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Data Sources and Methods for the for the Weather Warning Index Indicator

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1 Introduction

The Weather Warning Index (WWI) is part of the Canadian Environmental Sustainability Indicators (CESI) program, which provides data and information to track Canada's performance on key environmental sustainability issues.

2 Description and rationale of the WWI

2.1 Description

The index provides Canadians with an overview of the state of Environment Canada's severe weather warning program, thereby increasing transparency and allowing the public to understand and track performance of the program. Over time, Canadians will be equipped to track trends in performance of the severe weather warning program.

The Weather Warning Index (WWI) is calculated based on timeliness and accuracy information of six warning types that are representative of Canada's climate: rainfall, snowfall, freezing rain, wind, severe thunderstorm and marine gales.

3 Data

3.1 Data source

The index's data sources include timeliness performance information for the identified six severe weather warning types. This information is compiled by comparing warnings issued by Environment Canada against severe weather reports submitted by the public and data collected by Environment Canada's observation network.

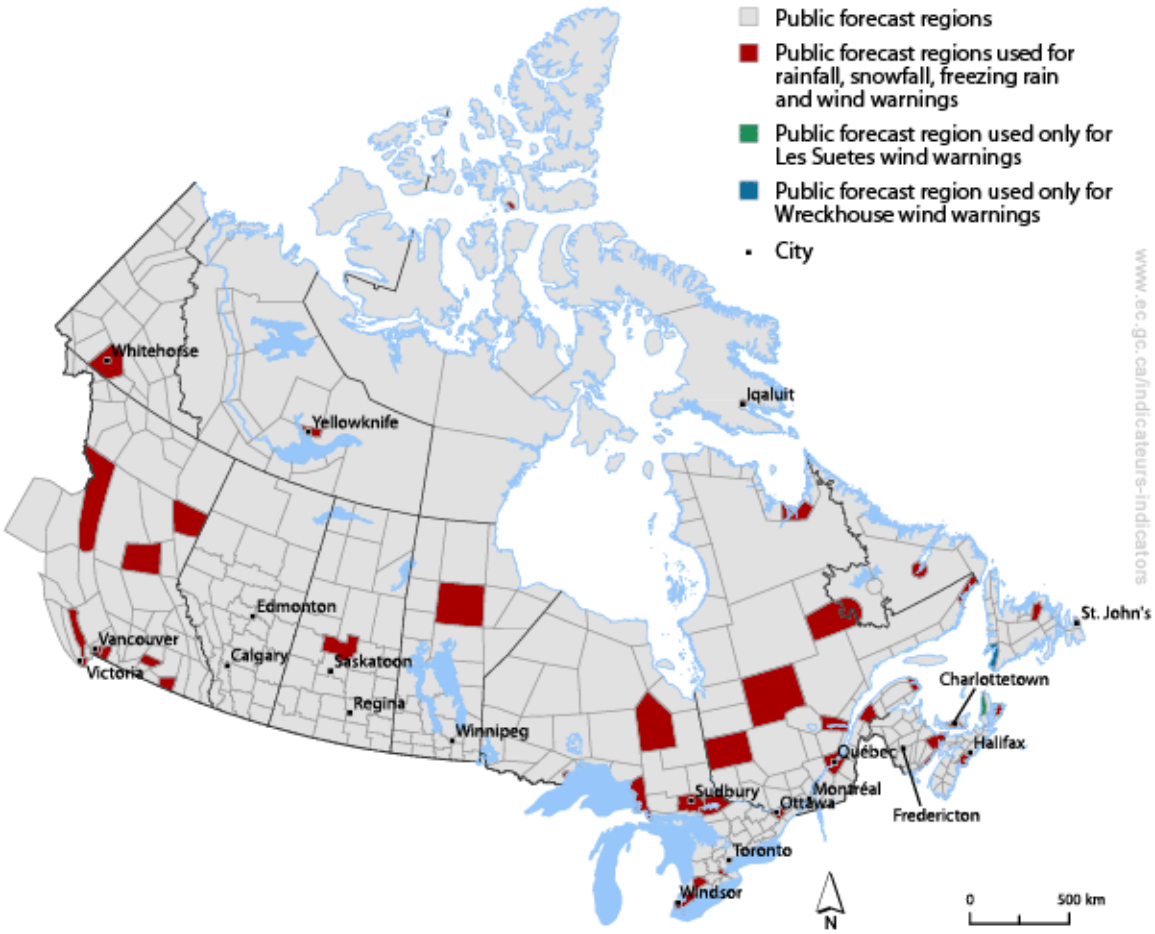
Timeliness statistics reflect the average lead-time and target lead-time for each of the six warning types, as determined by our warning performance targets. Accuracy statistics reflect the Extremal Dependency Index (EDI), which incorporates the number of hits, misses and false alarms for each of the six warning types.

