The Flood of 2023 in and upstream of Montpelier
Hydrological Aspects
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The Flood of 2023 was the third largest flood to have been recorded on the Winooski River in Montpelier. This paper looks at the hydrology of that flood and its effects at and upstream of Montpelier.

This analysis began with two simple questions.
1. How did the 2023 flood compare with the 1927 flood?
2. How did the 2023 flood compare with the maps and profiles of the National Flood Insurance Program?

While working on this analysis, the three sessions of the Vision and Action Dialogue held in Montpelier by Montpelier Alive! and the Montpelier Foundation raised additional questions and suggestions. Some of them can be addressed by the research and calculations done to answer the first two questions.

Summary of Findings

The 2023 flood was the third largest recorded flood to inundate Montpelier, since at least 1830. The largest flood was that of 1927. The second largest was before 1927, likely that of 1869.

<u>1. How did the 2023 flood compare with the 1927 flood?</u>
The short answer is that the 2023 flood was at least 3/4 the size of the 1927 flood and in some areas likely as great as the 1927 flood. The more complicated answer is that the comparison depends on whether one is looking at an unregulated watershed or a partially regulated watershed. And on how the 2023 rainfall compared to the 1927 rainfall.

Precipitation and peak discharge are the two measures used to compare the 2023 flood to the 1927 flood.

The driving force of the flooding is the rainfall and its associated runoff. The total rainfall in the 1927 flood was uniformly between 8" and 8 1/2" over the watershed of the Winooski River upstream of Montpelier. The total rainfall in the 2023 flood was between 3" and 8", with the majority of the area receiving between 6" and 8" of rainfall. The 2023 average over the watershed was about 80% as much as in 1927, with the range being 36% to 100% of the 1927 flood.

Flows at and upstream of Montpelier now are regulated by three dams, two more than in 1927. They regulate flow from 33% of the watershed upstream of Montpelier. These dams are the Wrightsville Dam (completed in 1935), the East Barre Dam (1935), and the Marshfield Dam (1926).

The peak discharge in the 2023 flood was 26,700 cfs at the U. S. Geological Survey's stream gage on the Winooski River at Montpelier. The peak discharge there in 1927 was 57,000 cfs. The 2023 peak discharge was 47% of that of 1927. Peak discharges in 2023 just upstream of the East Barre and Wrightsville dams were 56% and 68% those of 1927, respectively. Just downstream of those two dams peak discharges were 5% of the peaks in 1927. Just below a flood control dam, all the flow is regulated by the dam. Proceeding downstream, unregulated tributaries and direct runoff mean decreasing fractions of the runoff are regulated. Upstream of any flood control dam, all flow is unregulated.

If the dams at Wrightsville and East Barre had not been built, the peak discharge at Montpelier could have been about 42,200 cfs, 74% that of 1927.

2. How did the 2023 flood compare with the maps and profiles of the National Flood Insurance Program?
This part of the study compared observations of discharges and water surface elevations with the two Flood Insurance Studies that cover Montpelier. The elevations are from the U. S. Geological Survey's gages on the Winooski River at Cemetery Curve on U. S. Route 2 and on the North Branch at the Langdon Street bridge. The observed discharges are from the U. S. G. S. gage on the Winooski River. Montpelier's first Flood Insurance Study was issued in 1981. The second and current study was issued in 2013. The observations better match the flood profiles in the 1981 study. The 2013 flood profiles are a poor match to the observations.

Other findings that relate to some of the suggestions from the Vision and Action Dialogue
Less than 10% of the 2023 peak discharge at Montpelier came from the 33% of the watershed regulated by the three dams.

The 2023 flood is not the flood to design for. There will be another flood, a larger flood. The East Barre Dam and the Wrightsville Dam were designed for floods larger than this one. So we can expect larger floods.

The Wrightsville Dam did not spill water, even though it stored a larger volume of water than in the design flood and despite having lost 13% of its flood storage capacity when the minimum pool level was raised in 1965 for recreation and in 1985 for generation of electricity.

To prevent flooding in Montpelier, the peak discharge in the Winooski River would need to be less than half the discharge of the 2023 flood.   Doing that with new flood control dams alone would take dams equal in flood reduction capability to the dams at Wrightsville and East Barre combined.

The action level at the North Branch gage at Langdon Street in Montpelier is at or above the elevations of the cellar floors in many of the buildings along Main, State, Langdon, and Elm Streets.

The annual probability of water reaching the minor flooding stage at the North Branch gage at Langdon Street in Montpelier is greater than 10%.

The North Branch contributes minimally to peak discharges and flooding in Montpelier. The flow in the North Branch contributed about 5 inches to the water surface elevations in the downtown area.

A dam with gates in the Winooski River just downstream of the Main Street bridge was built for flood protection in 1934 as part of the same project that built the East Barre, Wrightsville, and Little River dams. The gates were removed and the dam altered in 1975 to what we now see. Removal of that dam is now being considered.

The Watershed

The Winooski River rises in the town of Cabot and flows through Marshfield, Plainfield, East Montpelier, and part of Montpelier before reaching the stream gage in Montpelier. The Winooski River also forms part of the town line between Montpelier and Berlin. Major tributaries upstream of the Winooski River gaging station are the North Branch, the Stevens Branch, the Kingsbury Branch, the Great Brook, and the Molly's Falls stream.

Three dams regulate flow in this part of the watershed: the Wrightsville Dam; the East Barre Dam, and the Marshfield Dam. These three dams regulate a combined area of 129 sq. mi., 33% of the watershed.   The Marshfield Dam was completed the year before the 1927 flood. It was built as part of a hydroelectric project by the Montpelier & Barre Light & Power Company. The other two dams were built for flood protection by the Corps of Engineers and the Civilian Conservation Corps, 1933 through 1935, in response to the depression and the 1927 flood.

Drainage Areas Upstream of Dams

Location	Year Completed	Drainage Area	Percent
Winooski River at the Montpelier gage.	---	397 sq. mi.	100
North Branch at the Wrightsville Dam	1935	66.5 sq. mi.	17
Jail Branch at the East Barre Dam	1935	38.8 sq. mi.	10
Molly's Brook at the Marshfield Dam	1926	24 sq. mi.	6

Gaging Stations

The United States Geological Survey measures water surface elevations at four gaging stations in Montpelier. There is a fifth gaging station in the watershed at East Barre. Two of the stations also provide the discharge at those stations. "Discharge" is a jargon word in hydrology meaning the volume of flow in a given time period. The standard unit now in use in the United States is cubic feet per second, abbreviated cfs.

The oldest of the four gages is on the right bank of the Winooski River at the start of Cemetery Curve on U. S. Route 2. This gage is located upstream of the Dog River and downstream of the North Branch. The station number of this gage is 04286000. It measures both water surface elevation and discharge. This gaging station operated intermittently from May 1909 to June 1914. Then continuously from July 1914 to September 1923 and then August 1928 to the present.

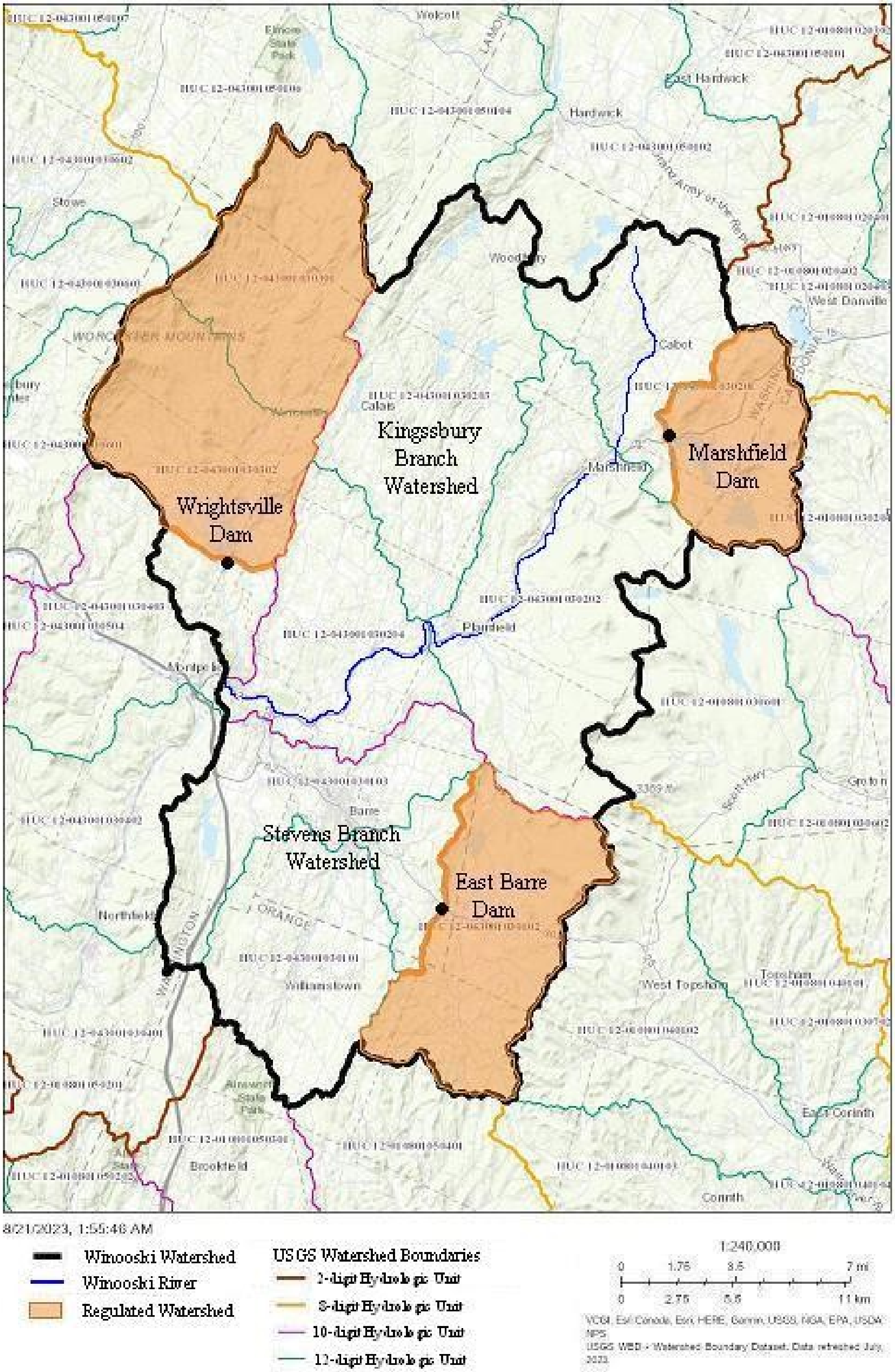
The newest (October 2017) gaging station in Montpelier is on the right bank of the North Branch at the Langdon Street Bridge. The station number of this gage is 04285800. This gaging station measures only the water surface elevation. The U.S.G.S. Water Year Summary shows the start of the period of record of this gage as October 2017. The display at the gage states that the U. S. G. S. began tracking water levels at the site beginning in 2007, even though these earlier data do not seem to be available on the U.S.G.S. Water Data internet site.

