port aux Basques (Port Aux Basques)	12-03-2024	90.9	98.6
64	Burnt Islands	12-03-2024	99.1	105.4
65	Rose Blanche	12-03-2024	101.8	107.6
66	Burgeo	12-03-2024	91.3	95.7
67	Burnt Islands	12-04-2024	104.2	111.9
68	Isle aux Morts	12-04-2024	98.7	110.6
69	Channel-Port aux Basques (Port Aux Basques)	12-04-2024	98.7	110.6
70	Rose Blanche	12-04-2024	104.2	111.9
71	Burgeo	12-04-2024	98.2	103.3
72	Deer Lake	12-04-2024	68.2	71.4
73	Burnt Islands	12-04-2024	94.5	101.8
74	Isle aux Morts	12-04-2024	94.5	101.8

	Site location	Issue Date	12-hourly Precipitation Forecast (mm)	24-hourly Precipitation Forecast (mm)
75	Channel-Port aux Basques (Port Aux Basques)	12-04-2024	94.5	101.8
76	Rose Blanche	12-04-2024	90.5	98.3
77	Deer Lake	12-04-2024	81.2	84.9

Legend (WRMD or EC Exceeded flood limit)

Exceeded 12-Hourly 20-yr flood limit
Exceeded 12-Hourly 100-yr flood limit
Exceeded 24-Hourly 20-yr flood limit
Exceeded 24-Hourly 100-yr flood limit

When not double-counting events where a site was alerted for two different thresholds at the same time, this season saw 77 alerts (if we double count, the alerts were 97). The 2024 season was less active than the 2023 season (77 vs 96 sites alerted). Most of the alerts were associated with 5 rainfall events through the season. The June 30-July 2nd rainfall event mainly affected eastern Newfoundland. The July 30th- August 1st rainfall event mainly affected western Newfoundland and Labrador. The October 9-10th rainfall event mainly affected Labrador. The October 24-26th rainfall event mainly affected southern and eastern Newfoundland. The December 3-4th rainfall event mainly affected southern Newfoundland.

Table 2 Monthly Analysis of Flood Alerts

Month	Total Alerts	12-hourly 20-yr alerts	12-hourly 100-yr alerts	24-hourly 20-yr alerts	24-hourly 100-yr alerts	Env. Can. & WRMD Obs.
June	8	0	0	8	0	0
July	18	9	3	3	3	0
August	5	4	0	1	0	0
September	0	0	0	0	0	0
October	37	12	0	24	1	0
November	3	0	0	3	0	0
December	26	14	7	5	0	0
Total:	97	39	10	44	4	0

Of the total 97 alerts issued (this number is higher than the 77 mentioned above because it counts each individual threshold crossed even if it's during the same event), 39 were 12-hourly 20-year alert, 10 were 12-hourly 100-year alerts, 44 were 24-hourly 20-year alerts, and 4 were 24-hourly 100-year alerts. Most of the alerts (63) were issued in October and December. To not double count alerts in the table, any time both 20-year and 100-year limits were exceeded, only the 100-year limit was used.

Table 3 Regional Analysis of Flood Alerts – Communities with two or more alerts (note that this table does not include all events, just those sites that included at least two alerts)

Community	Region	Total Number of Alerts
Hopedale	Labrador	5
Bay Roberts	Eastern	5
Cox's Cove	Western	4
Nain	Labrador	4
Channel-Port aux Basques	Southern	4
Isle aux Morts	Southern	4
Burnt Islands	Southern	4
Rose Blanche	Southern	4
Winterton	Eastern	3
Battle Harbour	Labrador	3
Mary's Harbour	Labrador	3
Parson's Pond	Western	3
Daniel's Harbour	Western	3
Rushoon	Eastern	3
Heart's Delight-Islington	Eastern	3
Whitbourne	Eastern	2
Ferryland	Eastern	2
Churchill Falls	Labrador	2
Hickman's Harbour	Eastern	2
Deer Lake	Western	2

From a geographic perspective:

- Thirteen (13) alerts were issued for the Western Region
- Twenty-two (22) alerts were issued for the Eastern Region
- Two (2) alerts were issued for the Central Region
- Twenty-two (22) alerts were raised for the Southern Region
- Eighteen (18) alerts were issued for Labrador

For this section and the table above, we only discuss the sites that were alerted. If a site was alerted for both 12-h and 24-h rainfall, it was only counted a single alert. Last year the eastern region saw no alerts issued whereas this year it was tied for the most alerted region (24 v. 0). The Western Region saw far few alerts than last year (13 v. 61). The rest of the region's alerts were like last year.

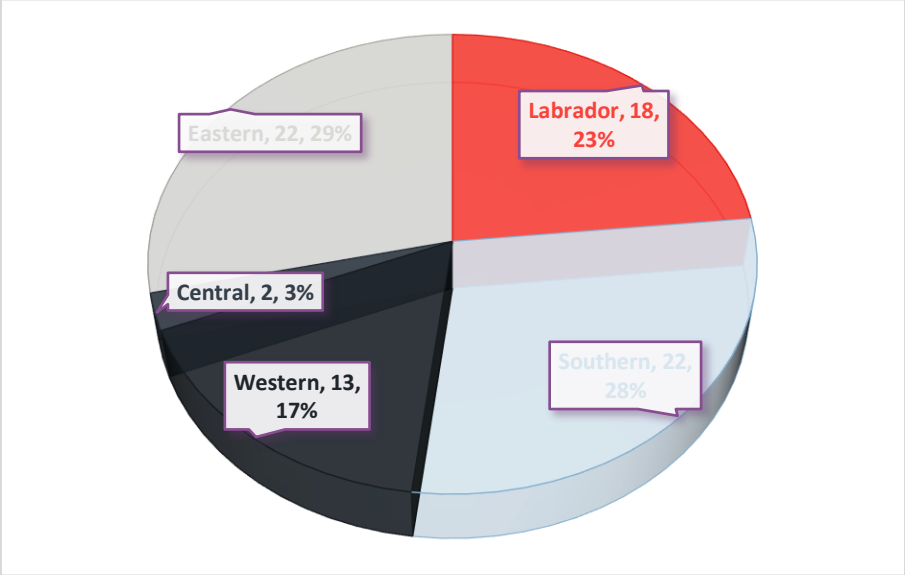


Figure 1. Alerts by Region

2 VERIFICATION OF ALERTS

The flood alerts were verified using three data sources/methods to compare with the forecasted values. These data sources include: ECCC rain gauge data, WRMD rain gauge data, and qualitative community-based reports. However, there remains some significant challenges with verification. Rainfall has very high spatial variability, meaning that stations only a few kilometres apart may record vastly different values. Nearby gauge comparison is a limited verification method due to the intense variability of precipitation over the changing terrain and within small (meso-) scale atmospheric features. Specifically, we find many of the heavy rain events forecasted in Burgeo will fall over the higher terrain north of the town while the town reports lower totals.

