STATE CLIMATE EXTREMES COMMITTEE MEMORANDUM

From: Michigan 24-hour Precipitation SCEC (Hoving and Dixon, authors)
Date: 19 September 2019 (for review); 21 February 2020 (final formatting)

Contents

Summary

Several rounds of thunderstorms impacted west central Lower Michigan during the daytime hours of 20 July 2019. The heaviest, most persistent storms, and the vast majority of the rainfall occurred between 5:00 am and 3:00 pm EDT. The following observation was reviewed to determine whether this was a new Michigan 24-hour precipitation record:

- Location: Sheridan Township, approx 6 mi. E of Fountain, MI
- Date: 20 July 2019
- Value: 12.92 inches

After considerable discussion and deliberation, **this value was confirmed unanimously to be the new statewide 24-hour precipitation record for Michigan**. It replaces the previous value of 9.78 inches near Bloomingdale on 31 August, 1914. The SCEC took the extraordinary step of confirming a non-network observation as a state record. The SCEC acknowledges that this is not standard, nor is it desirable, and would not have done so without multiple compelling factors.

About the SCEC

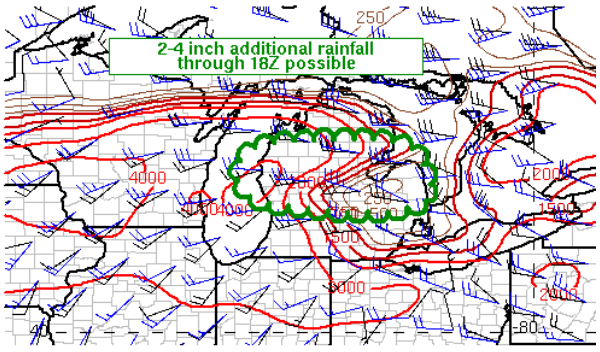
This State Climate Extremes Committee (SCEC) was composed of members representing five bodies: the National Weather Service (NWS) Weather Forecast Office in Grand Rapids, Michigan (WFO Grand Rapids; GRR), the NWS Central Region Acting Climate Program Manager, the Michigan State Climatologist's Office, the Midwest Regional Climate Center, and the National Centers for Environmental Information. It is convened to adjudicate potential records for validity, according to the practices defined in NWS Instruction 10-1004. If validated, the observation is considered the state record for that record type. More details about the SCEC are available online at https://www.ncdc.noaa.gov/extremes/scec/details.

Meteorological Background and Storm Environment

Several rounds of thunderstorms impacted west central Lower Michigan during the morning, afternoon, and early evening hours of 20 July 2019.

These storms developed in a roughly unidirectional vertical wind environment, conducive to training and repeating convection. Moreover, the lower atmosphere was very moist and supported deep convection and high precipitable water values. Given light mid-level winds, the threat of persistent, training, heavy, flood-producing rainfall was the threat of the day, as opposed to storm winds.

The NWS Weather Prediction Center issued two Mesoscale Precipitation Discussions relevant to the GRR forecast area during the heavy rain event (Fig. 1).

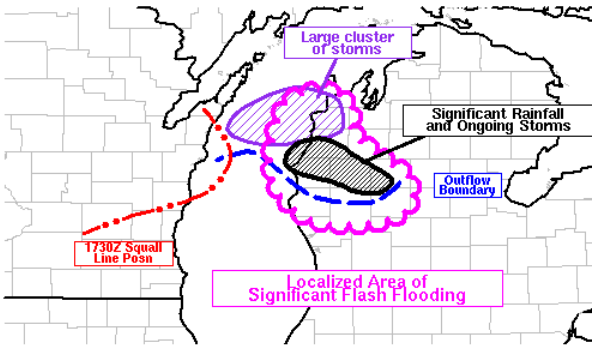


RAP32 MU CAPE 190720/1300f001
RAP32 850 MB WINDS 190720/1300f001
RAP32 700 MB WINDS 190720/1300f000
WPC MPD #0640

Mesoscale Precipitation Discussion 0640
NWS Weather Prediction Center College Park MD
1003 AM EDT Sat Jul 20 2019

Areas affected...central MI
Concerning...Heavy rainfall...Flash flooding possible
Valid 201403Z - 201830Z

Summary...An expansion of heavy rain across portions of central Lower MI is expected to lead to possible flash flooding through late this morning. Rainfall rates of 1-2 in/hr will be possible with localized 2-4 inch totals through 18Z.



WPC MPD #0643

Mesoscale Precipitation Discussion 0643
NWS Weather Prediction Center College Park MD
150 PM EDT Sat Jul 20 2019

Areas affected...Northwest Lower Michigan

Concerning...Heavy rainfall...Flash flooding likely

Valid 201746Z - 202100Z

Summary...Flash flooding is likely over a small part of northwest Lower Michigan, and significant flooding impacts will be possible. Radar estimates show up to around 10 inches of rain has already fallen in a localized area. Additional thunderstorms

	and heavy rain could occur for another 1-2 hours, exacerbating ongoing impacts.

Fig. 1. Mesoscale Precipitation Discussion (MPD) graphics, with partial text, issued by the NWS/NCEP Weather Prediction Center, germane to this report. These were (a) MPD 0640, issued at 10:03 am, and (b) MPD 0643, issued at 1:50 pm, both local time, on 20 July 2019. The images and text have been reformatted to fit the window. Full text available here: MPD 0640, MPD 0643.

The heaviest and most persistent storms occurred between 5am and 3pm EDT when the overwhelming majority of the rainfall occurred. Rainfall rates of 1"-3" per hour were suggested by radar across Mason and Lake Counties. Indeed, the early afternoon Mesoscale Precipitation Discussion explicitly mentioned Mason and Lake Counties. During the course of the event WFO GRR issued several flood products noting the increasing severity of the situation (Fig. 2).

MIC085-105-201600-
/O.NEW.KGRR.FA.Y.0014.190720T1258Z-
190720T1600Z/
/00000.N.ER.000000T0000Z.000000T0000Z.00000
0T0000Z.OO/
Lake MI-Mason MI-
858 AM EDT Sat Jul 20 2019
 	
The National Weather Service in Grand
Rapids has issued a
 	
* Flood Advisory for...
  Lake County in west central Michigan...
  Northern Mason County in west central
Michigan...
 	
* Until noon EDT.
 	
* At 857 AM EDT, Doppler radar indicated
heavy rain due to repeating thunderstorms.
This will cause minor flooding in the
advisory area. Two or more inches of rain
have already fallen.
 	
* Some locations that will experience
flooding include... Ludington SP, Luther,
Fountain, Free Soil, Freesoil, Irons,
Bristol and Wolf Lake.
	MIC085-105-210245-
	/O.NEW.KGRR.FA.W.0004.190720T1454Z-
	190721T0245Z/
	/00000.0.ER.000000T0000Z.000000T0000Z.00000
	0T0000Z.OO/
	Lake MI-Mason MI-
	1054 AM EDT Sat Jul 20 2019
	
	The National Weather Service in Grand
	Rapids has issued a
	
	* Flood Warning for...
	  Lake County in west central Michigan...
	  Mason County in west central Michigan...
	
	* Until 1045 PM EDT Saturday.
	
	* At 1041 AM EDT, Doppler radar and
	automated rain gauges indicated
	thunderstorms with heavy rain repeating
	over the same areas. Rainfall amounts of 2
	to 4 inches have likely fallen at this time
	with additional rounds of heavy rainfall
	expected through the evening. Flooding of
	low lying areas and small streams is
	expected. Campsites along streams may be at
	risk for flooding with campers needing to
	head to higher ground. Road washouts will
	be possible into the evening which will
	likely impact travel. Several inches of
	additional rain are possible through this
	evening.
	
	* Some locations that will experience
	flooding include... Ludington, Baldwin,
	Ludington SP, Scottville, Luther, Fountain,
	Free Soil, Freesoil, Chase, Custer,
	Nirvana, Wolf Lake, Idlewild, Irons,
	Walhalla and Bristol.

