An Evaluation of Index Flows in Twin Creek and Chippewa Creek, Tributaries of the Muskegon River, Osceola County, Michigan

Prepared for:

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Table of Contents

List of Figures

List of Tables

Section 1
Introduction

As part of environmental stewardship at its White Pine Springs location, Nestlé Waters North America Inc. (NWNA) has been monitoring stream flows and groundwater levels since late 2000. This monitoring is ongoing and is conducted to provide NWNA with an understanding of surface water and groundwater conditions in the vicinity of the production well at the White Pine Springs Site used by NWNA as water source for its bottling facility at Stanwood. Stream flow monitoring locations include Twin Creek just upstream of where it flows into the Muskegon River in Evart and Chippewa Creek upstream of where it flows into the Muskegon River at a location about two miles upstream of the mouth of Twin Creek.

The attached Figure 1 depicts the Twin Creek Water Management Area and the Chippewa Creek Water Management Area in Michigan's Water Withdrawal Assessment Tool (WWAT) and lists the index flows and drainage areas for these two Water Management Areas. Also shown on the figure are some of the stream flow monitoring locations maintained by NWNA.

An evaluation of the extensive flow monitoring data provides more accurate estimates of the index flows of Twin Creek and Chippewa Creek than those contained in the existing WWAT database. This report describes the stream flow monitoring data and calculation of index flows for Twin Creek and Chippewa Creek from the flow monitoring data.

Section 2
Calculation of Index Flows

The gaging locations used for calculating the index flows of Twin Creek and Chippewa Creek are shown on Figure 1. The Twin Creek gaging location is just upstream of the Muskegon River[1]. On Chippewa Creek there is a gaging location about 1.2 miles upstream of the Muskegon River on the main stem and a gaging location on a small tributary that enters the main stem from the north about 0.75 miles upstream of the Muskegon River[2]. The measured monthly flows during the summer months of July, August and September at the gaging locations on Twin Creek and Chippewa Creek are listed on Table 1. For purposes of calculating the index flow of Chippewa Creek at the Muskegon River the measured flows at the two gaging locations on Chippewa Creek were summed for each date when flows were measured at both locations and then this sum was adjusted for the ungaged portion of the watershed[3].

A median monthly flow was calculated for the summer months for Twin Creek and Chippewa Creek for each year with data[4]. The calculated monthly flows are listed on the table below along with a tabulation of the years of data used in the calculation and the total number of flow measurements in the month. The frequency of flow measurements at the gaging locations

	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

[1] The gaging location on Twin Creek (SF-13) is located on the east side of South Main Street where Twin Creek flows through a double box culvert.

[2] The gaging location on the main stem (SF-17) is on the east side of 90th Avenue at a box culvert and the tributary gaging location (SF-19) is on the north side of 8 Mile Road.

[3] The total area of the Chippewa Creek watershed is 3.976 square miles; 3.206 square miles (80.59 percent of the watershed) is upstream of the gaging locations SF-17 and SF-19 and 0.772 square miles (19.41 percent of the watershed) is downstream of the gaging locations. The flow in Chippewa Creek at the river was calculated by assuming that 80.63 percent of the total flow in the creek at the river originates in the gaged portion of the watershed and 19.37 percent originates in the ungaged portion. Thus, the flow in Chippewa Creek at the river is calculated as the flow in gaged portion divided by the fraction (percent divided by 100) of the basin represented by the gaged portion. For example, the September median flow in the gaged portion of watershed is 1,910 gpm and the calculated flow in the creek at the Muskegon River is 2,370 gpm (1,910 gpm divided by 0.8059 equals 2,370 gpm).

[4] The median monthly flow was calculated as the median of the average flow during the month in each year with data. These average monthly flows for Twin Creek and Chippewa Creek are listed on Table 2. The average flow was calculated for each year such that the median flow would not be biased by years with more frequent measurements. Summer flow data from 2001 through 2014 were used in the calculation of index flow.

was generally monthly or quarterly, and thus the variation in number of years of data among the months. The index flow is the minimum of the median flows calculated for the months of July, August and September.