Also, due to the risk involved with missed alerts, the implemented forecasting approach represents a worst-case scenario. The forecast is essentially the highest possible rainfall based on the current conditions instead of the most likely scenario rainfall. In 2024, we added an additional forecast parameter: the most likely precipitation amount. However, since alerts are more easily triggered based on the maximum precipitation amount, every season, by design, there are many alerts issued that are not required. As such, any issued alert will generally overestimate what is observed, creating alerts that will not verify. The system was designed to avoid missing an alert, as the consequence for missed alerts is very serious for the people and resources involved.

2.1 HURRICANE OUTLOOK VERIFICATION

Last May, WSP issued a Hurricane Season Outlook for NL WRMD. The basin forecasts issued by NOAA, Colorado State University (CSU), and Tropical Storm Risk, and referenced by WSP, were excellent with both the total number of hurricanes and the total number of major hurricanes (Table 2). On average, the total number of tropical storms were over-forecasted. Accumulated Cyclone Energy (ACE) is an aggregate measure of storm intensity, duration, and number. ACE biases toward long-lasting intense hurricanes rather than weak tropical storms because long-lasting intense hurricanes are more likely to cause destruction. The Accumulated Cyclone Energy (ACE) (not in the table below) was over-forecasted by TSR and CSU. CSU predicted an ACE of 210. TSR predicted an ACE of 217. The actual ACE was 160. The 20 to 30% over-forecast error on the ACE forecast was likely due to some unforeseen issues in August and September that caused less-than-anticipated activity.

For Newfoundland and Labrador, the season was less busy than we anticipated (Figure 2, 3), but not without close calls. Hurricane Ernesto passed relatively close to Cape Race early on August 20th, but because the storm was compact, symmetric and not interacting with another low, its effects were minor (Figure 4, 5). Cape Race gusted to 73 km/h on August 20th but received no rain. St. John's Airport gusted to 57 km/h but received no rain. This serves an important reminder that while hurricane season represents a significant threat to flooding and other damages in Newfoundland and Labrador, much of the flooding the province experiences is from non-tropical cyclone sources.

Table 2 2024 Agency Forecasts v. 2024 Hurricane Season Actuals

	NOAA	CSU	TSR	Actual
Named Storms	17-25[1]	23	23[3]	18
Hurricanes	8-13	11	11	11
Major Hurricanes	4-7	5	5	5