Fig. 2. Flood products issued by WFO GRR during the events of 20 Jul 2019, at (a) 8:58 am and (b) 10:54am The images and text have been reformatted to fit the window.

Among several reports of large precipitation values and associated flooding, a local storm total of 13.53 inches was reported at a site 6 miles east of Fountain in Sheridan Township, all falling within a 24-hour period. This is the observation considered by the SCEC for the state record, and will be referred to as the "Fountain observation" in this document. It is notable that this station is not part of an established observing network known to WFO GRR. It was, however, considered plausible and noteworthy at the time of the event.

The Grand Rapids Office issued a local storm report (LSR) noting the 13.53 inch total (Fig. 3). This area of lower Michigan is quite rural and is not served by many operationally reporting rainfall reporting stations.

0700 PM HEAVY RAIN 6 E FOUNTAIN 44.05N 86.06W
07/20/2019 M13.53 INCH MASON MI MESONET

STORM TOTAL RAINFALL FOR JULY 20 ENDING
AROUND 7PM. MOST FELL WITHIN AN 8 TO 9 HOUR
PERIOD DURING THE MORNING AND EARLY
AFTERNOON. RAINFALL WAS RECORDED WITH AN
AUTOMATED RAIN GAUGE. PRIOR REPORT WAS 12.43
INCHES YESTERDAY AFTERNOON BUT THE RAIN WAS
NOT OVER YET. SIGNIFICANT FLOODING OF THE
LITTLE SABLE RIVER WAS OBSERVED.

Fig. 3. Local Storm Report (LSR) issued by WFO GRR related to the event.

Validating against other data sources

Because the observation was not part of a standard observing network, its value prompted more scrutiny from WFO GRR and the SCEC following the event. In the interest of determining its validity, two comparable data sources were referenced. Both make use of radar estimated precipitation, given a general dearth of *in situ* observations in the immediate area.

Neighboring Gauge Reports

Given the rural area where the heaviest rain fell over, reports were limited during the event:

- 13.53" - 6 E Fountain (potential record site)
- 9.50" - 1 NNE Custer (public)
- *8.25" - 6 NNW Scottville (CoCoRaHS MI-MS-1)
- 7.42" - Luther (public)
- 4.56" - 1 S Baldwin (public)
- 3.38" - 2 SE Hersey (public)

*Note: The 6 NNW Scottville CoCoRaHS observer reported 1.32 inch at 5:00am on 20 July as a multi-day report (accumulation since July 12), plus another 6.93" for the 24-hour period ending 5:00am on 21 July. However, looking at https://water.weather.gov/precip/index.php?location_type=wfo&location_name=grr indicates that the entirety of the 1.32 inch should have fallen the morning of 20 July. When combined with the additional 6.93 inches, it suggests a storm total rainfall of 8.25 inches in about 12 hours.

Multi-Radar, Multi-Sensor (MRMS) Reflectivity Composite

A complete movie of the day's radar reflectivity in the area can be found at: https://drive.google.com/file/d/1mEyHhdkCaqo1VY18KjE8CvxBoD0hH4e9/view?usp=sharing.

The 24-hour precipitation total ending at 8:00 pm 20 July 2020 is provided as Figure 4. A large area of 9-plus

inch estimated totals stretches across Lake and Mason Counties. A second shade of purple indicates 10 to 12 inches in a large subset of that area, including the potential record observation. A few pixels in west central Lake County, NNW of the city of Baldwin, indicate precipitation totals of 12 to 14 inches. All but about one inch of this fell from 0900Z-1900Z (5:00 am to 3:00 pm EDT) on 20 July.

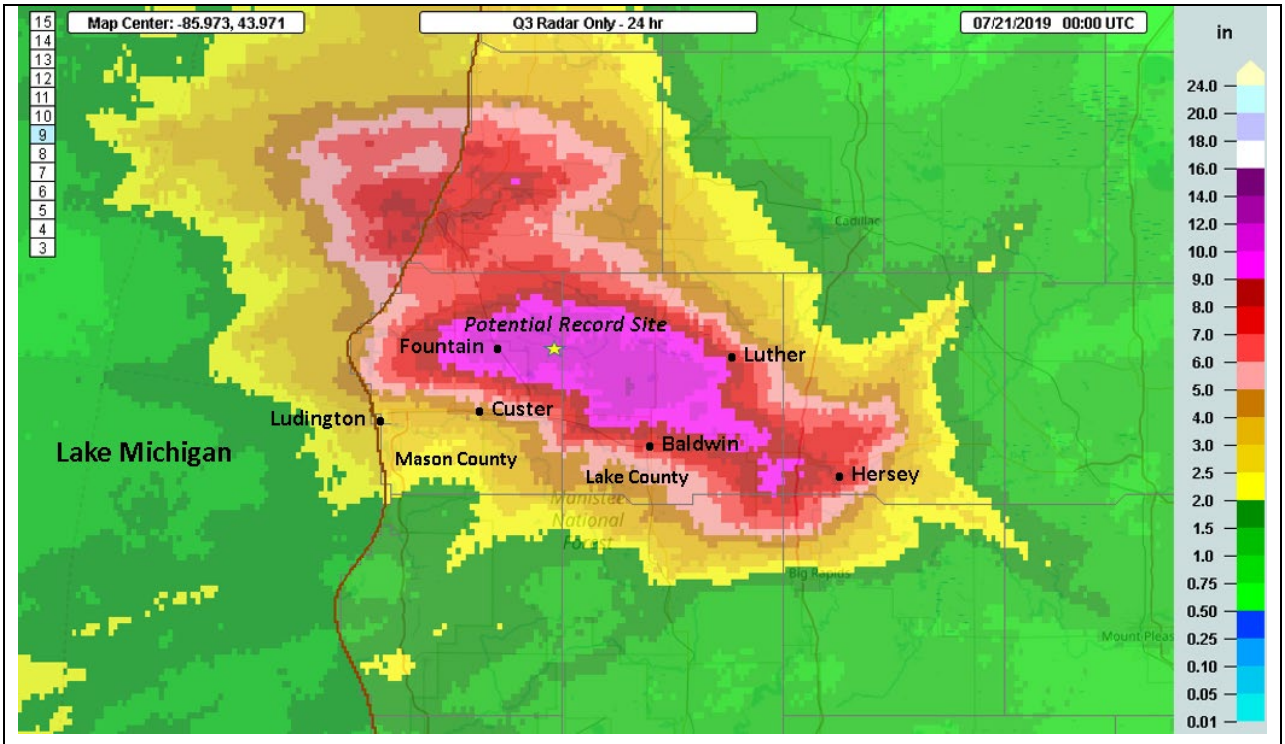


Fig. 4. Multi-Radar, Multi-Sensor 24-Hour Precipitation (MRMS24), Radar Only, Ending at 00z July 21

River Forecast Center Mosaic

The North Central River Forecast Center (NCRFC) in Chanhassen, MN is the definitive operational source for creating a mosaic of how much precipitation fell during each 24-hour period ending at 1200Z (8:00 EDT). Their precipitation field is based on a quality-controlled, radar-informed, gauge-corrected analysis. Because this rain event spanned the 8:00 am cutoff, two daily maps from the spanning dates are referenced to capture the entirety of this heavy rain event (Fig. 5).