The other two gaging stations are in Wrightsville, a settlement within Montpelier. They were installed in conjunction with the construction of the Wrightsville Dam. The older of these two (October 1933, start of construction of the dam) is on the right bank of the North Branch in Wrightsville 0.9 miles downstream of the Wrightsville Dam. The drainage area between the dam and the gage is 2.7 sq. mi. The station number of this gage is 04285500. This gaging station measures both water surface elevation and discharge. The newer of these two (November 1935, completion of the dam) is located on top of the Wrightsville Dam. The station number of this gage is 04285000. It measures the water surface elevation in the reservoir.

The U. S. G. S. also maintains a gaging station at the East Barre Detention Reservoir on the Jail Branch at East Barre. The station number of this gage is 04283500. It began operating in February 1936. This gaging station measures water surface elevations in the reservoir. Previously there was also a stream gaging station (04284000) on the Jail Branch at East Barre. This gage was on the right bank of the Jail Branch 1400 feet downstream of the East Barre Detention Reservoir. This gaging station operated from August 1920 to September 1923 and from October 1933 to September 1992.

Lack of co-operative funds (meaning the State failed to provide its share) is the reason gaging was discontinued at the end of September 1923.

Winooski Watershed above Montpelier



Base map from U.S.G.S. Watershed and dam information added by T. Weiss.

USGS

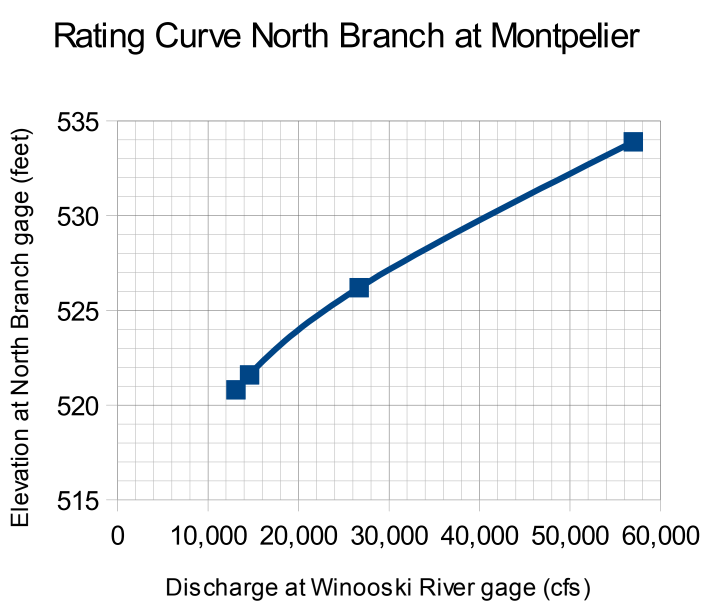
Flood History

Montpelier has been inundated by flooding ever since its founding. The largest recorded flood was 57,000 cfs at midnight on November 3, 1927. During that flood "the entire business district was under 8 to 10 feet of water." Individuals trapped in stores on the first floor had to climb to the ceilings to keep their heads above water.

The U. S. Geological Survey has installed a display of high water marks at the gage on the North Branch at Langdon Street The display is a series of markers on a pole. The markers show elevations at 5-foot intervals and high water elevations of five floods. The 1927 flood is the highest flood shown on the display. The peak water surface elevation of the 1927 flood at that gage was about 533.9 feet. The other floods shown are those of 1927, 2023 (temporary marking), 1992, May 2011, and August 2011.

The second largest recorded flood was likely that of 1869. The flood of 1869 was a large flood in much of Vermont. The U. S. Weather Bureau reported in 1927 that Montpelier had a high-water mark for the Winooski River 3.0 feet higher than a previous mark. This would have made the water surface elevation of that previous flood about 530.9 feet. The discharge of this flood was perhaps 45,000 cfs. The Weather Bureau's report did not identify that previous flood. The flood of 1869 was the previous large flood before 1927. So the author believes the 1869 flood likely is the flood which had that previous high water mark.

The water surface of the North Branch at Montpelier in that flood has been estimated based on a rating curve of the known water surface elevations (1927, 2023, May 2011, and August 2011) at Langdon Street with peak flows at the gage on the Winooski. The known elevation of the flood of 1992 was not used because that flood was caused by an ice jam and not by a high discharge. Using discharge of the Winooski as the abscissa is appropriate because the flood insurance profiles show that the water surface elevation in the North Branch downstream of the Spring Street bridge is determined by the water surface elevation in the Winooski River; and not by the discharge in the North Branch.



The third largest recorded flood was that of 2023. Unrecorded floods between 1830 and 1927 might have been larger than the 2023 flood. The peak discharge of the Winooski River at Montpelier was 26,700 cfs at 9 a. m. on July 11. If the dams at Wrightsville and East Barre had not been built, the peak would have been perhaps 42,200 cfs at 10:45 p. m. on July 10.

The fourth largest recorded flood depends on how one defines "large". If one ranks by discharge, then the flood of 1936 is fourth, with a discharge of 20,000 cfs at 6 p. m. on March 18. If one ranks by water surface elevation, then the ice-jam flood of March 11, 1992 is fourth. The peak discharge in the Winooski River during the 1992 ice-jam flood was 11,500 cfs. The ice-jam in 1992 was cleared by a crane dropping a weight onto the ice to break it up. After that the City of Montpelier arranged a system to pump treated wastewater a mile upstream from the normal outfall at times of potential ice jams. The wastewater melts the ice when it is pumped onto the ice. This system greatly reduces the chance of ice-jam flooding in Montpelier.

Comparison with the Flood Insurance Study

The 2023 flood was the third largest recorded flood to inundate Montpelier since at least 1830. The U. S. Geological Survey reported the peak discharge at the Winooski River gage at Montpelier was 26,700 cfs. They reported the peak elevation there to be 521.2 feet. This gage is located at the start of Cemetery Curve on lower State Street. U. S. G. S. also reported a peak water surface elevation at Langdon Street of 526.2 feet half an hour earlier than the peak reached the Winooski River gage, one mile downstream from the North Branch.

<u>Comparison with the 2013 Flood Insurance Study</u>
The current Flood Insurance Study for Washington County became effective March 19, 2013. In order to compare an observation with the flood profiles, one can match either the observed discharge or water surface elevation and see what the profile predicts the other will be. There are two observations that can be matched: the water surface elevation at the gage on the Winooski River and the water surface elevation at the gage on the North Branch. The closer the results of the matches are to the observations, the better the fit between the calculated flood profiles and the observations.

<u>2013 matches at Winooski River gage.</u> The profiles in the 2013 study show that a discharge of 26,700 cfs at the Winooski River gage has an elevation there of 523.8 feet and the annual probability is 0.2 %. This compares to the observed 521.2 feet at that gage. The 2013 profiles show that when the water surface elevation at the gage is 521.2 feet, the discharge is only 19,300 cfs and the annual probability is 1.3 %. The differences are large: 523.8 feet *vs.* the observed 521.2; 19,300 cfs *vs.* the observed 26,700 cfs. And a large difference in annual probabilities: 0.2 % and 1.3 %.

<u>2013 matches at North Branch gage.</u> Flood profiles show that backwater from the Winooski River controls the water surface elevations in the North Branch during flooding. The water surface elevations in the North Branch equal the elevations in the Winooski River as far upstream as Spring Street and in some cases as far as the dam at Vine Street.

The 2013 study shows that a discharge of 26,700 cfs at the Winooski River gage produces an elevation of 527.5 feet at the Langdon Street gage and an annual probability of 0.2 %. This compares to the observed 526.2 feet at the Langdon Street gage. When the water surface elevation at the Langdon Street gage is the observed 526.2 feet, the profiles show that occurs at a discharge of 21,800 cfs at the Winooski River gage and the annual probability is 0.6 %. The differences in these pairs are also large, indicating that the 2013 profiles do not well match the observation at the Langdon Street gage, either.

<u>Comparison with the 1981 Flood Insurance Study</u>
There is an older Flood Insurance Study for Montpelier that is no longer effective. This study had become effective August 17, 1981. This older study provides a better match to the observed data from the 2023 flood. Flood discharges at a given annual probability in the 2013 study are lower than in the 1981 study. The reason for this change has not been investigated.

<u>1981 matches at Winooski River gage.</u> The 1981 study shows that a discharge of 26,700 cfs at the Winooski River gage has an elevation there of 521.8 feet. The annual probability is 0.8 %. This compares to the observed 521.2 feet at that gage. The 1981 study shows that when the water surface elevation at the gage is 521.2 feet, the

discharge is 25,000 cfs and the annual probability is 1.0 %. The differences are closer together using the profiles of the 1981 study than they were using those of the 2013 study. Because the differences in the pairs are smaller using the 1981 profiles, the 1981 profiles better match the observation at the Winooski River gage.

1981 matches at North Branch gage. The 1981 study shows that a discharge of 26,700 cfs at the Winooski River gage produces an elevation of 526.4 feet at the Langdon Street gage and an annual probability of 0.8 %. This compares to the observed 526.2 feet at the Langdon Street gage. When the water surface elevation at the Langdon Street gage is the observed 526.2 feet, the profiles show that occurs when the discharge is 25,900 cfs at the Winooski River gage and the annual probability is 0.8 %. The differences in these pairs are also much smaller than the corresponding pairs from the 2013 profiles. This again indicates that the 1981 profiles better reflect the observation at the Langdon Street gage.

Comparison of Observed Data with the Flood Insurance Studies

Location	Observed		1981 Flood Insurance Study			2013 Flood Insurance Study		
	W. S. El. (feet)	discharge, Q (cfs)	W. S. El. (feet)	discharge, Q (cfs)	Annual prob. (%)	W. S. El. (feet)	discharge, Q (cfs)	Annual prob. (%)
Winooski River at Montpelier (match Q)	521.2	26,700	521.8	26,700	0.8	523.8	26,700	0.2
Winooski River at Montpelier (match W.S.El.)	521.2	26,700	521.2	25,000	1.0	521.2	19,300	≈ 1.3
North Branch at Montpelier (match Q)	526.2	26,700	526.4	26,700	0.8	527.5	26,700	0.2
North Branch at Montpelier (match W.S.El.)	526.2	26,700	526.2	25,900	0.9	526.2	21,800	0.6

Hydrological Aspects of the Flood of 2023

The 2023 flood was a major flood in Montpelier. Flood waters rose to a depth of four feet or more on the first floors in many homes and businesses along both downtown rivers. Cellars of homes and businesses outside the inundated areas filled with a mixture of flood waters and backed-up sewage.