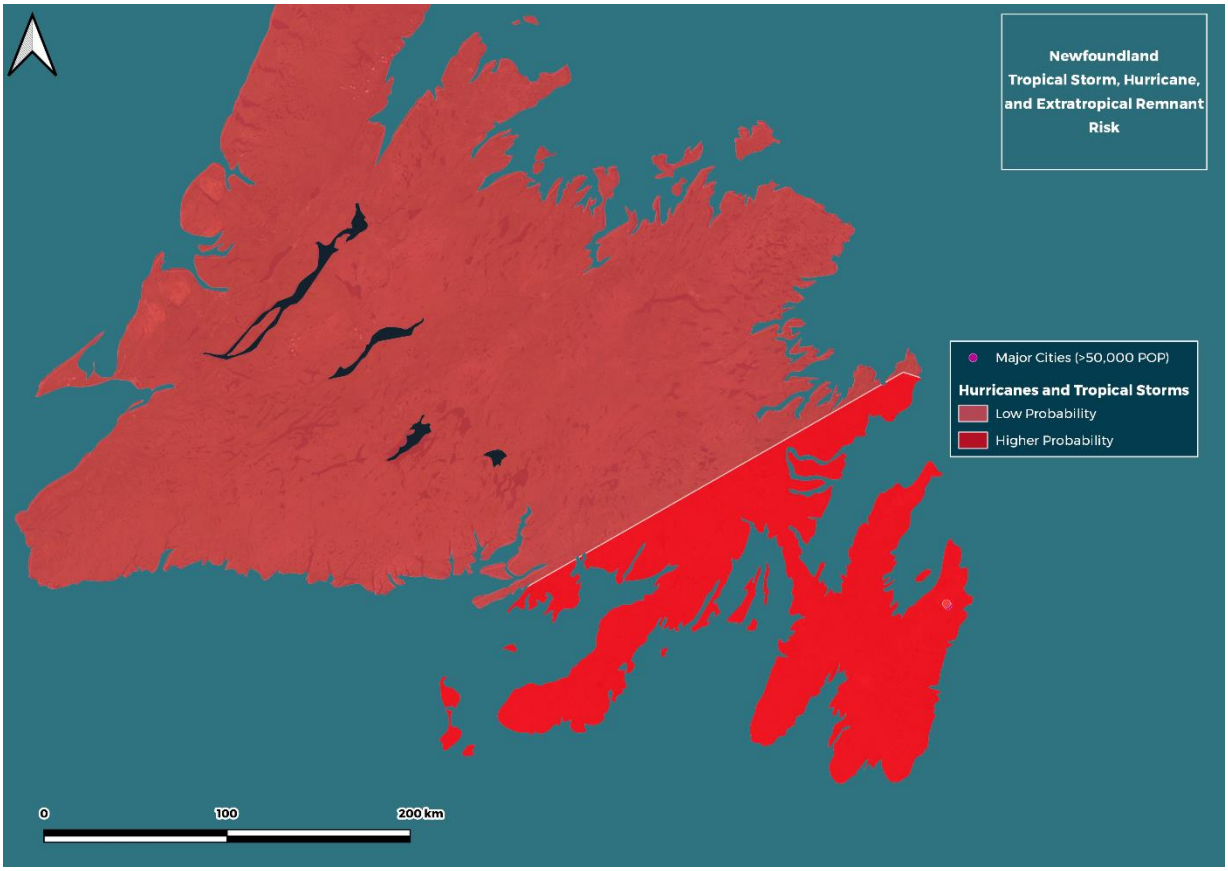


Figure 2. Newfoundland Hurricane Season Risk Map

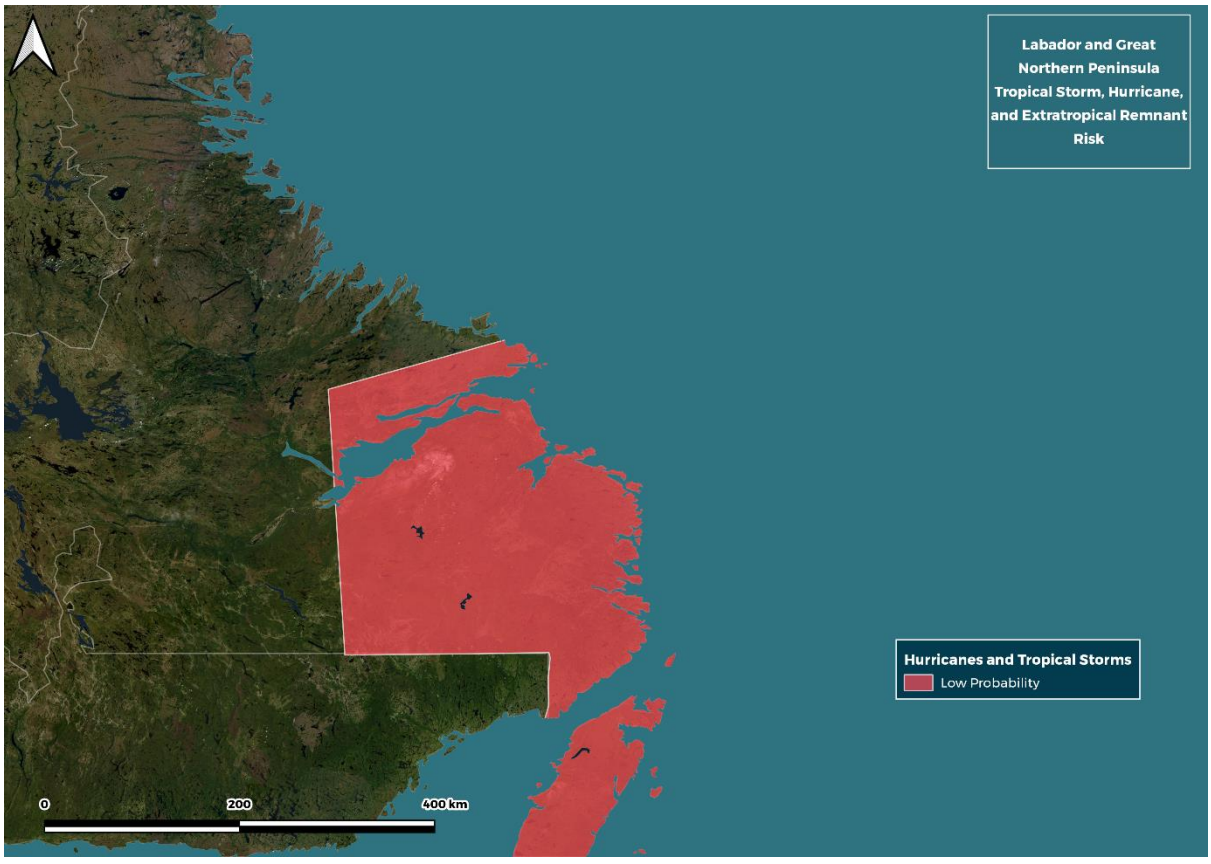


Figure 3. Labrador and Great Northern Peninsula Hurricane Season Risk Map

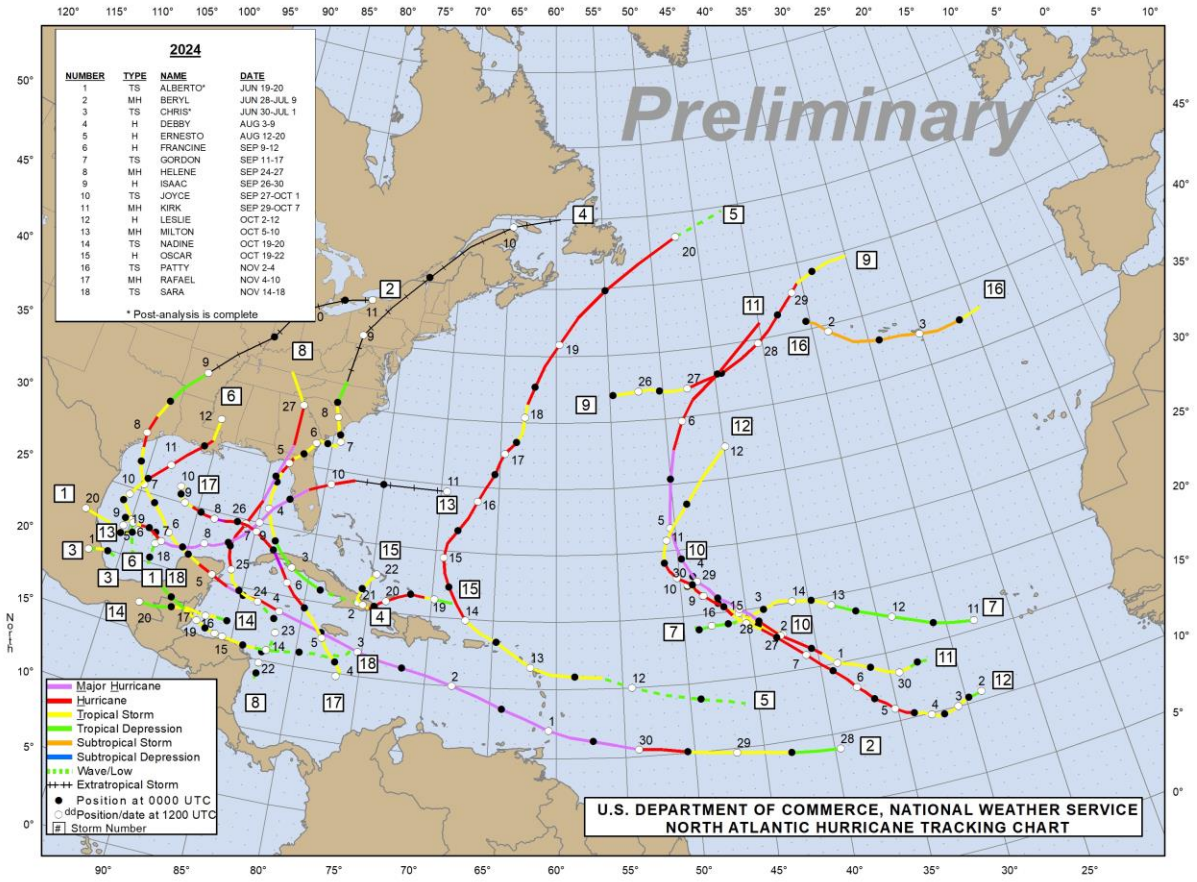


Figure 4. 2024 NHC Atlantic Hurricane Season Tracking Map

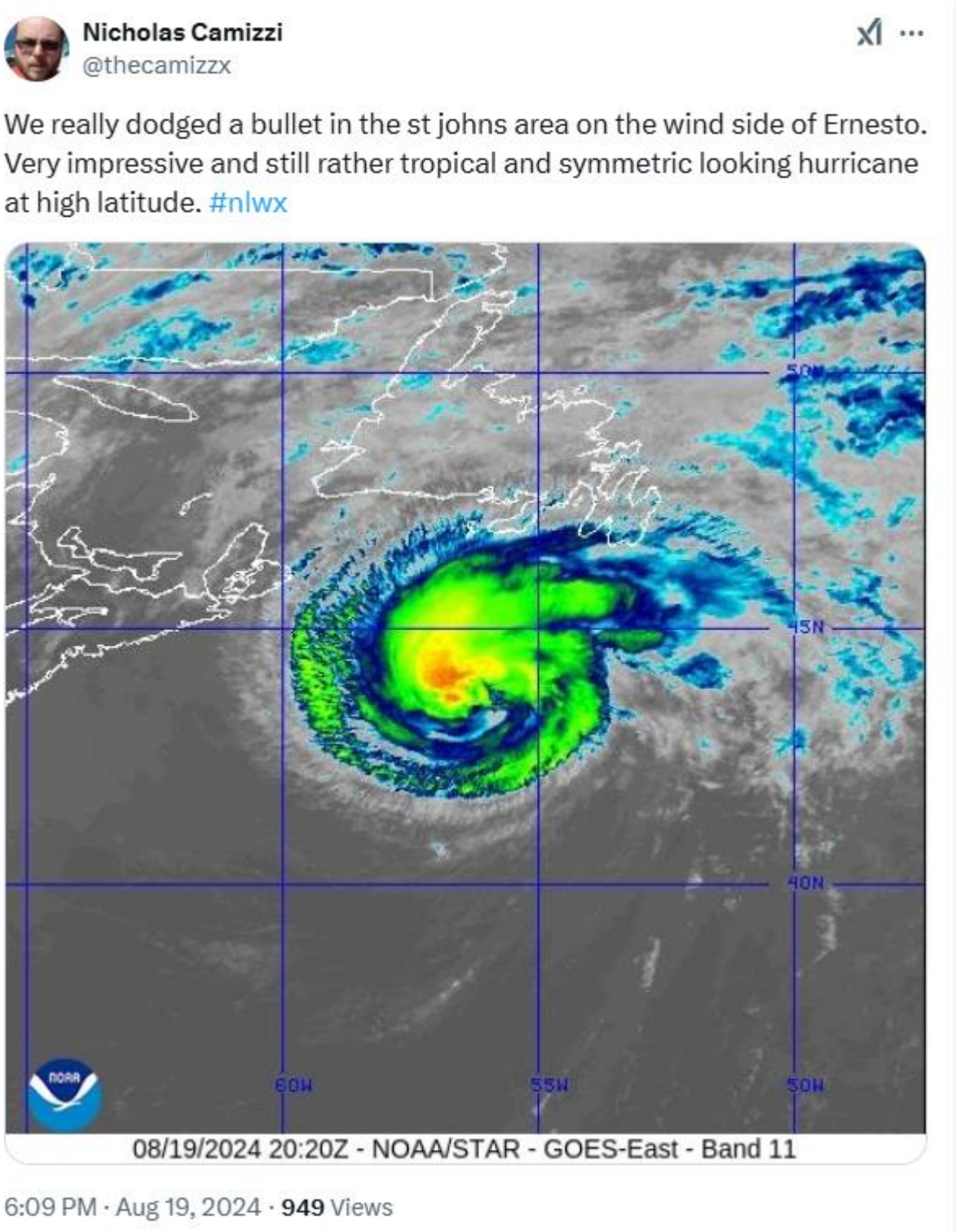


Figure 5. Hurricane Ernesto approaching southern Newfoundland, 5:50 PM NDT August 19th, 2024

2.2 COMMUNITY BASED FLOOD REPORTS

WSP works with Fire & Emergency Services – NL (FES-NL) whenever there are reports of flooding that may not have been forecasted. The concept was to create a qualitative field verification measurement that could further validate the statistical methods. Following a

forecasted flood event, the intention was for local officials to classify the event as having no, minor, or catastrophic flooding, and these eyewitness reports would be noted on the verification. In the absence of community accounts, local newspapers and social media were scanned to verify the alerts qualitatively.

- Some flooding of South Brook in Bowring Park in St. John's was reported on November 14th via social media. This event did not reach 12-h or 24-h limits in the St. John's area. Rainfall totaled 107.4 mm over 4 days at St. John's Airport.
- Significant flooding was reported along the Trans-Canada Hwy near Steady Brook due to intense heavy rainfall rates in thunderstorms on July 9th (Figure 6).