These statistics are compiled by Environment Canada from available meteorological observations, archived warning bulletins, and existing verification procedures. This information is available in the quarterly and annual reports from the Meteorological Service of Canada (MSC) warning program prepared by the Performance Management Division of the Business Policy Directorate.

3.2 Spatial coverage

Information reported in selected geographic regions for each warning group is used in calculating the WWI. These selected geographic regions are representative of Canada's climate and are areas that regularly have sufficient event data against which to compare severe weather warnings.

Public forecast regions with those used in the WWI highlighted – rainfall, snowfall, freezing rain and wind warnings

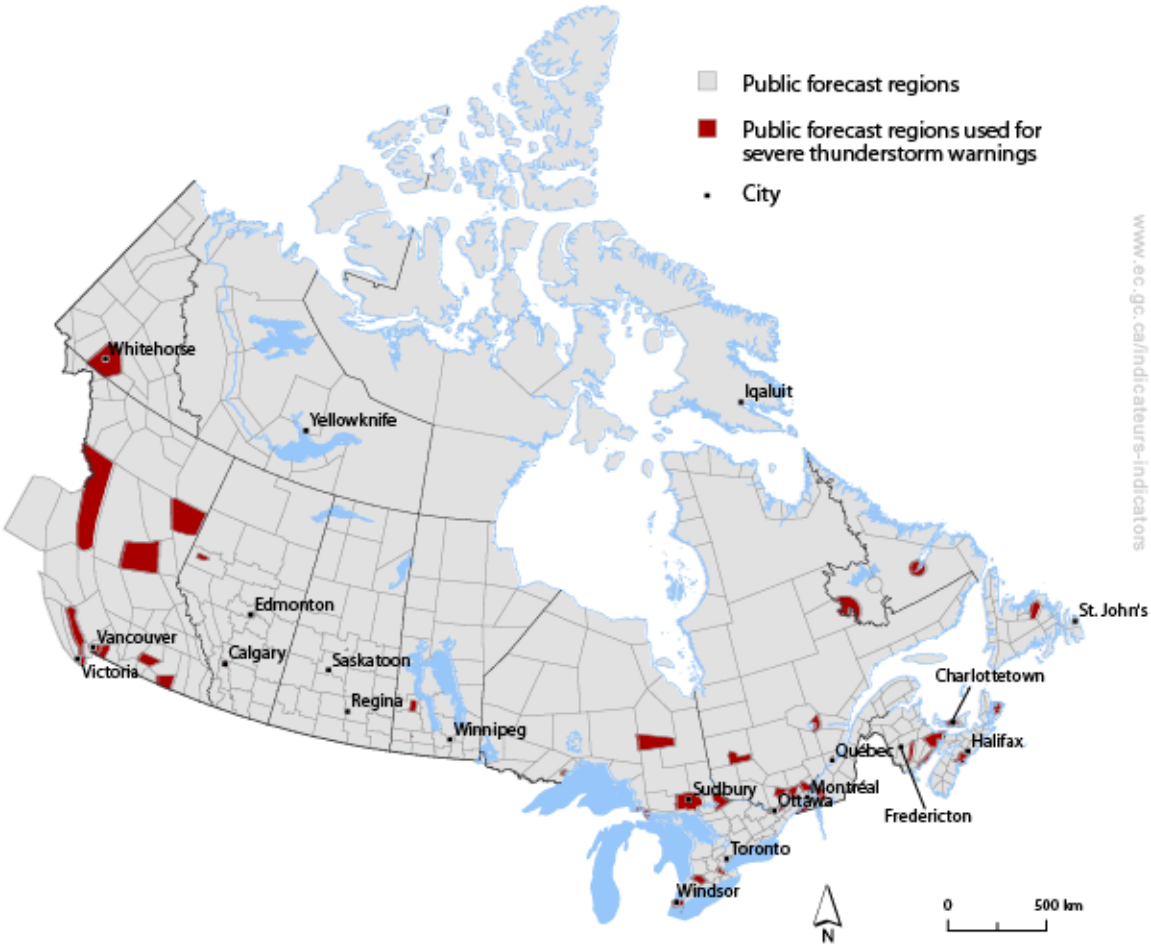


Note: Some public forecast regions are not visible at the national scale. See Table 1 for the complete list.