Downtown Montpelier floods when the Winooski River rises and causes the North Branch to rise. The North Branch rises due to backwater from the Winooski River as far upstream as the dam at Vine Street. The flow in the North Branch contributed about 5 inches to the peak flood elevation in Montpelier.

During normal flows, the North Branch drops over the weir (Trestle Dam) upstream of the pedestrian bridge near the mouth and tumbles over the rocks at the railroad bridge into the Winooski River.

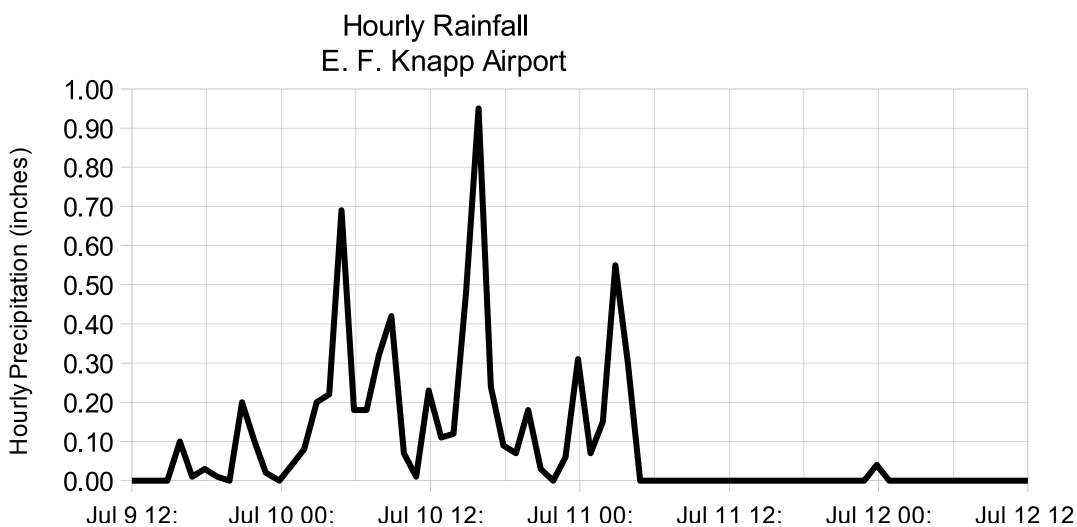
As the Winooski rises, it drowns the rocks and the weir, causing the North Branch to rise. When the Winooski rises high enough, the combined waters overflow into the parking lot on the right bank and then on the left bank, both downstream of State Street. The Winooski rises higher and the flood waters flow through the parking lots behind the buildings on the river side of State Street. When the Winooski rises high enough, the flood waters flow down State Street. When the Winooski rises still higher, as it did during the height of the 2023 flood, water enters Stonecutters' Way at a low spot in the bank behind the Recreation Building and flows along the railroad tracks to Main Street. This occurs at an elevation downtown somewhere above 525.4 feet. When water arrives at Main Street from the railroad tracks, water is already on the first floors of most buildings downtown.

Precipitation

The 2023 flood was the largest flood to have inundated Montpelier since 1927, and the third largest recorded flood since at least 1830. The flood was caused by intense precipitation. Rain started in Montpelier about 4 p. m. (EDT) on July 9 and continued into the pre-dawn hours of July 11.

The National Weather Service records hourly rainfall at the E. F. Knapp Airport in Berlin. The airport is about four miles from downtown Montpelier. The storm lasted about 36 hours at the airport: 4 p. m. on July 9 through 4 a. m. on July 11. Total rainfall in those 36 hours was 6.82".

The rain fell in five waves. ("Wave is used here to denote a period between no or little rainfall. For example, the second wave occurred 8 p. m. to midnight, July 9.) The longest two waves each lasted about 10 hours. The first of these long waves (midnight July 9 through 10 a. m. July 10) had two peaks. The second long wave (11 a. m. through 9 p. m. on the 10th) had three peaks, including the highest of the storm. That highest amount was 0.95" between 3 and 4 p. m. on the 10th. When the runoff from that peak reached Montpelier, the situation changed rapidly: Before that runoff reached Montpelier, the water levels had reached the action stage at the Langdon Street gage although flood stage had not been reached. As the runoff pushed into Montpelier, water surface elevations rose through the three stages of flooding, to the major flood stage. This rapid rise was 7 feet in 7 hours, from 4 p. m. through 11 p. m. on the 10th.

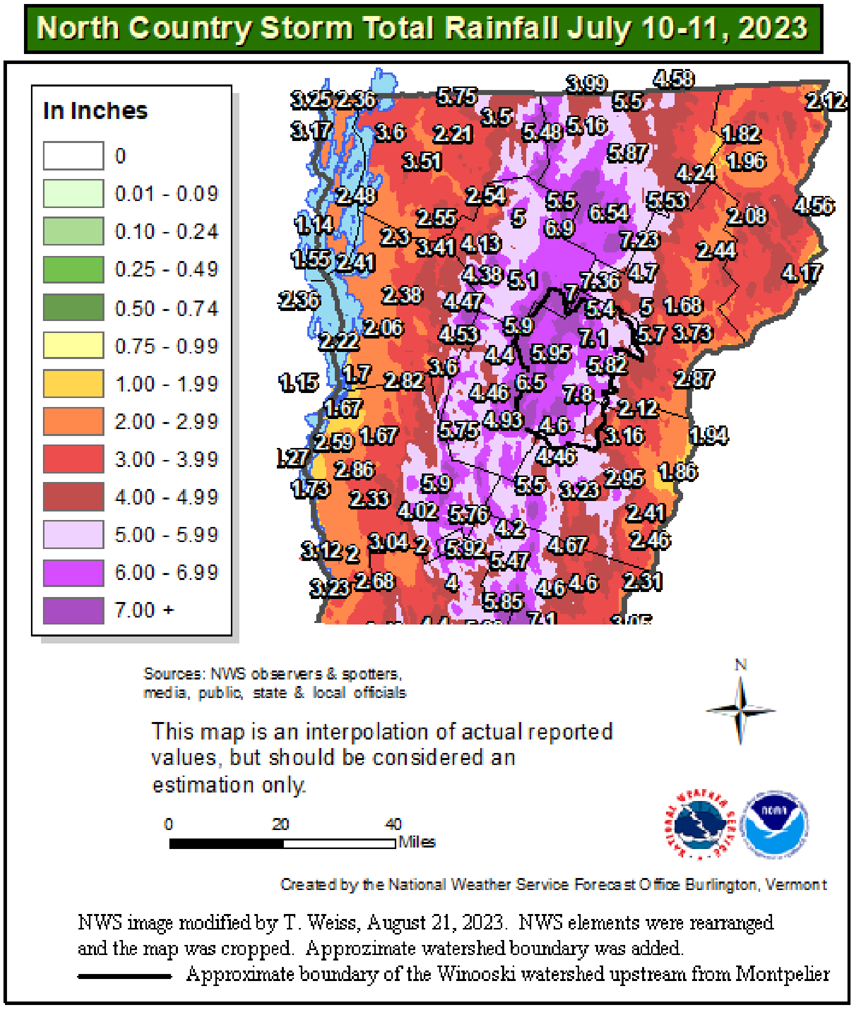


The National Weather Service issued "The Great Vermont Flood of 10 - 11 July 2023 Preliminary Meteorological Summary " It contains a map showing rainfall amounts during the 48 hours 8 a. m. July 9 through 8 a. m. July 11. The approximate boundary of the Winooski River watershed upstream of Montpelier has been superposed for reference. The map shows that rainfall ranged from 3" to 8" over the watershed.

Rainfall over the bulk of the drainage area upstream of Montpelier was between 6" and 8". Rainfall along the easterly edge of the watershed was between 3" and 6". An eyeball estimate is that perhaps 80% of the watershed upstream of Montpelier had rainfall of 6" to 8". The remaining 20% had rainfall of 3" to 6". An area-weighted average could be around 6.6".

The areas of least rainfall were over the watersheds of the Jail Branch upstream of the East Barre Dam (3" to 7") and Molly's Brook upstream of the Marshfield Dam (4" to 6").

Rainfall was highest (between 7" and 8") over: the Worcester Mountains and along the hills to Montpelier; along the hills between the watersheds of the North Branch and Kingsbury Branch; the upper watershed of the Kingsbury Branch; Barre City; and the ridge containing Paine Mountain.



<u>Water surface elevations (W.S.El.'s)</u>

<u>Winooski River gage</u>

The action level at the gage on the Winooski River at Montpelier is at 511 feet. The action level was reached at 9:45 a. m. on July 10. The water level at the gage on the North Branch in Montpelier was then at 516 feet, one foot above its action level. The peak water surface elevation at the Winooski River gage was 521.2 feet at 9 a. m. on the morning of July 11.

It took 6 1/2 hours for the water surface elevation at the Winooski River gage to rise from the action level to minor flooding.

It took only 1 1/2 hours for the river to rise from minor flood stage (515 feet) to major flood stage (517.5 feet) on July 10. It took 4 1/4 hours for the river to drop that far on the 11th.

<u>North Branch gage in Montpelier</u>

One major use of this North Branch gage is to alert downtown property owners and tenants that the North Branch is rising. The action level at the gage on the North Branch at Montpelier is at 515 feet. The action level was reached at 9 a. m. on July 10. The peak water surface elevation at this gage was 526.20 feet at 8:15 and 8:30 a. m. on July 11. To put these water surface elevations into perspective, the deck of the Langdon Street Bridge is at an elevation about 522 ½ feet. The timing of the peak corresponds to the author's observation that flood waters began receding about 9 a. m. That observation was the edge of water creeping back toward the North Branch along School Street at the intersection of School Street and Loomis Street.

It took 8 1/2 hours for the North Branch gage to rise from the action level to minor flooding.

It took 3 hours for the North Branch to rise from minor flood stage (520 feet) to major flood stage (524 feet) on July 10. It took 6 1/2 hours for the river to drop that far on the 11th.

The table shows the various stages, when the W.S.El. reached each elevation, and how much time the water was above each stage.

