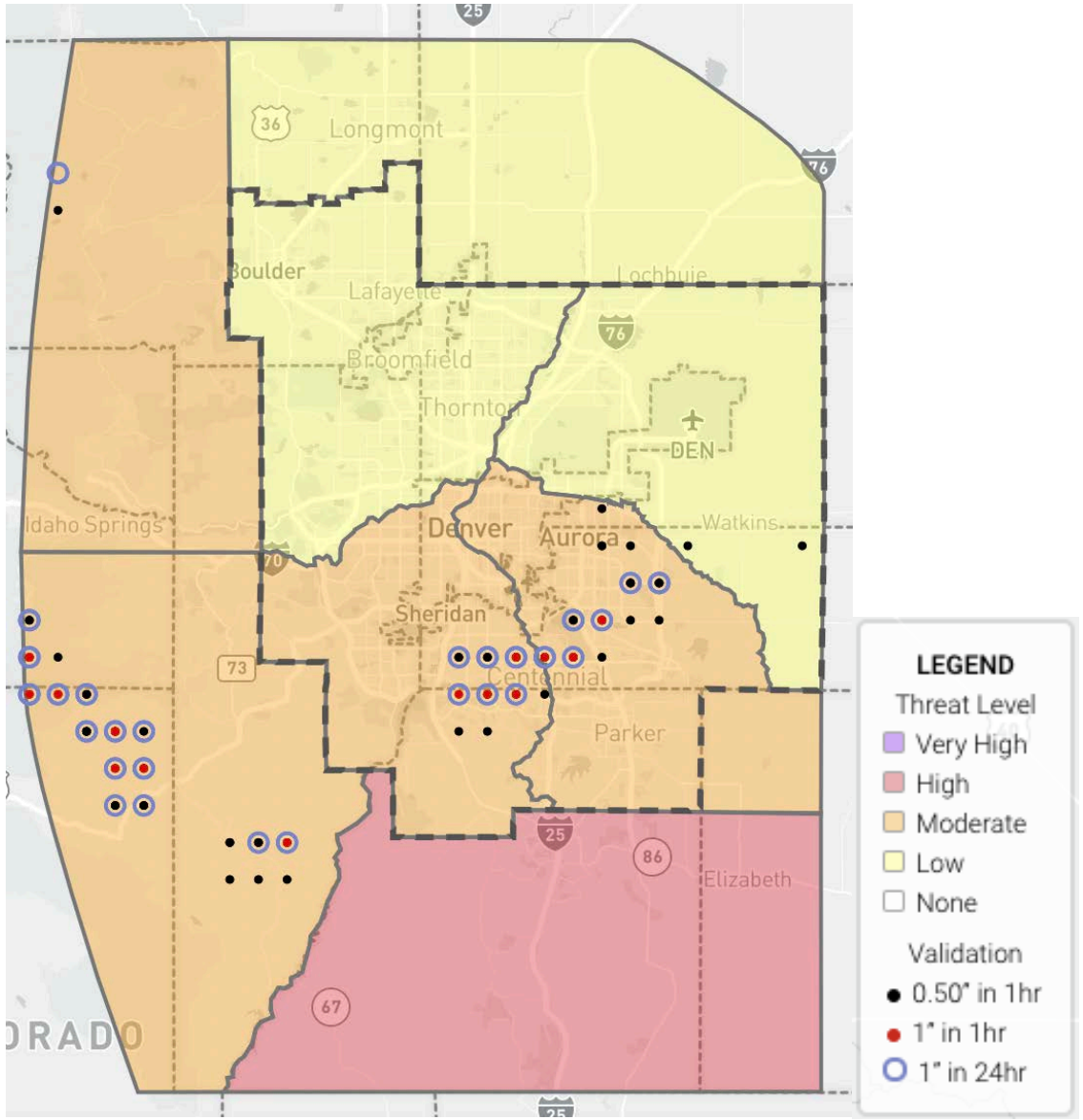

Heavy Rainfall Threat Analysis for the Denver Metro Area

2021 Training Workshop

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Kevin Stewart, Flood Warning Services
(MHFD)

About Us

- Involved with designing & updating Tool since 2014
- 15 years of combined experience in applied hydromet projects
- Lead forecasters of Colorado Flood Threat Bulletin since 2015
- Engineering-centric background working within Water Resources and Climate Resiliency groups

Outline

- Tool Overview
- Navigating website
- 2021 Case studies

Tool Overview

Main Objective

Provide guidance on whether a "Flood Day" will occur within MHFD boundary and immediate surrounding drainage areas with a lead time of several hours.

Terminology

A **"Flood Day" occurs when rainfall exceeds one of these thresholds:**

- 1.0 inch in 1 hour
- 2.25 inches in 3 hours
- 3.5 inches in 6 hours
- 4.5 inches in 24 hours

Rainfall Intensity (value)

- **QPF** – Quantitative Precipitation Forecast
  - **QPF-Max: maximum QPF over given duration (e.g. 1 hour)**
- **QPE** – Quantitative Precipitation Estimate

Probability (%)

- **PoE** – Probability of Exceedance
  - **PoP** – Probability of Precipitation

The Need

NWS Product	Lead Time	Performance
(Flash) Flood Warning	Near zero	Low **False Alarm** Rate Low **Miss** Rate
Areal Flood Advisory	Near zero	Low/Moderate **False Alarm** Rate Low **Miss** Rate
Flash Flood Watch	Hours+	Moderate **False Alarm** Rate Very High **Miss** Rate

- **False Alarm**: a forecast that heavy rainfall will occur, but none is observed
- **Miss**: Not forecasting a heavy rainfall occurrence
- **Lead time:** the effective warning time between forecast issuance and when event occurs

