Addendum to
"An Evaluation of Index Flows in Twin Creek and Chippewa Creek, Tributaries of the Muskegon River, Osceola County, Michigan" dated February 2015

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Section 1
Introduction

The report "An Evaluation of Index Flows in Twin Creek and Chippewa Creek, Tributaries of the Muskegon River, Osceola County, Michigan" dated February 2015 (Evaluation Report) recommended that the index flows of Twin Creek and Chippewa Creek used in Michigan's Water Withdrawal Assessment Tool (WWAT) be modified on the basis of summer stream flow data collected by Nestlé Waters North America Inc. (NWNA) between 2002 and 2014. The Evaluation Report, based on stream flow monitoring data, recommended an index flow of 2,948 gpm for the Twin Creek Water Management Area and recommended an index flow of 2,370 gpm for the Chippewa Creek Water Management Area. The recommended index flow for Twin Creek, based on monitoring data, is significantly smaller than the index flow in the WWAT of 8,014 gpm and the recommended index flow for Chippewa Creek is significantly larger than the index flow in the WWAT of 887 gpm. Figure 1, which is taken from the Evaluation Report, shows the location of the Twin Creek Water Management Area and the Chippewa Creek Water Management Area and the gaging locations used for purposes of calculating the index flows.

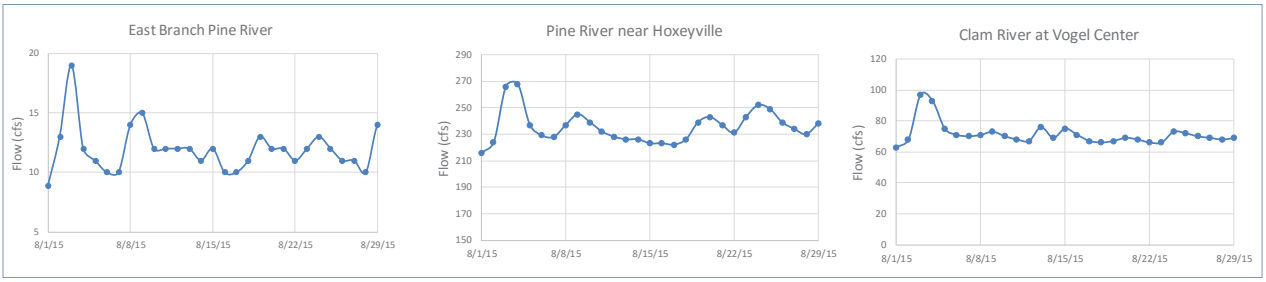
NWNA conducted additional stream flow monitoring in August 2015 to check the reasonableness of the recommended index flows in the Evaluation Report. The flow of Twin Creek was measured at SF-13 and the flow of Chippewa Creek was measured at SF-17 and SF-19 on August 4th, 11th, 18th and 26th, 2015. The stream flows were measured by personnel from Advanced Ecological Management of Reed City, MI using the U.S. Geological Survey (USGS) stream gaging protocols. The details of the flow measurement procedures are described in the accompanying report prepared by Advanced Ecological Management (2015).

This addendum to the Evaluation Report describes regional climatic and stream flow conditions in August 2015, summarizes the additional monitoring data collected in August 2015, describes the significance of the new monitoring data for purposes of evaluating index flows, and provides our conclusions as to the best estimate for index flows of Twin Creek and Chippewa Creek.

Section 2
Climatic and Stream Flow Conditions in August 2015

August 2015 was a relatively dry month in west-central Michigan. The total precipitation recorded at the NOAA gage at Big Rapids was 2.30 inches which is 1.74 inches less that the normal August precipitation of 4.04 inches[1]. July was also a relatively dry month in west-central Michigan with total precipitation of 2.45 inches recorded at Big Rapids; normal precipitation in July is 3.35 inches. The Big Rapids precipitation gage is located about 20 miles to the southwest of the Twin Creek and Chippewa Creek watersheds.

The USGS maintains streamflow gaging stations on three small streams in the vicinity of the Twin Creek and Chippewa Creek watersheds as shown on Figure 2. These gaging stations include: East Branch of the Pine River near Tustin located about 19 miles northwest of Evart (station 04124500), the Pine River near Hoxeyville located about 32 miles northwest of Evart, and the Clam River at Vogel Center located about 18 miles to north-northeast of Evart. The flows measured at these gaging locations in August 2015 are shown below.



The daily stream flows at all three gaging locations showed no significant trend during the month of August. The median monthly flows at the three gaging locations were: 12 cfs at the East Branch gage, 237 cfs at the Pine River gage and 69 cfs at the Clam River gage. The median flows on the four days that measurements were collected on Twin Creek and Chippewa Creek, the 4th, 11th, 18th and 26th of August, were 11.5 cfs, 236 cfs, and 69 cfs, respectively. These values are nearly identical to the median monthly flow based on daily flow data. This indicates that flow measurements on only these four days in August provides an accurate estimate of the median monthly flow based on daily stream flow data.

