

July 2023 storm: preliminary analyses

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VTDEC Clean Water Conversation
Series

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[Vermont History Museum](#)

- Rain
- River flow
- Phosphorus delivery
- Lake level
- Lake water quality



**Observations
and statistics**



Compare to

- Typical
- Tropical Storm Irene
- TMDL

- Important impacts **not covered** in this talk

- Loss of life and property
- Displacement, evacuations
- Farms – crop loss and contamination
- Infrastructure
- Wastewater discharges and overflows

An aerial photograph showing a large, muddy river that has overflowed its banks, flooding a residential area. The water is brown and turbulent. Several houses and buildings are partially submerged, with only their roofs and upper floors visible. The surrounding landscape is lush green with many trees. In the background, there are rolling hills and mountains under a cloudy sky. A road and a railway line are visible on the left side of the image.

Results are provisional

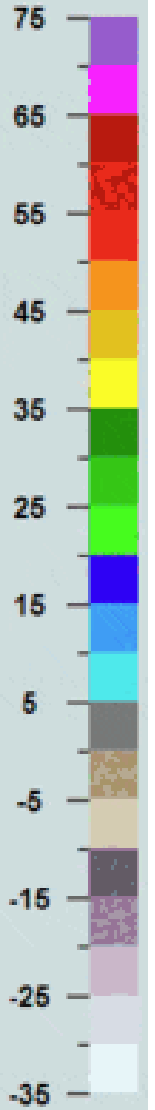
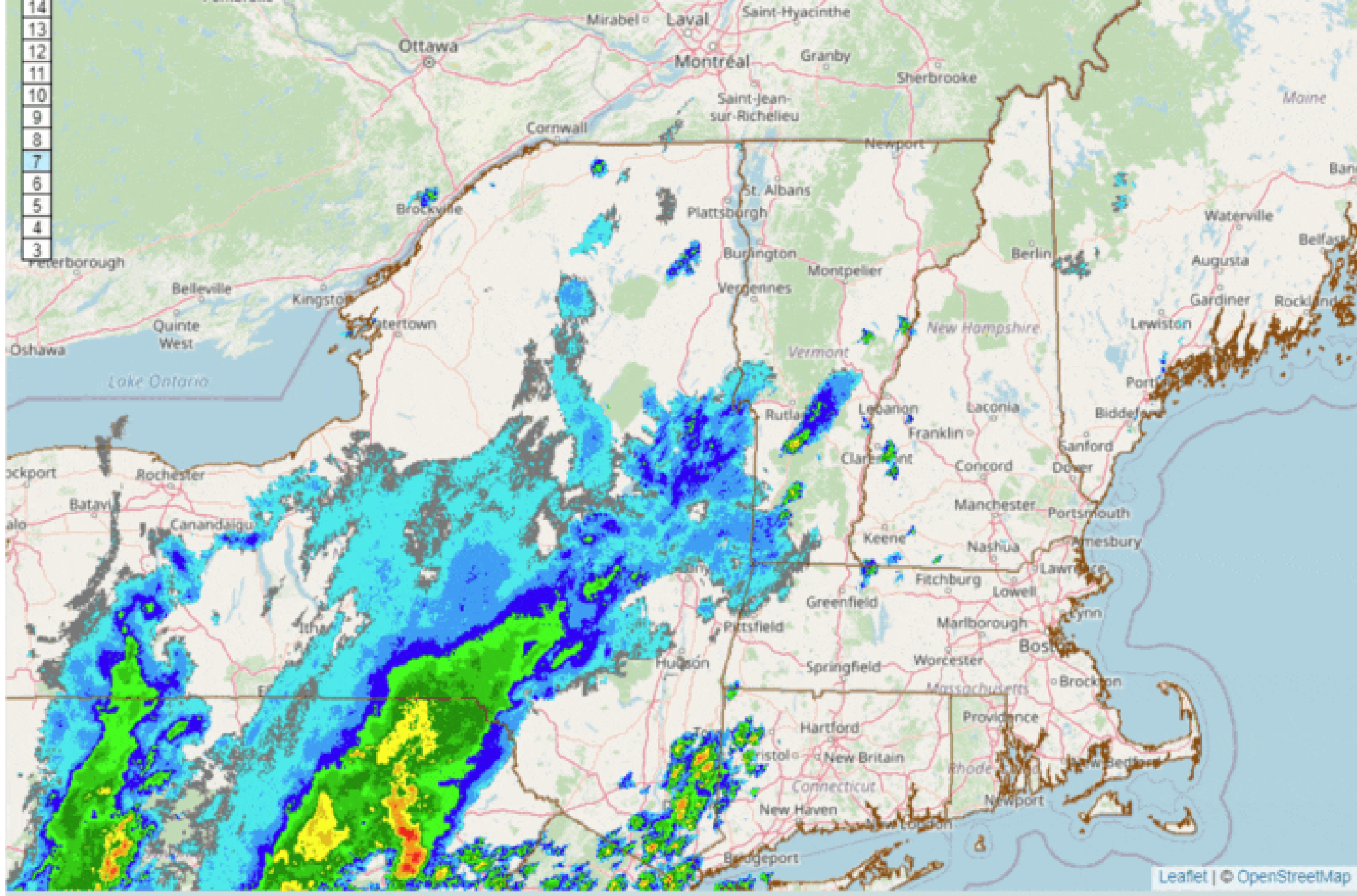
- 15
- 14
- 13
- 12
- 11
- 10
- 9
- 8
- 7
- 6
- 5
- 4
- 3

Map Center: -73.80, 43.48

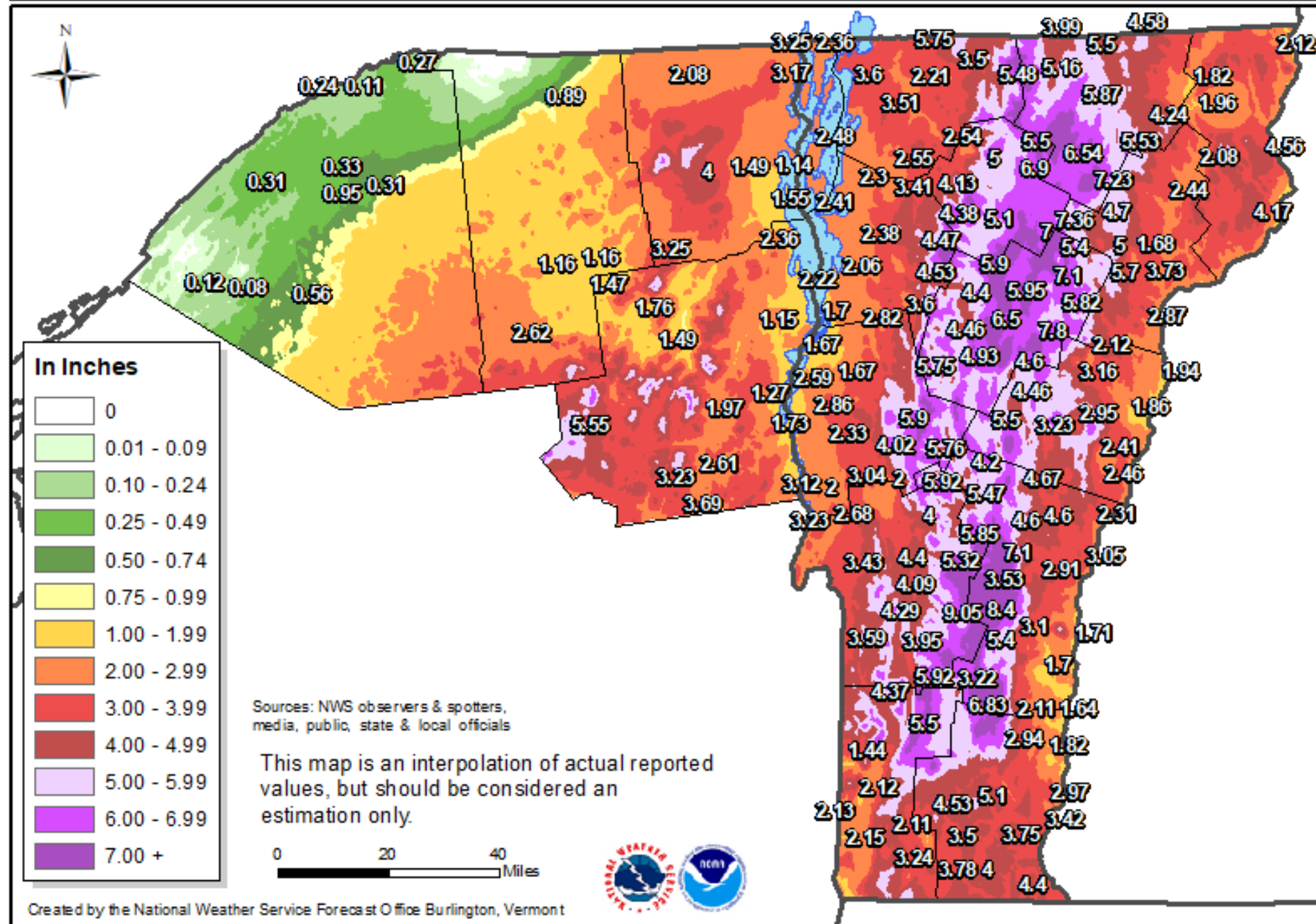
Composite Reflectivity

07/09/2023 15:02 UTC

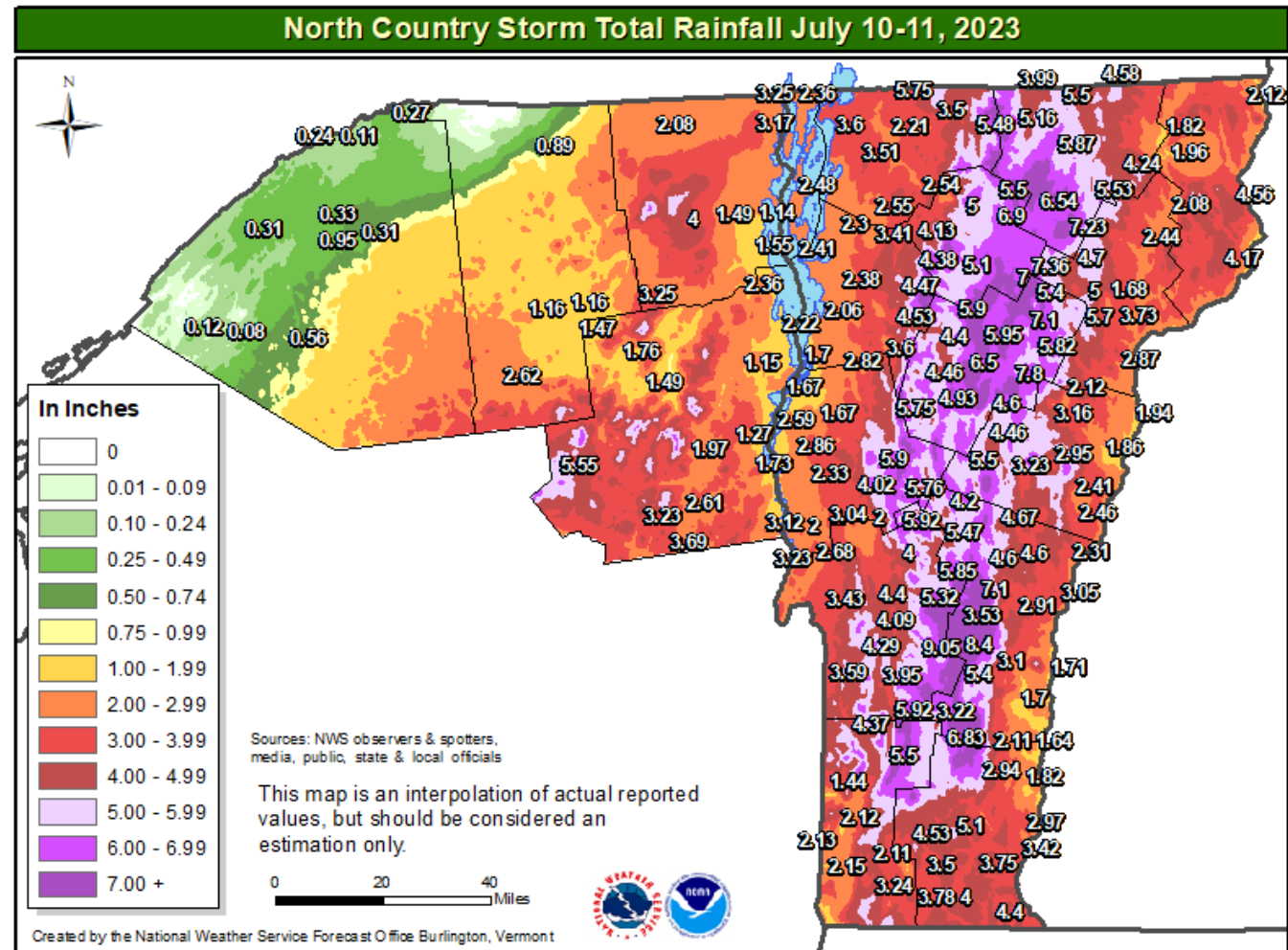
dBZ



North Country Storm Total Rainfall July 10-11, 2023



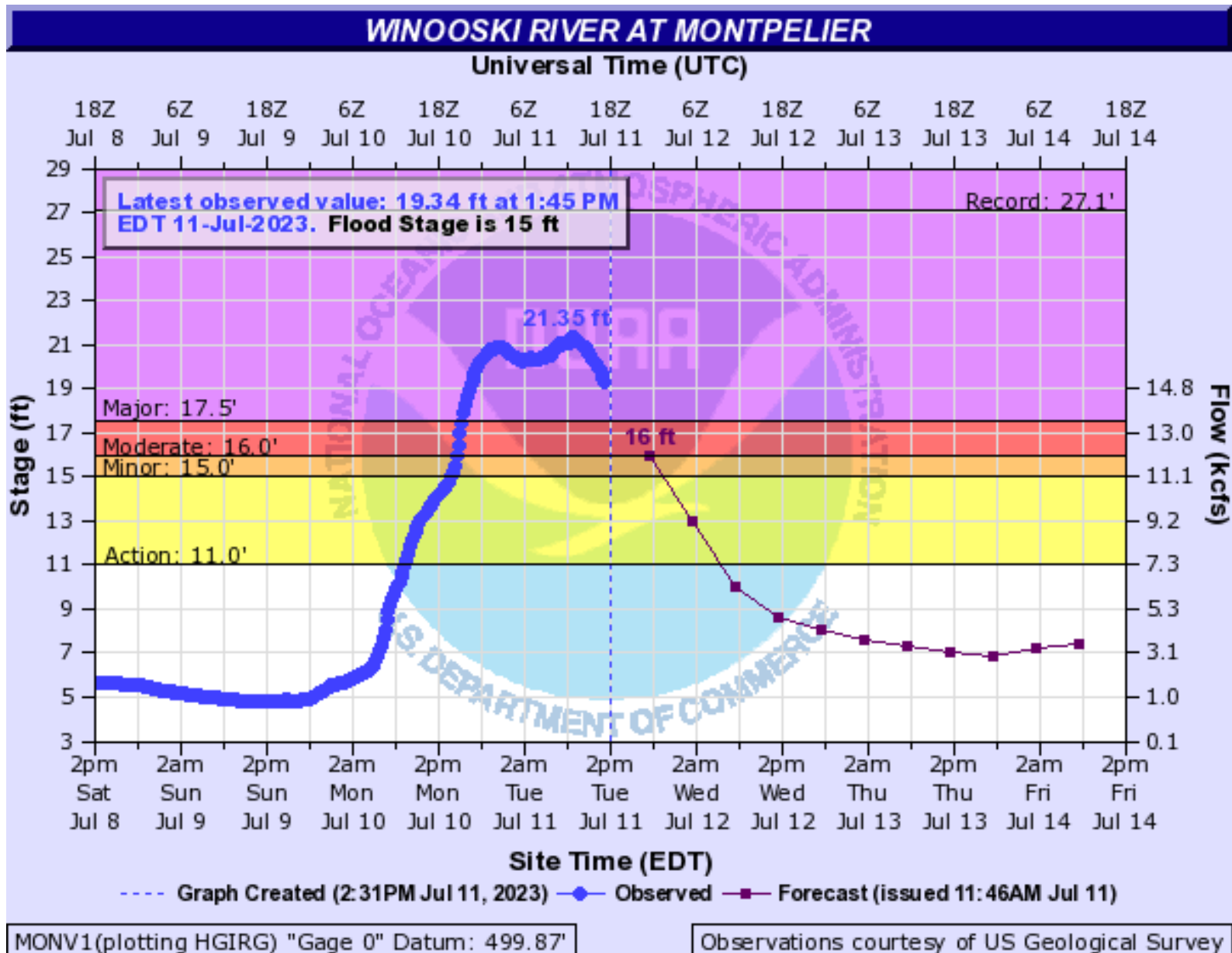
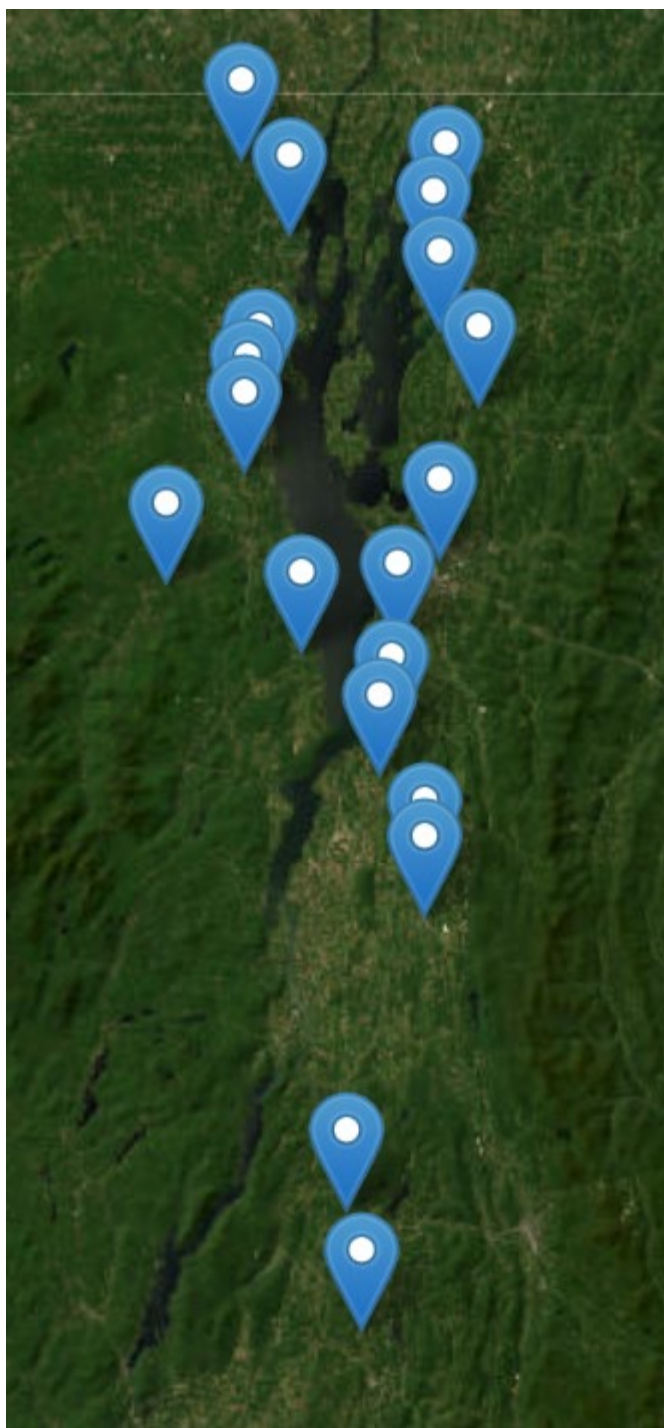
- 48-hour rainfall: **3 – 9 inches**
- Highest 48-hour rainfall: **9.20 inches** (Calais, VT)
- Montpelier stats:
 - Broke **daily rainfall record with 5.28 inches** (previous record Irene; 5.27 inches)
 - Broke **monthly rainfall record with 12.06 inches** (previous record 10.69 inches in August 1989; average 3.86 inches)