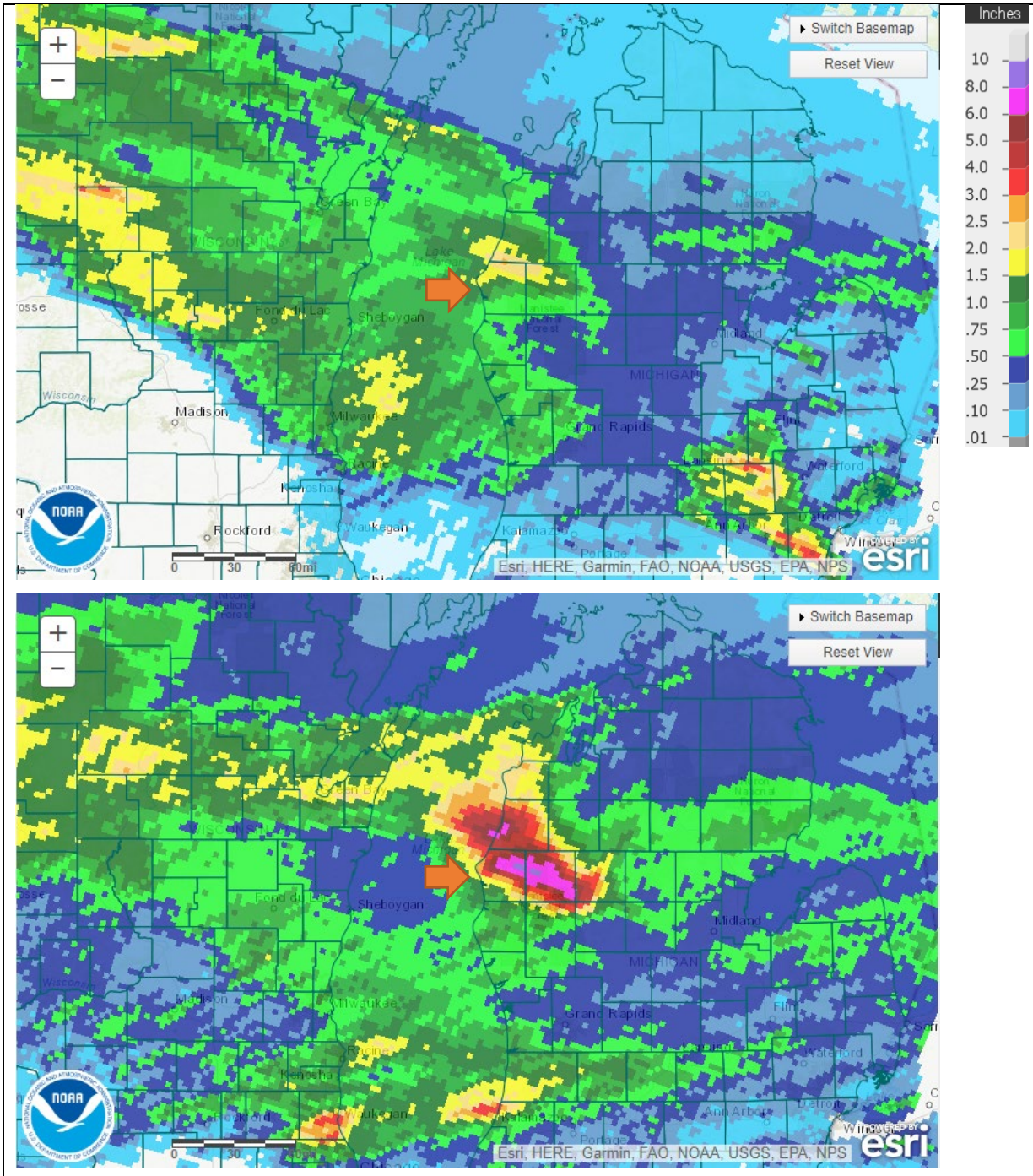


Fig. 5. 24-hour rainfall totals from the North Central River Forecast Center in Chanhassen, MN, for the periods ending (a) 8:00 am local time 20 July 2019, and (b) 8:00 am local time 21 July 2019. Mason and Lake Counties lie immediately east of the orange arrows. Mason County is immediately adjacent to Lake Michigan, and Lake County just to its east.

Summing these two daily maps together blocks together, the NCRFC analysis supports the plausibility that 10 inches or more of rain fell across a significant portion of both Mason and Lake Counties during this event.

Other Unofficial Reports

Public-facing social media provided other, less official, corroborating reports of more than 10 inches during

the event. WFO GRR did not see these reports from the Lake County Road Commission Facebook page (Fig. 6) until several days after the event. The report of 14.5 inches (later revised to 16 inches) by “Dave Titus” was not confirmed despite multiple efforts to obtain more information, and the gauge type is unknown. His claimed location is very near to areas with MRMS estimates of 12 to 14 inches.

This comment thread indicates that several other people observed 8 to 12 inches across Lake County. Another comment thread on the NWS Grand Rapids Facebook page listed a report from the Baldwin/Luther town lines whose six-inch capacity rain gauge overflowed twice, with another 3” on top of that (bringing their total to at least 15 inches). WFO GRR tried unsuccessfully to reach out to this person for more information and pursue a verification effort.

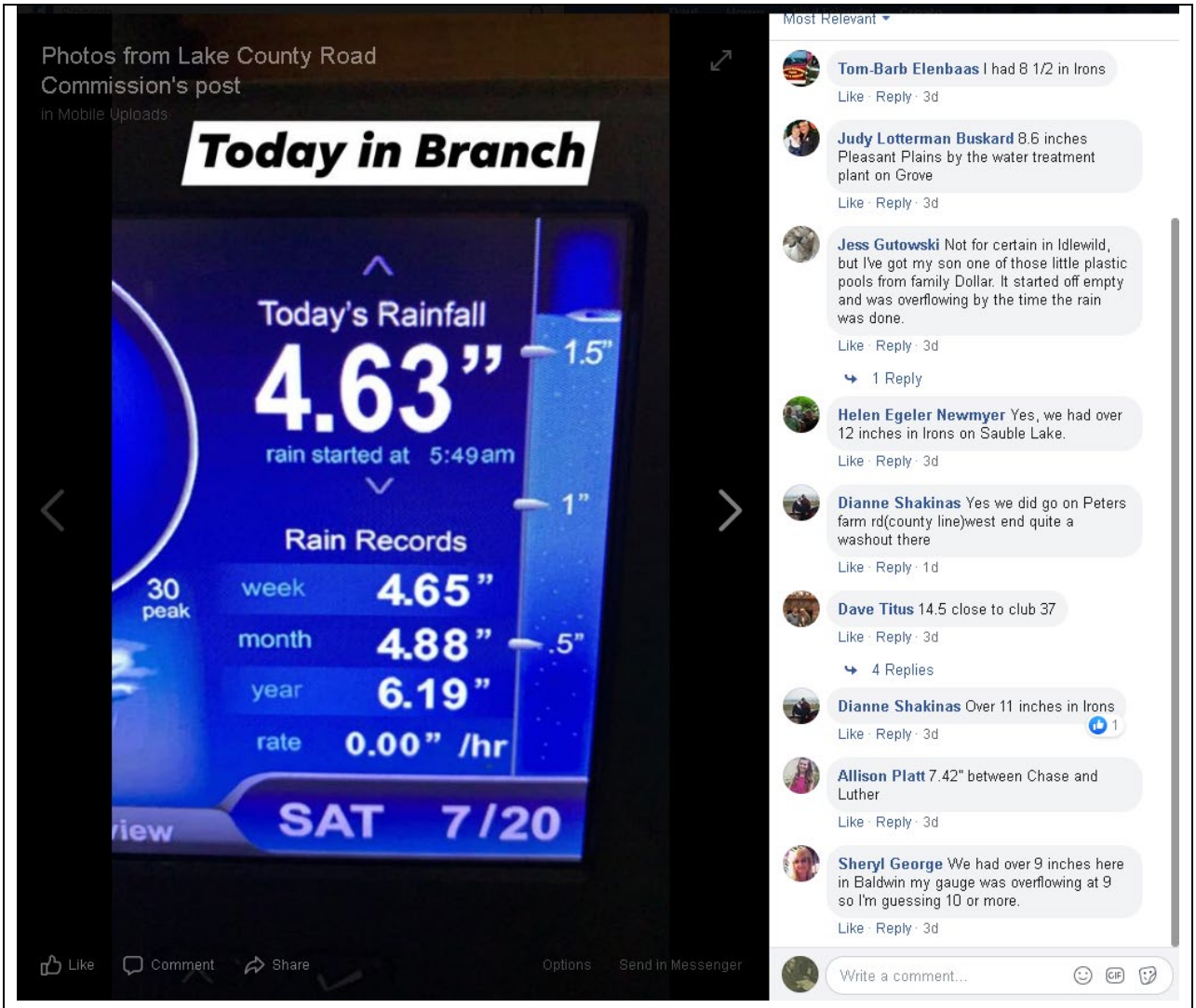


Fig. 6. Social media post from the Lake County Road Commission with comments indicating high rainfall totals in areas not covered by the Cooperative or CoCoRaHS networks.