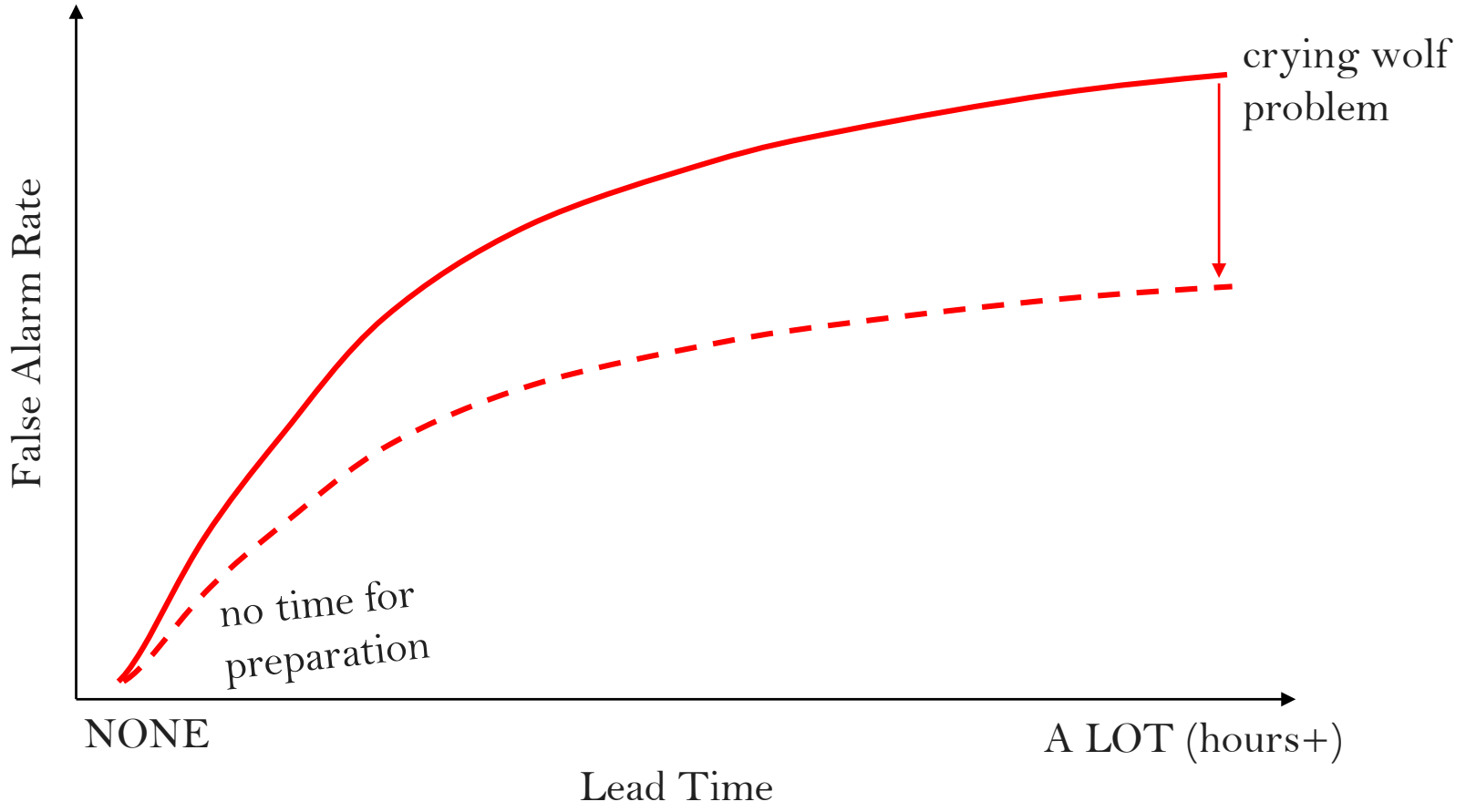
➢ Lowering the False Alarm rate generally leads to a higher Miss rate and vice versa!

Motivation

- **The primary metric the Tool is built around is the Probability of Exceeding 1 inch of rainfall per hour (a "Flood Day")**

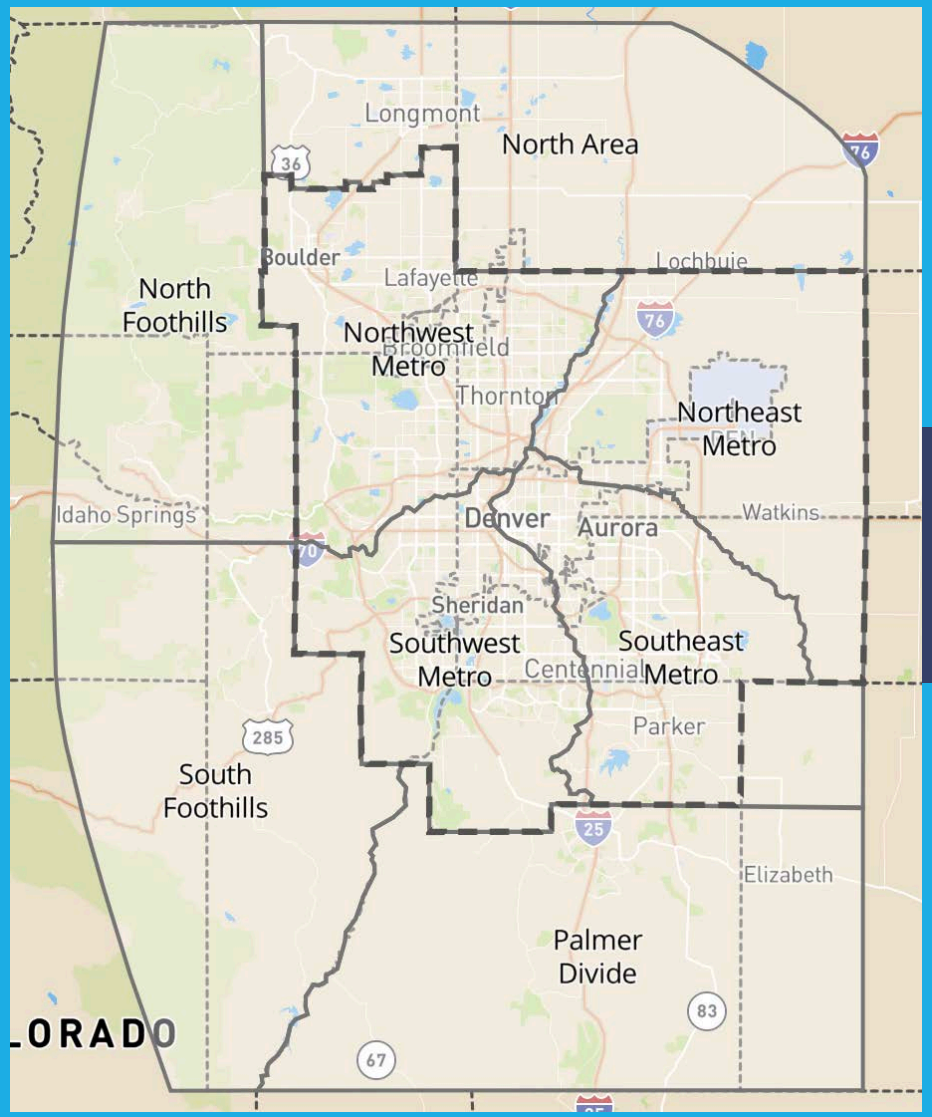
- Over the 2015-2020 forecast seasons (918 days), there were:
  - **172** days when rain intensity exceeded **1.0 inch/hr**
  - **108** days when rain intensity exceeded 1.25 inch/hr
  - **61** days when rain intensity exceeded 1.5 inch/hr
  - **17** days when the NWS issued a Flash Flood Watch