- Widespread flooding
- Winooski, Lamoille, Otter reached major flood stage
- Flash flooding from smaller rivers and streams

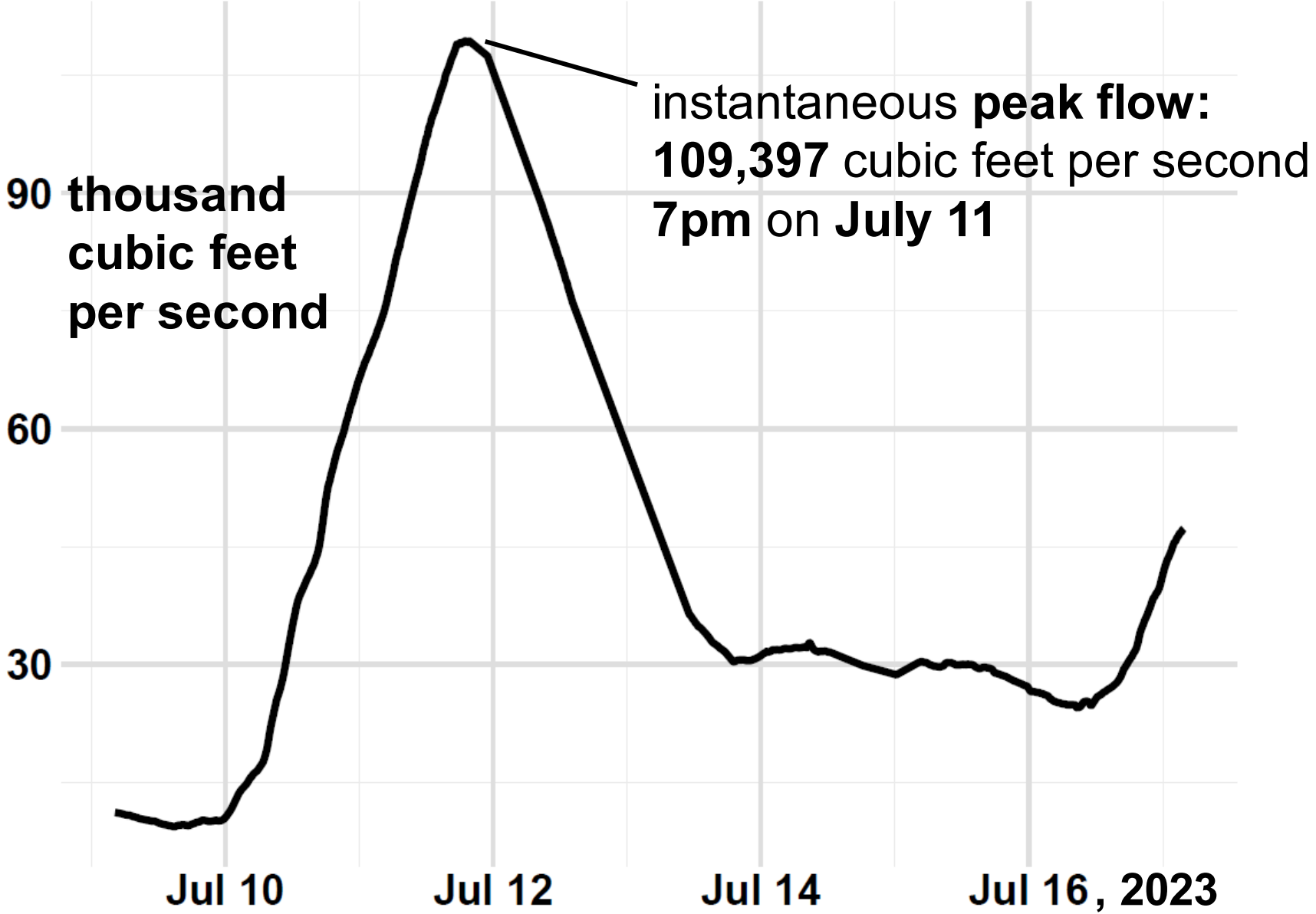


[Montpelier, VT on July 11, 2023 \(NASA\)](#)

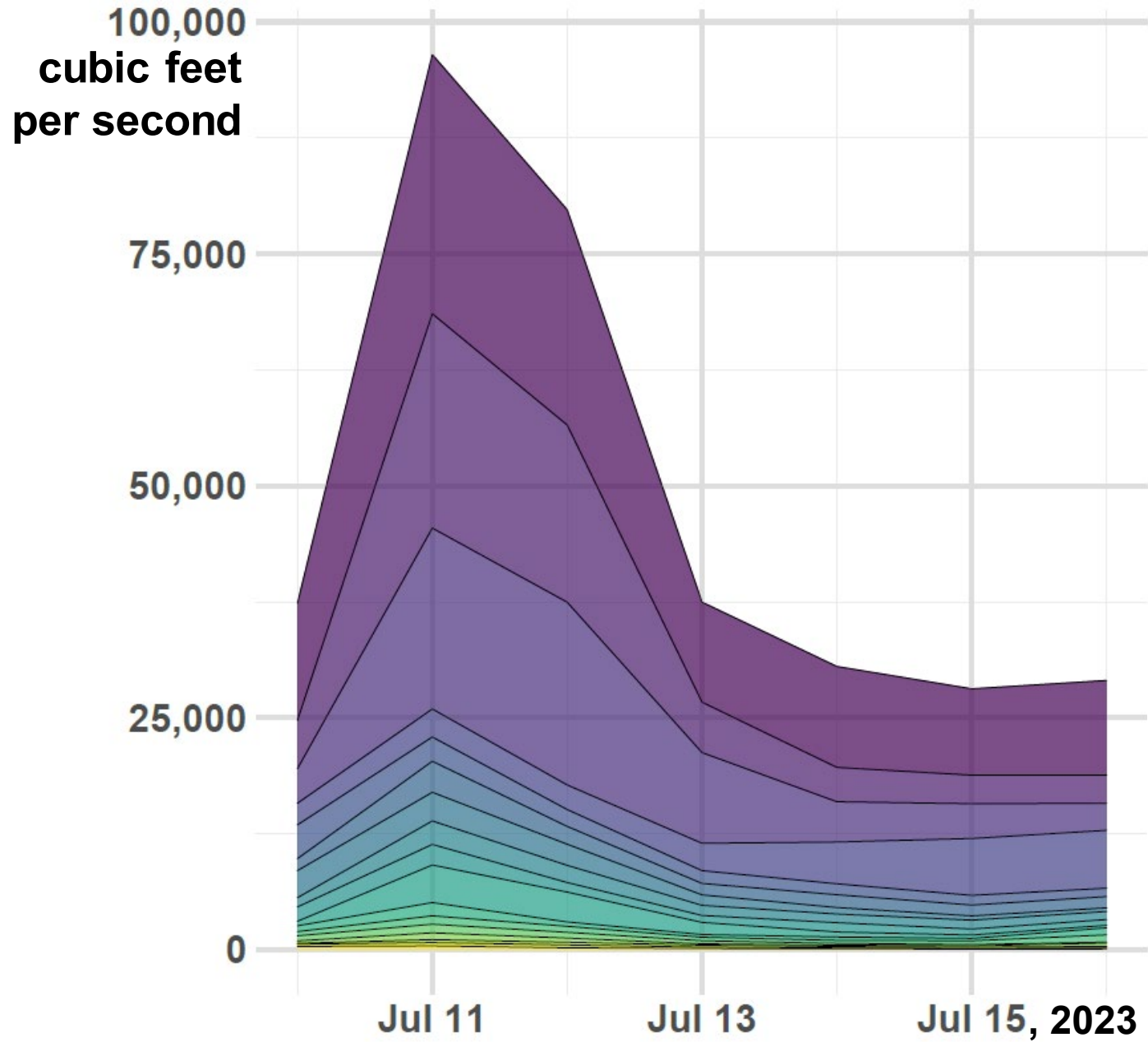


Total measured water flow to Lake Champlain

19 tributaries combined; represents roughly 3/4 of watershed



Daily average flow from each tributary



7-day water flux:

- Top **five** delivered **80%**
- **219 billion** gallons
- **829 million** cubic meters

- Winooski
- Lamoille
- Missisquoi
- Otter
- Saranac

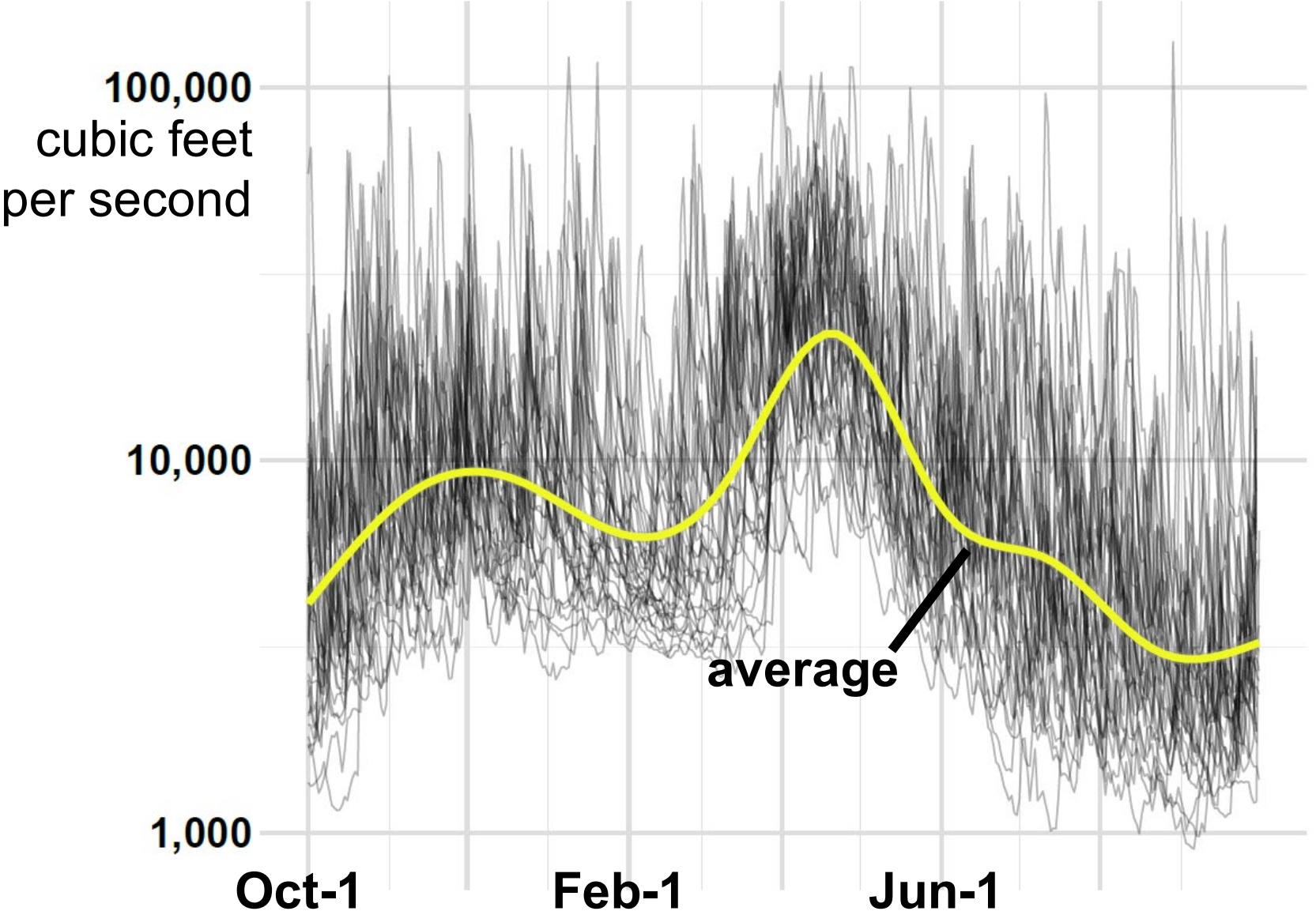
Stats dating back to 1990
**July 11, 2023 daily average
flow was:**

- **greater than 90th flow percentile** for all tributaries
- **Highest ever** for **Lamoille River**
- Second highest ever for Winooski River
- **highest flow ever for this date** for **nearly all tributaries** (2nd for 2)