Gage	Winooski River at Montpelier			North Branch at Montpelier		
	W.S.El. (feet)	Time Reached	Duration above stage (hours)	W.S.El. (feet)	Time Reached	Duration above stage (hours)
Peak	521.2	9:00, July 11	< 1/4	526.2	8:15, July 11	1/4
Major Flooding	517.5	17:45, July 10	22 1/2	524	20:30, July 10	17 1/4
Moderate Flooding	516	17:00, July 10	25 3/4	522	18:15, July 10	20 3/4
Minor Flooding	515	16:15, July 10	28 1/4	520	17:30 July 10	26 3/4
Action Level	511	9:45, July 10	48	515	9:00 July 10	56 3/4

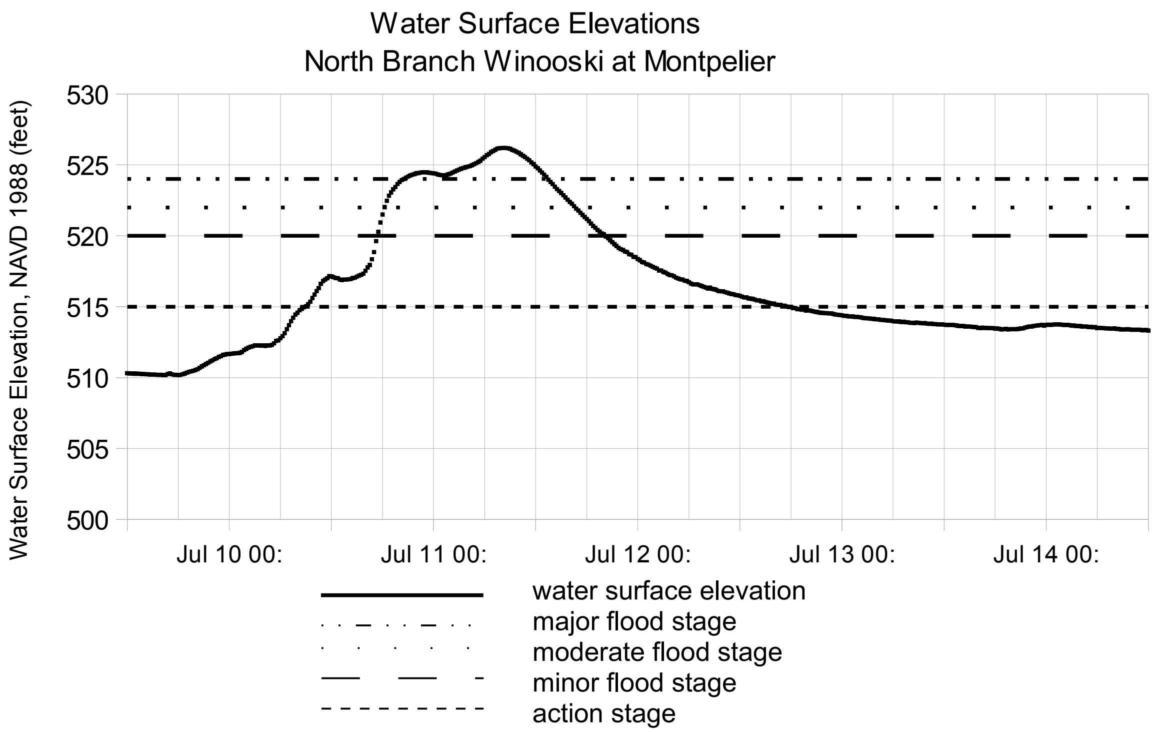
The USDA Soil Conservation Service conducted a Floodwater Management Study after the 1992 ice-jam flood. The report documented the flood elevation, first floor elevation, yard elevation, and several other elevations for each building within the zone of the flood of 1% annual probability.

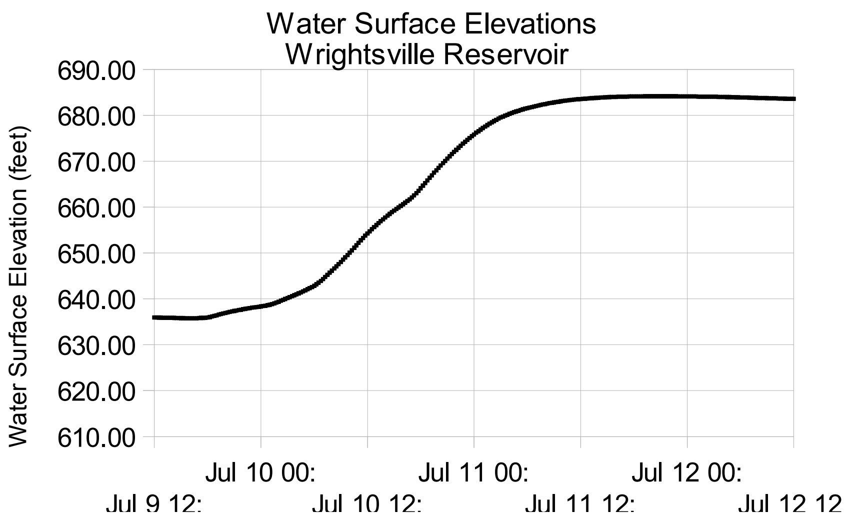
The information in the SCS report suggests that the action level and flood stages at the gage on the North Branch should be lowered. The first floors of many flooded buildings are around 523 feet. If the cellar floors are only 8 feet lower than the first floor, many cellar floors will be at the point of water and sewage backing up into them at or below the action level. In 2023 buildings that were not in inundated areas also had flood damage. Water and sewage backed up into cellars of many of these buildings.

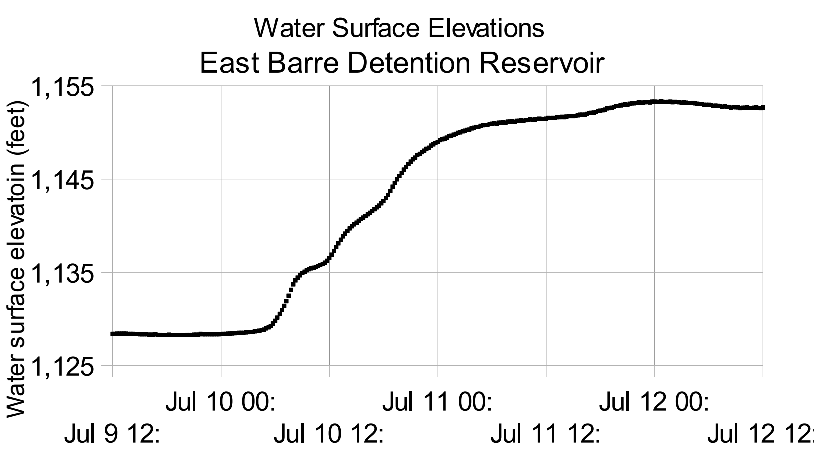
The table shows first floor elevations of the buildings in the inundated area. The peak flood elevation was 526.2 feet in this area. All cellars in these locations are below the peak flood elevation.

Location	First floor elevation
16 to 162 Elm Street	522.9 feet to 529.2 feet
All of Langdon Street	523.0 feet to 524.0 feet
11 to 154 Main Street	522.4 feet to 528.2 feet
2 to 50 State Street	523.0 feet to 526.4 feet

The following figures show water surface elevations at the North Branch in Montpelier, the Wrightsville Reservoir, and the East Barre Reservoir. Time scales have been aligned in the three figures.


Water Surface Elevations
North Branch Winooski at Montpelier
Water Surface Elevation, NAVD 1988 (feet)
530
525
520
515
510
505
500
Jul 10 00:
Jul 11 00:
Jul 12 00:
Jul 13 00:
Jul 14 00:
water surface elevation
major flood stage
moderate flood stage
minor flood stage
action stage


Water Surface Elevations
Wrightsville Reservoir
Water Surface Elevation (feet)
690.00
680.00
670.00
660.00
650.00
640.00
630.00
620.00
610.00
Jul 10 00:
Jul 11 00:
Jul 12 00:
Jul 9 12:
Jul 10 12:
Jul 11 12:

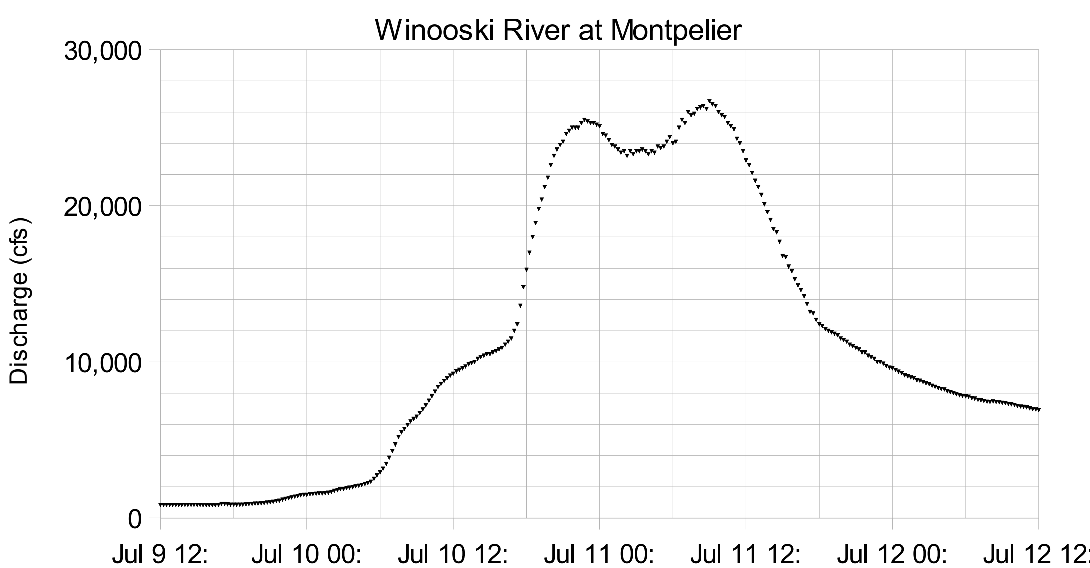

Water Surface Elevations
East Barre Detention Reservoir
Water surface elevatoin (feet)
1,155
1,145
1,135
1,125
Jul 10 00:
Jul 11 00:
Jul 12 00:
Jul 9 12:
Jul 10 12:
Jul 11 12:

The following table shows elevations from the SCS report and durations of submergence at selected downtown locations.