➢ **During only about 1 in 10 "Flood Days" is there significant lead time in predicting heavy rainfall**



Forecasts: striking a balance

MHFD Heavy Rainfall Threat Analysis



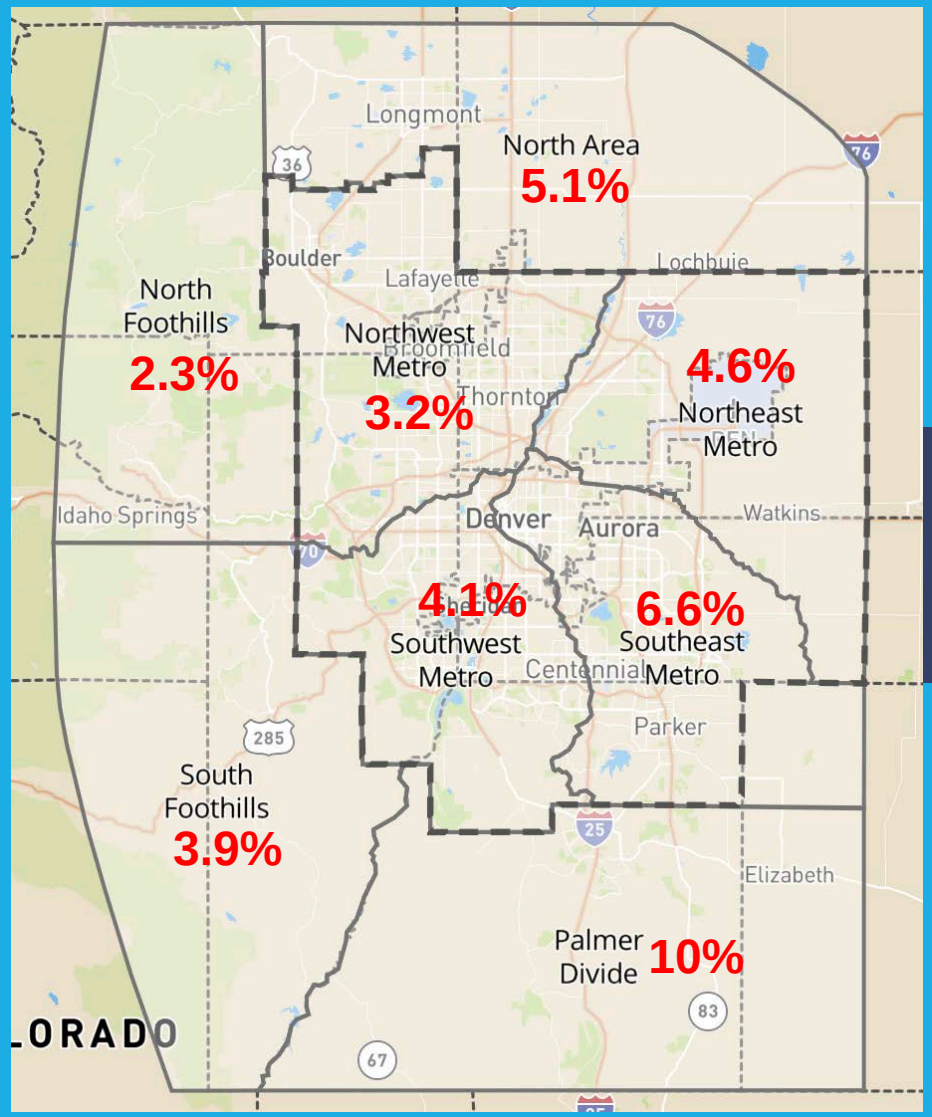
https://qpf.mhfd.org

- **OBJECTIVE**: Inform end-users on timing, location, intensity and confidence of heavy rainfall with lead time of several hours
- **UPDATES**: 6x per day, beginning at 7AM
- **FORECAST ZONES**: 8 total zones; 4 zones within MHFD boundary, and 4 zones along N, S and W periphery

Tool's History

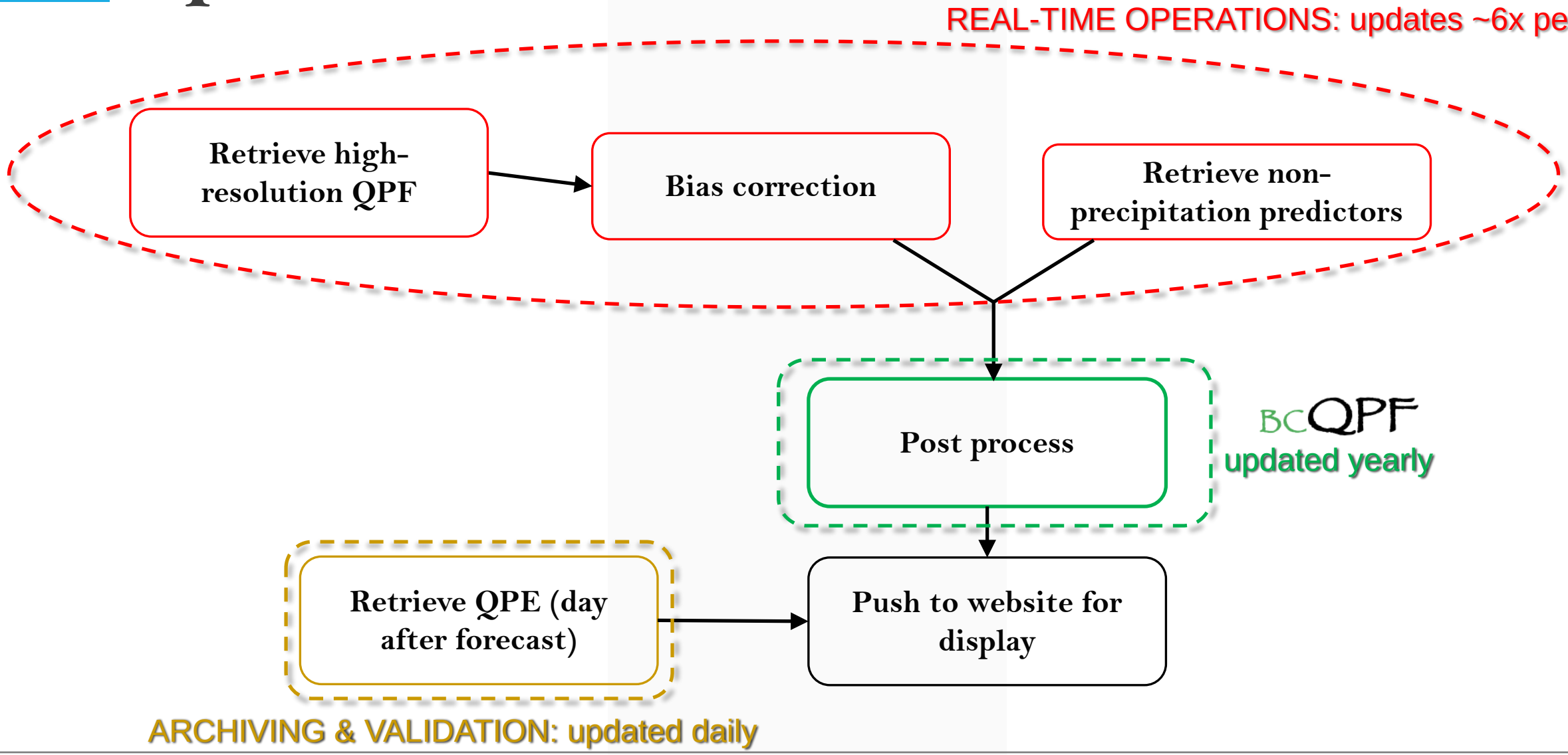
- 2014: Conceptual design and website development
- 2015: First year of real-time operations; used 4-6 high-resolution weather models
- 2016: First implementation of post-processing
- 2017-2020: Yearly updates of post-processing
- **2021: Upgraded web map; addition of detailed archive and validation; reduction in forecast zone size for better resolution; uses 30-50 high resolution weather models**