Hydrologic Impacts and Survey

We surveyed the flood damage of Mason and Lake Counties on July 23, three days after the heavy rain event. Mason County Emergency Management as well as the State of Michigan Emergency Management Division District Coordinator attended the survey. Fortunately, the corridor of heaviest rain fell across multiple watersheds, with 4 main watersheds taking the brunt of the rainfall. As a result, the main stem rivers avoided

severe flooding. However, many of the tributaries in the hardest hit areas experienced major flooding, with some rivers rising to previously unseen levels.

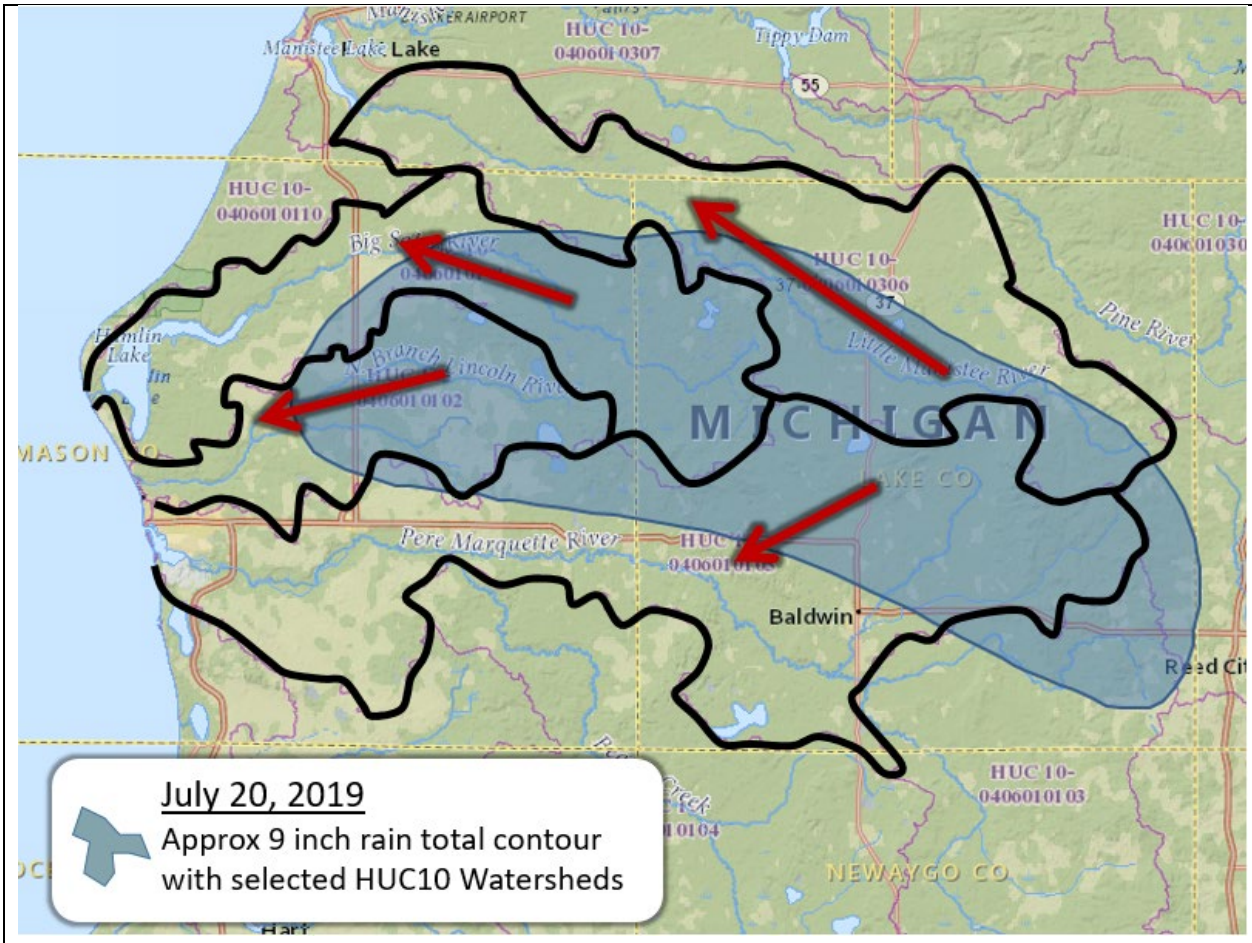


Fig. 7. Generalized map of the basin distribution of the heaviest rainfall of the 20 July 2019 event. The core precipitation area was fairly distributed across four watersheds, mitigating the magnitude of major flooding on any of the main stems.

As the water worked its way through the rivers and into Lake Michigan, the outlet currents at the river mouths increased very significantly. The river runs through Hamlin Lake, directly adjacent to Lake Michigan, before emptying into Lake Michigan. Hamlin Lake rose considerably due to the heavy rainfall on 20 July. The river remained elevated and dangerous for days after the rain event.

At the mouth of the Big Sable River near Ludington, multiple swimmers got into trouble in the week after this heavy rain event. Tragically, two swimmers drowned after being swept into Lake Michigan from anomalously strong currents associated with the event. One fatality was reported 22 July (media article), and another on 25 July (media article), at the mouth of the Big Sable River as it exits into Lake Michigan.

Notably, the geography of the event distributed the excessive rainfall into at least four watersheds, perhaps mitigating an even greater flood on a main stem river. Moving this rainfall footprint a few miles in several directions would have resulted in a more “direct hit” on one or two main stem watersheds.

Site Survey and Instrument Post-Calibration

The Fountain observer has owned his Davis Vantage Vue precipitation gage for about one year (Fig. 7). Prior

to this he operated an AcuRite home weather station, and before that, he operated a La Crosse Technology home weather station. The observer's data from the Davis Vantage Vue is currently in-house only and unavailable on the web. He is not a part of any NOAA sanctioned network, nor a part of the Citizen Weather Observer Program (CWOP). Some sensor details and specifications follow:

- Age of Equipment: About 1 year old
- Manufacturer published range of observable rainfall rates: 0.04"/hr to 40"/hr
- Manufacturer accuracy: +/- 5% when rate is under 5"/hr
- Rainfall collector area: 116 cm2 (18.0 in2). Diameter: 4.78"
- Rain collector type: Tipping spoon, 0.01" per tip
- Update interval: 20 to 24 seconds

Rainfall

Resolution and Units	0.01" or 0.2 mm (user-selectable) (1 mm at totals ≥ 2000 mm)
Range	0 to 199.99" (0 to 6553 mm)
Rain Rate	0 to 40"/hr (0 to 1016 mm)
Accuracy	Greater of 4% or 1 tip
Storm Determination Method	0.02" (0.5 mm) begins a storm event, 24 hours without further accumlulation ends a storm event
Current Data	Totals for Past 15-min, Past 24-hour, Daily, Monthly, Yearly (start date user-selectable) and Storm (with begin date); Umbrella is displayed when 15 minute total exceeds zero
Historical Data	Totals for 15-min, Daily, Monthly, Yearly (start date user-selectable) and Storm (with begin and end dates)
Alarms	High Threshold from Latest Flash Flood (15-min. total, default is 0.50", 12.7 mm), 24-hour Total, Storm Total,
Range for Rain Alarms	0 to 99.99" (0 to 999.7 mm)

Rain Rate

Resolution and Units	0.01" or 0.2 mm (user-selectable) at typical rates (see Fig. 3 and 4)
Range	0, 0.04"/hr (1 mm/hr) to 40"/hr (0 to 1016 mm/hr)
Accuracy	±5% when rate is under 5"/hr (127mm/hr)
Update Interval	20 to 24 seconds
Calculation Method	Measures time between successive tips of rain collector. Elapsed time greater than 15 minutes or only one tip of the rain collector constitutes a rain rate of zero.
Current Data	Instant and Hourly, Daily, Monthly and Yearly High
Historical Data	Hourly, Daily, Monthly and Yearly Highs
Alarm	High Threshold from Instant Reading

Fig. 7. Specification sheet from the instrument manufacturer.