Elevations and Durations of Submergence at Selected Downtown Locations					
Location	Yard elevation (feet)	1st floor elevation (feet)	Time flood reached elevation (EDT)	Time flood dropped below elevation (EDT)	Duration of flood above elevation (hours)
Bent Nails 4 Langdon Street	521.7	 *523.8*	18:00 7/10 *20:00 7/10*	17:00 *7/11* *13:45 7/11*	23:00 *17:45*
City Center 89 Main Street	522.8	 *526.3*	18:45 7/10 ---	15:15 *7/11* ---	20:30 *none*
City Hall 37 Main Street	523.1	 *524.9*#	19:00 7/10 *04:15 7/11*	14:45 *7/11* *12:00 7/11*	19:45 *7:45*
Woodbury Mtn. Toys 24 State Street	523.6	 *524.1*	19:45 7/10 *20:45 7/10*	14:00 *7/11* *13:30 7/11*	18:15 *16:45*
Capital Grounds 27 State Street	524.4	 *525.1*	22:00 7/10 *05:00 7/11*	12:45 *7/11* *11:45 7/11*	14:45 *6:45*
# Elevation is for a low entry (below the first floor)					

Stream discharges

Discharge at the gaging station on the Winooski River was between 800 and 900 cfs until 8 p. m. on the 9th. Discharge then increased in three stages. Slowly until about 5 a. m. on the 10th. Then the runoff from the peak of the third wave of precipitation reached the gage. This faster rate of increase lasted until 5 p. m. on the 10th. Then the runoff from the most intense hour of rainfall (fourth wave) reached Montpelier about 5 p. m. on the 10th. This caused the discharge to rise much faster. Discharge reached a first peak of 25,500 cfs at 10:45 p. m. Discharge dropped to 23,300 cfs as the fourth wave subsided. Discharge rose to a new peak of 26,700 cfs at 9:00 a. m. on the 11th as runoff from the fifth wave arrived. Discharge then dropped to 12,000 cfs about 6 p. m. on the 12th, then decreased more slowly after that.



The peak discharge at the North Branch gage at Wrightsville was 1320 cfs at 17:45 on July 10. This was the time of the peak rainfall intensity as recorded at the E. F. Knapp Airport. The discharge through the outlet of the dam then was about 800 cfs.

Peak discharge from the Wrightsville Reservoir is at the peak water surface elevation in the reservoir. The peak elevation was 684.15 feet on July 11 between 7:45 p. m. and 10:15 p. m. Discharge from the dam during the reservoir's peak W.S.El. was 935 cfs. Discharge at the gage on the North Branch in Wrightsville was 951 cfs during this period. The difference is the amount of runoff from the intervening watershed (2.7 sq. mi. (69.2 - 66.5)) between the dam and the gage. Rainfall had stopped at the airport at 05:00 on the 11th. So runoff between the dam and the gage was decreasing at the time of the peak discharge from the dam.

At the time of Montpelier's peak discharge, the gage at Wrightsville had a discharge of 984 cfs and the reservoir was discharging 927 cfs. The unit discharge between the dam and the gage was 21.2 cfs / sq. mi. Applying that rate to the area between the gage and the mouth of the North Branch (10.8 sq. mi.), yields a discharge of 1200 cfs at the mouth. This adds about 5 inches to the peak flood elevations in Montpelier.

Effects of the East Barre and Wrightsville Dams

Flood detention dams were built at East Barre and Wrightsville during the years 1933 through 1935. The dams were built by the Civilian Conservation Corps in response to the depression and the 1927 flood. This work was done for the U. S. Army Corps of Engineers. This part of the analysis estimates the discharge in the Jail Branch and in the North Branch if the dams had not been built.

The flow at each dam, if the dam had not been built, would be the inflow into the reservoir.

Inflow hydrographs have been created at each dam for this flood. The U. S. G. S. records water surface elevation behind each dam at intervals of 15 minutes. The U. S. Army Corps of Engineers has tables which provide the capacity (volume of water) of the reservoir at one-foot intervals. The Corps also has graphs that show the discharge through the outlet *vs.* reservoir water surface elevation.

The method used to calculate inflow is based on inflow = change in storage + outflow.

Change in storage is determined by taking the difference in volumes at two successive intervals. The 15-minute interval worked well for the Wrightsville Reservoir. It did not work well at East Barre. At East Barre, the calculation using the 15-minute interval provided a spiky estimate of inflow. The inflows at East Barre are based on a one-hour interval instead.

The change in storage is then converted to a discharge. Storage volumes are determined from the Corps of Engineers' elevation-capacity table at 1-foot intervals. The U. S. G. S. provides water surface elevations with a precision of 0.01 foot. The calculations use linear interpolation to determine the capacity at each interval. This approach needs to be used with caution when trying to determine a small number (the change in volume) when subtracting one large number from a slightly larger number (the total volumes at the end and beginning of the period). Slight differences in the accuracy and precision of the two large numbers make large differences in the resultant small number. This is not a negative comment on the accuracy or precision of the U.S.G.S. instruments and data; nor on the precision of the Corps of Engineer's stage-capacity and outlet curves. Rather it is an acknowledgment that this calculation is doing something the equipment and data were not intended for.

Outflow is determined from the Corps of Engineers' outlet rating curve, using the average water surface elevation of each interval. The calculation converts the curve to a table at one-foot intervals and then uses linear interpolation.

Inflow is then determined by adding change in storage to outflow.

In the case of the East Barre Dam, the peak inflow was 6400 cfs. However, the flow through the outlet was 500 cfs at the time of the peak inflow. The effect of the outflows from the dam are already shown on the flows at the gage on the Winooski River at Montpelier. Thus it is the net increase of 5900 cfs that would additionally affect the discharge and height of the gage at Montpelier.

East Barre Dam

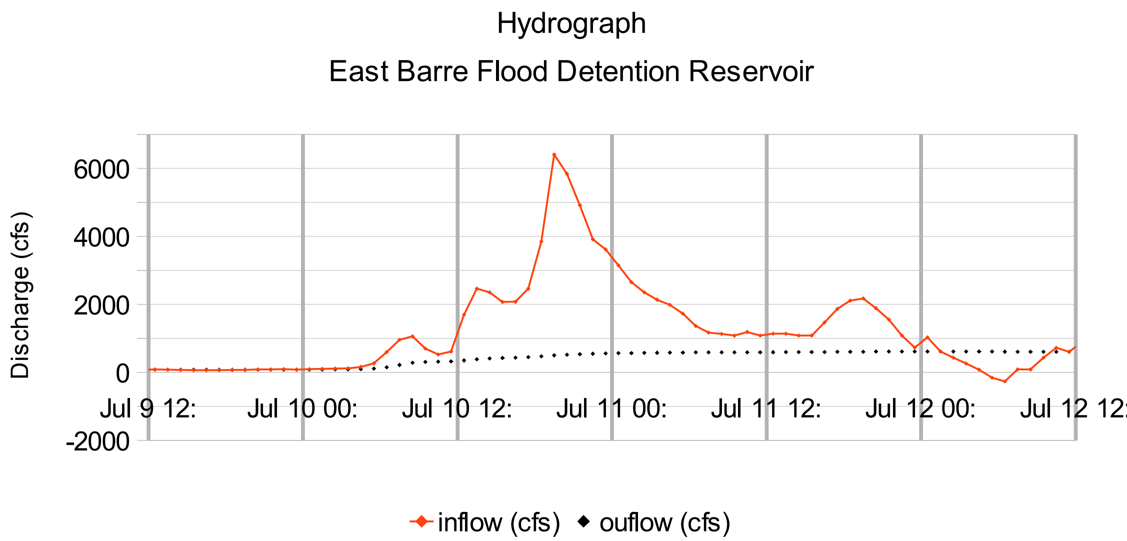
The East Barre dam has an outlet structure and a spillway. The outlet structure is unregulated, a rectangular tunnel through the dam near the base at elevation 1124.9 feet. The spillway is at an elevation of 1165 feet. The top of the dam is at 1185 feet. The dam is 65 feet high. The water surface elevation behind the dam was about 1128 feet before the storm began. The water surface elevation in the reservoir did not reach the spillway crest. The drainage area upstream of the dam is 38.8 sq. mi. This is 10% of the drainage area at the Winooski River gage in Montpelier.

The following table shows conditions at the East Barre Dam and Montpelier at three times. The times are those for: peak inflow at East Barre; peak discharge of the Winooski River at Montpelier; and peak outflow at East Barre.

<u>Conditions at peak inflow to East Barre</u>		
Peak inflow (cfs) and time	6411	1930, July 10
Outflow (cfs)	499	
Additional outflow without the dam (cfs)	5912	
Water Surface Elevation (feet)	1144.97	
Fraction held back by the dam	92 %	
Peak inflow (cfs / sq. mi.)	165	
Flow reduction (cfs / sq. mi.)	152	
Discharge at Montpelier (cfs)	19,100	
<u>Conditions at East Barre 3 hours before the peak at Montpelier</u>		
Peak at Montpelier (cfs) and time	26,700	0900, July 11
Estimated travel time to Montpelier (hours)	3	
Time of East Barre's contribution to the peak at Montpelier		0600, July 11
Inflow (cfs)	1548	
Outflow (cfs)	584	
Net additional flow (cfs)	624	
Water Surface Elevation (feet)	1150.96	
<u>Conditions at peak outflow at East Barre</u>		
Peak water surface elevation (feet) and time	1153.34	2245, July 12
Inflow (cfs)	615	
Outflow (cfs)	615	
Additional outflow without the dam (cfs)	0	
Discharge at Montpelier (cfs)	5,570	

The East Barre Dam held back 92% of the peak inflow to the dam. The peak discharge from the dam occurred 1 1/2 days after the peak discharge on the Winooski River. The peak discharge from the dam was 615 cfs at the time of maximum elevation in the reservoir.

The discharge at Montpelier at the time of the peak inflow to the East Barre Dam was 19,100 cfs. There would be both lag time and dispersion if that additional flow of 5900 cfs had been conveyed to the gage at Montpelier. Also, the gage at Montpelier was still rising then. In order to determine the effect of that 5900 cfs at Montpelier, one would need to do a non-steady-state flood flow analysis. The East Barre Dam is 13 miles from the Montpelier gage. Travel time has been calculated from distances and floodway velocities at each cross section, taken from the 2013 Flood Insurance Study.



Project design flood.

The project design flood at the East Barre Dam is the 1927 flood. The 2023 flood at the East Barre Dam was much smaller than the design flood. The peak 2023 discharge to the dam was about 60% of the design discharge. The total volume stored by the reservoir in 2023 was about 54% of the design volume. Unused capacity is that remaining before the water surface elevation reaches the crest of the spillway.

Comparison of 2023 flood with the project design flood

	design flood	2023 flood
Peak discharge (cfs)	11,500	6,400
Inflow volume (acre-feet)	11,400	8,300
Duration of inflow (hours)	72	52 (0100, July 10 through 0500, July 12)
Maximum pool elevation (feet)	1161.1	1153.24
Maximum outflow (cfs)	710	615
Maximum storage (acre-feet)	9,760	5,300
Unused storage capacity (ac.-ft.)	2,290	6,650

Wrightsville Dam

The Wrightsville Dam has an outlet structure, an overflow spillway, and a turbine discharge. The outlet structure has an intake that maintains a minimum water surface elevation in the reservoir. The elevation at the spillway is 685 feet. The top of the dam is at 715 feet. The dam is 115 feet high. The turbine for hydroelectricity was added in 1985. The outlet structure is set to maintain a minimum pool elevation at 635 feet for production of electricity. The water surface elevation in the reservoir was about 636 feet before the storm began. The water surface elevation in the reservoir did not reach the spillway crest. The drainage upstream of the a dam is 66.5 sq. mi. This is 17% of the drainage area at the Winooski River gage in Montpelier.