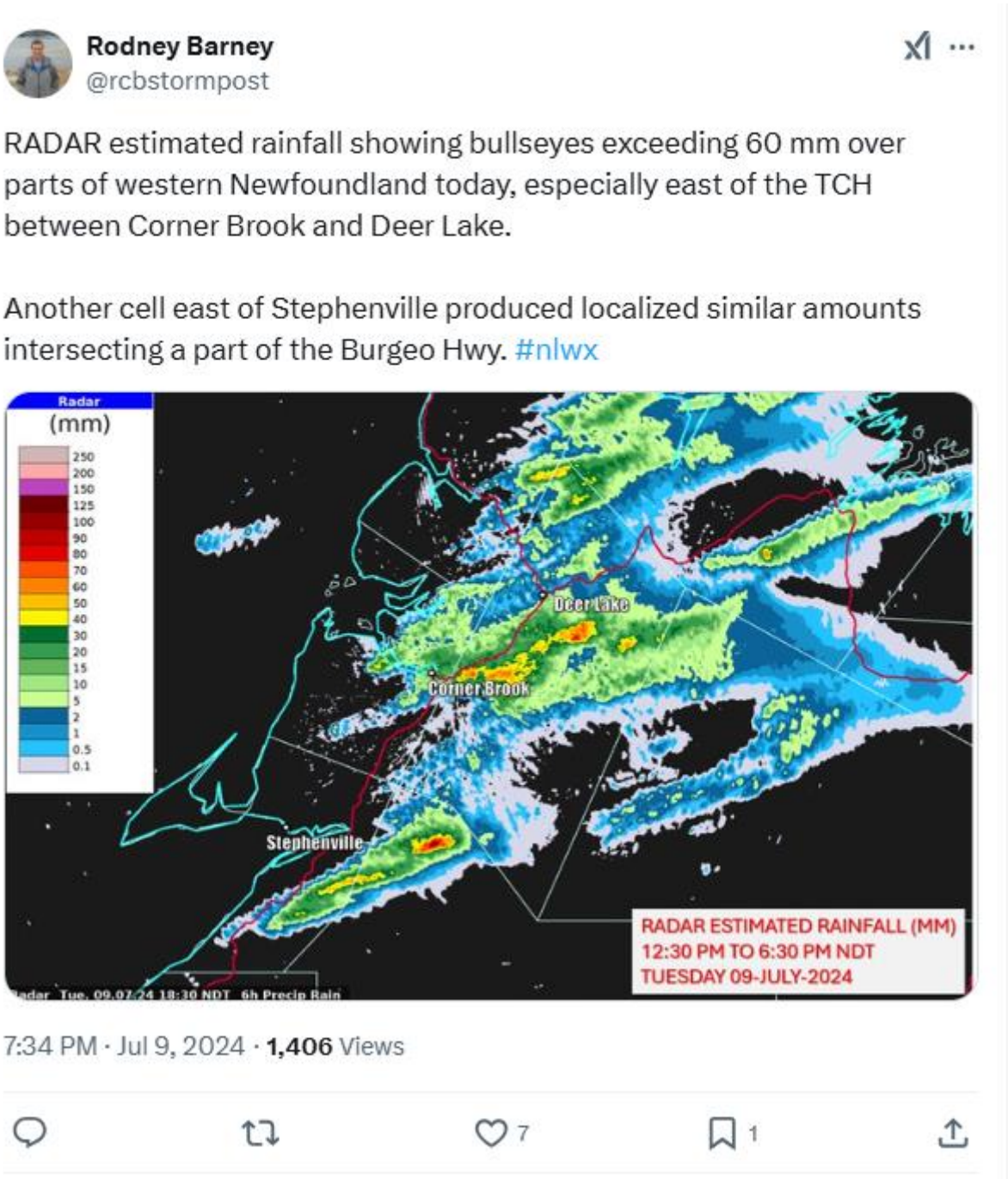


Figure 6 Radar Estimated Rainfall (mm), Rodney Barney / ECCC

- A river flooded over Route 210 in North Harbour, Newfoundland on October 25th during a heavy rainfall event which occurred over southern, central, and eastern Newfoundland.

2.3 POTENTIAL MISSED ALERTS

- 12-hour rainfall on July 9th likely exceeded 20-year limits in the vicinity of Corner Brook, Steady Brook, and Deer Lake. It may have approached or exceed 100-year limits. Much of this rainfall fell within 3 hours or so which increased the flash flooding risk.
- 12-h and 24-h rainfall 20-year rainfall limits may have been approached in St. Anthony on August 1st. 66.8 mm was recorded at St. Anthony Airport.
- 12-h rainfall reached 103.4 mm in Bonavista on November 20th. The 12-h 20-year flood limit for Bonavista is around 117 mm. It's possible that somewhere in that general area approached this limit. No reports of flooding were received. November ended up as Bonavista's rainiest month in history. WSP's forecast in the lead up to this heavy rainfall event was too low.
- 12-h and 24-h rainfall 20-year rainfall limits may have been reached around Badger and Millertown on October 25th. Rainfall for Badger was 83.5 mm on October 25th with a total of 105.3 mm for the October 24th-26th event. Rainfall for Millerstown was 91.2 mm on October 25th with a total of 113.0 mm for the October 24th-26th event. Alerts were issued for Appleton/Glenwood but the worst of the rain fell west of there, from Badger west to Millertown.
- 12-h and 24-h rainfall 20-year rainfall limits may have been reached around Rushoon around October 24th-26th. This was forecasted and alerted. It is likely that 12-h and 24-h rainfall 100-year limits were reached for North Harbour, Placentia Bay given both the rainfall totals near 200 mm there (Figure 7) and the embedded heavy rainfall rates with associated thunderstorms (Figure 8).