Table 1: Public forecast regions used in the WWI for rainfall, snowfall, freezing rain and wind warnings

Pacific and Yukon	Prairie and Northern	Ontario	Quebec	Atlantic
Metro Vancouver	City of Winnipeg	Windsor – Essex – Chatham-Kent	Metro Montreal - Laval	Saint John and County
Fraser Valley-West Including Abbotsford	Thompson – Nelson House – Split Lake	London - Middlesex	Quebec	Moncton and Southeast New Brunswick
East Vancouver Island	City of Regina	City of Hamilton	Saguenay	Halifax Metro and Halifax County West
Greater Victoria	City of Saskatoon	City of Toronto	Rimouski – Mont Joli	Charlottetown (Queens County P.E.I.)
North Coast – Inland Sections	Prince Albert – Shellbrook – Spiritwood – Duck Lake	City of Ottawa	Forillon National Park - Gaspe - Perce	Sydney Metro and Cape Breton County
Central Okanagan – Including Kelowna	City of Calgary	North Bay – West Nipissing	Abitibi	Inverness County (Les Suetes Wind only)
West Kootenay	City of Edmonton	Greater Sudbury and Vicinity	Chibougamau	St. Georges (Wreckhouse Wind only)
Prince George	Yellowknife Region	Sault Ste. Marie – St. Joseph Island	Sept-Iles – Port-Cartier	Gander and Vicinity
BC North Peace River	Resolute	City of Thunder Bay	Blanc Sablon	St. John's and Vicinity
Whitehorse	Iqaluit	Kapuskasing - Hearst	Fermont	Goose Bay and Vicinity
			Kuujjuaq	Labrador City and Wabush

Public forecast regions with those used in the WWI highlighted – severe thunderstorm warnings