The August 2015 flow data from the three USGS gaging locations were used to assess how an index flow calculated using only the August 2015 data compared to the index flow calculated using long-term data from August. The table below lists the median August flows for the three USGS gaging locations based on 1) data from August 2015, 2) data from August 2002 through August 2015, and data from variable periods of records as calculated by Hamilton and others (2008). The median flow in the period 2002 through 2015 was evaluated as that is the period for which there are summer stream flow data from the NWNA monitoring for Twin Creek and Chippewa Creek.

[1] Normal precipitation based on daily data collected at Big Rapids between 1981 and 2010.

USGS Gaging Location	August 2015 Median Flow	Median Flow in August 2002-2015	August Median Flow from Hamilton and other (2008)[2]
East Branch of Pine River near Tustin	12 cfs	12 cfs	9.9 cfs
Pine River near Hoxeyville	237 cfs	226 cfs	230 cfs
Clam River at Vogel Center	69 cfs	79 cfs	73 cfs

The median August flows in 2015 at the three USGS gaging locations were fairly similar to the August median flows based on the last 14 years of data (2002 to 2015). The East Branch of the Pine River is the smallest of the three streams with USGS gaging data and it is the stream located closest to the Twin Creek and Chippewa Creek watersheds (Figure 2). As a result, the gaging data from the East Branch provide the best analog for stream flows in Twin Creek and Chippewa Creek. At this station, the median flow in August 2015 was identical to the median August flow during the period 2002 through 2015. This indicates that the August 2015 stream flow data from Twin Creek and Chippewa Creek provide a reliable estimate of the long-term median August flow in these streams.

[2] Data from water years used to calculate August median flows are: East Branch of Pine River – 1952 to 1963 and 1992 to 2005, Pine River – 1952 to 1982, and Clam River – 1966 to 2005 (Hamilton and others, 2008).

Section 3
Stream Flow Monitoring Data – August 2015

The measured flows of Twin Creek at SF-13 and Chippewa Creek at SF-17 and SF-19 in August 2015 were the following:

	Twin Creek	Chippewa Creek		
	SF-13	SF-17	SF-19	SF-17 and SF-19
August 4	3,770	1,735	169	1,904
August 11	3,274	1,904	206	2,110
August 18	4,349	2,000	204	2,204
August 26	3,244	1,892	215	2,107
Median	3,522	1,898	205	2,109

Gaging location SF-13 is located just upstream of where Twin Creek flows into the Muskegon River in downtown Evart. Thus, the flow at this gaging location represents the total flow in the Twin Creek watershed.

The gaging locations on Chippewa Creek, SF-17 and SF-19, are located some distance upstream of where the creek flows in the Muskegon River as described in the Evaluation Report. As discussed in the Evaluation Report, an estimate of the flow of Chippewa Creek at the Muskegon River is calculated by dividing the combined flows measured at SF-17 and SF-19 by 0.8059 to adjust the flow for the ungaged portion of the watershed. Thus, the estimate of the median August flow in 2015 in Chippewa Creek where it flows into the Muskegon River is 2,616 gpm (2109/0.8059).

Section 4
Evaluation of Index Flows

The Evaluation Report contained the following summary of median monthly flows in Twin Creek and Chippewa Creek based on measured summer stream flows between 2002 and 2014.

	Twin Creek at River (SF-13)			Chippewa Creek (SF17+SF19)			Chippewa Creek at River Median Flow (gpm)[3]
	Median Flow (gpm)	Years of Data	Count	Median Flow (gpm)	Years of Data	Count	
July	3,644	9	9	2,281	7	8	2,858
August	3,096	8	8	2,092	8	8	2,595
September	2,948	12	13	1,910	9	9	2,370
Index Flow	2,948			1,910			2,370

In both Twin Creek and in Chippewa Creek, the month with the lowest median flows was September unlike the three nearby USGS gaging locations described above where August is the summer month with the lowest median flows. As a result, the median September flows in Twin Creek and Chippewa Creek were recommended for use as the index flows for the corresponding Water Management Areas in the Evaluation Report. Note that in Twin Creek the median September flow is approximately five percent less than the median August flow and in Chippewa Creek the median September flow is approximately nine percent less than the median August flow.

The calculated median August 2015 flow of Chippewa Creek at the Muskegon River was 2,616 gpm as described in the previous section. This median flow is almost identical to the median August flow of 2,595 gpm calculated from the stream flow measurements collected between 2002 and 2014. Therefore, it is concluded that the historical data provide a reliable data set for estimating the index flow of the Chippewa Creek Water Management Area. The best estimate of the index flow is 2,370 gpm based on all of the available stream flow data.