The observer reported, and examination of his data display confirmed, a peak rainfall rate during the event that exceeded 15 inches per hour (Fig. 8).

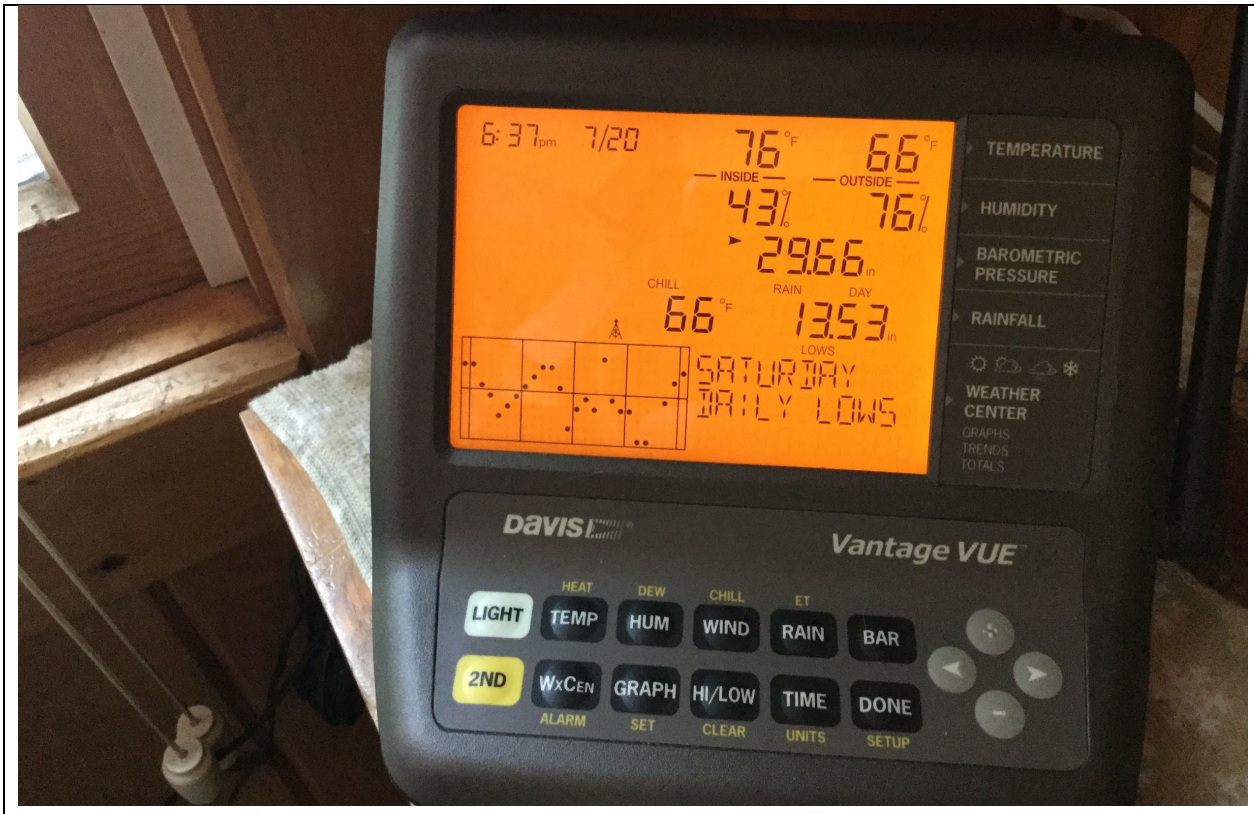


Fig. 8. The observer's Davis Vantage Vue screen showing the 13.53" daily total on 20 July 2019.

NWS Grand Rapids Senior Service Hydrologist (SSH) Andy Dixon operates an identical Davis Vantage Vue at his personal residence and is well acquainted with the equipment. The WFO has a commercial rain gauge calibration kit (Novalynx Model 260-2595 Rain Gauge Calibrator), which Dixon brought on the visit to the observer's residence to determine the accuracy of the tipping bucket rain gauge. The kit included:

- A digital scale
- A bottle with graduated markings for measurement
- A 10 mL syringe
- A covering plate for the bottle
- Multiple nozzles for the bottle outlet to allow water out at exact flow rates

Based on the known manufacturer dimensions of the Davis Vantage Vue rain collector, SSH Dixon measured out the exact volume of water that would represent 1" of "rainfall" on the gauge (295 mL). A nozzle with opening of 1/32" was selected as the best option based on a rain collector total area of 116 square cm. The 1/32" nozzle was the smallest nozzle available in the calibration kit, and best suited for the relatively small collection area of the Davis Vantage Vue gauge. The water flow rate from the 1/32" nozzle into the Davis Vantage Vue was equivalent to a rainfall rate of about 6.7-inches per hour.

Ensuring that the tipping bucket was completely empty prior to testing, the bottle was inverted and placed over the tipping bucket gauge to drip the contents of the bottle into the gauge for exactly 100 tips of the tipping bucket. If the gauge registered exactly 1.00 inch after the 100 tips it would have an error rate of 0%. Dixon performed two tests during the visit.

Test Results:

- Test #1: 100 tips registered 1.04" on the Davis Vantage Vue display (error rate of 4% too high)
- Test #2: 100 tips registered 1.05" on the Davis Vantage Vue display (error rate of 5% too high)

- Average error rate: (4% + 5%) / 2 = 4.5% too high

The WFO believes the error rate is due to a slightly unlevel mounting of the gauge, leaning in the direction of the tipping axis (this equipment has a single tipping bucket rain gauge).

Other site survey considerations included:

- The sharp elevation angles of nearby trees. None of these hung over the gauge.
- The fairly close proximity to the house. The survey indicated that there would not have been "splash off" going into the gauge from the roof.
- The aforementioned slightly unlevel mounting of the gauge, and
- The 4.5% average error during calibration testing.

During our visit, none of these four factors were deemed to be disqualifying of his rainfall amount. Please reference Appendix II for more photo documentation of the site survey.

Findings of Committee

This was an historic rain event for not only for the WFO GRR forecast area but for the state of Michigan. The combination of unofficial reports, corroborated with MRMS 24-hour precipitation estimates, strongly suggests that the reported 24-hour rainfall total exceeded the current state record of 9.78".

Extenuating factors

Given this is a non-NOAA sanctioned observation, our perspective is to balance the 10-1004 requirements with the preponderance of evidence from this particular event. The 10-1004 instruction does not factor in such preponderance of evidence, which is surprising, but nevertheless must be factored in our decision.

The Fountain observation of 13.53 inches is plausible, but given the non-network status, the SCEC thought it prudent to use an "adjusted" value of 12.92 inches, which factors in the 4.5% calibration error rate with the original observation: (13.53 - (13.53 x 0.045) = 12.92).

The State Climate Extremes Committee (SCEC) notes that the observer's property is fairly typical of rural areas of Mason and Lake Counties that are within the Manistee National Forest area. Idealized siting requirements of World Meteorological Organization, Office of the Federal Coordinator for Meteorology, and NOAA are difficult or impossible to meet across much of this region due to the heavily forested landscape.