Area Climatology (May 1 – September 30)

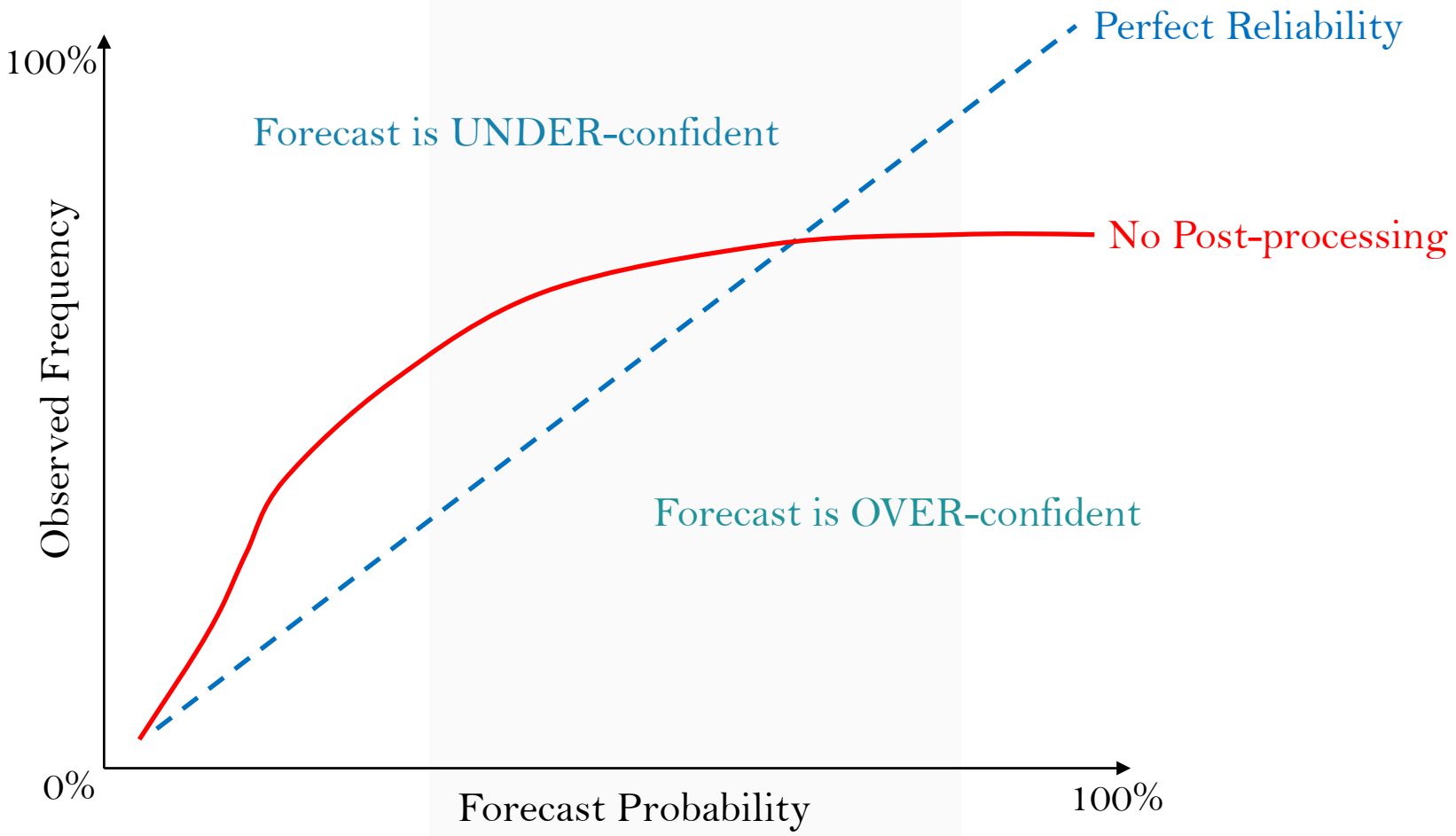


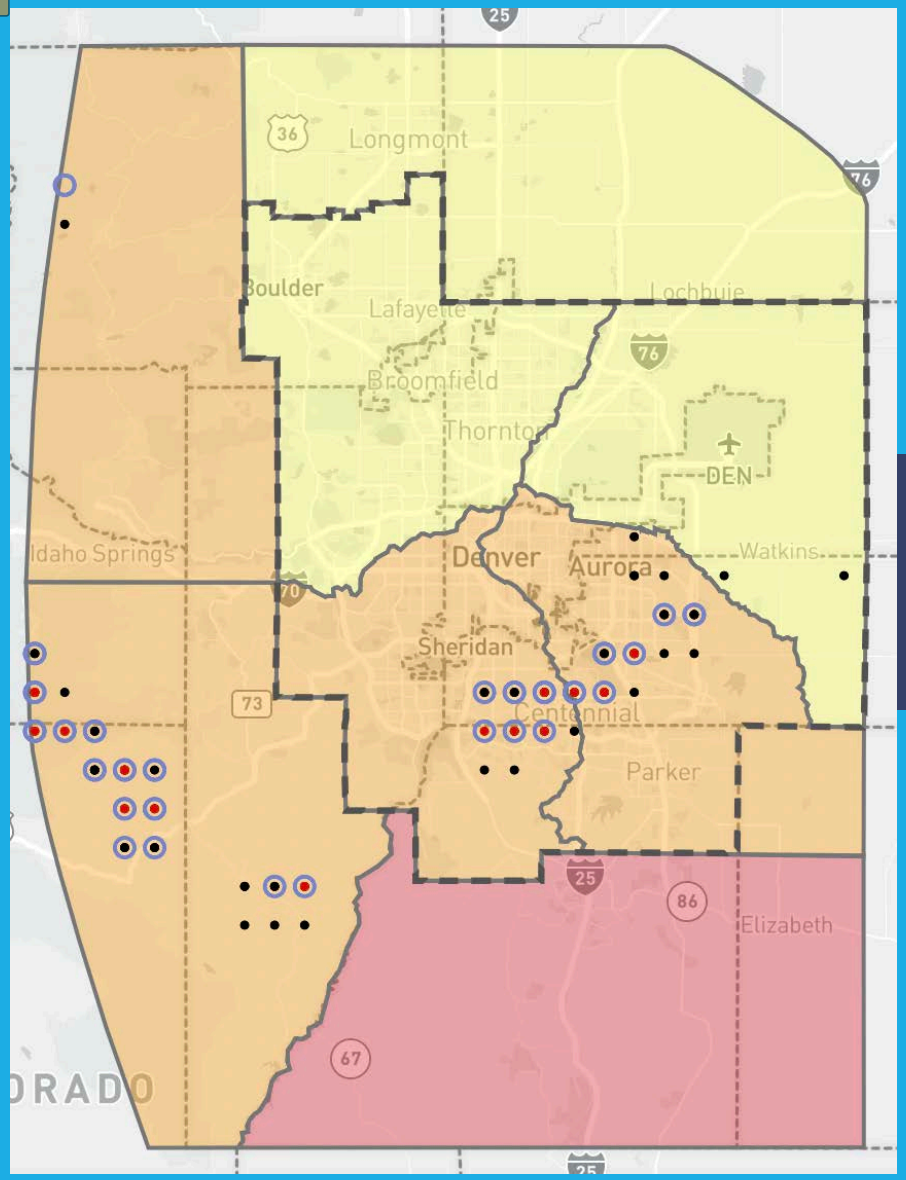
			”Flood Day” Information		
Zone	Elev. (ft)	ALERT #	Days/Yr	Pre-monsoon	Monsoon
N. Foothills	6.0 - 11.3k	61	4	2.7%	2.0%
S. Foothills	6.0 - 13.0k	18	6	3.8%	4.0%
Palmer Divide	6.0 - 9.3k	33	15	7.0%	13%
North Area	4.8 - 6.8k	8	8	5.4%	4.9%
NW Metro	5.0 - 7.8k	40	5	4.0%	2.7%
SW Metro	5.2 - 7.9k	36	6	4.3%	4.0%
SE Metro	5.1 - 6.6k	56	10	6.7%	6.6%
NE Metro	5.0 - 6.1k	6	7	5.4%	4.0%
All Zones	4.8 - 13.0k	258	29	18.0%	19.0%

Operational Process Flow



Why Post Process?





How are threat levels determined?