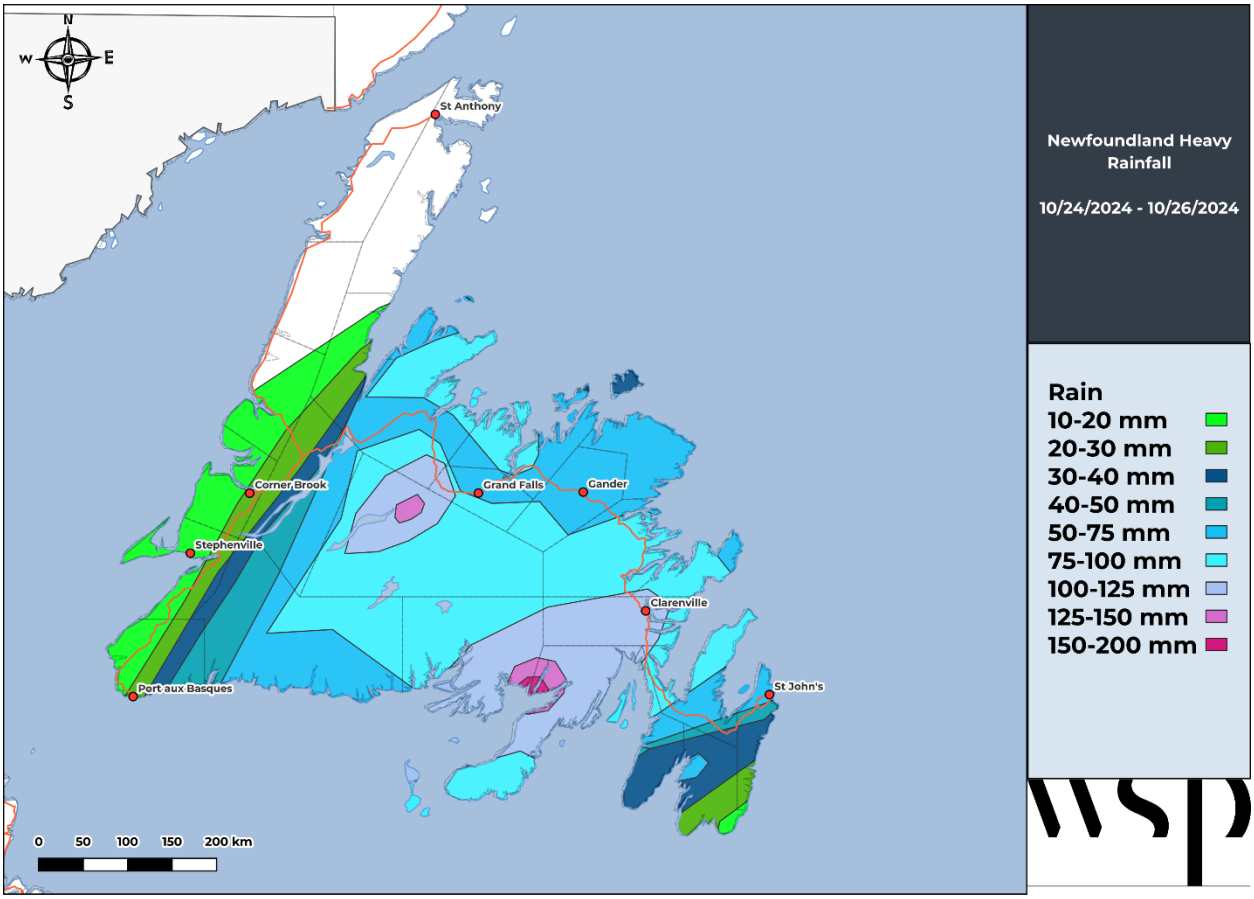


Figure 7 WSP Analysis of Heavy Rainfall, October 24-26th, 2024

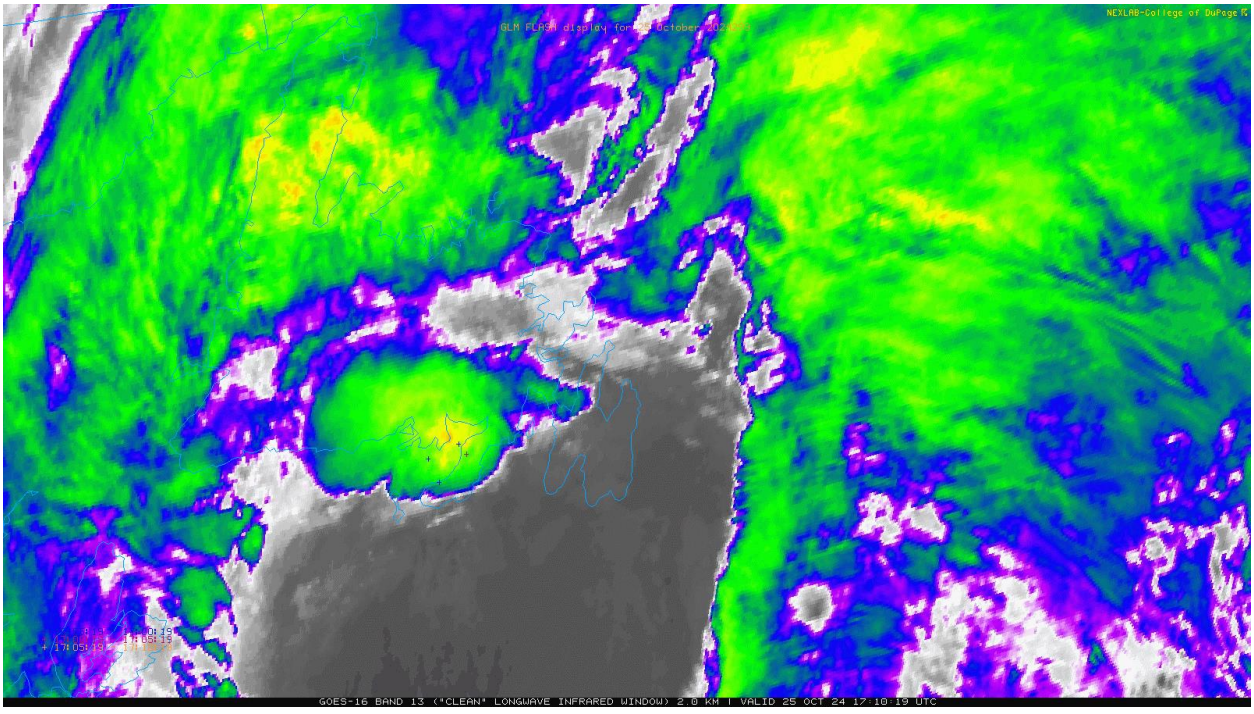


Figure 8 GOES Satellite along with the Global Lightning Mapper overlayed, 240 PM NDT October 25th, 2024

2.4 CLIMATE NORMALS

Airport reports of rainfall across NL were examined to determine how the 2024 HSFAS season compared to the climatological normals. The 2024 months are colour-coded in red if they were substantially above normal and blue if they were substantially below normal. St. John's rainfall was well above normal in June and throughout the fall and early winter.