The correspondence between the index flows calculated from stream flow data and the index flows in the existing WWAT is poor. The index flow of Twin Creek calculated from the monitoring data is 2,948 gpm, whereas the index flow in the WWAT is 8,014 gpm. The index flow of Chippewa Creek calculated from the monitoring data is 2,370 gpm, whereas the index flow in the WWAT is 887 gpm. Thus, the Twin Creek index flow in the WWAT **overestimates** the actual index flow of Twin Creek by a factor of about 2.7, and the Chippewa Creek index flow in the WWAT **underestimates** the index flow of Chippewa Creek by a factor of about 2.7. The poor correspondence, in large part, is the result of the characteristics of groundwater conditions in the glacial deposits in these watersheds. In general, groundwater basins, especially in headwater streams, do not correspond with surface watersheds. In the regression equation used in the WWAT to calculate index flows, the calculated index flow is proportional to the surface water drainage area. Thus, for those Water Management Areas where the area of the groundwater basin contributing flow to the streams differs significantly from the surface watershed area, the WWAT estimated index flows differ significantly from the index flows calculated from gaging data. This is the case for both Twin Creek and Chippewa Creek.

The area of the groundwater basin contributing flow to Twin Creek is significantly smaller than the surface watershed and the area of groundwater basin contributing flow to Chippewa Creek is significantly larger than the surface watershed. The groundwater basin contributing flow to Chippewa Creek includes a portion of the Twin Creek surface watershed as well as a portion of an unnamed surface watershed to the north of the Chippewa Creek surface watershed.

The index flows calculated for Twin Creek and Chippewa Creek from flow monitoring data are based on a limited number of flow measurements collected since 2001 on Twin Creek and 2003 on Chippewa Creek. The estimates of the index flow will improve as additional stream flow measurements are made as part of the long-term monitoring program at the White Pine Springs Site. The stream flow data that have been collected clearly show that the index flows of Twin Creek and Chippewa Creek in the WWAT are incorrect and provide a strong basis for adjusting the index flows for Twin Creek and Chippewa Creek in the WWAT with the understanding that there remains some uncertainty in the measurement derived estimates of index flow due to the limited number of flow measurements on which they are based.

Section 3
Summary

We recommend that the index flows of Twin Creek and Chippewa Creek in the existing WWAT be modified to reflect the results of stream flow monitoring data collected on these streams by NWNA since 2001. The recommended index flow for the Twin Creek Water Management Area is 2,948 gpm and the recommended index flow for Chippewa Creek Water Management Area is 2,370 gpm.