The median August 2015 flow of Twin Creek at the Muskegon River was 3,522 gpm as described in the previous section. This flow is approximately 12 percent greater than the median August flow of 3,096 gpm estimated based on historical data. The median flow of Twin Creek in August 2015 was about 426 gpm greater than the median August flow in the historical period most likely because of significantly less pumping from the City of Evart well field located adjacent to the creek in 2015[3]. The total pumping from the well field in August 2015 was about 350 gpm less than the average August pumping rate between 2006 and 2014. The pumping was less in 2015, than in previous years, because of reduced industrial water demand. As such, we recommend at this time that the historical data be used as the basis for establishing the index flow of Twin Creek. The best estimate of the index flow is 2,948 gpm based on all the available data.

[3] The average pumping rate from the City of Evart Twin Creek Well Field in August 2015 was about 605 gpm. The average rate in August from 2006 through 2014 was approximately 955 gpm, approximately 350 gpm more than in August 2015. Pumping data prior to 2006 were not available.

Section 5
Summary

We conclude that the best estimates of the index flows of Twin Creek and Chippewa Creek are as discussed above in this addendum. The best estimate of the index flow for the Twin Creek Water Management Area is 2,948 gpm and the best estimate of the index flow for the Chippewa Creek Water Management Area is 2,370 gpm.

Section 6
References

Hamilton, D., R. Sorrel, and D. Holtschlag, 2008. A Regression Model for Computing Index Flows Describing the Median flow for the Summer Month of Lowest Flow in Michigan. USGS Scientific Investigations Report 2008-5096.