Table 3 Monthly Rainfall Totals (in millimetres) compared to climate normals

Location	Jun 2024	Jun Norm	Jul 2024	Jul Norm	Aug 2024	Aug Norm	Sep 2024	Sep Norm	Oct 2024	Oct Norm	Nov 2024	Nov Norm	Dec 2024	Dec Norm
St. John's	214.6	88.1	76.8	100.1	66.8	99.8	72.6	125.8	165.4	155.7	325.4	132.4	171.6	102.9
Gander	105.6	89.8	102.7	107.2	71.9	106.5	75.7	121.1	112.9	116.0	202.3	80.4	47.9	54.7
Deer Lake	NA	72.9	54.1^	106.6	64.5^	108.5	19.2^	98.3	44.4 ^	90.2	47.7^	66.8	NA	34.5
Goose Bay	51.6	86.9	65.8	111.8	63.8	107.2	127.8	85.8	68.0	67.2	67.0	26.3	39.8	6.6

Notes:
^Multiple days of missing precipitation data through month

2.5 SUMMARY

Eastern Region had above normal rainfall in four of the seven months and only below normal in two of the months. Moreover, November was the rainiest November on record for many places in Eastern, as well as one of the rainiest months ever there. Western Region had below normal rainfall in four of the seven months and only above normal rainfall in one month. Southern Region had no months with above normal rainfall.

Table 4 Forecast Regions and Rainfall Observed Compared to Normals

Month	Eastern Region	Central Region	Western Region	Southern Region	Labrador
June	Above normal	Above normal	Above normal	Near normal	Below normal
July	Near normal	Near normal	Below normal	Below normal	Below normal
August	Below normal	Below normal	Below normal	Below normal	Below normal
September	Below normal	Below normal	Below normal	Below normal	Near normal
October	Above normal	Near normal	Below normal	Near normal	Near normal
November	Above normal	Above normal	Above normal	Near normal	Above normal
December	Above normal	Below normal	Near normal	Near normal	Above normal

*Rainfall from climate sites and spatial rainfall anomaly data from the NCEP/NCAR Reanalysis were used to categorize

3 LESSONS LEARNED

Eastern Region and Southern Region received the bulk of anomalous rainfall this season. As individual seasons continue to depart further from climate normals, customized alerting services such as this become more critical. Record-breaking dry or wet spells emphasize the growing importance of nowcasting and advanced weather monitoring on a very local scale.

Flooding is a complex phenomenon and can occur with amounts significantly less than the 20-year or 100-year thresholds and vice versa – no flooding may occur with amounts significantly higher than those. The HSFAS product, along with the services provided by WRMD, such as water level monitoring and reporting, are key components that work well together to help provide advance warnings to communities to better prepare for potential flooding.

Validation and incremental improvements to the HSFAS service are aided by having a network of observations. While a product such as the ECCC High Resolution Deterministic Precipitation Analysis (HRDPA) helps, this still represents a precipitation model which could vary significantly from true observations. As we have indicated in the past, the best solution would be to fill the gaps in the available monitoring networks. Using only the ECCC and WRMD gauge data limits our ability to verify the forecasts in some areas. Many communities require additional measurements, access, and/or studies. Without adequate instrumentation for measuring precipitation, it can be almost impossible to know for certain in high terrain areas whether the forecasted precipitation was accurate. Attempts have been made to fill these gaps through community-based flood reports and the use of local media sources to try to collaborate sparse gauge data.

4 CONCLUSION

It would be beneficial to pursue additional improvements to the data sources and available forecast products, as follows:

1. Additional rain gauges could be installed, particularly in the regions that generated significant alerts.
2. Flood Risk Mapping Studies could be considered for the communities that triggered alerts based on Intensity-Duration-Frequency (IDF) curves.
3. The July 9th flash flooding event was discussed in some detail during the client visit to the WSP office on December 5th. This event was very impactful yet under forecasted due to the current product format not being suited for its identification.

   Convective rainfall and thunderstorm development are more chaotic than the type of rainfall we often see in the fall and early winter. The rainfall rates are higher, but the rainfall is usually more localized. As an innovation to better communicate risk associated with such events, we suggest a subjective forecaster risk assessment on a scale of 1 to 5. The WSP forecaster can assess the various factors that could lead to a localized heavy rainfall and flooding event (atmospheric moisture, instability, and forcing features) and represent the risk to a given region on the 1 to 5 scale during the summer. This will be especially helpful as summer temperatures and moisture in Newfoundland increases and convective rainfall events become more frequent.
4. For events of convective nature that are highly localized and may not adequately be captured with the current forecast format, NL WRMD would likely find WSP-issued storm reports helpful. These reports represent a probabilistic areal risk forecast rather than a deterministic point forecast and are thus much better suited for thunderstorm-induced flooding (Figures 9 and 10). They are issued for a combination of impactful weather, like heavy rain and high winds, and in the winter – heavy snow and freezing rain. In the summer, they are issued for both synoptic-type events (i.e., widespread heavy rain such as that in Figure 9), as well as convective events (localized heavy rainfall, such as that in Figure 10). They are typically issued 24 to 72 hours in advance in the winter and 24-48 hours in advance in the summer. These could be helpful to WRMD to get a more spatial overview of the risks, a discussion of uncertainty, and see heavy rainfall events that can and do cause flooding that fall outside of the 12-h and 24-h 20-year limits, or cause flash flooding.