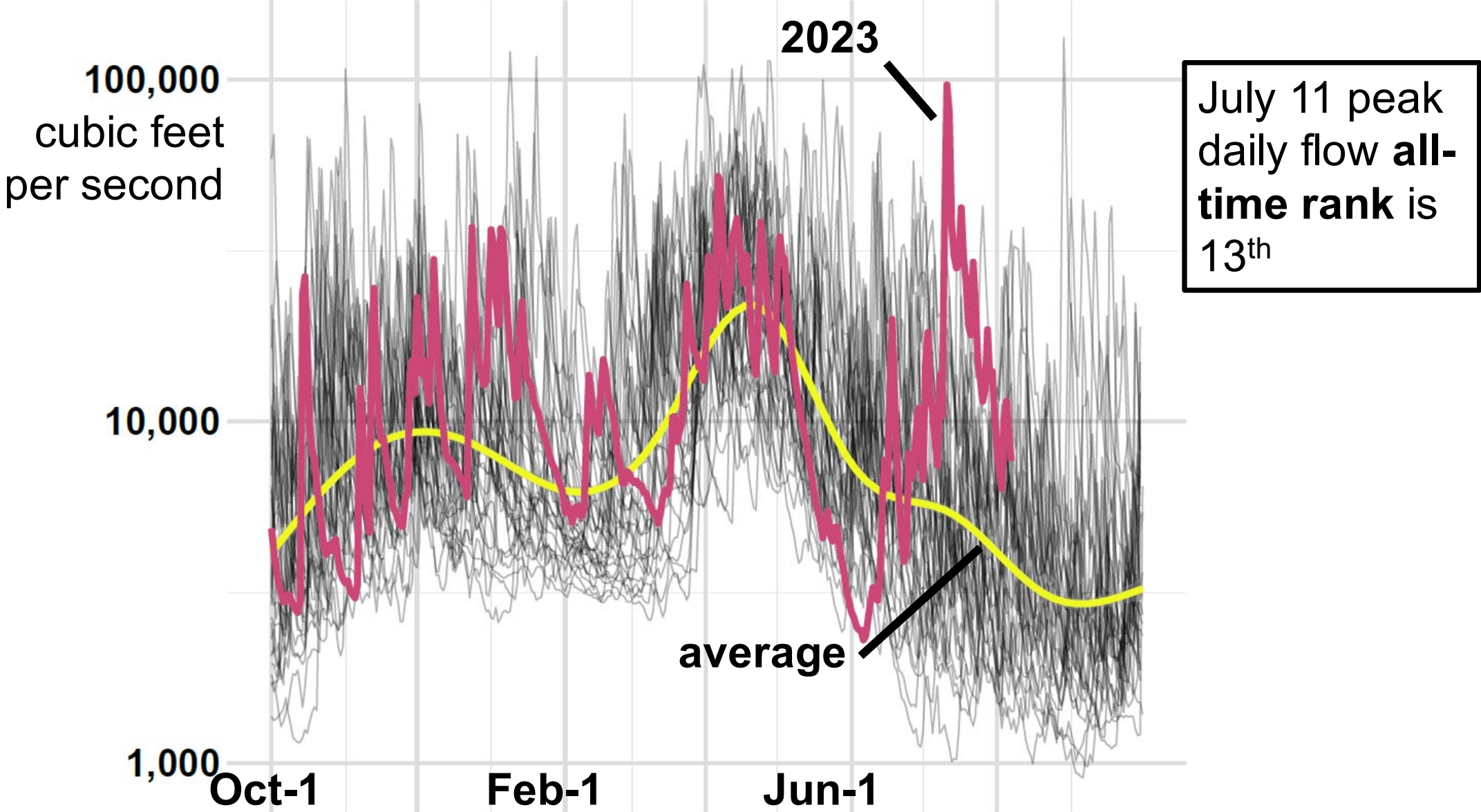
Total measured water flow to Lake Champlain

17 tributaries combined; all years since 1991



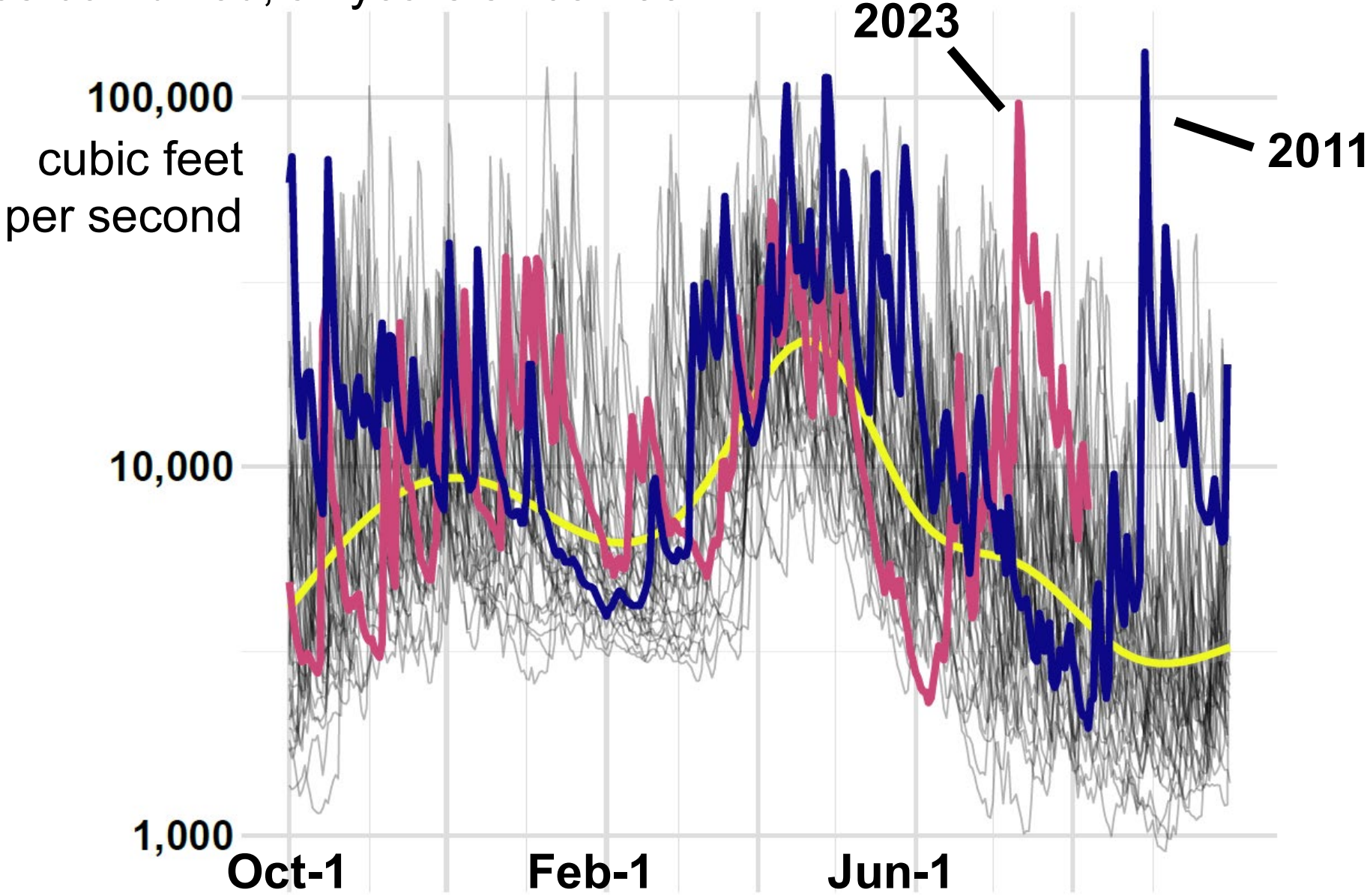
Total measured water flow to Lake Champlain

17 tributaries combined; all years since 1991



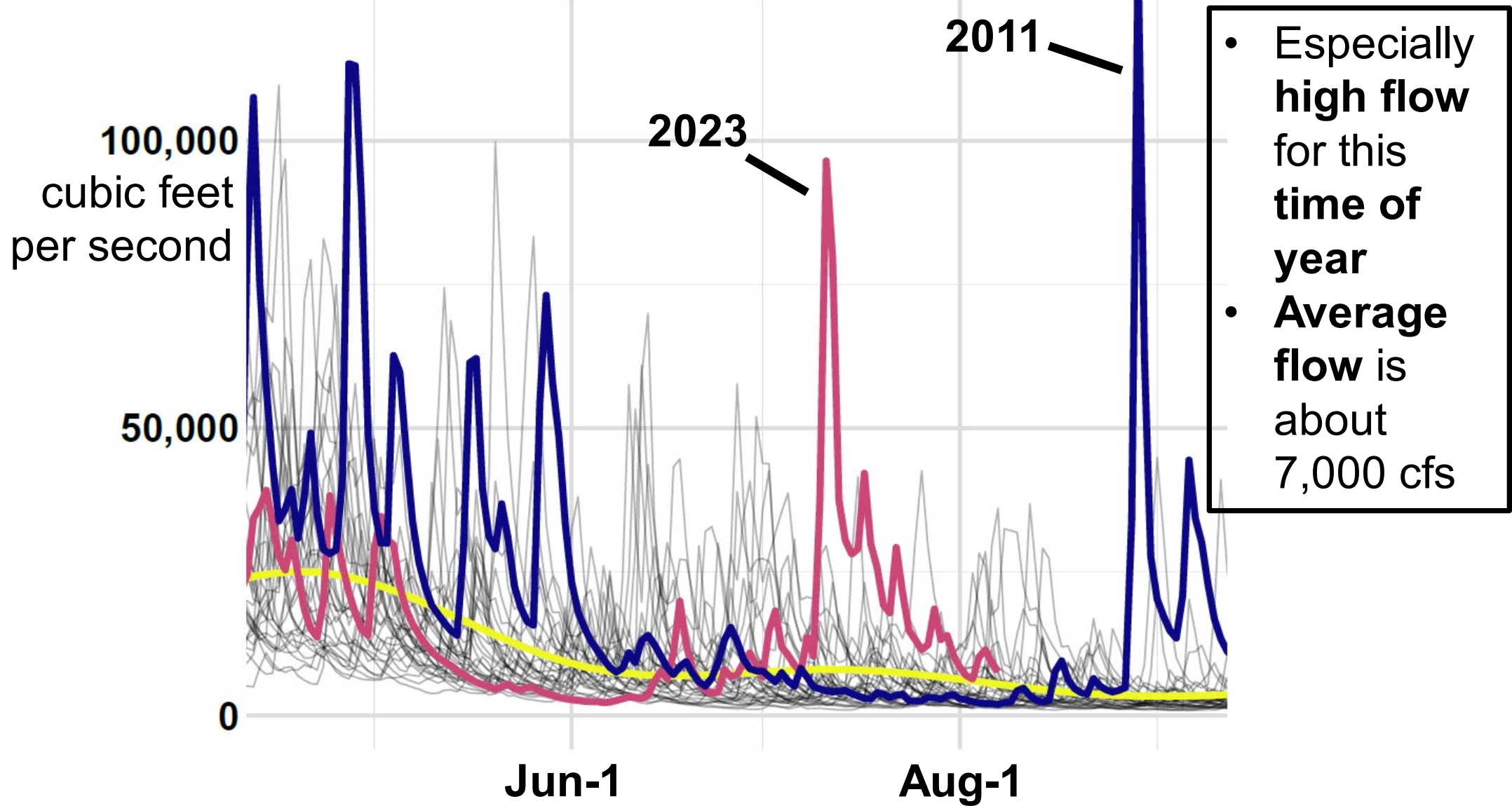
Total measured water flow to Lake Champlain

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Total measured water flow to Lake Champlain

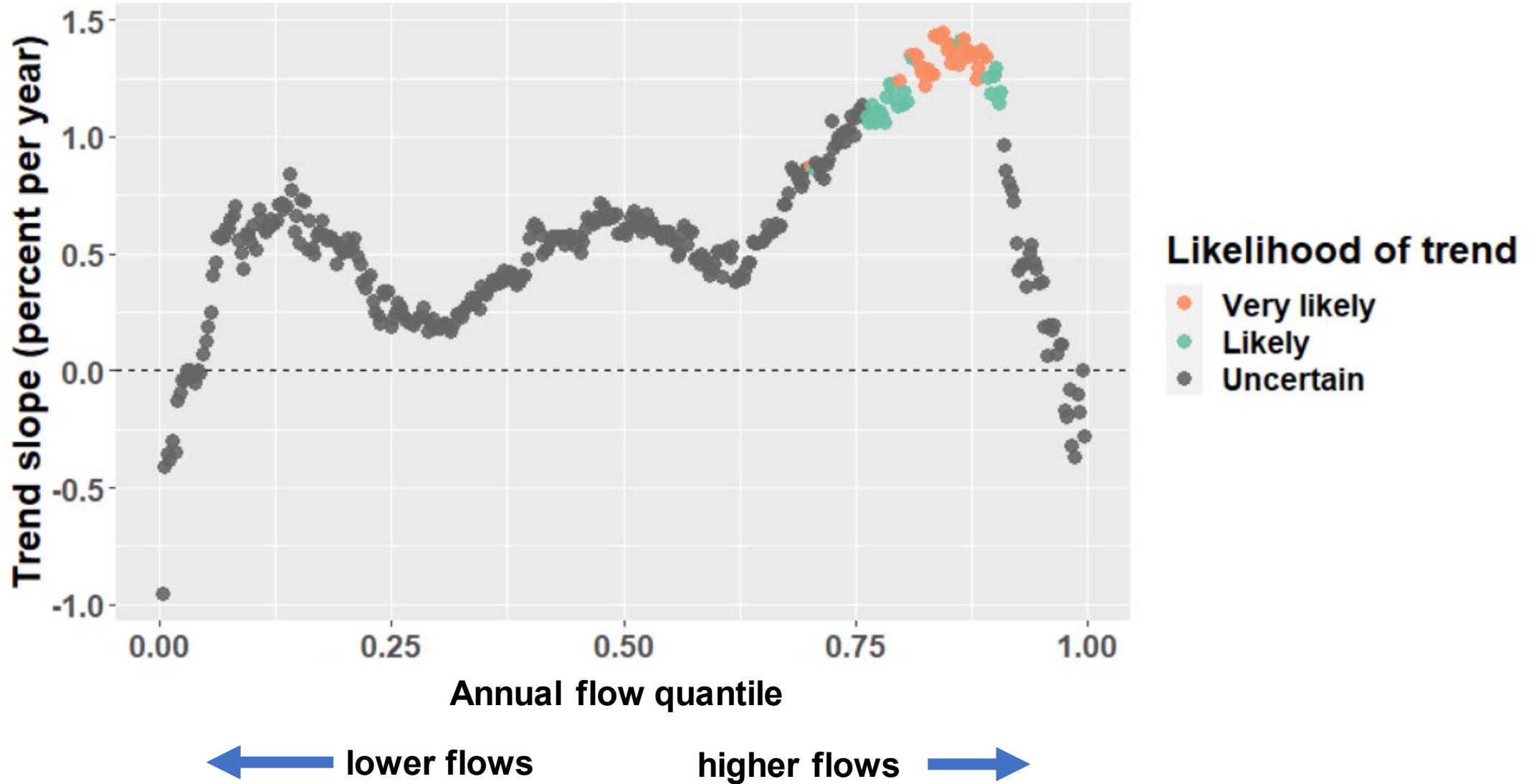
17 tributaries combined; all years since 1991



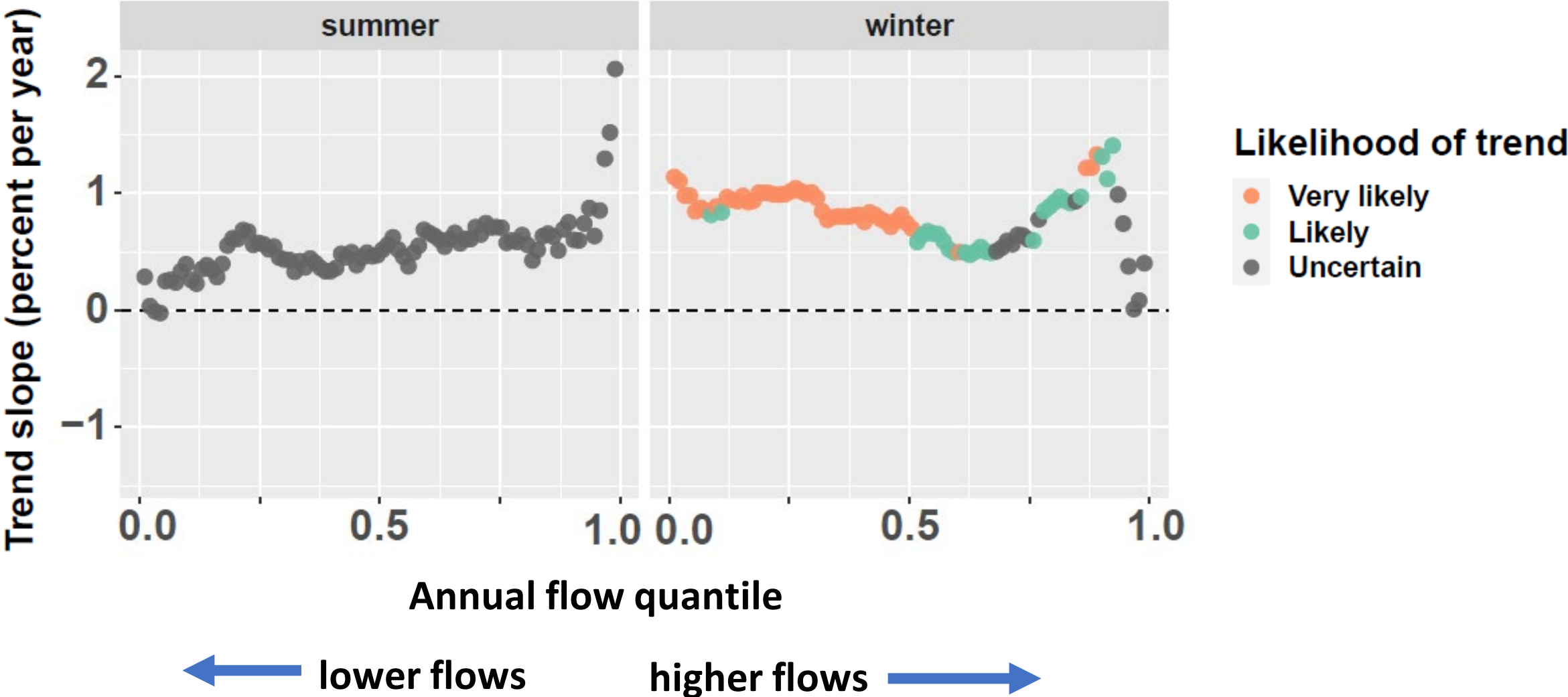
Context: **timing** and **distribution** of **flow** is **changing**