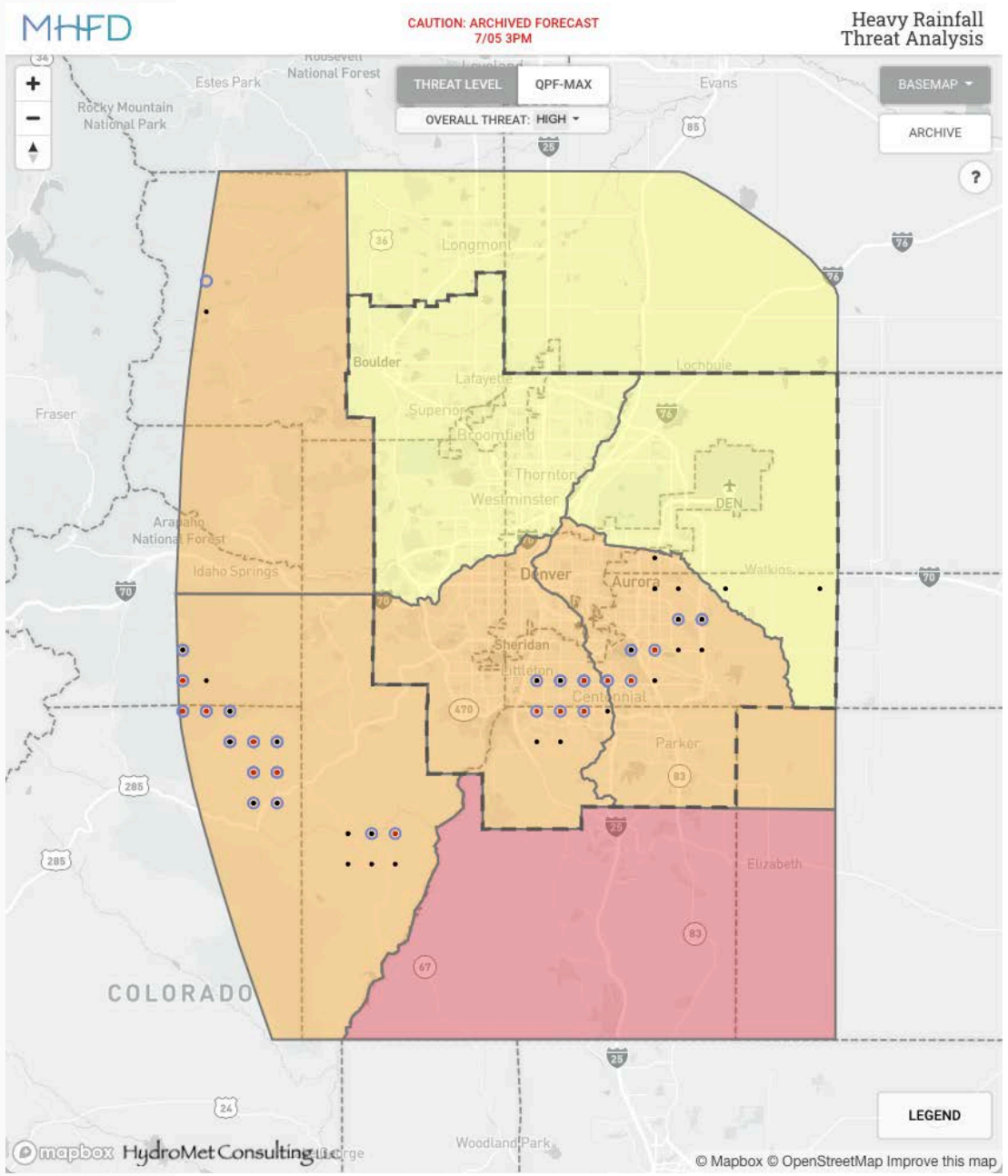
Threat Classification System

Threat	Zone-Specific Threshold	All Zone Threshold
LOW	PoE >= 8%	PoE >= 20%
MODERATE	PoE >= 16%	PoE >= 44%
HIGH	PoE >= 26%	PoE >= 66%
VERY HIGH	Undergoing testing	

*PoE = Probability of Exceeding "Flood Day" thresholds

Website navigation

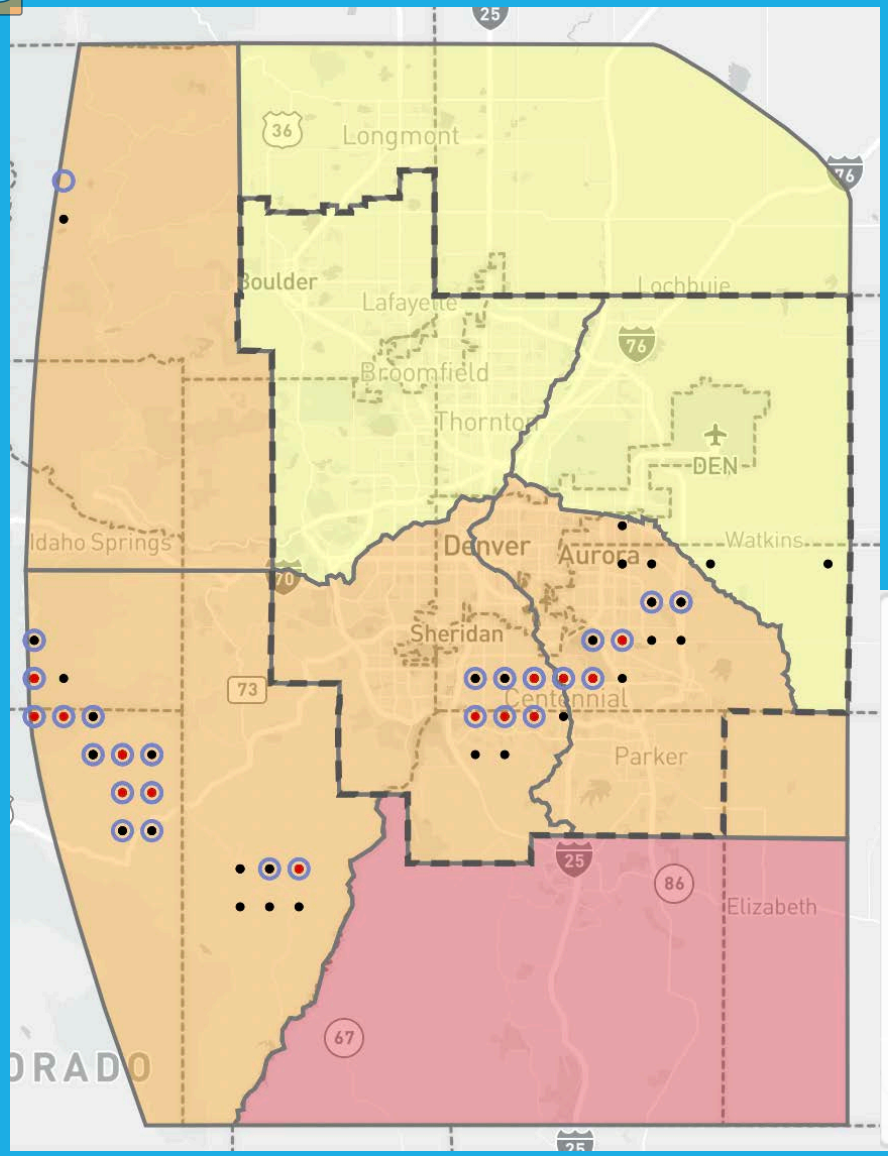
- Threat Layer
  - Forecast Summary
- QPF-MAX Layer
  - Max 1-hour rainfall
  - Timing
- Archive
  - Accessing past forecasts & estimates of heavy rainfall over MHFD



2021 Case Studies

- July 5th: localized heavy rainfall
- May 16th: false alarm
- June 13th: missed localized heavy rainfall
- July 1st: widespread heavy rainfall

July 5th, 2021



- Tool able to resolve higher threat over southern areas
- A few clusters of 1.0 in/hour storms were observed