Precedent has already been set by the National Climate Extremes Committee to accommodate observations from networks not sanctioned by NOAA. The new national 24-hour precipitation record was set by a non-NOAA observation in Hawaii in April 2018. Like the Fountain, Michigan observation, the Hawaii observation featured the following:

- non-NOAA platform
- The gauge was slightly tilted and not 100% level
- No permanent archive of the long-term record
- Post-event calibration by NOAA personnel
- No archive of the metadata

There are also differences between the two events, such as lack of prior relationship with the Michigan observer and perhaps fewer ground-truth reports nearby.

The Public Interest

The SCEC recognizes that using a non-network value as an established state record is unorthodox – and should be – generally discouraged. However, the magnitude of the event greatly exceeded the previously established record over a large area, and is consistent with long term regional trends towards heavier and

more frequent extreme precipitation events in recent decades. Local impacts in the area were extreme (see Appendix I), and tragic, and this event should remain in the collective consciousness of Michigan NWS personnel and public safety partners. Collectively, the SCEC determined it was in the public interest for preparedness and engineering concerns, to acknowledge this event and give the non-network observation due consideration.

The SCEC ultimately agreed, unanimously, to acknowledge the adjusted value as the new record for Michigan.

Committee Members (* - voting member):

- Brandon Hoving* - NWS Grand Rapids, Michigan, Observing Program Leader (OPL)
- Tim Kearns*, NWS Central Region, Regional Climate Program Manager (Acting)
- Bryan Peake*, Midwest Regional Climate Center
- Dr. Jeffrey Andresen*, Michigan State Climatologist
- Deke Arndt*, Chief, Monitoring Section, National Centers for Environmental Information
- Andy Dixon - NWS Grand Rapids, Michigan, Senior Service Hydrologist (SSH)

Recommendations

The SCEC strongly recommends that NWS Directive 10-1004 be revisited to provide clearer guidance for non-network stations.

The SCEC further recommends that this guidance:

- Reinforce the primacy of known-network observations, and that non-network observations need much more post-event scrutiny, but:
- Provide guidance and advice for situations in which the evidence (ie. field survey, calibration of equipment, surrounding reports, MRMS, etc.) clearly supports the validity of a non-network observation, to help balance the public interest in understanding known extremes with the public interest in long-term discoverability of data;
    - For example, in this Michigan 24-hour rainfall case, the SCEC's confidence in the validity that the observation exceeded the previous record by a significant amount, combined with actions taken to ensure a conservative representation of the non-network data were determined to outweigh the potentially disqualifying non-network status of the observation.

NCEI Climate Monitoring Chief Decision:

Approved as recommended:	**Not approved** returned to SCEC with no action taken:
ARNDT.DEREK.SHANE.1384496519 Digitally signed by ARNDT.DEREK.SHANE.1384496519 Date: 2020.03.30 13:50:37 -04'00'	

Appendix I: Additional Damage and Impacts photos

Partial road collapse and landslide

High water / debris mark on a tree

Several road washouts / culvert failures were observed

Additional culvert failures

A bridge that was partially destroyed

High water mark still visible on pole

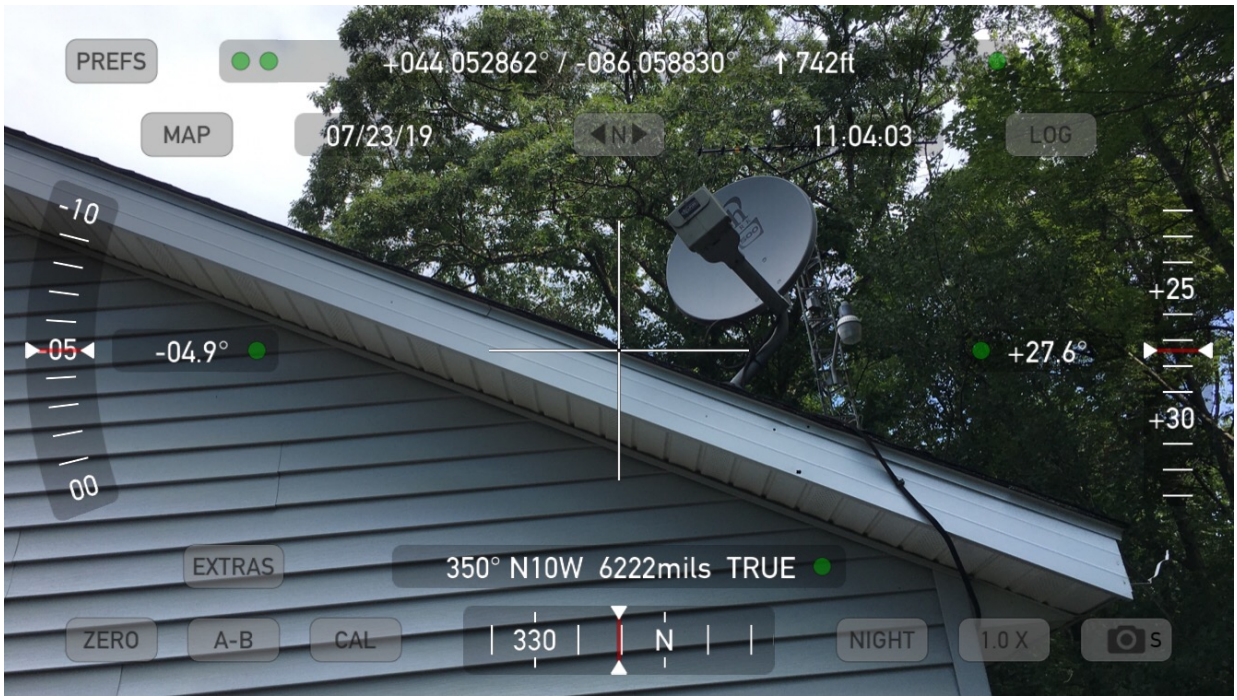
A receding Baldwin River that caused first floor flood damage

Water flowing exceeded culvert capacity, resulting in sheet flow over the road

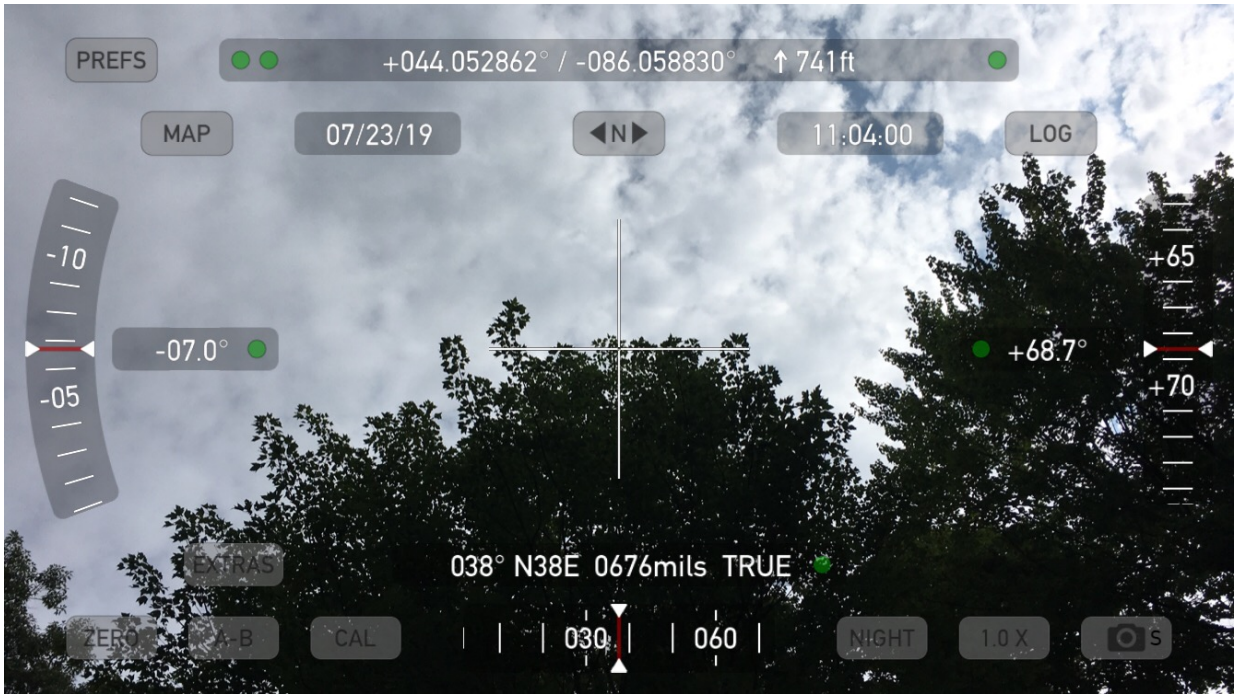
Same location as the photo above, after the water had receded. Note destruction of road bed slope and surface