Winooski River – discharge trends by quantile



Winooski River – discharge trends by quantile and season

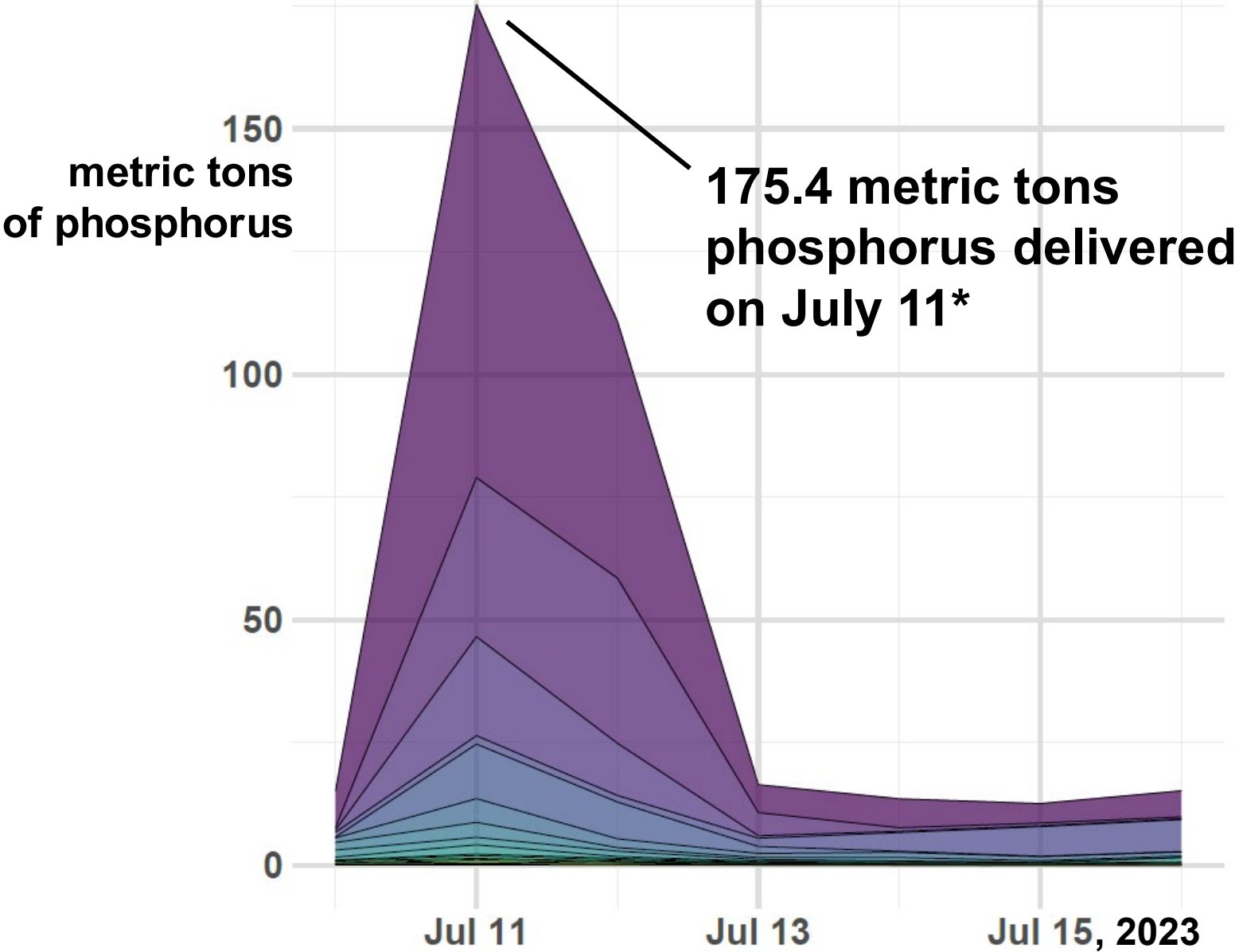


An aerial photograph showing a wide, muddy river winding through a dense forest. The water level is high, submerging many trees and creating a series of small islands. In the background, there are rolling hills and mountains under a cloudy sky. A few buildings are visible on the right side of the river.

Next: **phosphorus** delivery

Peregrine Productions

Daily phosphorus load from each tributary to Lake Champlain



7-day load:

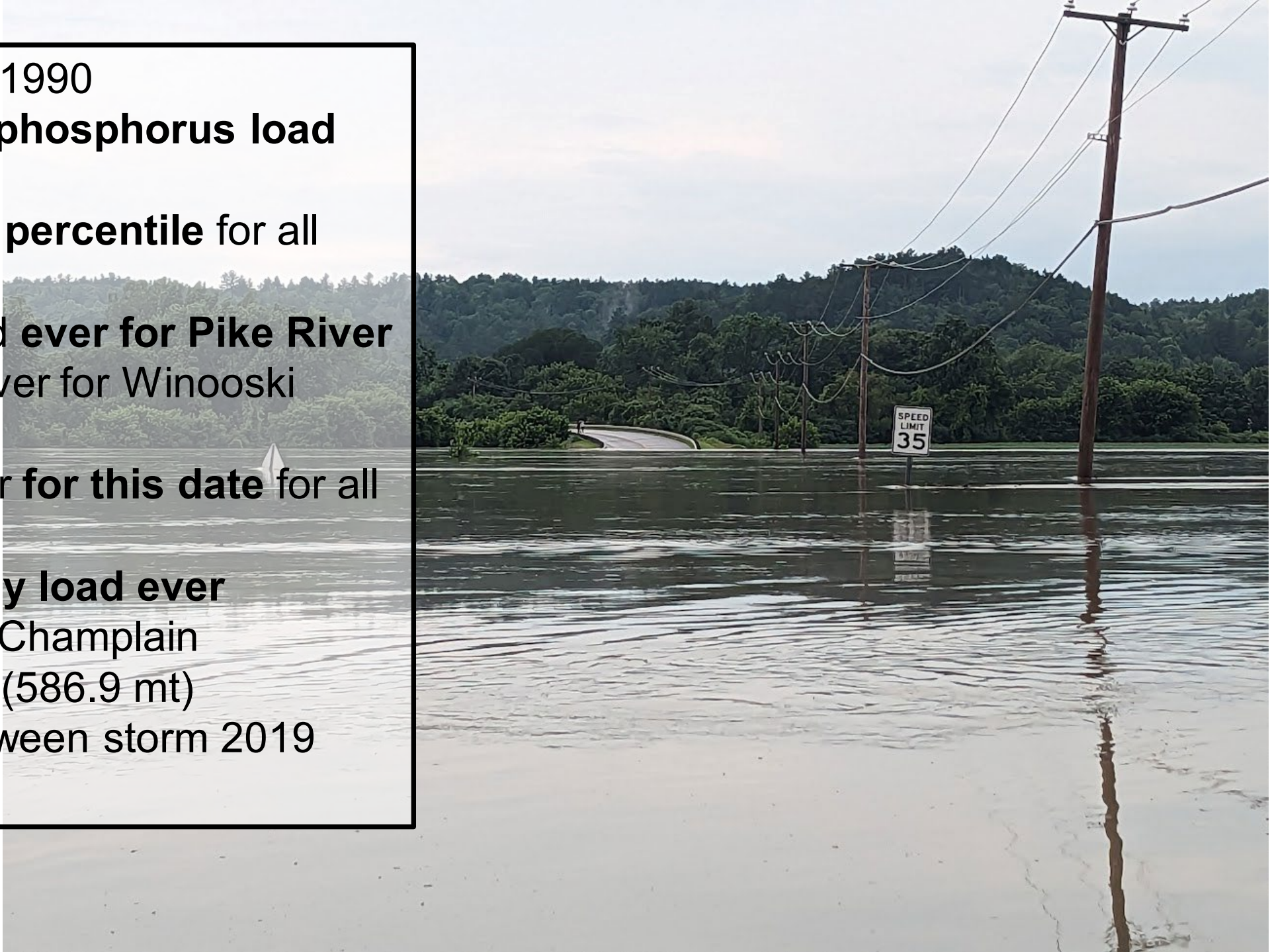
- Top **five** delivered **90%**
- **359** metric tons*
- **62 - 85%** of full-lake TMDL*

- Winooski
- Missisquoi
- Lamoille
- Otter
- Pike

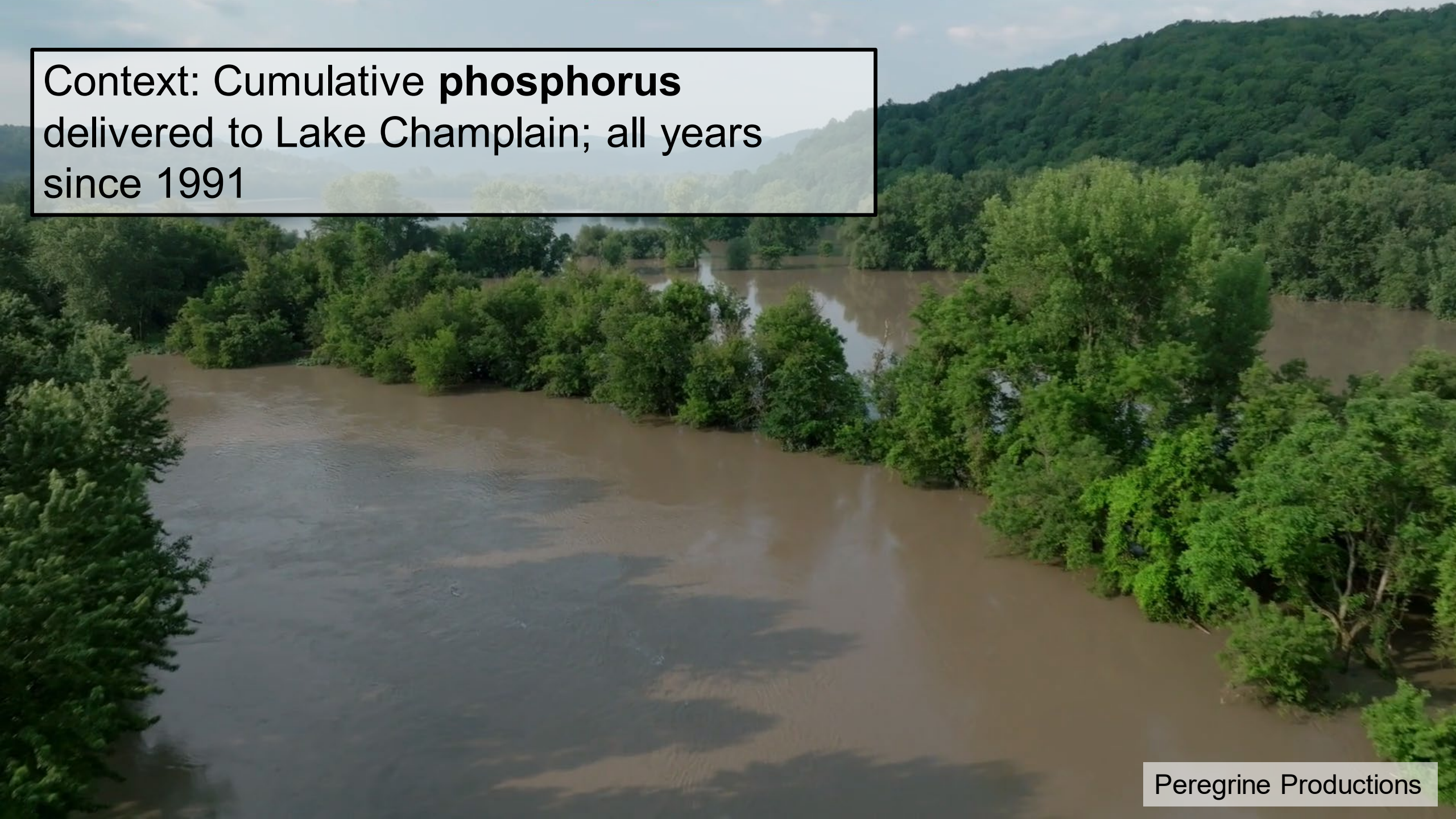
Stats dating back to 1990

July 11, 2023 daily phosphorus load was:

- **greater than 90th percentile** for all tributaries
- **Highest** daily load **ever for Pike River**
- Second highest ever for Winooski River
- **Highest load ever for this date** for all but two tributaries
- **Third largest daily load ever** delivered to Lake Champlain
 - Highest: Irene (586.9 mt)
 - Second: Halloween storm 2019 (187.7 mt)



Context: Cumulative **phosphorus**
delivered to Lake Champlain; all years
since 1991