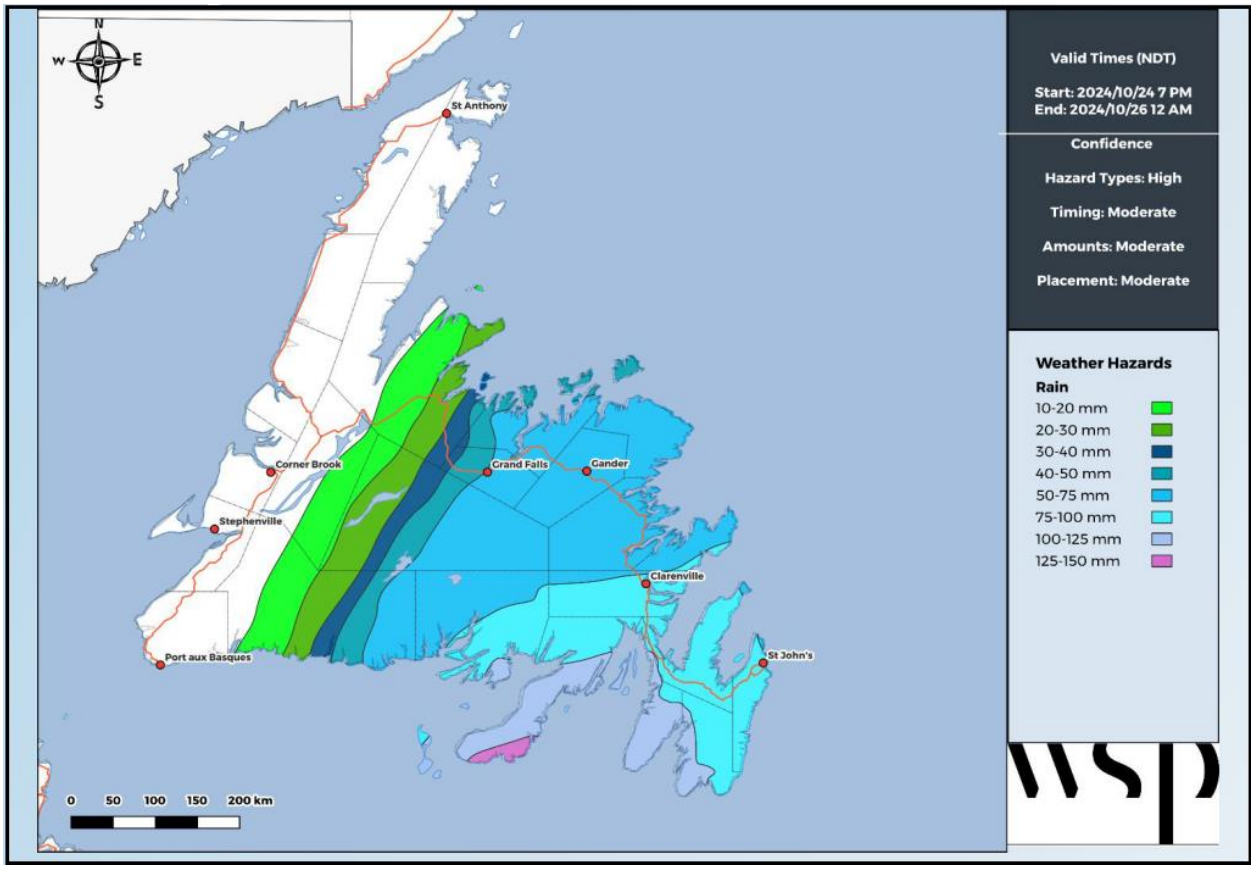


Figure 9 Example Newfoundland Storm Report Map

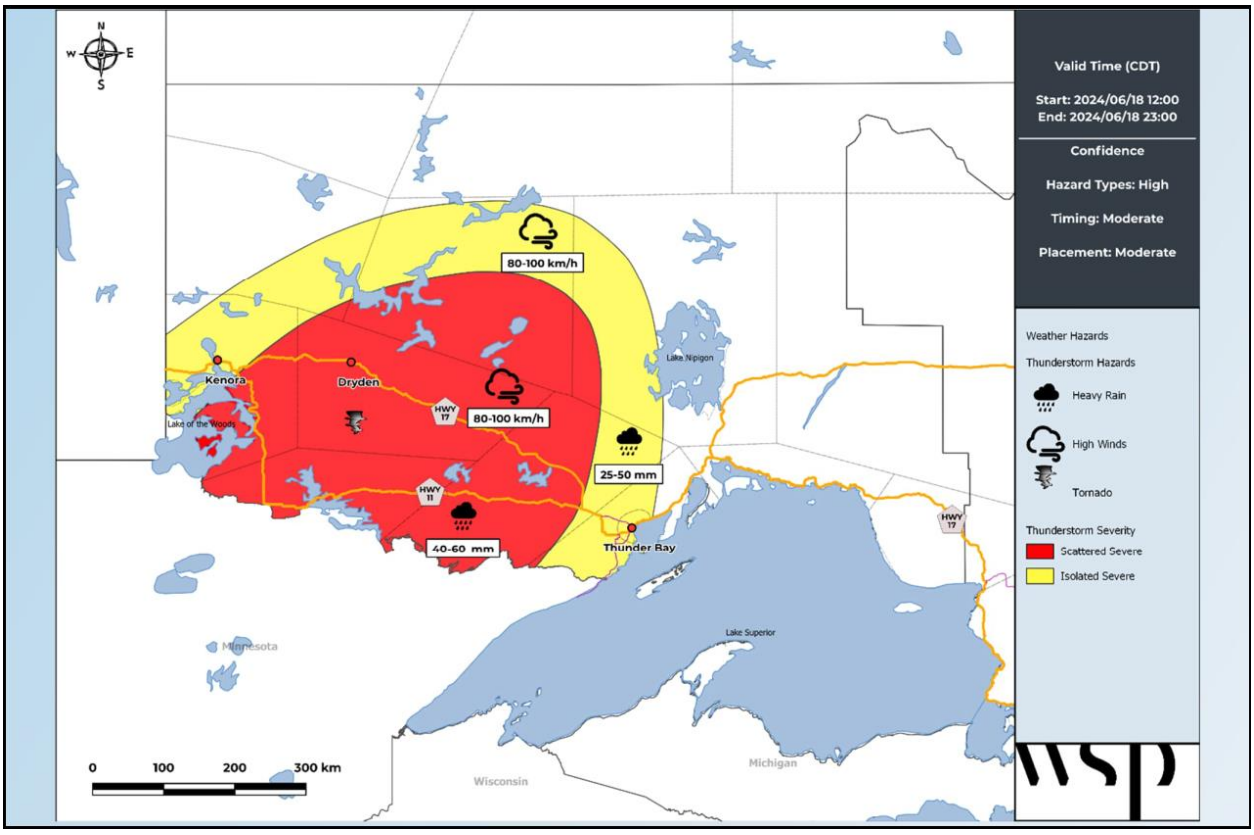


Figure 10 Example Ontario Severe Storm Report Map

5 CLOSURE

We trust that this report meets your needs. Please do not hesitate to contact the undersigned if you have any questions or comments regarding the hurricane season outlook.

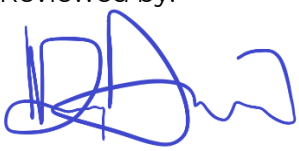
Yours sincerely,

WSP Canada Inc.

Prepared by:

Nick Camizzi
Weather and Climate Consultant

Reviewed by:



Nikolay Damyanov
Weather Operations Manager
Project Manager