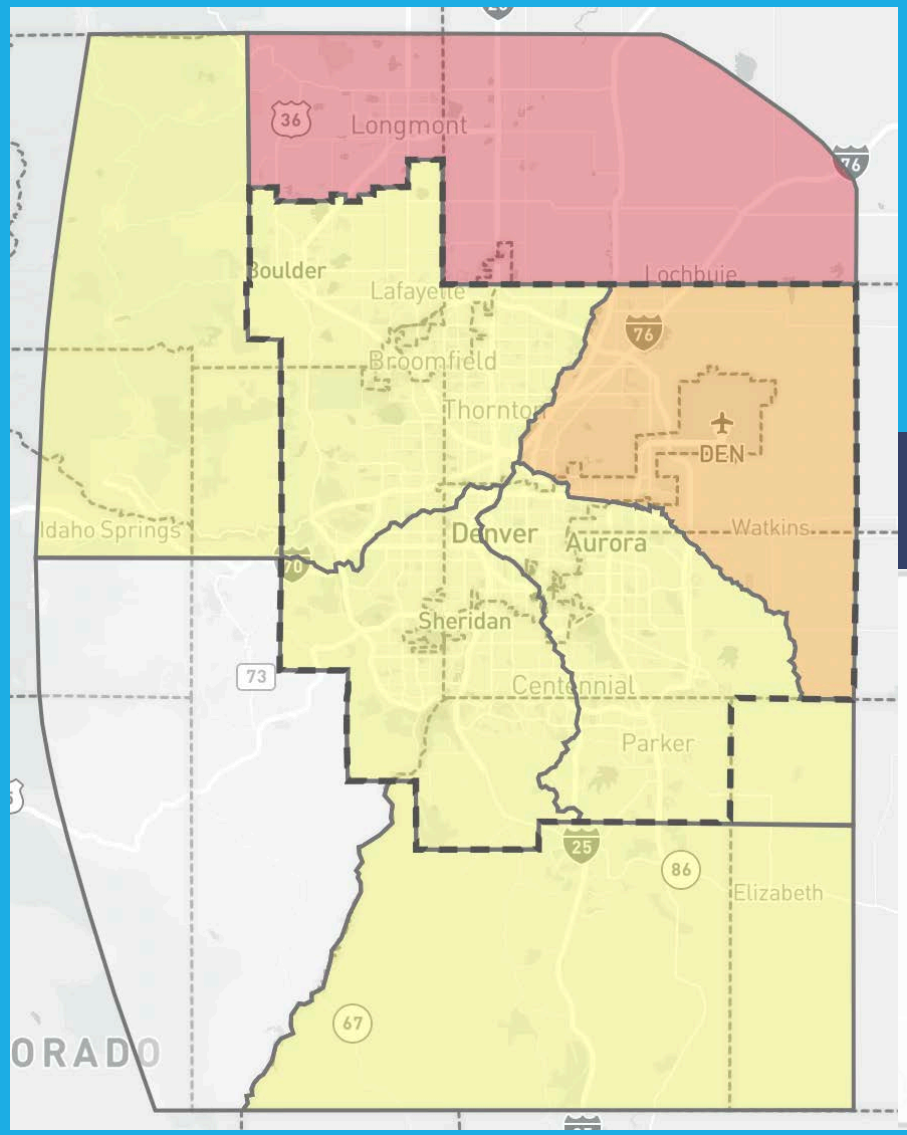
ALL ZONES QPE QPF

Overall Threat	HIGH
% precipitation	>90%
% exceeding 1in. in 1hr	62%
% exceeding 2.25in. in 3hr	15%
% exceeding 3.5in. in 6hr	5%
% exceeding 4.5in. in 24hr	<5%
QPF-MAX	2.28

ALL ZONES QPE QPF

QPE STATS	Number of Pts/Gages
ST4 0.5in. in 1hr	36
ST4 1in. in 24hr	22
MRMS 0.5in. in 1hr	33
MRMS 1in. in 24hr	19
ALERT 0.5in. in 1hr	9
ALERT 1in. in 24hr	3
QPEMAX 1hr/24hr (in.)	2.1/2.48

May 16th, 2021



- High threat forecast in northeast areas
- Cloud cover limited instability and storms did not materialize

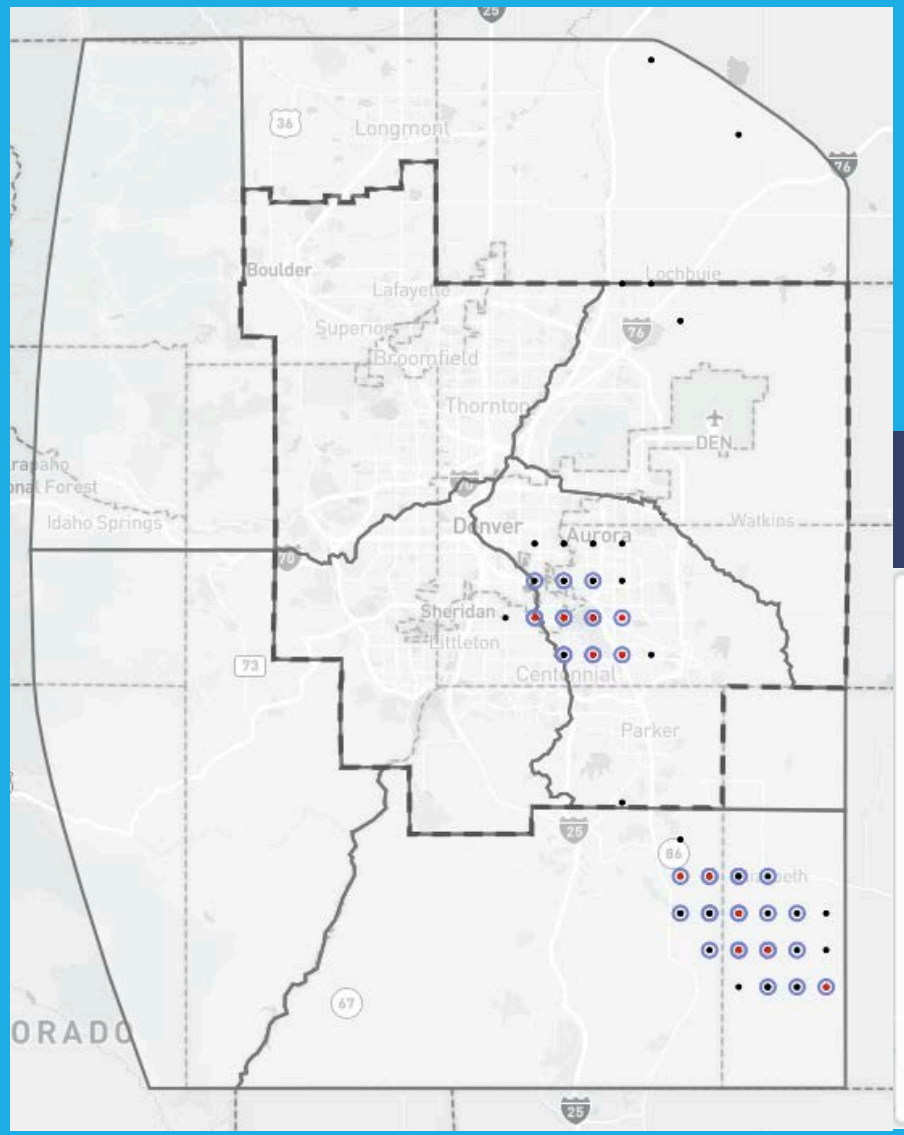
ALL ZONES QPE QPF

Overall Threat	HIGH
% precipitation	>90%
% exceeding 1in. in 1hr	61%
% exceeding 2.25in. in 3hr	12%
% exceeding 3.5in. in 6hr	<5%
% exceeding 4.5in. in 24hr	<5%
QPF-MAX	1.99