Cumulative phosphorus delivered to Lake Champlain

17 monitored tributaries combined; all years since 1991

2,000 metric tons of phosphorus

1,500

1,000

500

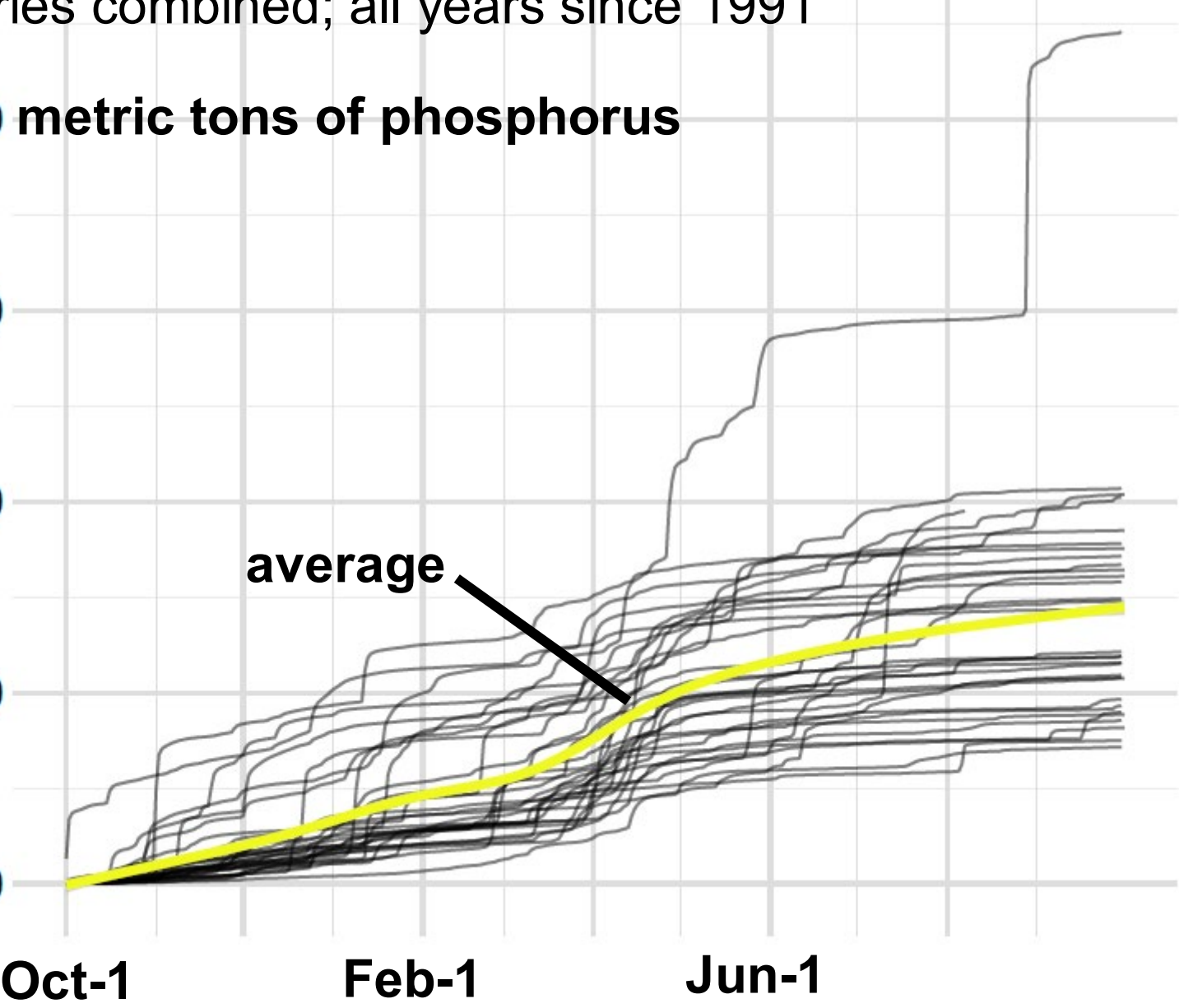
0

average

Oct-1

Feb-1

Jun-1



Cumulative phosphorus delivered to Lake Champlain

17 monitored tributaries combined; all years since 1991

2,000 metric tons of phosphorus

1,500

1,000

500

0

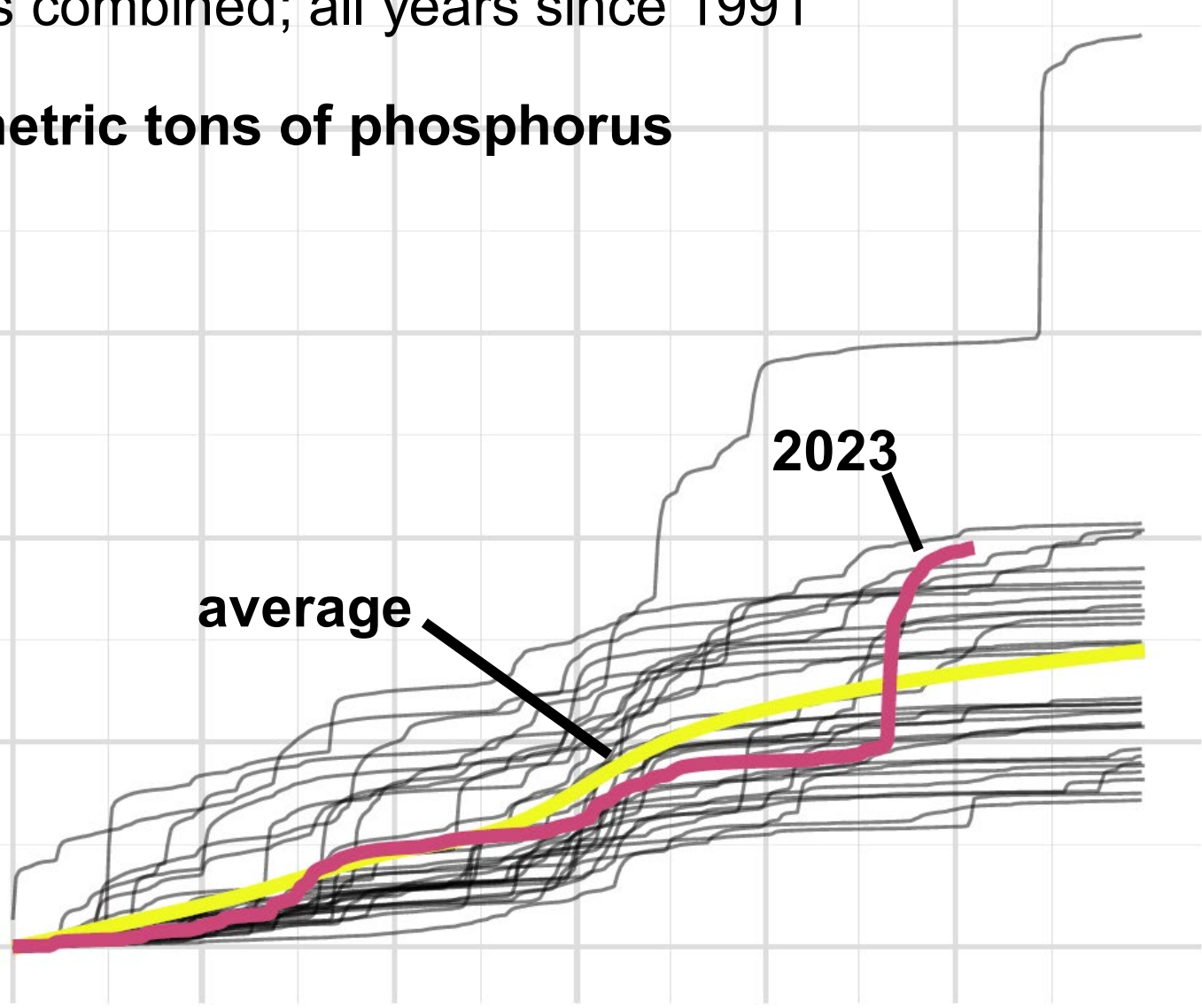
Oct-1

Feb-1

Jun-1

average

2023



Cumulative phosphorus delivered to Lake Champlain

17 monitored tributaries combined; all years since 1991

2,000 metric tons of phosphorus

1,500

1,000

500

0

Oct-1

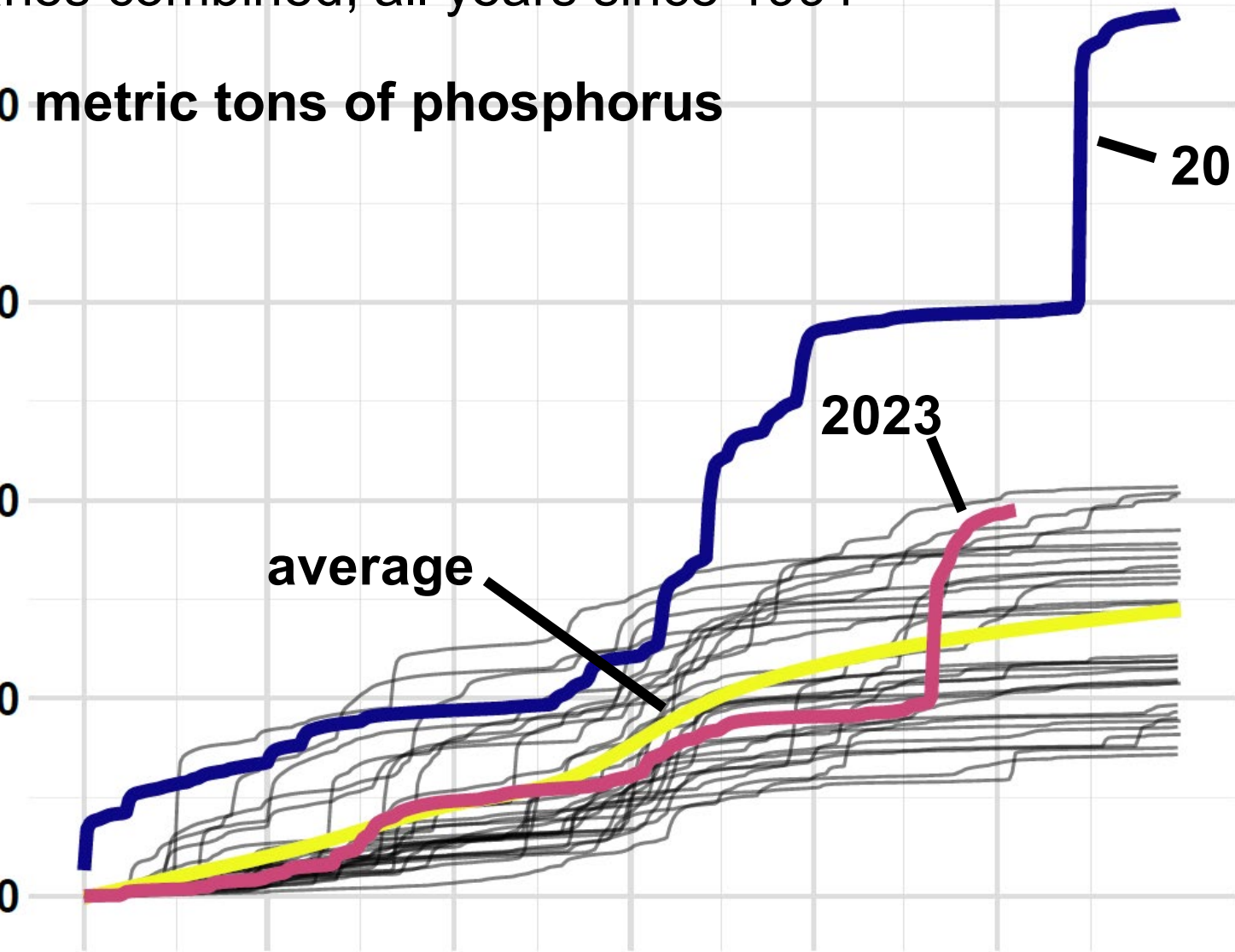
Feb-1

Jun-1

average

2023

2011





Next: Cumulative **phosphorus** delivered
to Lake Champlain **by lake segment**

- all years since 1991
- adjusted for unmonitored area
- compared to TMDL allocations