Appendix II: Additional Post-Calibration Images

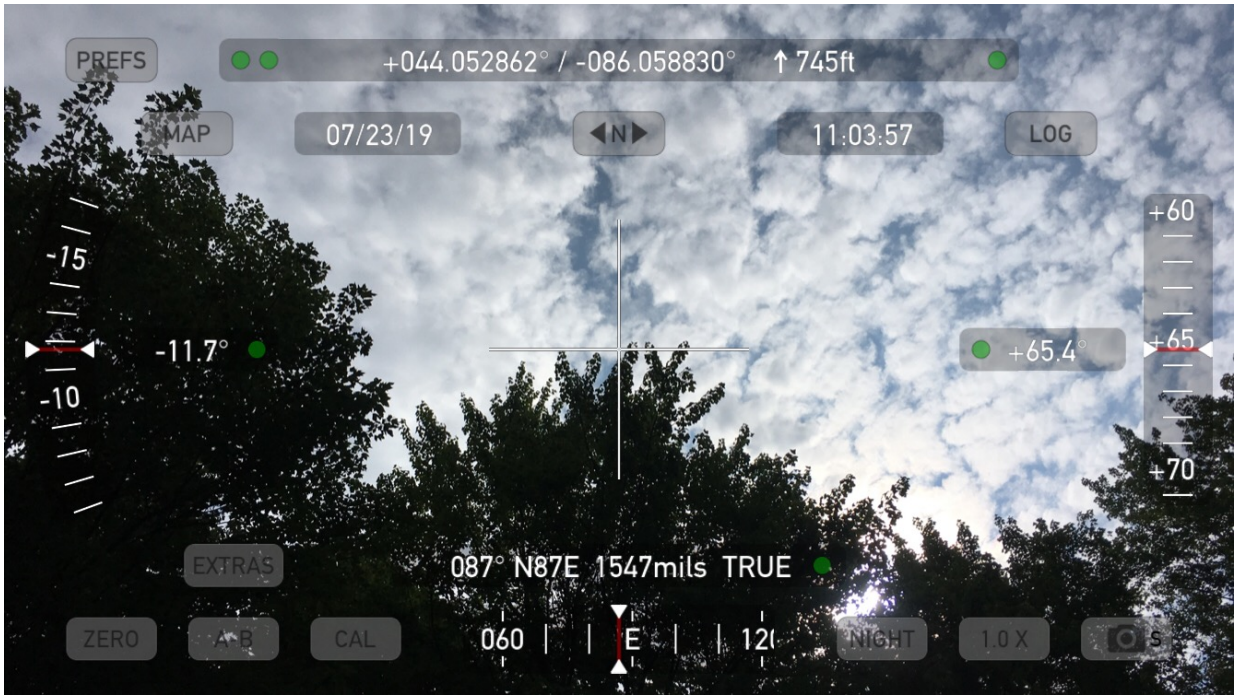
The equipment was slightly unlevel (notice lean to the left).



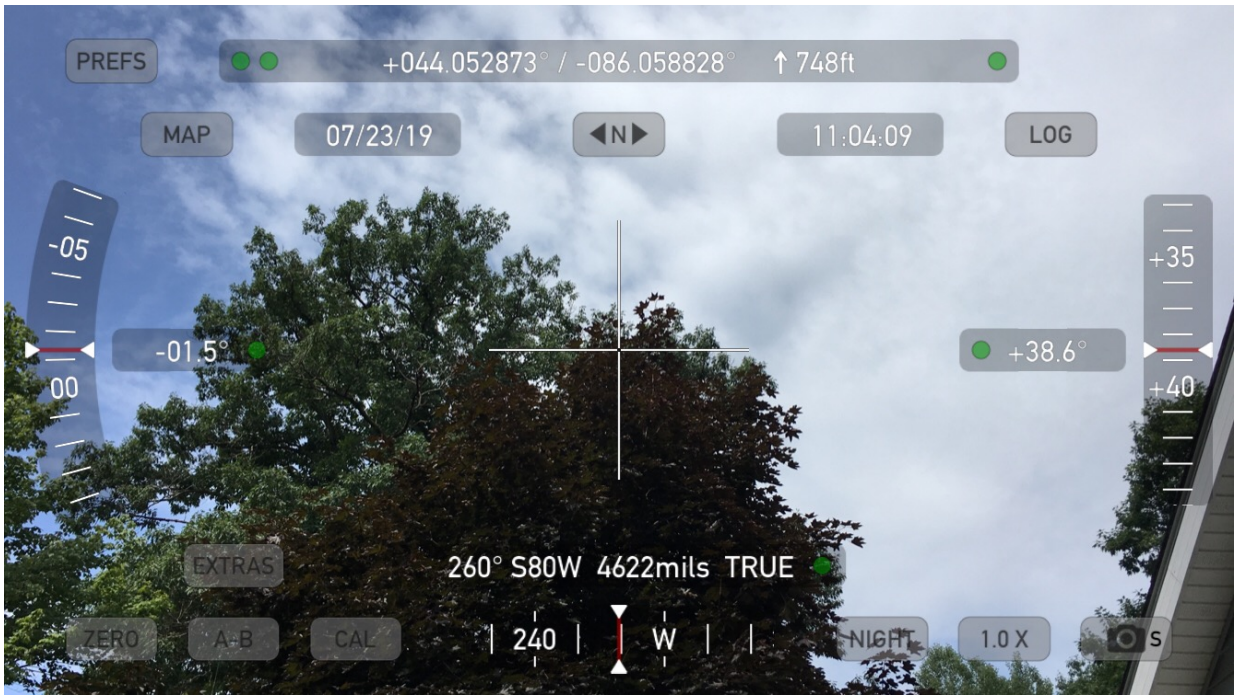
The side of the house is approximately 10 ft from the gauge location, at 28° elevation.