The following table shows conditions at the Wrightsville Dam and Montpelier at three times. The times are those for: peak inflow at Wrightsville; peak discharge of the Winooski River at Montpelier, and peak outflow at Wrightsville.

Conditions at peak inflow to Wrightsville

Peak inflow (cfs) and time	11,700	2100, July 10
Outflow (cfs)	840	
Additional outflow without the dam (cfs)	10,900	
Water Surface Elevation (feet)	670.57	
Fraction held back by the dam	93 %	

Peak inflow (cfs / sq. mi.)	176	
Flow reduction (cfs / sq. mi.)	163	
Discharge at Montpelier (cfs)	24,100	

<u>Conditions at Wrightsville 1 3/4 hour before the peak at Montpelier</u>

Peak at Montpelier (cfs) and time	26,700	0900, July 11
Estimated travel time to Montpelier (hours)	1 3/4	
Time of Wrightsville's contribution to the peak at Montpelier		0715, July 11
Inflow (cfs)	3,585	
Outflow (cfs)	923	
Net additional flow (cfs)	2,662	
Water Surface Elevation (feet)	682.45	

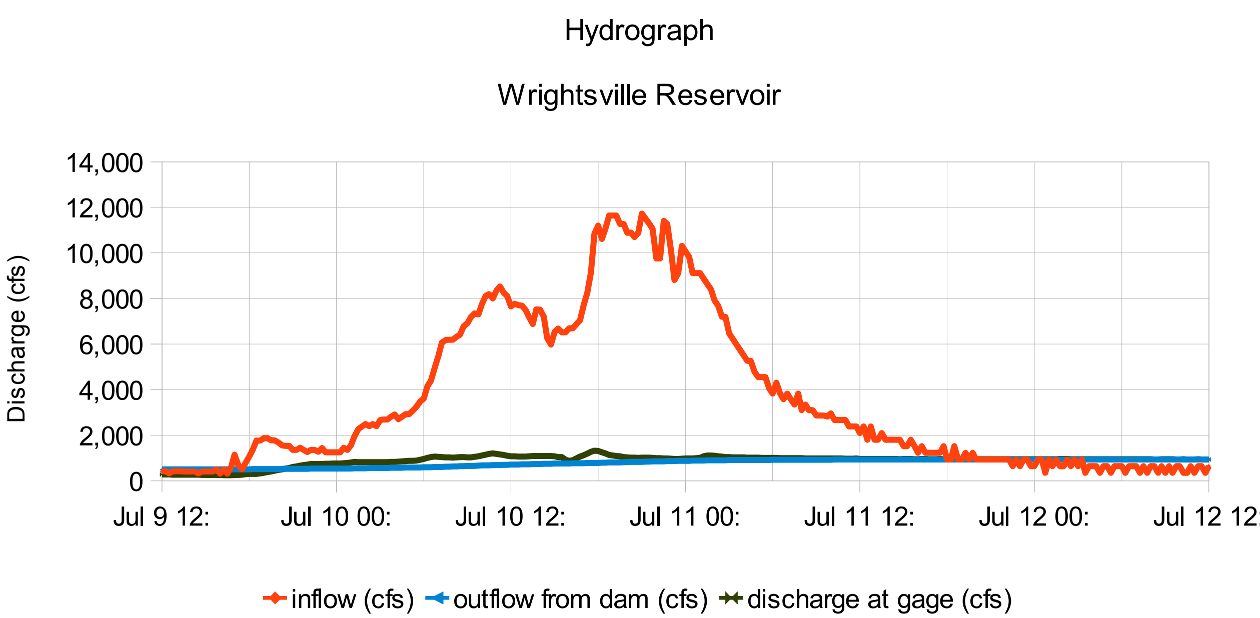
<u>Conditions at peak outflow at Wrightsville</u>

Peak water surface elevation (feet)	684.15	1945 to 2215 July 11
Inflow (cfs)	935	
Outflow (cfs)	935	
Additional outflow without the dam (cfs)	0	
Discharge at Montpelier (cfs)	11,500 to 10,000, declining	

The peak water surface elevation in the Wrightsville Reservoir was 684.15 feet from 1945 to 2215 p. m. on July 11. The level had been above 684 feet beginning at 1545 on July 11 and continuing through 0400 on July 12.

The Wrightsville Dam held back 93% of the peak inflow to the dam. The peak outflow from the dam occurred half a day after the peak discharge on the Winooski River. The peak discharge from the dam was 935 cfs at the time of maximum elevation in the reservoir.

The discharge at Montpelier at the time of the peak inflow to the Wrightsville Reservoir was 24,100 cfs. There will be both lag time and dispersion if that flow of 10,900 cfs had been conveyed to the gage at Montpelier. Also, the gage at Montpelier was still rising then. In order to determine the effect of that 10,900 cfs at Montpelier, one would need to do a non-steady-state flood flow analysis. The Wrightsville Dam is 5 miles from the Montpelier gage. Travel time has been calculated from distances and floodway velocities at each cross section, taken from the 2013 Flood Insurance Study.



Project design flood.
The project design flood at the Wrightsville Dam has a peak almost equal to that of the 1927 flood. It has a much shorter duration of inflow than the 1927 flood. The peak 2023 inflow to the reservoir was about 2/3 of the design inflow. The total volume was 6% greater than the volume of the design flood.

The maximum pool elevation of the design flood was 680.3 feet. This gave the project design flood a freeboard of 4.7 feet. The reservoir's unused capacity was 2550 ac.-ft.

The reservoir has lost 2530 ac-ft. of flood storage capacity in the years after it was built. In June 1965, the pool elevation was raised to 620 feet, to increase the recreation value of the reservoir. This reduced the capacity of the reservoir for flood storage by 520 ac.-ft. In September 1985 the pool elevation was raised to 635 feet to raise the head for generation of electricity. This reduced the capacity of the reservoir for flood storage an additional 2010 ac.-ft. Following these two modifications, the capacity of the reservoir for flood storage without flowing over the spillway became 17,770 ac.-ft.

The inflow volume of the 2023 flood was about 20,400 ac-ft. Even though the 2023 flood had a smaller peak discharge than the design flood, its duration was longer. The estimated flood volume in 2023 was 2100 ac-ft. greater than the volume of the project design flood.

The 2023 flood crested at 684.15 ft., 0.85 feet below the crest of the spillway. Even though the 2023 flood had more inflow volume than the reservoir could hold, there was no discharge over the spillway. This is mostly due to the longer duration of the 2023 flood. The longer duration of the 2023 flood allowed more water to be discharged through the outlet of the dam between the start of inflow until the time of maximum pool elevation.

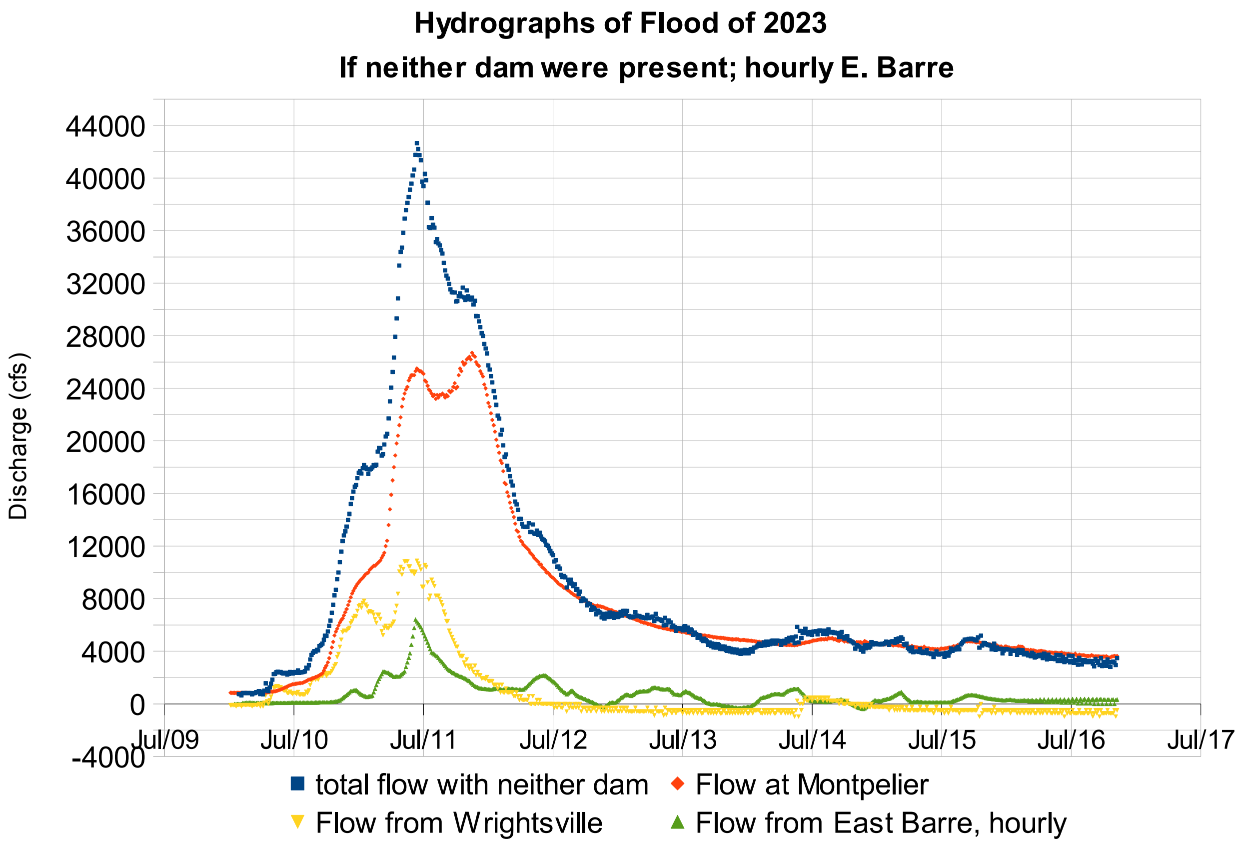
Comparison of 2023 flood with the project design flood

	design flood	2023 flood
Peak inflow (cfs)	17,600	11,700
Inflow volume (acre-feet)	19,300	20,400
Duration of inflow (hours)	26.5	52 (1700 July 9 through 2100 July 11)
Maximum pool elevation (feet)	680.3	684.15
Maximum outflow (cfs)	910	935
Maximum storage (acre-feet)	17,750	17,460 (636 ft. at start of flood to 684.15 ft.
Unused storage capacity (ac.-ft.)	2,550	510

Combined effects of the two dams at Montpelier
The two flood control dams did what they were designed to do. They reduced and delayed the peak flow at Montpelier. They also reduced the peak water surface elevation in Montpelier. Without the dams, the peak flow at Montpelier would have been around 42,200 cfs around 2245 on July 10. The actual peak was around 26,700 cfs at 0900 the next morning. The estimated peak of 42,200 cfs is composed of 25,500 cfs at Montpelier (recorded flow) plus an estimated additional flow from Wrightsville of 10,900 cfs and from East Barre of 5800 cfs.