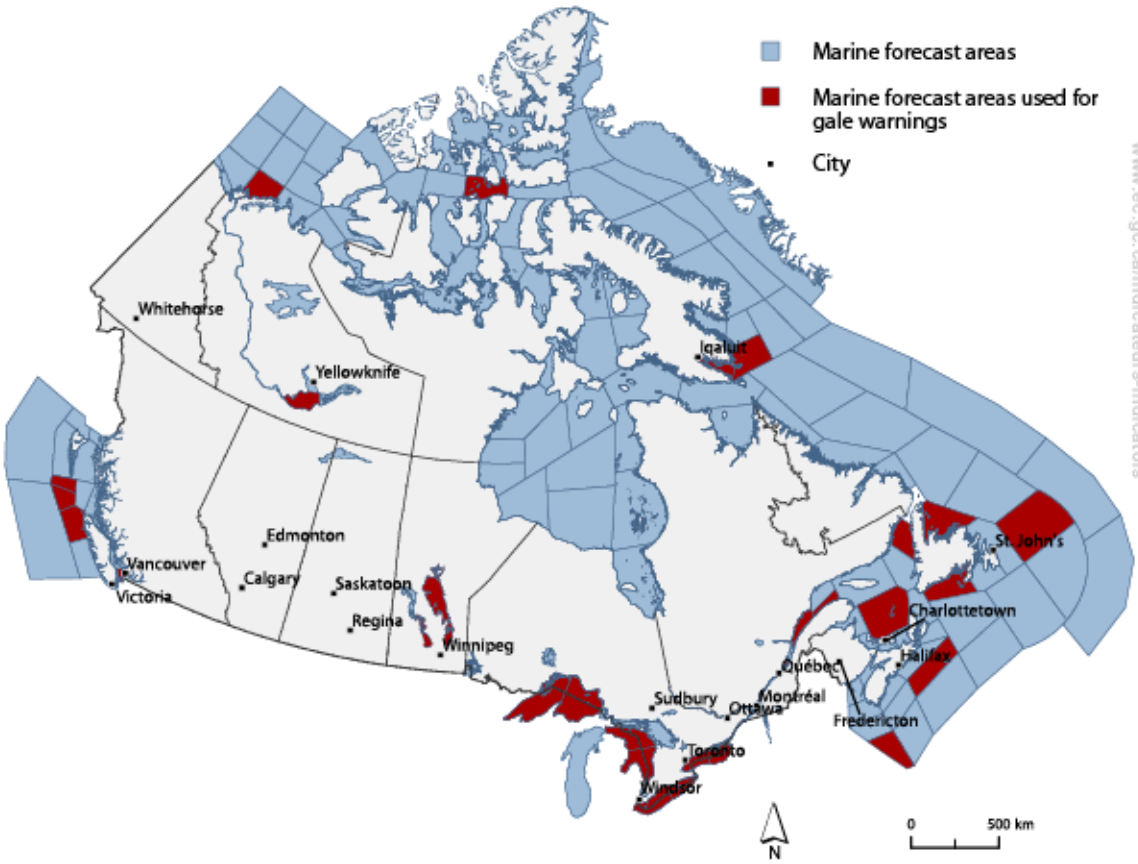


Note: Some public forecast regions are not visible at the national scale. See Table 2 for the complete list.

Table 2: Public forecast regions used in the WWI for severe thunderstorm warnings

Pacific and Yukon	Prairie and Northern	Ontario	Quebec	Atlantic
Metro Vancouver	City of Winnipeg	Windsor – Essex – Chatham-Kent (*Windsor - Leamington - Essex County*)	Montréal métropolitain – Laval (*l'ile de Montréal*)	Saint John and County
Fraser Valley-West Including Abbotsford	Brandon – Carberry – Treherne (*City of Brandon*)	London – Middlesex (*London - Parkhill - Eastern Middlesex County*)	Vaudreuil - Soulanges – Huntingdon (*Huntingdon*)	Moncton and Southeast New Brunswick
East Vancouver Island	Dauphin – Roblin – Winnipegosis (*R.M. of Dauphin including Sifton and Valley River*)	City of Hamilton	Vallée du Richelieu - Saint-Hyacinthe (*Saint-Hyacinthe - Acton Vale*)	Halifax Metro and Halifax County West
Greater Victoria	City of Regina	City of Toronto	Lanaudière (*Rawdon - Joliette*)	Charlottetown (Queens County P.E.I.)
North Coast – Inland Sections	City of Saskatoon	City of Ottawa (*Ottawa North - Kanata - Orléans*)	Lachute - Saint-Jérôme (*Lachute*)	Sydney Metro and Cape Breton County
Central Okanagan – Including Kelowna	Prince Albert – Shellbrook – Spiritwood – Duck Lake (*City of Prince Albert*)	North Bay – West Nipissing (*North Bay - Powassan - Mattawa*)	Laurentides (*Mont-Tremblant - Sainte Agathe*)	Oromocto and Sunbury County
West Kootenay	City of Calgary	Greater Sudbury and Vicinity	Haute-Gatineau - Lièvre – Papineau (*Reserve Papineau-Labelle*)	Gander and Vicinity
Prince George	City of Edmonton	Sault Ste. Marie - Superior East (*Sault Ste. Marie - St. Joseph Island*)	Abitibi (*Val D'Or - Louvicourt*)	St. John's and Vicinity
BC North Peace River	Lethbridge – Taber – Milk River (*City of Lethbridge*)	City of Thunder Bay	Estrie (*Granby - Waterloo*)	Goose Bay and Vicinity
Whitehorse	Grande Prairie – Beaverlodge – Valleyview (*Co. of Grande Prairie near Grande Prairie and Wembley*)	Kapuskasing - Hearst (*Kapuskasing - Hearst - Smooth Rock Falls*)	Québec	Labrador City and Wabush
			Lac Saint-Jean (*Alma - Desbiens*)	

Marine forecast areas with those used in the WWI highlighted – gale warnings



Note: Some marine forecast areas are not visible at the national scale. See Table 3 for the complete list.