Cumberland Bay

60 metric tons of phosphorus

TMDL allocation

20

0

average

Main Lake

750

500

250

0

Malletts Bay

150

100

50

0

Missisquoi Bay

400

200

0

Oct-1

Feb-1

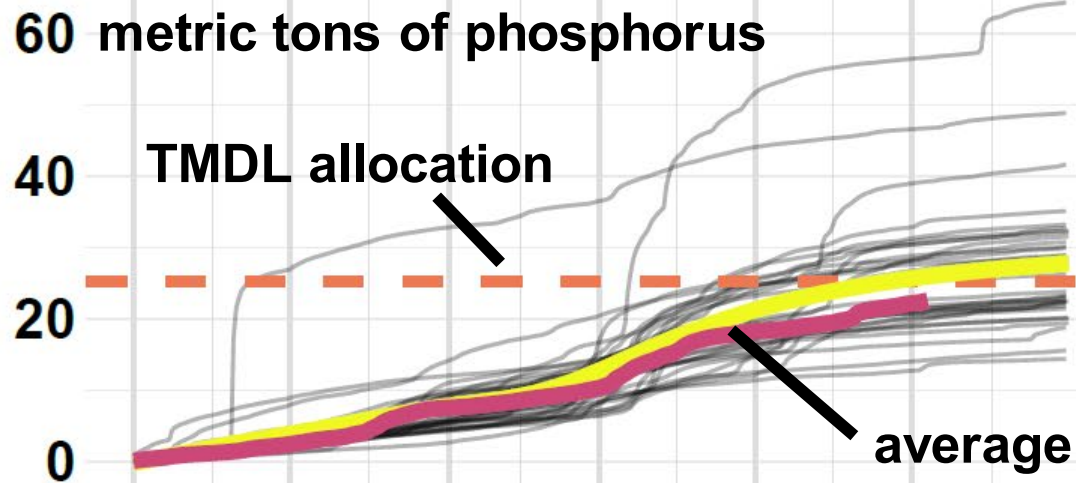
Jun-1

Oct-1

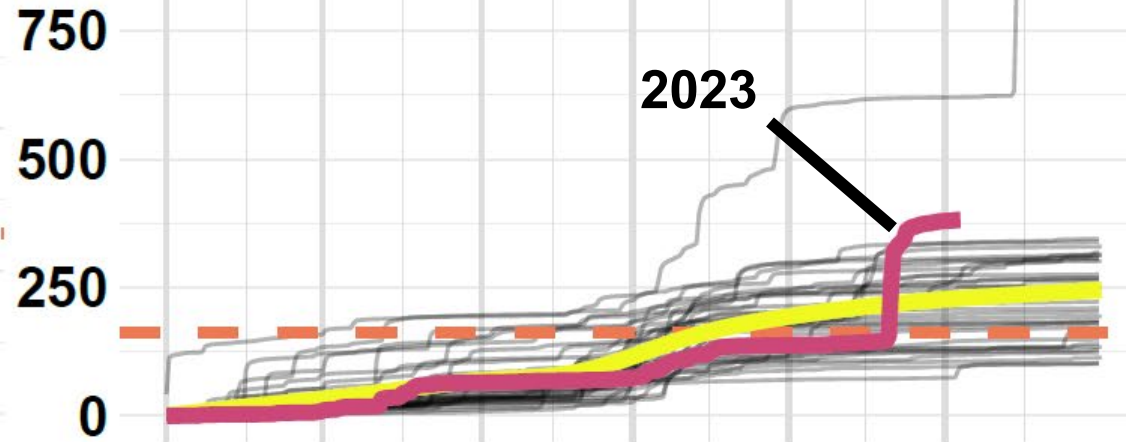
Feb-1

Jun-1

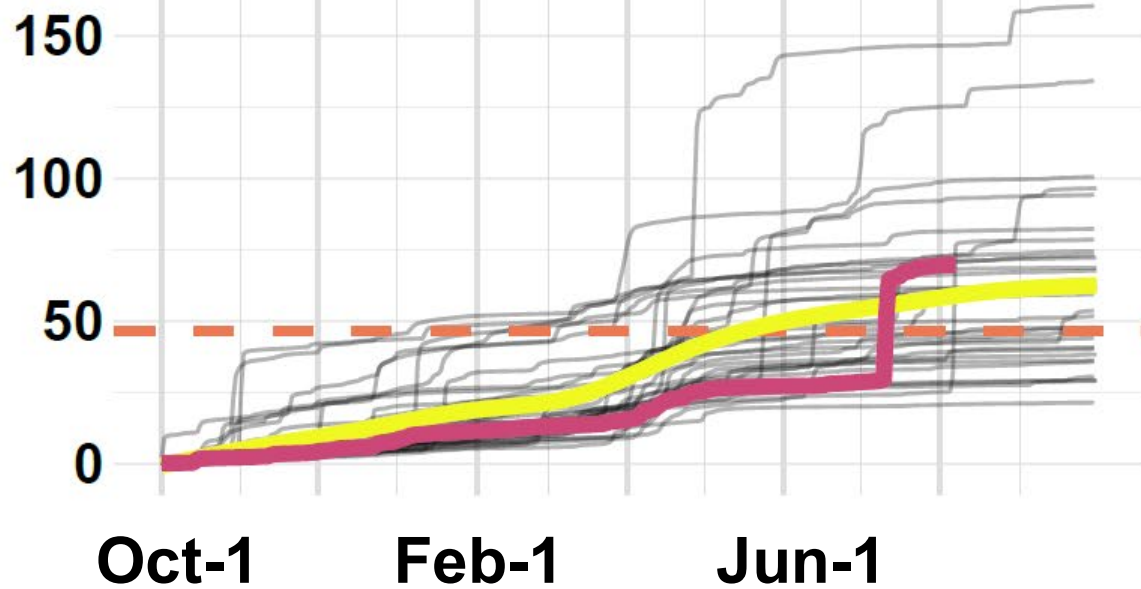
Cumberland Bay



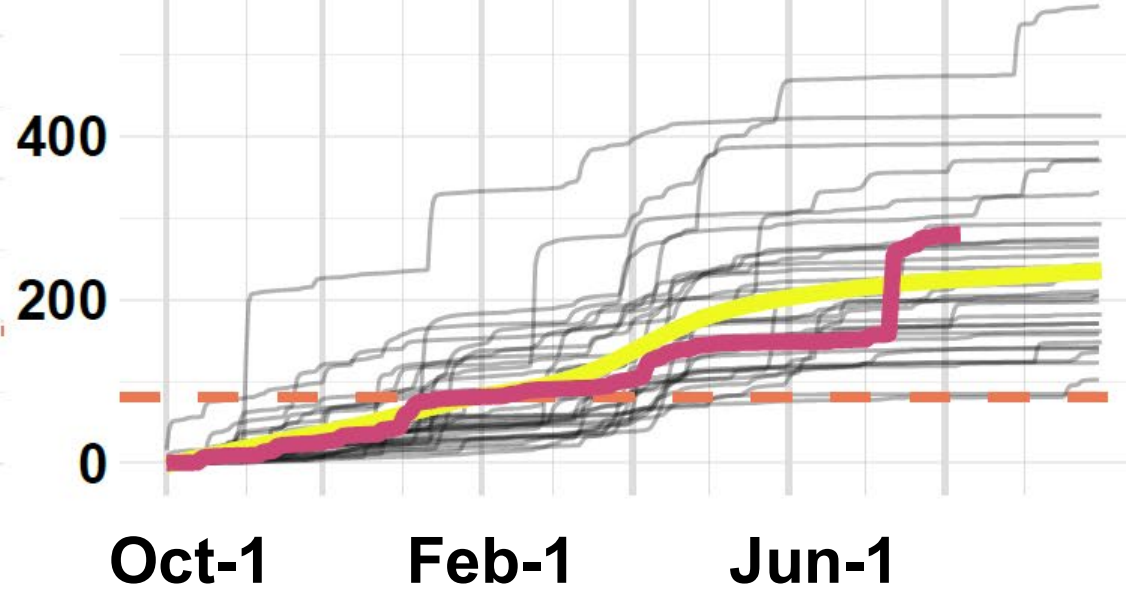
Main Lake

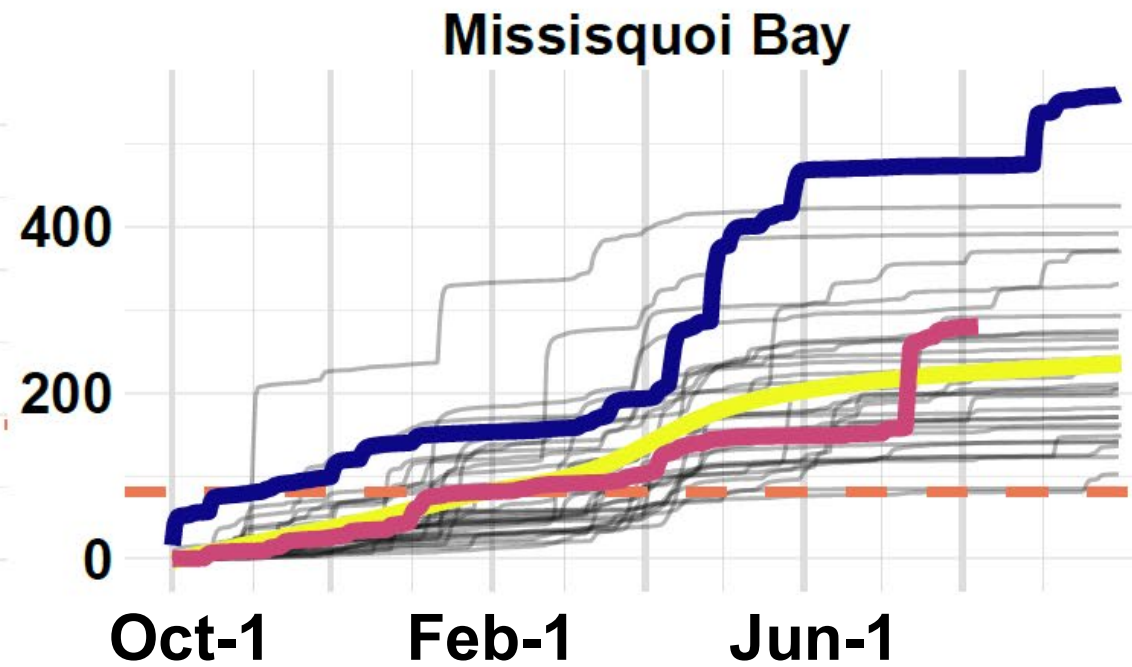
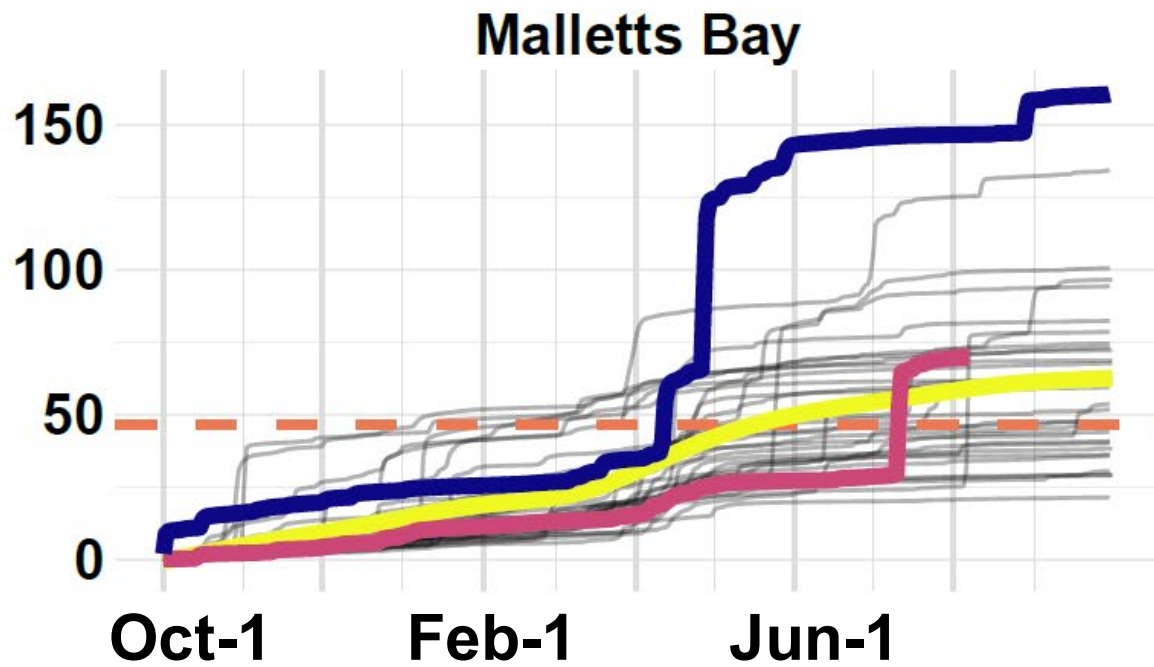
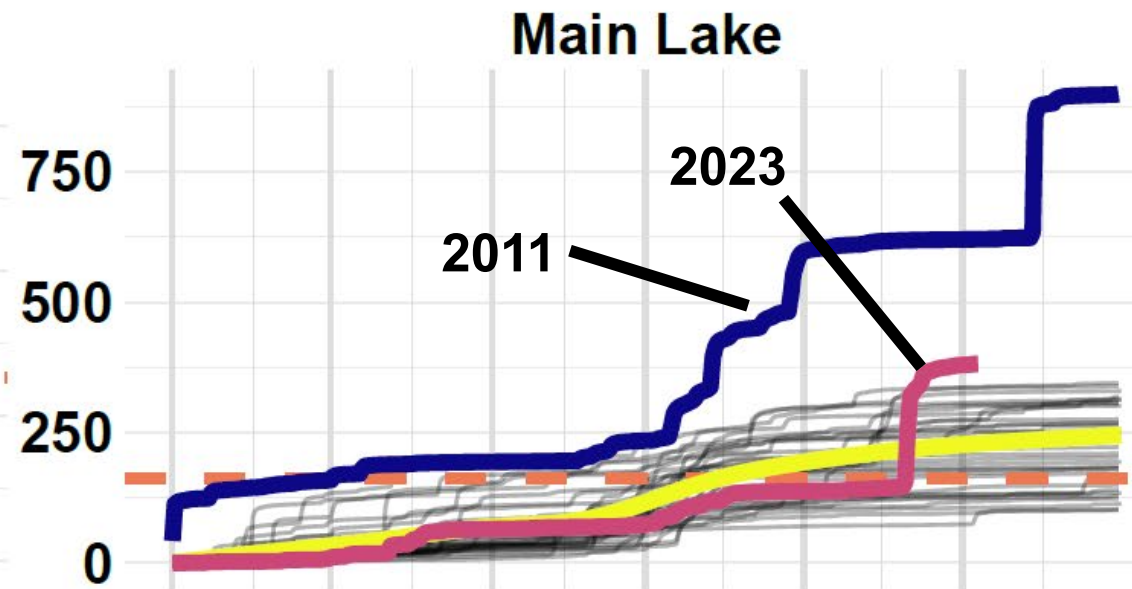
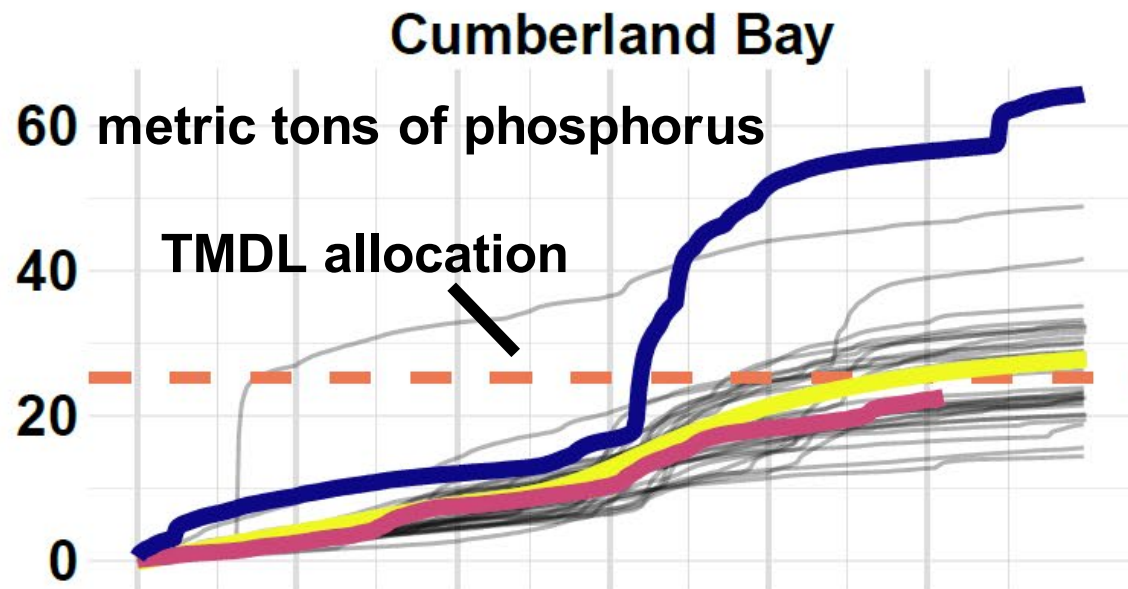


Malletts Bay



Missisquoi Bay





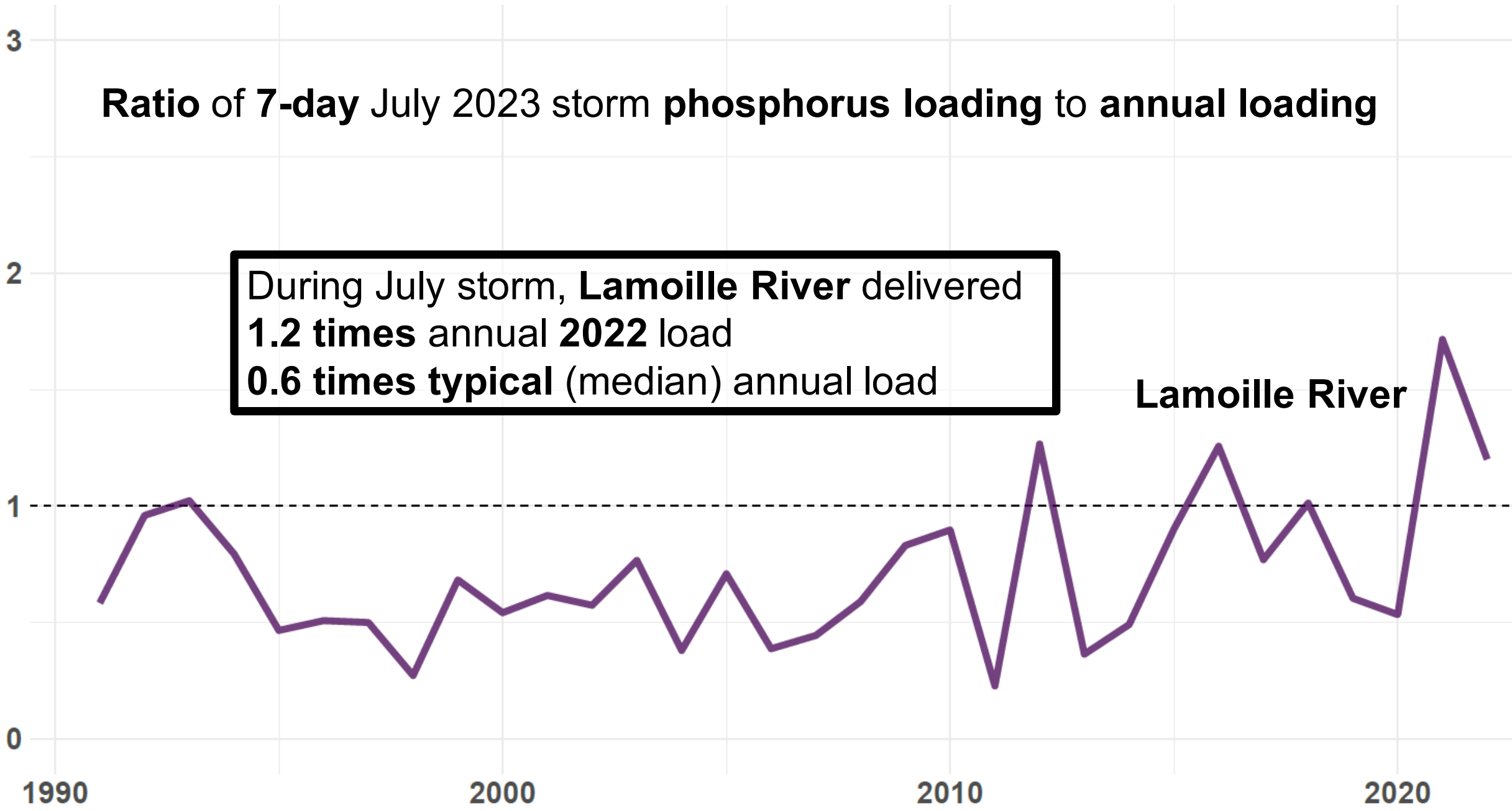
Next: how did **July 2023 storm**
phosphorus load compare to **annual**
phosphorus loads?



Ratio of 7-day July 2023 storm phosphorus loading to annual loading

During July storm, **Lamoille River** delivered **1.2 times** annual **2022** load
0.6 times typical (median) annual load

Lamoille River

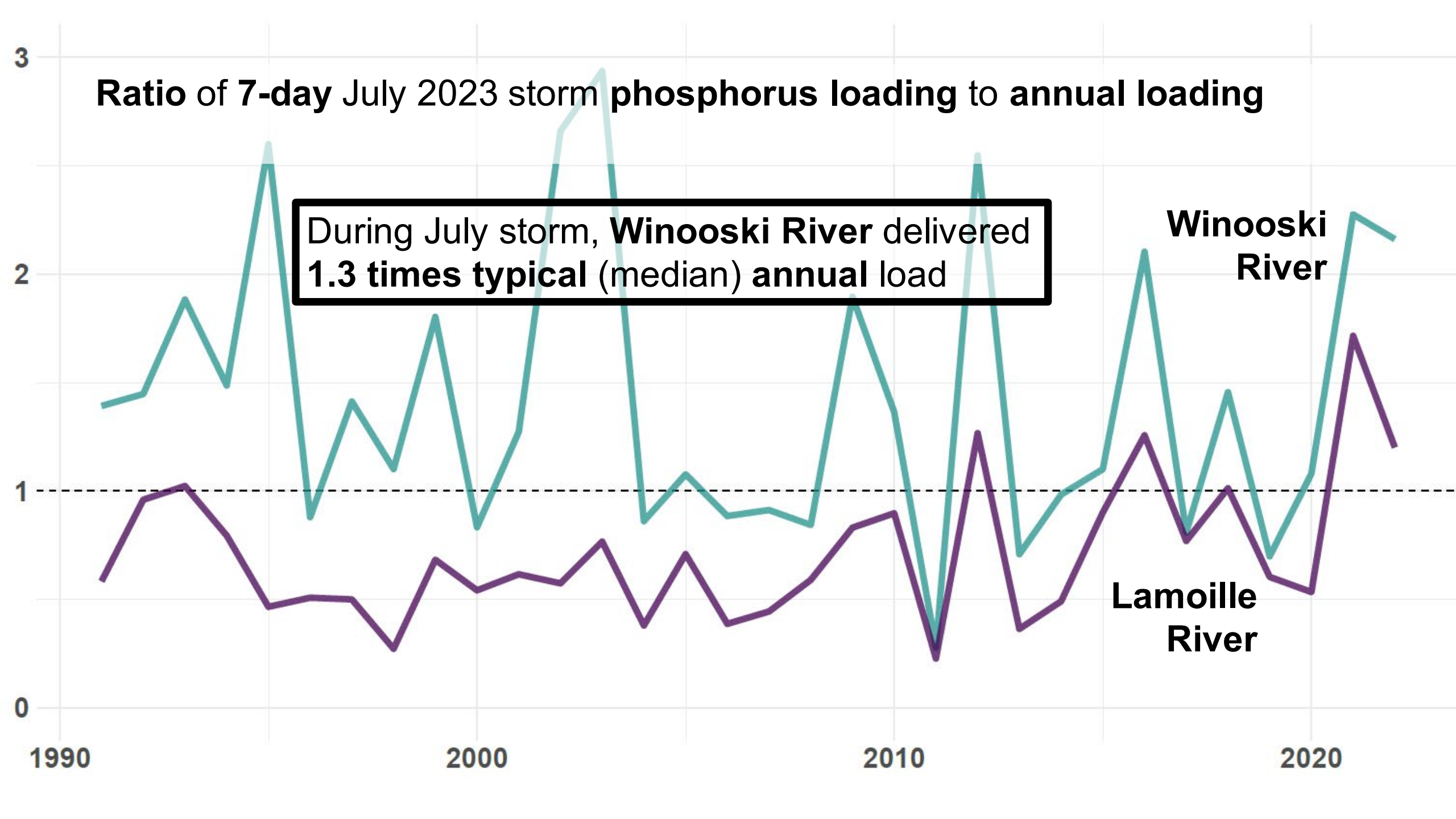



Ratio of 7-day July 2023 storm phosphorus loading to annual loading

During July storm, **Winooski River** delivered **1.3 times typical** (median) annual load