ALL ZONES QPE QPF

QPE STATS	Number of Pts/Gages
ST4 0.5in. in 1hr	0
ST4 1in. in 24hr	0
MRMS 0.5in. in 1hr	0
MRMS 1in. in 24hr	0
ALERT 0.5in. in 1hr	0
ALERT 1in. in 24hr	0
QPEMAX 1hr/24hr (in.)	0.46/0.51

June 13th, 2021



- First day of mid-June heat wave: instability present but strong "cap" also in place
- Storm over Aurora broke cap and produced 1.1in/hour and 700 cfs at Cherry Creek

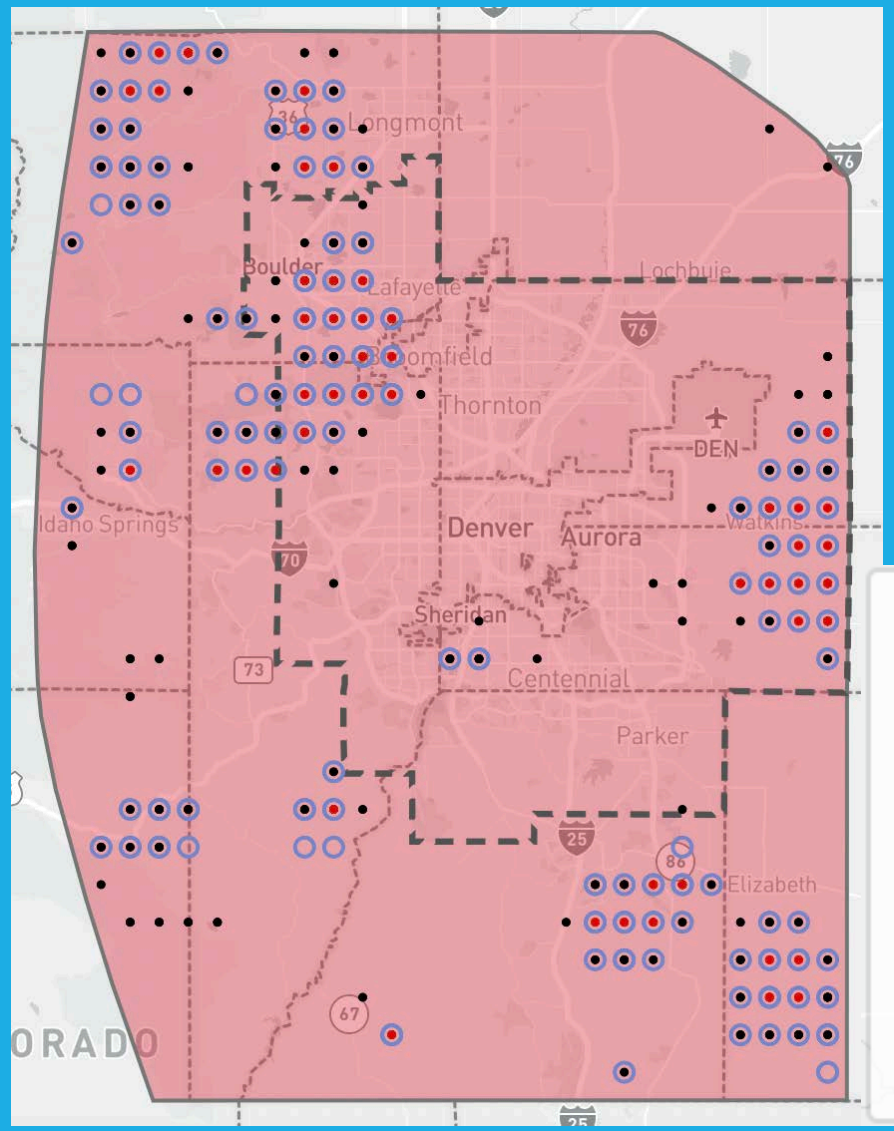
ALL ZONES QPE QPF

Overall Threat	NONE
% precipitation	63%
% exceeding 1in. in 1hr	10%
% exceeding 2.25in. in 3hr	<5%
% exceeding 3.5in. in 6hr	<5%
% exceeding 4.5in. in 24hr	<5%
QPF-MAX	1.2

ALL ZONES QPE QPF

QPE STATS	Number of Pts/Gages
ST4 0.5in. in 1hr	24
ST4 1in. in 24hr	11
MRMS 0.5in. in 1hr	51
MRMS 1in. in 24hr	24
ALERT 0.5in. in 1hr	4
ALERT 1in. in 24hr	2
QPEMAX 1hr/24hr (in.)	2.35/3.18

July 1st, 2021



- HIGH threat for each zone from ~Noon through ~10pm
- QPF-Max: 2.64 in/hr
- Many areas where 1.0in/hr was exceeded
- Boulder Creek went from 180 to 850 cfs

ALL ZONES QPE QPF

Overall Threat	HIGH
% precipitation	>90%
% exceeding 1in. in 1hr	87%
% exceeding 2.25in. in 3hr	37%
% exceeding 3.5in. in 6hr	10%
% exceeding 4.5in. in 24hr	7%
QPF-MAX	2.64

ALL ZONES QPE QPF

QPE STATS	Number of Pts/Gages
ST4 0.5in. in 1hr	141
ST4 1in. in 24hr	107
MRMS 0.5in. in 1hr	132
MRMS 1in. in 24hr	85
ALERT 0.5in. in 1hr	32
ALERT 1in. in 24hr	15
QPEMAX 1hr/24hr (in.)	1.93/2.93

Conclusions

- Significant re-design of legacy Tool but main features intact
  - Update to the hourly charts still coming
- Performance is encouraging, both with ability to resolve location as well as confidence (i.e. Threat) level
- New archive/validation web map allows for easy look at past events
- Ongoing work of improving QPE, which ultimately controls many aspects of Tool performance

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EARLY FLOOD PREDICTION & DETECTION

Welcome to the **MHFD** ***ALERT System***. Touch or click on the logo to access our most popular live rain map. Advanced users may also like our **ArcGIS** webmap for viewing a variety of real-time storm & flood data layers.

This website was developed primarily for our flood warning partners. Our **Contrail®** website offers many other nice features such as the **NWS Weather Story & Twitter Feeds** dashboard. The **NWS weather map** also displays rainfall, wind and temperature measurements from the ALERT system. Discover interesting historical facts about the region's worst floods from Boulder County's **Story Map**.

See **F2P2** & **QPF-Max** concerning current flood threats.

To report flooding use the **Colorado Flood Threat Bulletin** website or contact MHFD's Flood Prediction Center at **303.458.0789**

We hope you find this website easy to use.

https://alert5.udfcd.org
https://qpf.mhfd.org

Questions & Discussion

HydroMetConsulting@gmail.com