Table 3: Marine forecast areas used in the WWI for gale warnings

Pacific and Yukon	Prairie and Northern	Ontario	Quebec	Atlantic
Strait of Georgia – South of Nanaimo	Great Slave Lake Basin	Western Lake Superior	Donnacona to Isle-aux-Coudres	Georges Bank
West Vancouver Island North	Tuktoyaktuk	Eastern Lake Superior	Tadoussac to Pointe-des-Monts	Sable
Queen Charlotte Sound - Western Half	Frobisher Bay	Northern Lake Huron	Pointe-des-Monts to Anticosti - southern half	Gulf – Magdalen
	West Brevoort – southern half	Southern Lake Huron		Northeast Gulf
	Barrow	Western Lake Erie		Southwest Coast
	Lake Manitoba	Eastern Lake Erie		Northeast Coast
	Lake Winnipeg – South Basin	Western Lake Ontario		Northern Grand Banks
	Lake Winnipeg – North Basin	Eastern Lake Ontario		

3.3 Temporal coverage

To reduce volatility from year to year, a three-year moving average is used for reporting purposes. Data from calendar years 2009, 2010 and 2011 are used in the calculation of the first iteration of the index. Furthermore, the WWI will be updated annually. Each spring, a value is calculated for the previous calendar year using available information.

3.4 Data completeness

Data for selected geographic regions for each warning type are used in calculating the WWI. These regions are representative of Canada's climate and are areas that regularly have sufficient event data against which to compare severe weather warnings.

3.5 Data timeliness

Data are available for each calendar by the end of February of the following year. The index will be updated each year in the spring with these data.

4 Methods

4.1 Definitions

There are several definitions of note with regard to the WWI, indicated below.

An **event** is an individual instance of a weather or environmental hazard that meets hazard criteria thresholds.

The **event time** is the time at which the criteria threshold is first met for an event. For alerts where the criteria thresholds are accumulated precipitation, the event time is the time at which the accumulated precipitation total first equals or exceeds the criteria amount.

The **issue time** is the time at which the alert has been transmitted by the Environment Canada forecaster.

The **lead time** is the difference between the time that an alert is issued and the event time. For example, if an alert is issued at 09:00 and the event time is 09:30, the lead time is 30 minutes.

The **target lead time** is Environment Canada's performance goal for the timeliness of alerts. The target lead time is intended to provide adequate time for the public to take appropriate action when alerted of a predicted event. Other factors such as the predictability of an event and the ability of the public and media to receive notice of the message may influence the actual lead times provided.

Each of the six severe weather warnings that comprise the WWI has an associated performance target lead time, in terms of issuance of a warning. The target lead times for the six warning types are as indicated below in Table 4.

Table 4: Target lead time by severe warning type (Warning Performance Target)

Severe weather warning type		Target lead time
Land components	rainfall	greater than or equal to 12 hours
	freezing rain	greater than or equal to 6 hours
	wind	greater than or equal to 12 hours
	snowfall	greater than or equal to 18 hours
	severe thunderstorm	greater than or equal to 30 minutes
Marine component	gale	greater than or equal to 18 hours

A **hit** is defined as "a warning event was forecast and it occurred."

A **miss** is defined as "a warning event occurred but there was no advance warning provided or no alert was issued."

A **false alarm** is defined as "a warning event was forecast but conditions did not reach warning criteria."

A **correct negative** is defined as "no warning was issued and no event was reported."

4.2 Methodology

The index will range from 0 to 10 and can be constructed by taking a weighted mean of timeliness and accuracy statistics. To reduce volatility from year to year, a three-year moving average will be used for reporting purposes.

Weighting

The WWI considers demographic and recreational statistics in its calculations. More specifically, given the statistic that 20 percent of Canadians engage in marine activities,[1] a 20 percent weight is assigned to the marine gale component of the index. The remaining severe weather warning types (severe thunderstorm, wind, rainfall, snowfall and freezing rain) are assigned a combined 80 percent weight in the index. In addition, each of these land components is weighted based on its frequency of occurrence during the reporting periods, which also reflects its impact on the overall population.

Timeliness factors

To calculate the average lead time for each warning component, the warning issue time is subtracted from the time when the warning event occurred. The lead times so obtained are then averaged over the year to obtain the "average lead time". Missed events are assigned 0 lead time. This value is then compared to the target lead time for the specific warning type. The resultant value represents the "timeliness" aspect of the WWI.