Location	actual peak flow (cfs)	time of actual peak flow	estimated peak flow w/o dams (cfs)	time of estimated peak flow	Reduction (%)	drainage area (sq. mi.)	flow reduction per sq. mi. (cfs)
East Barre	615	2245, July 12	6411	1930, July 10	92	38.8	152
Wrightsville	935	1730, July 11	11,723	2100, July 10	92	66.5	163
Montpelier	26,700	0900, July 11	42,200	2245, July 10	37	397	---
The estimated travel time from the East Barre Dam to the Winooski gage is three hours. The estimated travel time from the Wrightsville Dam to the Winooski gage is one and 3/4 hours.							

The graph shows what the flows at Montpelier might have been if the two dams did not exist. Flows have been adjusted for the estimated travel time from the dam to the gage at Montpelier. No adjustment has been made for diminution of the peak as it traveled downstream.



Flood Reduction Using Additional Flood Control Dams

This section gives a rough estimate of what might be required to protect Montpelier with more flood control dams. It might take two dams in the size range of the East Barre and Wrightsville Dams. A detailed analysis would need to be made to determine the effects on floods in Montpelier caused by a particular dam at a particular location

There are now three dams that reduce flooding in Montpelier. The dams at Wrightsville and East Barre were built during 1933 through 1935 in response to the depression and the flood 1927. The Marshfield Dam, with its Molly's Falls reservoir, was completed in 1926 as part of a hydroelectric development. It was not built for flood protection although it does reduce peak flows during floods. This dam was in place during the 1927 flood.

These three dams delay runoff from 33% of the watershed upstream of Montpelier. These delays reduce peak flood flows and elevations in Montpelier, as described in the previous section.

The reservoirs at East Barre and Wrightsville each have a surface area about 1 1/2 sq. mi. when filled to the top of the dam.

The U. S. G. S. considers flooding to begin when the water surface elevation at the Langdon Street gage reaches 520 feet. That is six feet lower than the elevation (526.2 feet) of the July 2023 flood there. Water levels at

Langdon Street and in downtown Montpelier are due to backwater from the Winooski River. For comparison, the deck of the Langdon Street Bridge is at an elevation about 522 ½ feet.

The water surface elevations at Langdon Street during floods are set by backwater from the Winooski River..

Difference in Water Surface Elevations Between the Winooski Gage and the Mouth of the North Branch

Annual probability 2013 FIS (%)	flow (cfs)	W.S.El. at Winooski gage per flood profile (feet)	W.S.El. at North Branch per flood profile (feet)	Difference
0.2	26,500	523.8	527.4	3.6
1	20,000	522.3	525.7	3.4
2	18,700	520.2	524.7	4.5
10	13,500	517.2	521.2	4.0

The table shows that a flow as low as 10% annual probability will be 1.2 feet above the flood stage at the Langdon Street gage. The probability of exceeding flood stage could be as much as 20%.

In order to reduce the water surface elevation at Langdon Street to 520 feet, the elevation at the Winooski River gage would need to be 516.0 feet. The flow at this elevation would be 12,100 cfs. This would be a reduction of 14,600 cfs from the 2023 flood.

Combined effects of the two dams at Montpelier show that the Wrightsville and East Barre Dams reduced peak flows at the dam sites by 152 and 163 cfs / sq. mi. respectively. The two dams reduced peak flows a combined 17,400 cfs at the dam sites. That resulted in a reduction of 15,700 cfs at the gage on the Winooski River. That indicates that 90% of the reduction at the dams shows up at Montpelier.

Working backwards. A reduction of 14,600 cfs at Montpelier could require a reduction of 16,200 cfs at the dam site(s). At a reduction of 160 cfs / sq. mi. at the dam sites, the watersheds above the dams would need to have a total area of 101 sq. mi. For comparison, the combined drainage areas at Wrightsville and East Barre are 105.3 sq. mi. If such new dams were built, that would mean almost 60% of the watershed upstream of Montpelier would have its runoff controlled by a dam.

This table shows drainage areas upstream of Montpelier. These are shown to compare watershed areas with the needed 101 sq. mi. estimated above.

<u>Drainage areas at selected locations upstream of Montpelier</u>

Gunners Brook at confluence with Stevens Branch	8.1 sq. mi.	
Jail Branch at Barre City / Town line	47.7 sq. mi.	(less 38.8 sq. mi.)
North Branch at confluence with Winooski River	80.0 sq. mi.	(less 66.5 sq. mi.)
Stevens Branch at confluence with Winooski River	115.2 sq. mi.	(less 38.8 sq. mi.)
at d/s Barre City / Town line	96.9 sq. mi.	(less 38.8 sq. mi.)
above Gunners Brook	86.3 sq. mi.	(less 38.8 sq. mi.)
above Jail Branch	34.8 sq. mi.	
at u/s Barre City / Town line	34.6 sq. mi.	
Winooski River above Dog River	395.5 sq. mi.	(USGS gage u/s is 397)
above Stevens Branch	114.0 sq. mi.	
above Great Brook No. 2 (Plainfield)	97.0 sq. mi.	
above Naismith Brook	76.0 sq. mi.	

Source: Flood Insurance Study, Washington County, Volume 1, Table 4, effective March 19, 2013

Comparison with the Flood of 1927

The 1927 flood was the largest flood to inundate Montpelier since at least 1830. The 2023 flood was the deepest flood to inundate Montpelier subsequent to the 1927 flood. There was at least one flood before 1927 that was deeper than the 2023 flood. This section compares the 2023 flood with the 1927 flood.

The comparison of 2023 to 1927 needs to consider that 33% of the watershed is now regulated, when in 1927 it was only 6%. The comparison for areas below the flood control dams will be much less than for areas not directly downstream of any flood control dam. Precipitation and peak discharge are the two measures used to compare 2023 to 1927. Total runoff, sometimes given as inches of runoff is another measure that can be used to compare floods. Total runoff of the 1927 flood was not found, so this comparison could not be made.

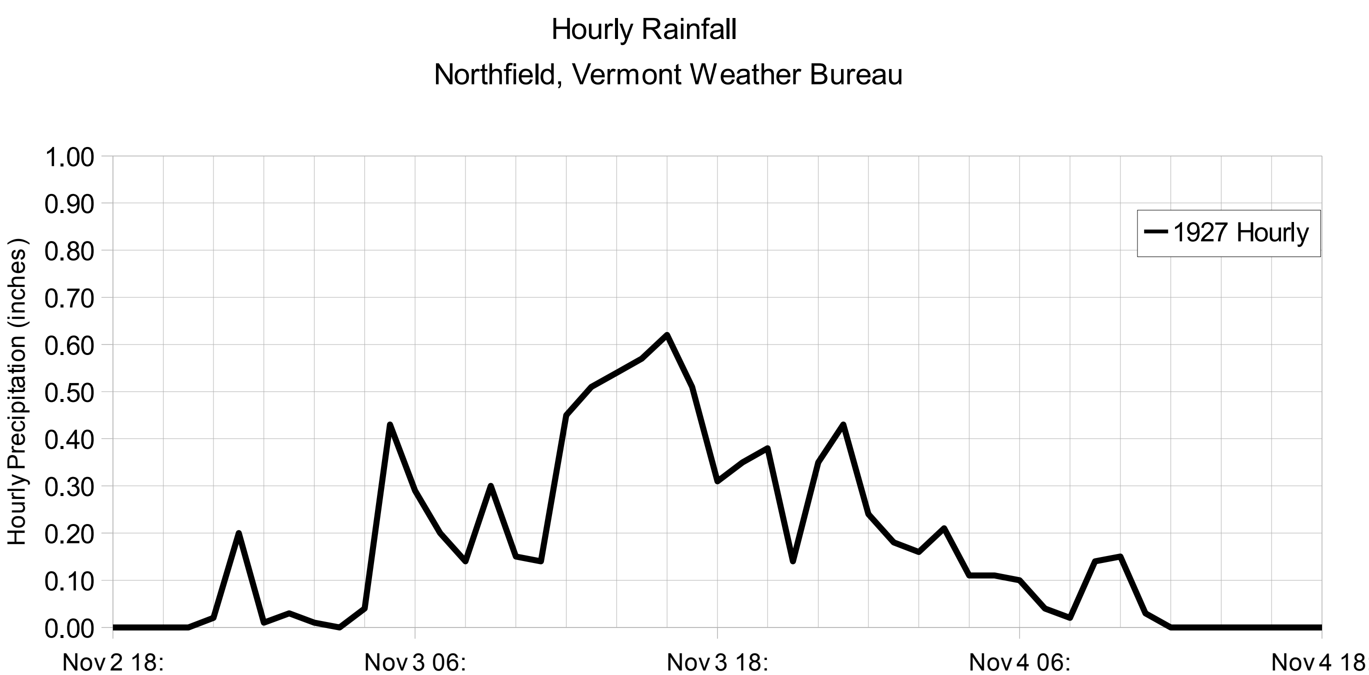
<u>Precipitation</u>

Total precipitation during the 1927 flood is provided in a publication of the U. S. Geological Survey. This isohyetal map shows that rainfall in the watershed upstream of Montpelier was predominantly between 8" and 8 1/2 ".