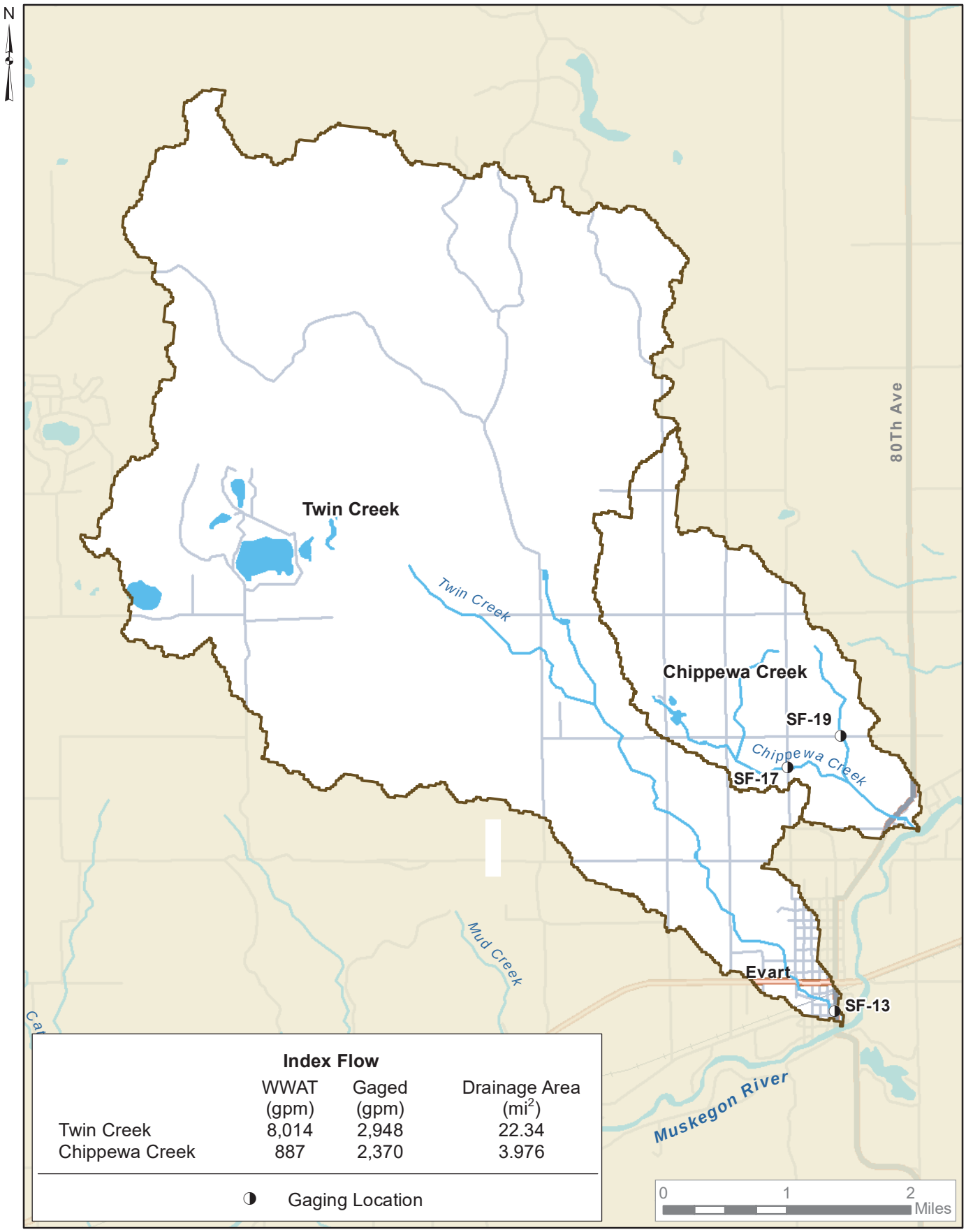


Figure 1 Twin Creek Water Mangement Area and Chippewa Creek Water Management Area

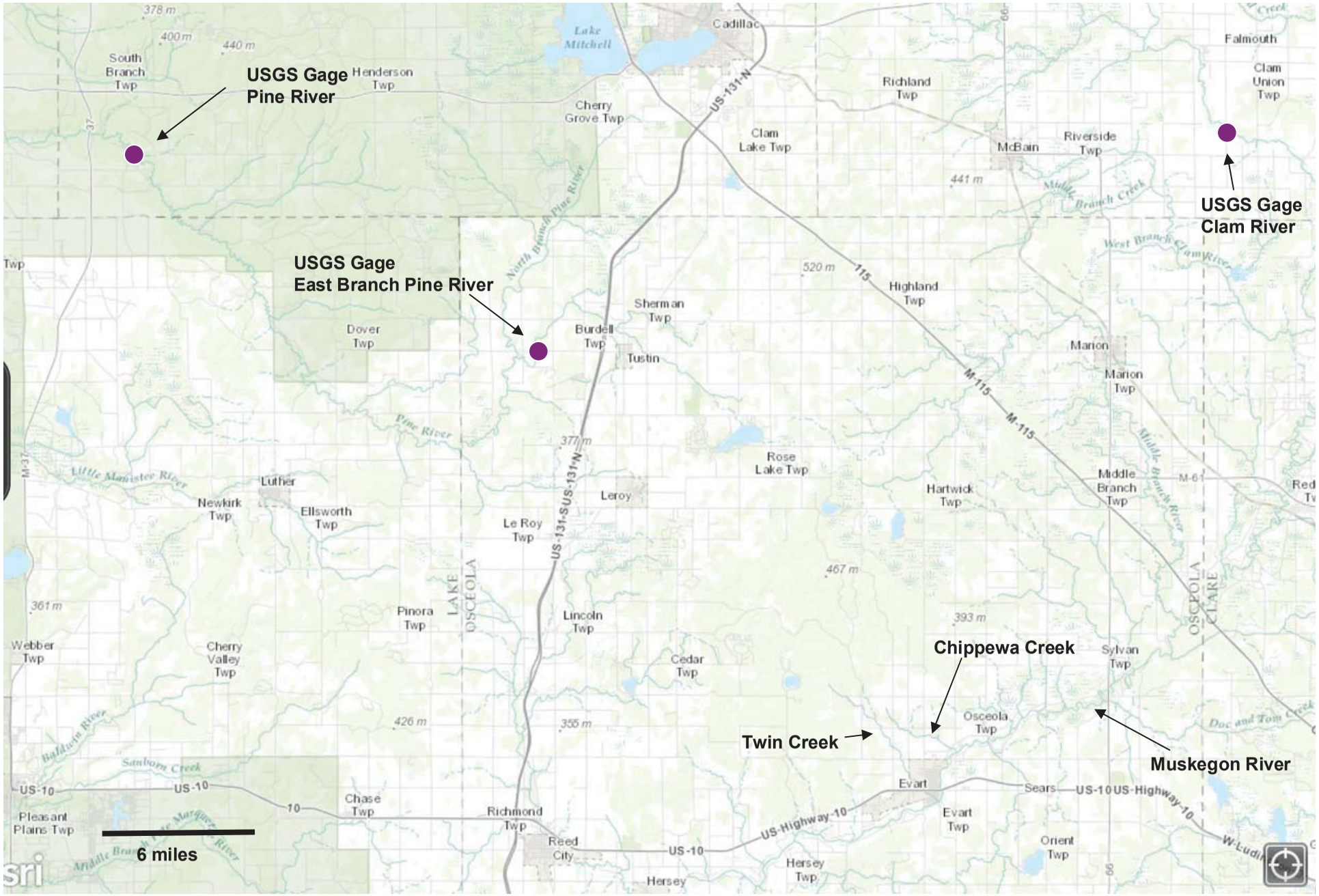


Figure 2 Location of USGS Stream Gaging Stations