[1] NMMA (2007) Discover Boating Canada. The economic impact of recreational boating in Canada: 2006 summary report (available from: http://www.cmma.ca/cmma/eir.cfm?menu=sub11).

Accuracy Factors
The number of successfully detected events (hits), the number of missed events and the number of false alarms represents the "accuracy" aspect of the WWI. These values are used to calculate the Extremal Dependency Index (EDI).

$$EDI = \frac{\log(\text{False Alarm Rate}) - \log(\text{Hit Rate})}{\log(\text{False Alarm Rate}) + \log(\text{Hit Rate})}$$

The Hit Rate is calculated using the number of hits and misses, and the False Alarm Rate is based on the number of false alarms and number of correct negatives (Non-events). This requires an estimation of the number of periods of time during the year that no warning would be required (Non-events). Since the EDI is a ratio of logarithms, it does not matter which base is used.

Hit Rate = Hits / (Hits + Misses)

False Alarm Rate = False Alarms / (False Alarms + Non-events)

WWI calculation
The WWI will range between zero and ten. It will attain a value of ten if all component warnings meet warning criteria and there are no missed events or false alarms.

The scoring formula for each warning component is as follows:

Case 1
If the Average Lead Time is equal to or greater than the Target Lead Time (ALT ≥ TLT), the WWI component score becomes

$$[EDI + (0.5 \times (AverageLeadTime/TargetLeadTime - 1) \times (1 - EDI))] \times 10$$

Case 2
If the Average Lead Time is less than the Target Lead Time (ALT ‹ TLT), the WWI component score becomes

$$EDI \times (AverageLeadTime/TargetLeadTime) \times 10$$

Assumptions

All lead times are greater than or equal to zero.
Individual lead times greater than twice the target lead time are assigned a value of twice the target lead time.

Table 5: WWI Calculation, timeliness and accuracy statistics, 2009, 2010 and 2011

2009-2011	Rain	Snow	Freezing Rain	Wind	Severe Thunderstorm	Marine Gale
Hits	192	290	103	305	167	1905
Misses	103	122	56	118	110	473
False Alarms	143	141	90	196	1218*	600
Correct Negatives	6762	9572	3801	19631	26855	5122
TOTAL	7200	10125	4050	20250	28350	8100
Hit Rate	0.65085	0.70388	0.64780	0.72104	0.60289	0.80109
False Alarms Rate	0.02071	0.01452	0.02313	0.00989	0.04339	0.10486
Extremal Dependency Index (EDI)	0.801	0.847	0.793	0.868	0.722	0.821
Average Lead Time (in hours)	12.29	15.58	5.36	12.03	0.34	19.71
Target Lead Time (in hours)	12	18	6	12	0.5	18
Weight	15	21	8	22	14	20
WWI component score	*8.03*	*7.33*	*7.09*	*8.68*	*4.89*	*8.29*
Individual weighted WWI component score	**1.21**	**1.54**	**0.58**	**1.88**	**0.69**	**1.66**
Weather Warning Index	**WWI is the sum of the individual weighted WWI component scores: 7.55**					

* False alarms are not available for severe thunderstorm alerts. A convective warning bias of 5 is used to estimate the number of false alarms, where:

False alarms = Convective Warning Bias x (hits + misses) - hits

5 Caveats and limitations

Calculation of the WWI does not consider when weather warnings are received by Canadians, as this factor varies considerably depending upon how warnings are received (for example, via a media outlet or via a website). Additionally, the index does not represent all forecast regions in Canada; instead, it represents areas that regularly have sufficient event data against which to compare severe weather warnings.

6 References and further reading

NMMA (2007) Discover Boating Canada. The economic impact of recreational boating in Canada: 2006 summary report. Retrieved on 29 February, 2012. Available from: http://www.cmma.ca/cmma/eir.cfm?menu=sub11.

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Ferro C *et al*. (2011) Extremal Dependence Indices: Improved Verification Measures for Deterministic Forecasts of Rare Binary Events. Weather and Forecasting 26(5):699–713. Available from: http://journals.ametsoc.org/doi/pdf/10.1175/WAF-D-10-05030.1.

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