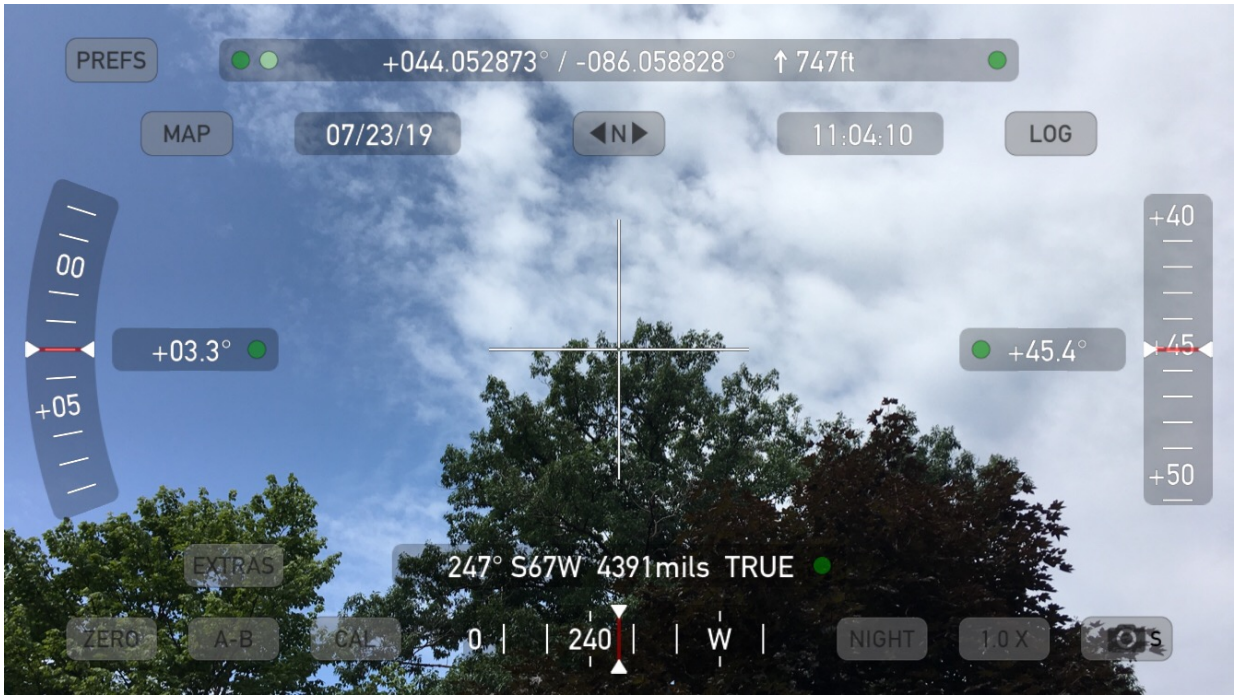
These trees are approximately 30-50 ft from the gauge at 69° elevation



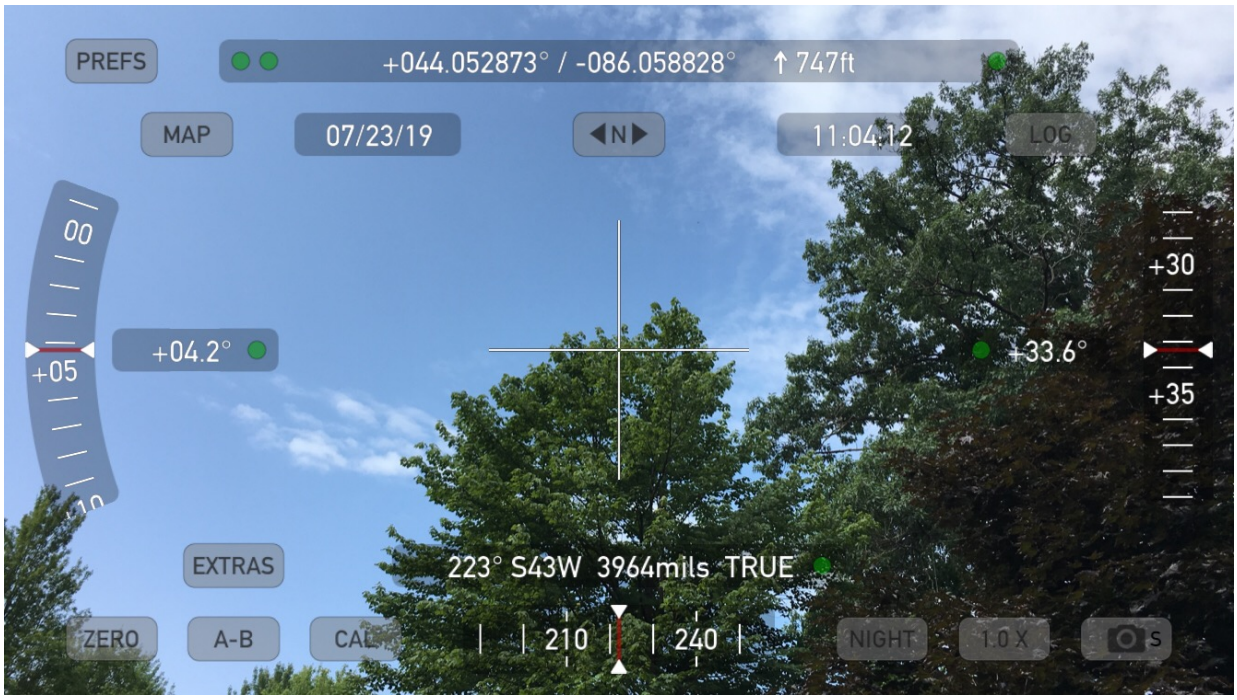
These trees are approximately 30-50 ft from the gauge at 65° elevation.



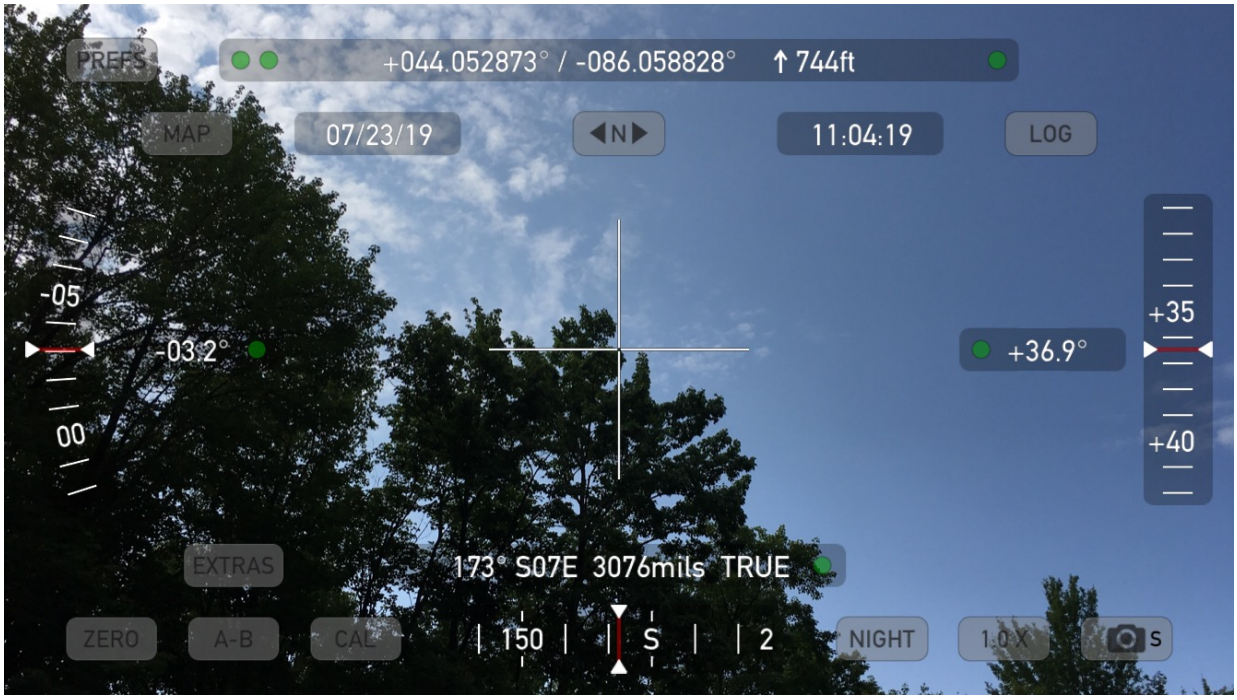
This tree is approximately 40 ft from the gauge at 39° elevation.



This tree is approximately 100 ft from the gauge at 45° elevation.



This tree is approximately 130 ft from the gauge at 34° elevation.



These trees are approximately 70-100 ft from the gauge at 37° elevation.

These trees are approximately 30-50 ft from the gauge at 48° elevation.

GRR SSH preparing the calibration materials.

GRR SSH beginning the calibration test