Winooski River

Lamoille River

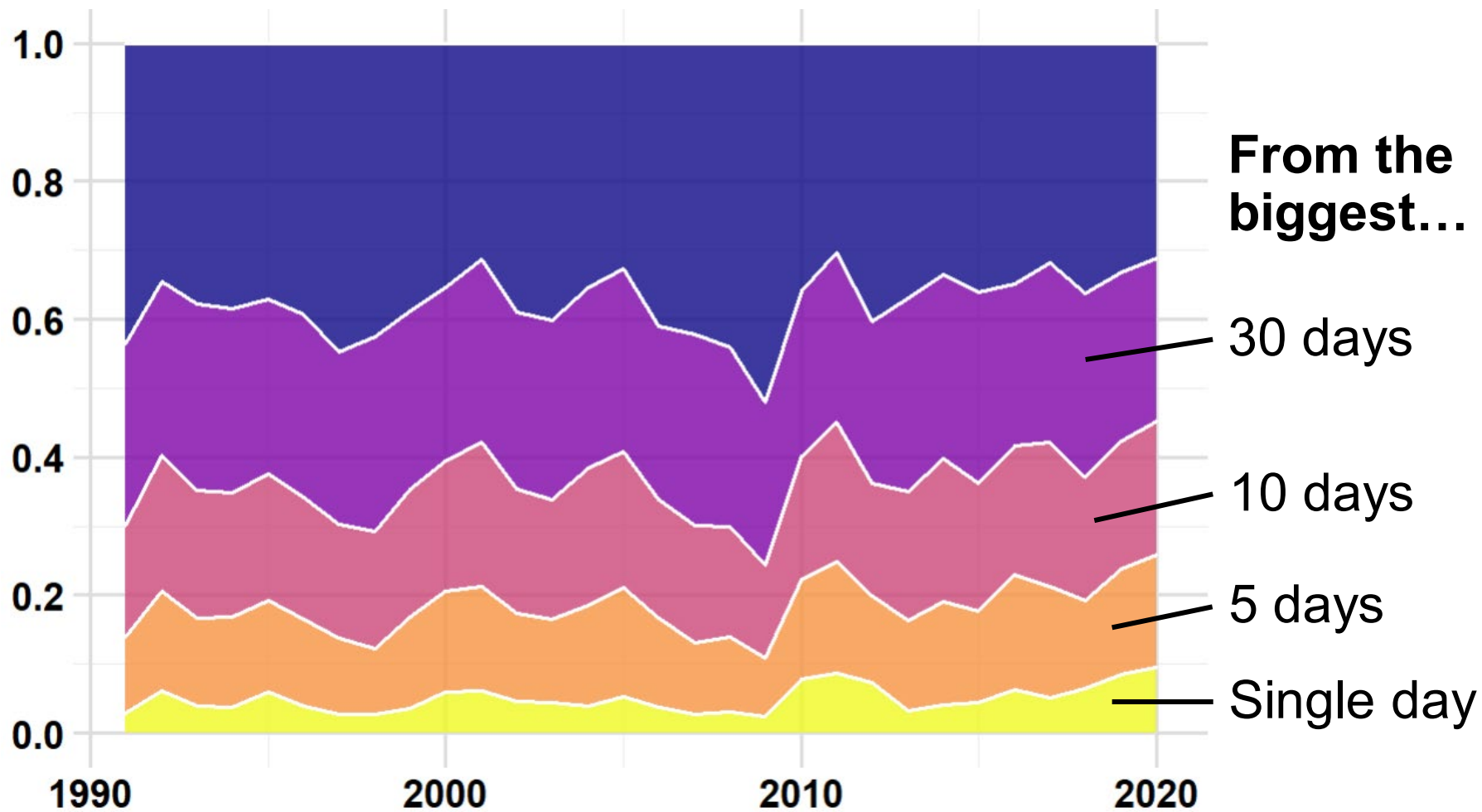


An aerial photograph of a wide, muddy river. The river flows from the top to the bottom of the frame. On the left bank, there is a dense line of green trees. On the right bank, there is a gravelly area with a row of trees, followed by a road with a white dashed line. A white text box with a black border is positioned in the upper left quadrant of the image.

Context: **high flows** are always important for **nutrient delivery**

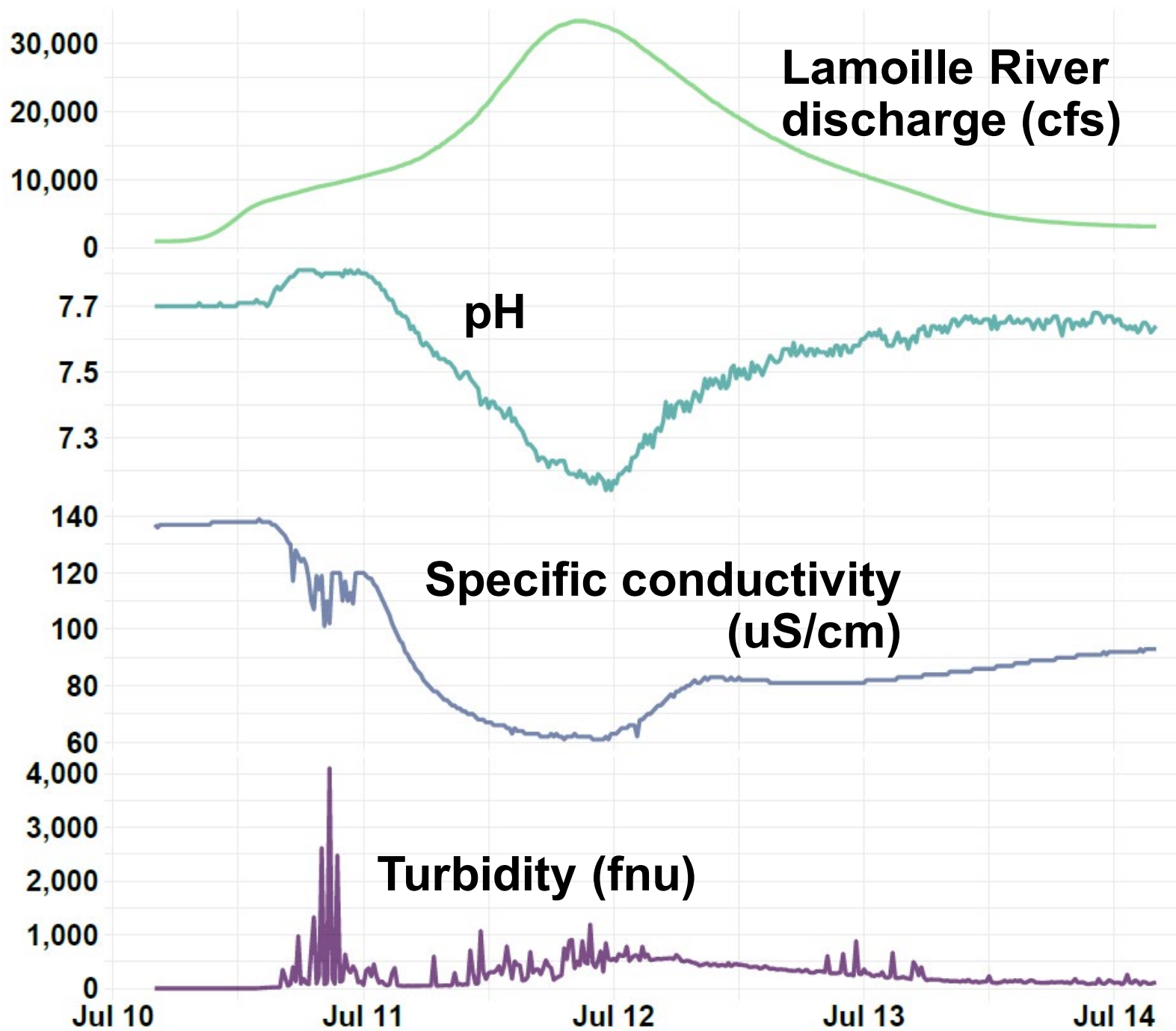
Winooski River


Portion of phosphorus load contributed







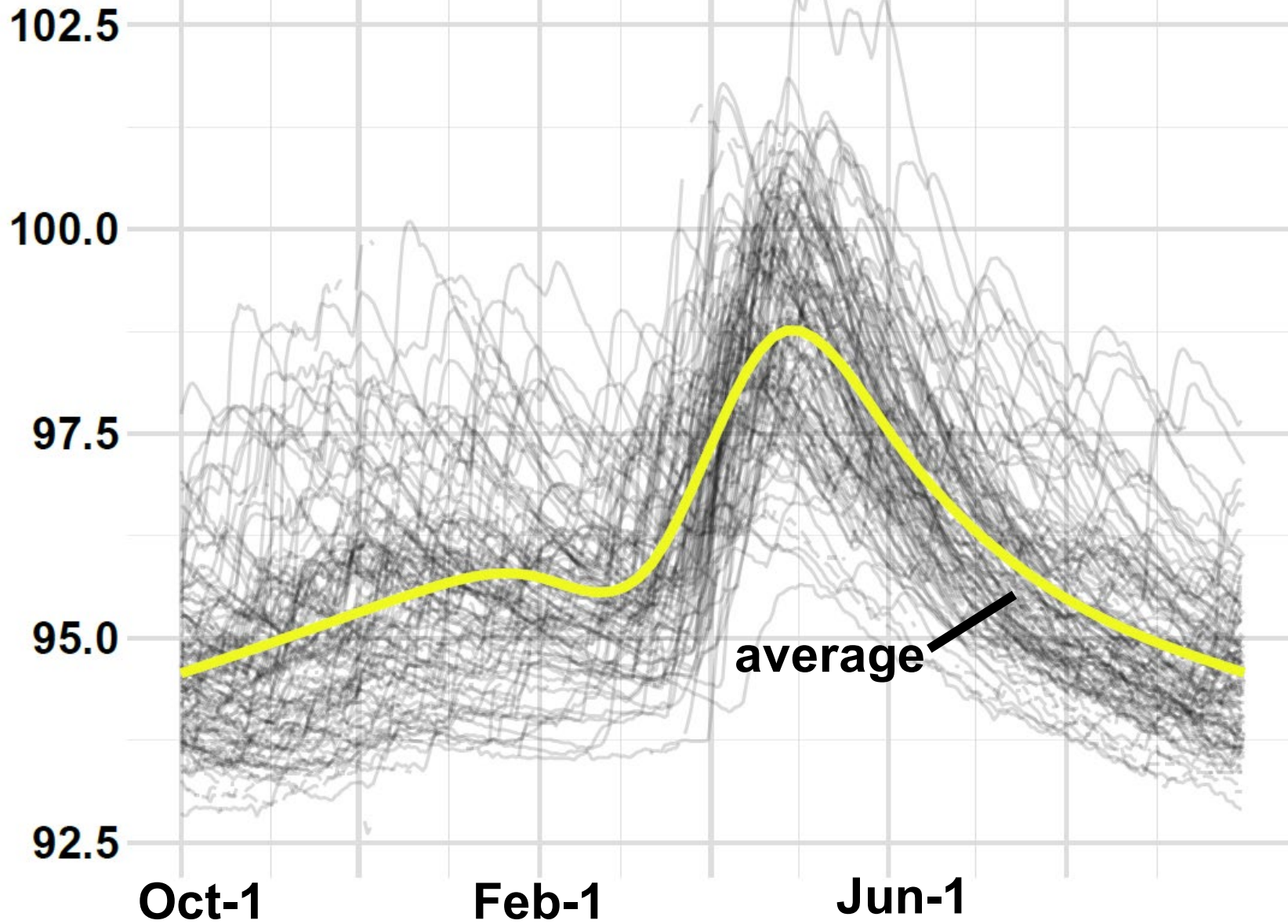


An aerial photograph showing a large, brownish lake on the left side. A large, forested peninsula extends into the lake from the right. In the foreground, a residential area with several houses and a green lawn is visible, situated on the edge of the peninsula. The background shows a vast expanse of water under a cloudy sky.

Next: lake **level**
and **water quality**

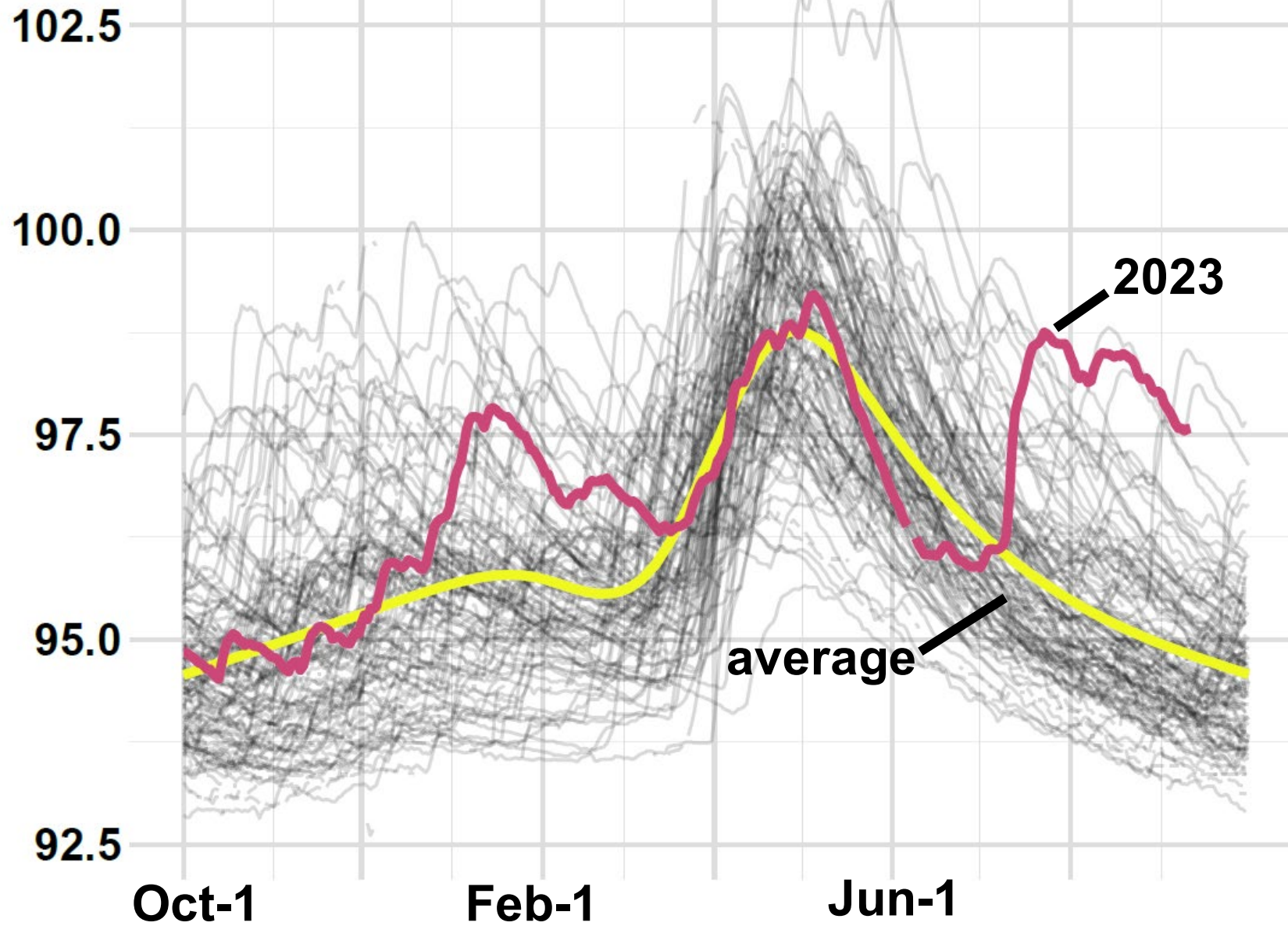
Lake Champlain level, Burlington (ft above sea level)

All years, starting 1907



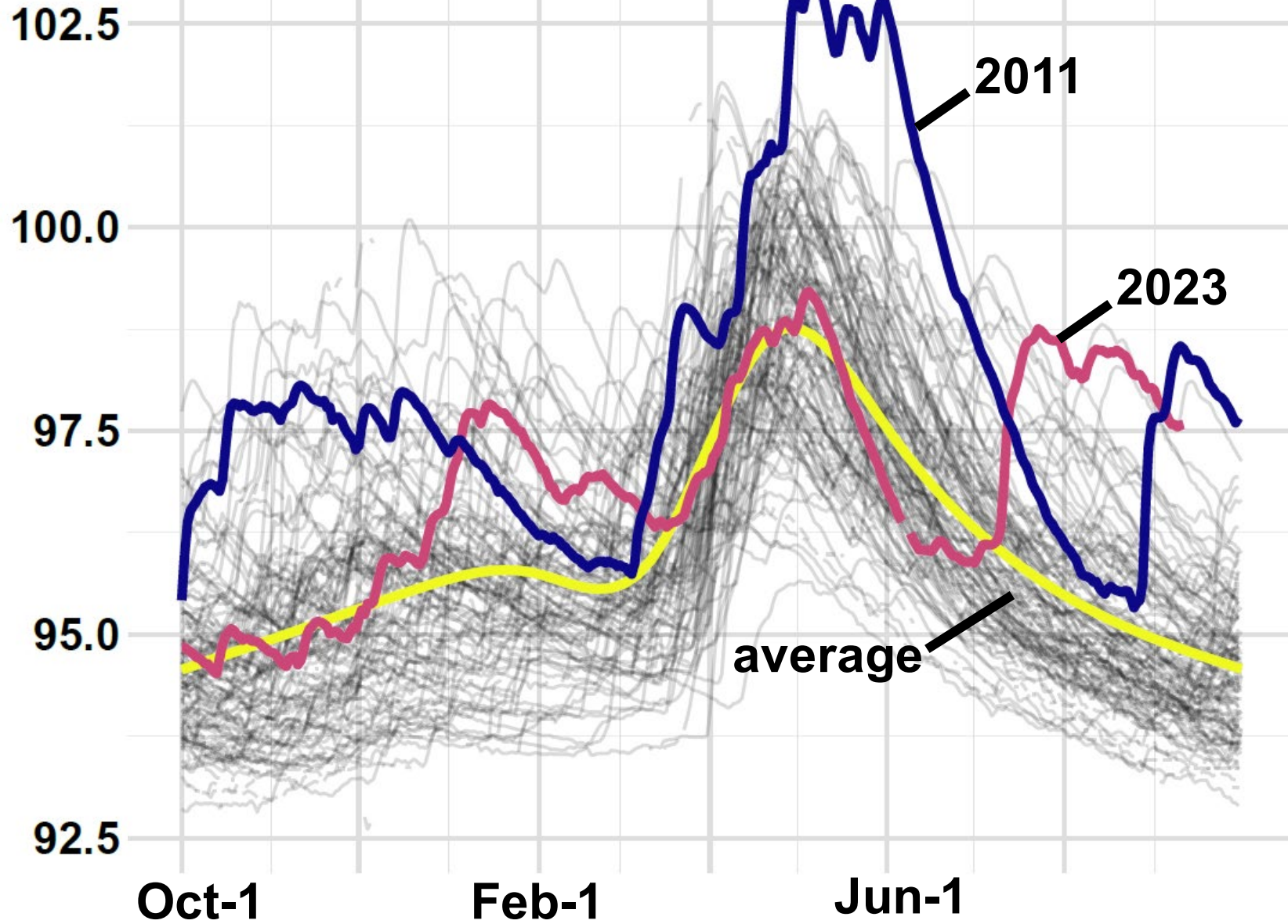
Lake Champlain level, Burlington (ft above sea level)