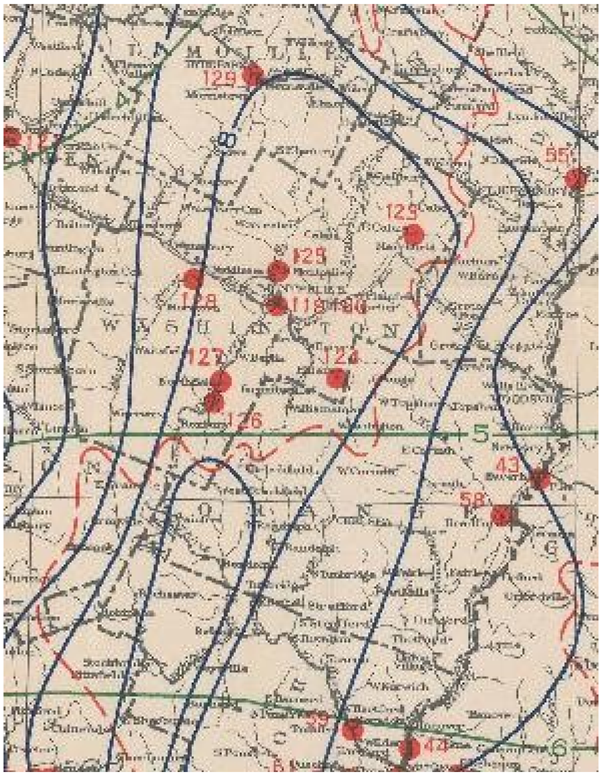
Hourly rainfall data are available at the Northfield Weather Station for the 1927 flood. Total rainfall was 8.61". The length of the storm was 38 hours at Northfield. The peak hourly rainfall was 0.62". The rain came in three waves. The longest wave lasted about 28 hours and it had 6 peaks within that period.

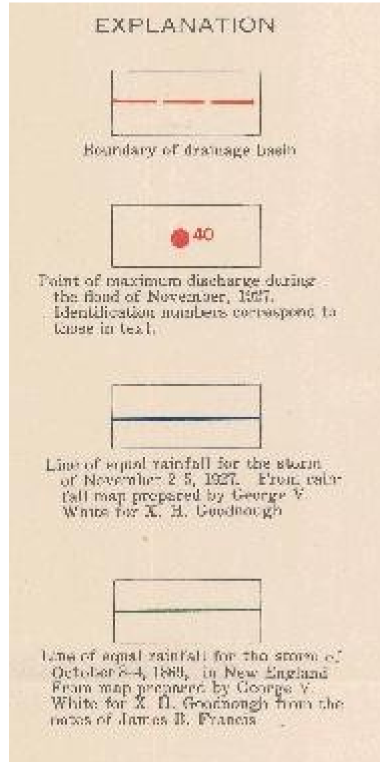
The duration of rainfall at the two gauged locations was the same in both years: 37 and 38 hours.

Rainfall in 1927 was 8" to 8 1/2" over the entire watershed of the Winooski River upstream of Montpelier. Rainfall in 2023 was 3" to 8" over the same area. This means that rainfall in 2023 was 35% to 95% of the rainfall in 1927. The bulk of the watershed, including the North Branch, in 2023 had rainfall of 6" to 8", about 85% of 1927's rainfall.



Source of hourly precipitation: "The Flood, November 3 and 4, 1927, Montpelier Vermont", Joseph G. Abair, Capital City Press, 1928





Source: The New England Flood of November 1927, H. B. Kinnison, Water Supply Paper 636-C, U. S. Geological Survey, 1930, plate 2

Stream discharges

The effect of regulation on streamflow is limited to the streams to which the flood control dams discharge. These are:

- Molly's Falls Stream from the Marshfield dam to the Winooski River
- Jail Branch from the East Barre Dam to its confluence with the Stevens Branch
- Stevens Branch from its confluence with the Jail Branch to its confluence with the Winooski River
- North Branch from the Wrightsville Dam to its confluence with the Winooski River
- Winooski River from Molly's Falls Stream to the Middlesex town line.

None of the watersheds above the three dams is regulated. Each dam regulates the discharge to the stream below it. None of the tributaries to the streams listed above are regulated. The available data limit the comparison to the 1927 flood to the locations with gaging stations.

The peak recorded discharge on the Winooski River at Montpelier occurred on November 3, 1927 at midnight. The maximum discharge was 57,000 cfs. That flow is the largest recorded since at least the flood of 1830.

The peak discharge from the Molly's Falls Reservoir was 581 cfs at 7 a. m. on November 5, 31 hours after the peak in Montpelier, according to the U. S. G. S. They also reported that without the dam, the peak discharge would have been about 6,000 cfs. "The big downpour started with the water at a low level in the storage basin of the Molly's Falls hydro-electric development at Cabot—a circumstance that proved exceedingly fortunate. The huge reservoir absorbed the inflow from the headwaters of the Winooski River and none left the spillway until danger below was passed." (Johnson, p. 5).

Discharges in the North Branch at Wrightsville and in the Jail Branch in East Barre were determined by the U. S. Geological Survey at the time of the 1927 flood. They are shown in the table below: 17,300 cfs and 11,500 cfs respectively. Peak inflows at Wrightsville and East Barre were 257 and 303 cfs / sq. mi., respectively

The inflows to those two reservoirs in the 2023 flood were calculated to be 11,700 and 6400 cfs, respectively.

Discharge at Montpelier in 2023 would have been much higher, except for the dams at Wrightsville and East Barre. If the dams had not been built, the discharge at Montpelier is estimated to be 42,200 cfs, as determined above.

Water Surface Elevations

The 1927 peak water surface elevation, as shown on the North Branch gage at the Langdon Street bridge was about 533.9 feet. This is 7.7 feet higher than the recorded peak flood elevation (526.2 feet) during the 2023 flood. High water marks of the 1927 flood were recorded around Montpelier. Markers and bronze tablets show the 1927 flood elevation on the wall beside the entrance to the Union Mutual Building (Main Street at State Street) and inside above the elevated first floors of City Hall and the Kellogg-Hubbard Library.

A discharge of 42,200 cfs would result in a water surface elevation about 530.3 feet at the Langdon Street gage. This is about 4.1 feet higher than the recorded 2023 flood; and about 3.6 feet lower than the 1927 flood.

The following data compare the 1927 flood with the 2023 flood with and without the dams at Wrightsville and East Barre. The comparison depends on the parameter and the location within the watershed upstream of Montpelier. The 2023 flood was 56% to 85% as severe as the 1927 flood, depending on which parameter is evaluated.

Comparison of the 2023 Flood to the 1927 flood.

Parameter	1927 Flood	2023 Flood (no dams)	Ratio of 2023 no dams: to 1927	2023 Flood (Actual)	Ratio of 2023 actual to 1927
Precipitation:					
Watershed u/s of Montpelier	8" to 8 1/2"	ca. 6.6"	ca. 0.80	ca. 6.6"	ca 0.80
Nfld. (1927) & Mont. (2023)	8.61 "	6.82"	0.79	6.82"	0.79
Winooski R. at Montpelier	8" to 8 1/2"	3" to 8"	0.36 to 1.00	3" to 8"	0.36 to 1.00
Wrightsville Dam	8" to 8 1/2"	6" to 8"	0.73 to 1.00	6" to 8"	0.73 to 1.00
East Barre Dam	8" to 8 1/2"	3" to 7"	0.36 to 0.85	3" to 7"	0.36 to 0.85
Bulk of the watershed	8" to 8 1/2"	6" to 8"	0.73 to 1.00	6" to 8"	0.73 to 1.00
Duration of Rainfall (hours)	37	37	1.00	37	1.00
Water Surface Elevation: (feet)					
Langdon Street Bridge	533.9	530.3	3.6 feet lower	526.2	7.7 feet lower
Peak Discharge (cfs)					
Winooski R. at Montpelier	57,000	42,200	0.74	26,700	0.47
Wrightsville Dam	17,300	11,700	0.68	900	0.05
East Barre Dam	11,500	6,400	0.56	600	0.05
Watershed Area					
Winooski R. at Montpelier	397	397		397	
Wrightsville Dam	67	66.5		66.5	
East Barre Dam	38	38.8		38.8	
Unit Peak Discharge (cfs / sq. mi.)					
Winooski R. at Montpelier	144	108	0.75	67	0.47
Wrightsville Dam	257	176	0.68	14	0.05
East Barre Dam	303	165	0.54	15	0.05

The Bailey Dam

The dam in the Winooski River just downstream of the Main Street bridge in Montpelier was built at the same time as part of the same project that built the dams at Wrightsville and East Barre. The dam was built for local flood protection. The dam was completed in October 1934. The dam was built with tainter gates to control river levels upstream of the dam. In 1975 the dam was modified by removing the tainter gates and by raising the sill three feet. This dam has several names. It was originally called the Montpelier Dam. The flood profiles in the Flood Insurance Studies label it as the Clothespin Dam. The Corps of Engineers now uses Bailey Dam.

It is ironic that a study is being conducted to evaluate the effects of removing the dam entirely. The dam was built for flood control. The dam was modified 41 years later for flood control. And now, 48 years after that, the dam is being studied for removal for flood control. The present study will also evaluate effects on water quality and habitat.

Conclusions

The 2023 flood was 56% to 85% as severe as the 1927 flood, depending on which parameter is evaluated. In the uncontrolled watersheds upstream of Montpelier, the 2023 flood was about 74% as severe as the 1927 flood. In some places likely as severe as the flood of 1927.

The 1981 Flood Insurance Study more closely matches the observations of the 2023 flood than does the 2013 Flood Insurance Study.

Flooding of some cellars in Montpelier begins before the water level in the North Branch reaches the action stage. The action level might be adjusted to give earlier notice to those with low-lying cellars. The hydrology shows that the annual probability of water reaching the minor flooding stage at the North Branch gage in Montpelier is greater than 10%. The store owners don't need a study to tell them this; they know by their direct experience.

To prevent flooding in Montpelier, discharges in the Winooski River need to be less than half the discharge observed during the 2023 flood. If that reduction were done with dams designed for the 2023 flood, it would require new flood control dams equal to the dams at Wrightsville and East Barre combined. The design flood should be larger than the 2023 flood and at least as large as the 1927 flood. As shown in this study, portions of the watershed upstream of Montpelier experienced rainfall equal or almost equal to that of the 1927 flood.

The dams at East Barre and Wrightsville performed as well as or better than designed. The 2023 storm lasted longer and produced more runoff than the project design flood for the Wrightsville Dam.

Less than 10% of the 2023 peak discharge at Montpelier came from the three dams that regulate flow from 33% of the watershed upstream of Montpelier.

This review did not re-evaluate the discharge-frequency curve. It does show that the no-longer-valid 1981 Flood Insurance Study for Montpelier fits the 2023 observations better than does the 2013 study.

Sources

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- Surface water: Peak streamflow
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- Water surface elevations at 15-minute intervals
- Water -Year Summary
- Water Data Reports

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Thomas Weiss worked on the hydrology and stream flow hydraulics of some of the first Flood Insurance Studies and Flood Plain Information Reports in Vermont from 1976 through 1982. Within this watershed, the studies he worked on were for the Towns of Williamstown, Barre, and East Montpelier. He was also project engineer on the report for the Montpelier Hydroelectric Company on the effects of raising the pool behind the Wrightsville Dam for the proposed hydroelectric generating station.