FIGURE

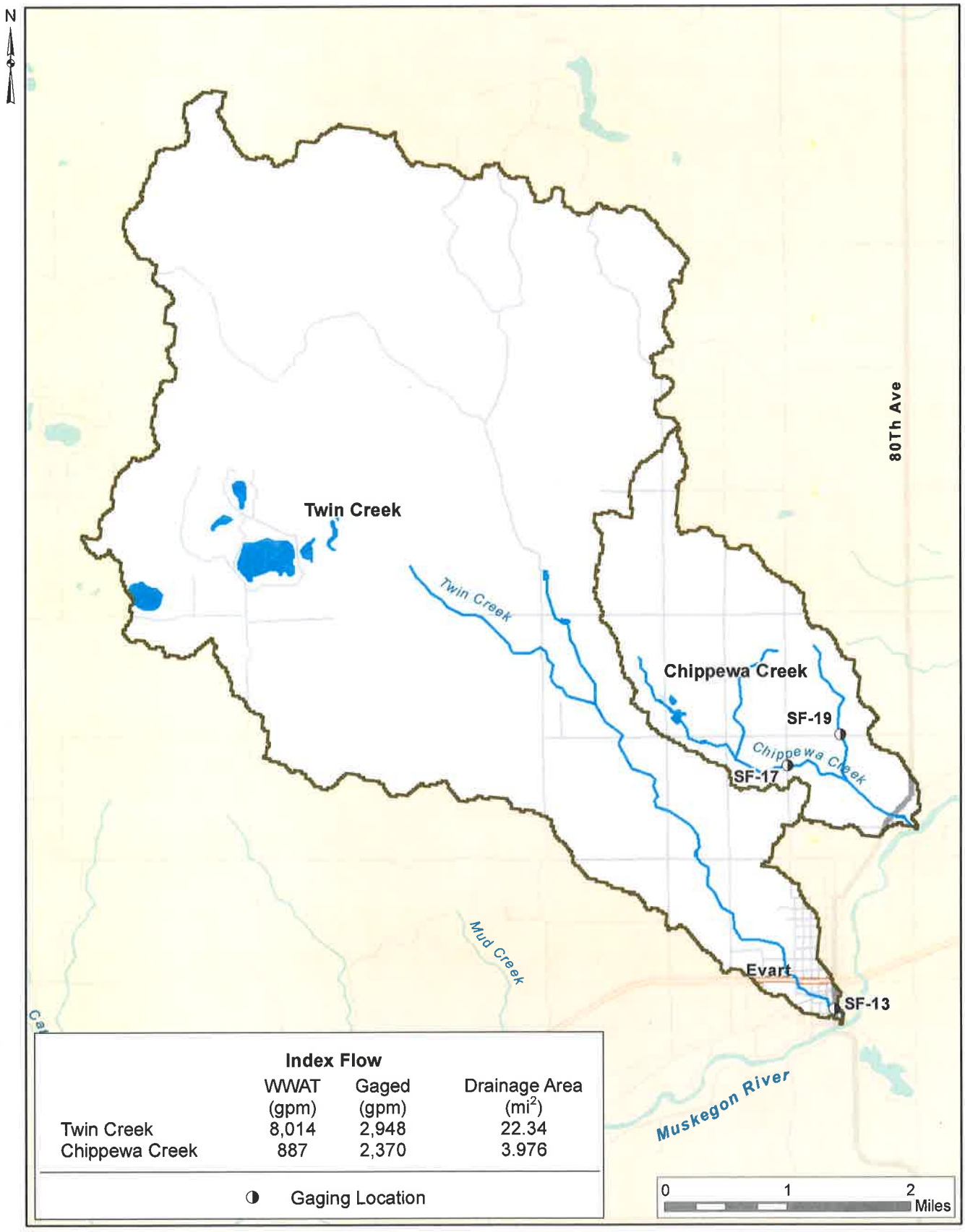

Figure 1 Twin Creek Water Mangement Area and Chippewa Creek Water Management Area

TABLES

Table 1

Measured Summer Flows in Twin Creek and Chippewa Creek 2001 to 2014

Twin Creek		Chippewa Creek			
SF-13		SF-17		SF-19	
Date	Flow (gpm)	Date	Flow (gpm)	Date	Flow (gpm)
07/18/02	2636	07/01/03	1898	07/01/03	237
07/21/04	2088	07/22/03	2003	07/22/03	178
07/26/05	15199	07/21/04	2001	07/21/04	265
07/12/06	3932	07/26/05	8343	07/25/07	202
07/24/07	3120	07/12/06	2197	07/23/08	197
07/22/08	3644	07/25/07	2087	07/23/09	328
07/22/09	3015	07/23/08	2030	07/21/10	222
07/21/10	3992	07/23/09	2454	07/19/11	111
07/19/11	3759	07/21/10	2121	08/12/03	214
08/08/02	3065	07/19/11	1785	08/25/04	257
08/25/04	2408	08/12/03	1767	08/22/07	236
08/21/07	5496	08/25/04	1846	08/19/08	212
08/18/08	2795	08/22/07	2356	08/27/09	186
08/27/09	3453	08/19/08	2456	08/24/10	183
08/24/10	3128	08/27/09	1681	08/16/11	142
08/16/11	3327	08/24/10	1899	08/08/12	178
08/08/12	2201	08/16/11	1582	09/12/03	163
09/18/01	2800	08/08/12	1229	09/22/04	123
09/03/02	3642	09/12/03	2138	09/19/07	219
09/17/02	2653	09/22/04	1645	09/24/08	197
09/12/03	1977	09/24/08	1935	09/17/09	193
09/22/04	2417	09/17/09	1822	09/13/10	162
09/19/06	4269	09/13/10	1749	09/13/11	178
09/18/07	2991	09/13/11	1493	09/17/13	190
09/23/08	3337	09/17/13	1600	09/11/14	81
09/16/09	3080	09/11/14	2047		
09/13/10	2906				
09/13/11	2742				
09/18/13	1851				
09/11/14	4563				

Table 2

Monthly Average Flows in Twin Creek and Chippewa Creek
2001 to 2014

Year	Twin Creek at SF-13 (gpm)			Chippewa Creek at Muskegon River (gpm)		
	July	August	September	July	August	September
2001			2800			
2002	2636	3065	3148			
2003			1977	2965	2748	2393
2004	2088	2408	2417	2810	2608	2193
2005	15199					
2006	3932		4269			
2007	3120	5496	2991	2838	3213	272
2008	3644	2795	3337	2762	3308	2644
2009	3015	3453	3080	3450	2315	2499
2010	3992	3128	2906	2905	2581	2370
2011	3759	3327	2742	2352	2138	2072
2012		2201			1745	
2013			1851			2220
2014			4563			2639
Median	3644	3096	2948	2838	2595	2370
Count	9	8	12	7	8	9