All years, starting 1907



Lake Champlain level, Burlington (ft above sea level)

All years, starting 1907



Malletts Bay

Secchi depth 0.4 m
on July 20

Typically about 2.5 m

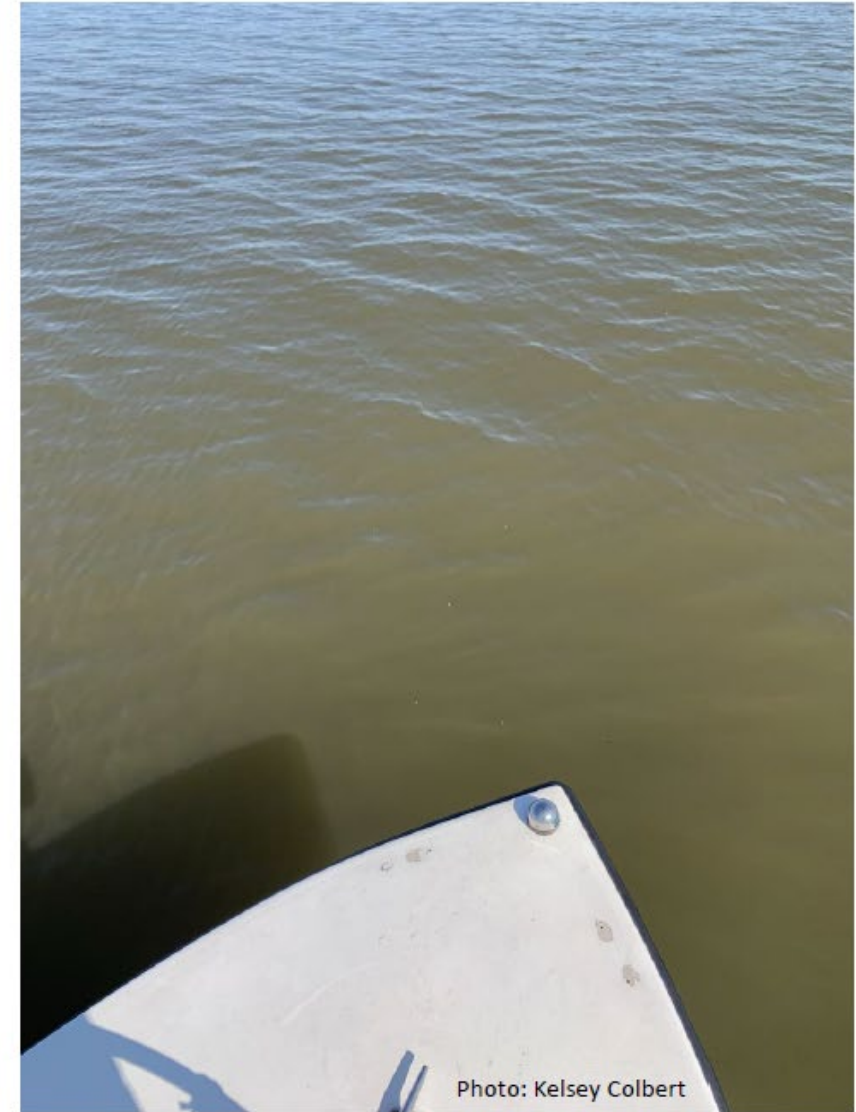
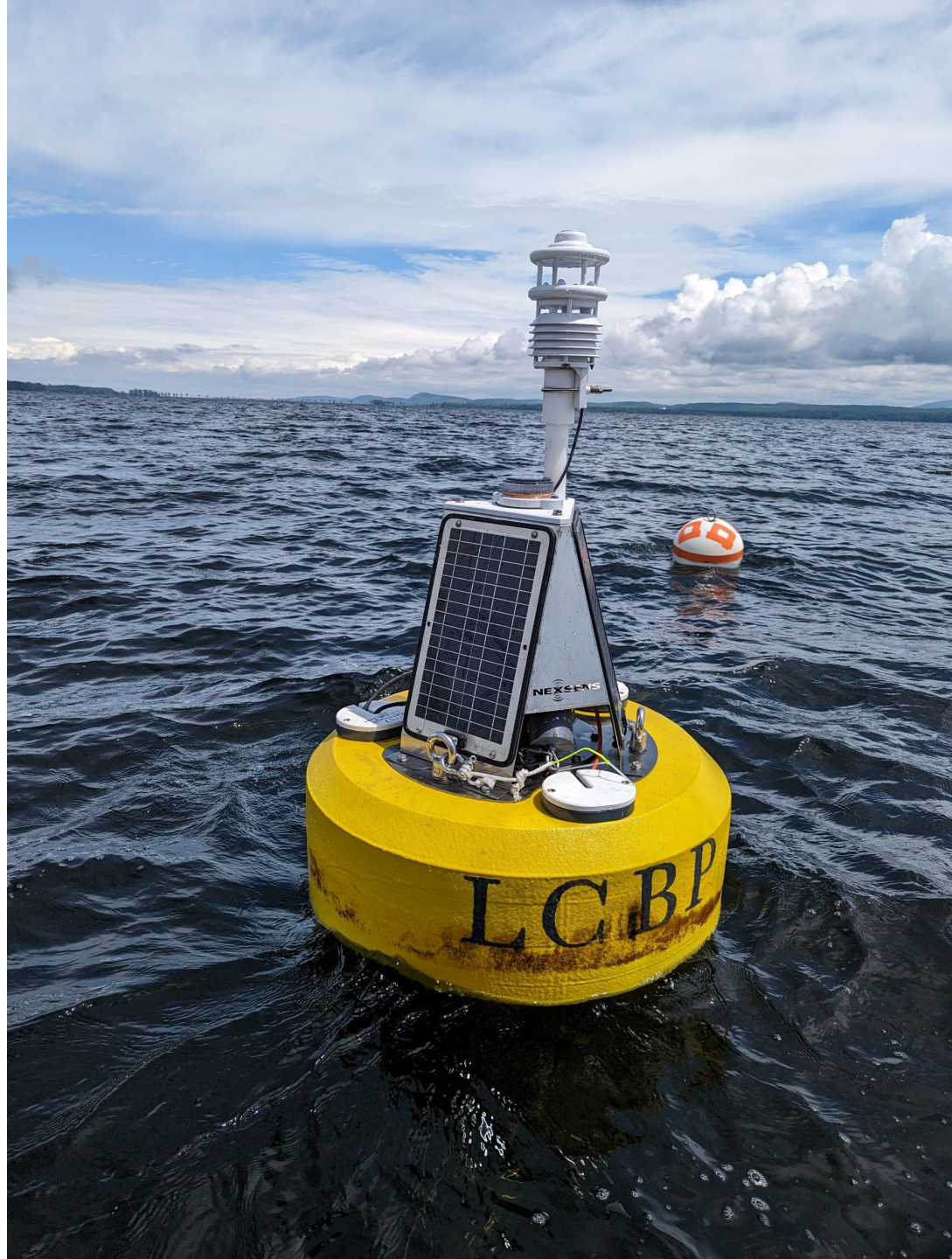
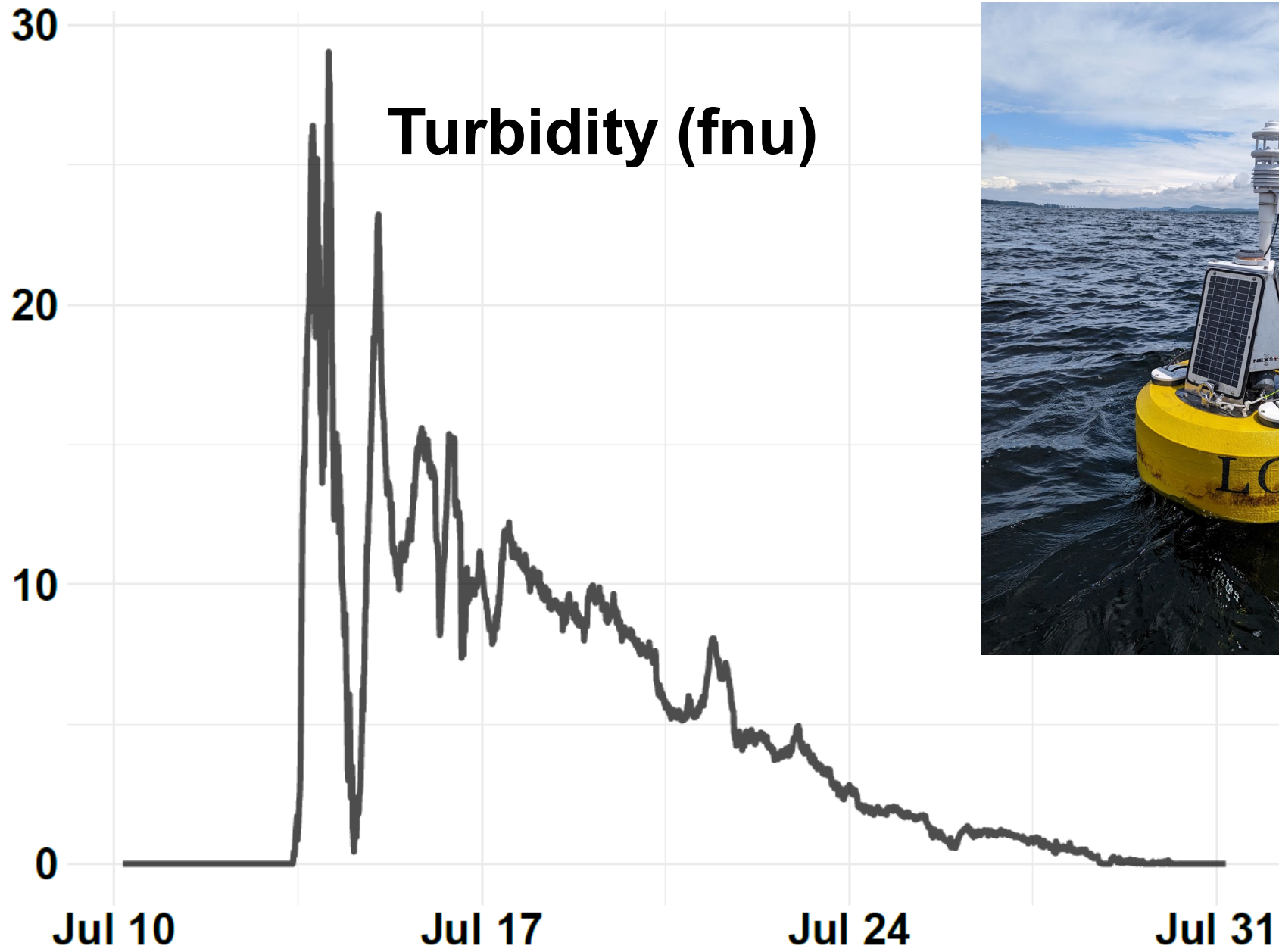
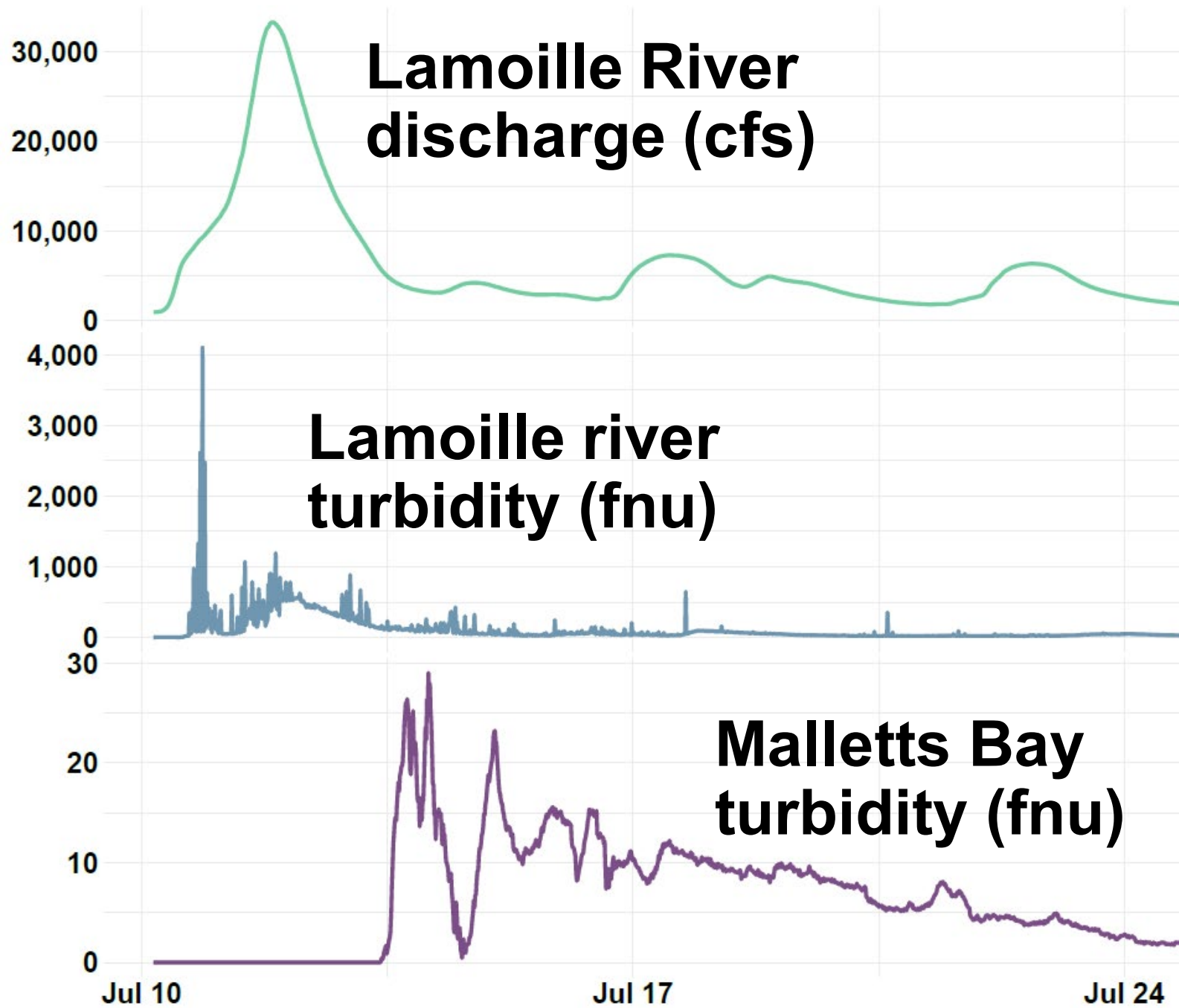


Photo: Kelsey Colbert
Adapted from Peter Isles' presentation







Summary

Historic **rainfall** amounts

- 48-hour totals: **3 – 9 inches**

Summary

Very high **river flows**

- **> 90th daily flow percentile** for all tributaries
- daily record for **Lamoille**, 2nd for **Winooski**
- Unusually high for the **time of year**
- Consistent with **climate change** trends

Summary

Phosphorus delivery

- Preceded by a dry spring
- Five tributaries delivered 90% of 7-day storm flux
- **More than half** of full-lake annual **TMDL** delivered in 7 days
- Esp. significant for **Main Lake**
- Consistent with **climate change** trends (time of year)

Summary

Lake level

- Rose about **3 feet**
- From **average to record high for season**, near normal for spring

Summary

Lake water quality

- High **turbidity**
- Primary productivity likely suppressed
- **Dissolved nutrients** available for later season growth
- **Short-term bacteria impacts;** not widespread
- Waiting on 2023 data

Summary

Restoration

- TMDL **margin of safety**
- Inter-annual **variability**
- Climate **change**
- Ongoing efforts and projects will provide **resilience**

Resources

- [July 2023 flooding summary](#)
- Real-time data: data.lcbp.org
- Science blog: lcbp.org/science-blog

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Lake Champlain
Basin Program



NEIW
PCC

Springfield, Vt.

Vermont Historical Society

TOWARD FALLS BRIDGE NOV. 4 '27
-SLADE-

