Memo

AEM | ADVANCED ECOLOGICAL MANAGEMENT

To: Arlene Anderson-Vincent, Senior Natural Resources Manager, Nestle Waters North America

From: Doug Workman, Ph.D. Advanced Ecological Management, LLC.

Date: September 17, 2015

Re: WPS August 2015 Streamflow Measurements

Advanced Ecological Management (AEM) collected streamflow measurements at SF 13 (Twin Creek), SF 17 (Chippewa Creek) and SF 19 (Chippewa Creek) once each week during the month of August 2015 (Figure 1). The purpose of the streamflow measurements was to collect data using a method that was consistent with the USGS streamflow gaging protocol that would subsequently be used to determine the index flow for Twin and Chippewa Creeks. The streamflow gaging protocol used for this index flow determination was adopted by Nestle Waters North America in March 2015 and has been used in all 2015 streamflow measurements (NWNA 2015).

Streamflow Measurement

Streamflow was measured in three locations on August 4, 11, 18, and 26, 2015 by AEM (Figure 1). The sixth-tenths-depth-method (NWNA 2015) was used to measure streamflow in all three locations, and stream velocity was measured for a duration of 40 seconds in each interval of all locations and depths measured by AEM personnel.

The Twin Creek location (SF13) was measured using the SonTek Flow Tracker® (Flow Tracker) Acoustic Doppler Velocimeter. The stream channel at SF 13 was approximately 21-feet wide and water depth was less than 1.5 feet during all August measurements. The main tributary of Chippewa Creek (SF17) was also measured using the Flow Tracker. The stream channel at SF-17 was approximately 16-feet wide and water depth was less than 1.5 feet during all August measurements.

A smaller tributary of Chippewa Creek (SF19) was measured using the Marsh McBirney Flo-Mate™ 2000. The stream channel at SF 19 was approximately 2.6-feet wide and water depth was typically less than 0.2 feet during all August measurements.

Streamflow data for all three measurement locations and all four measurement dates during August 2015 are presented in Table 1.

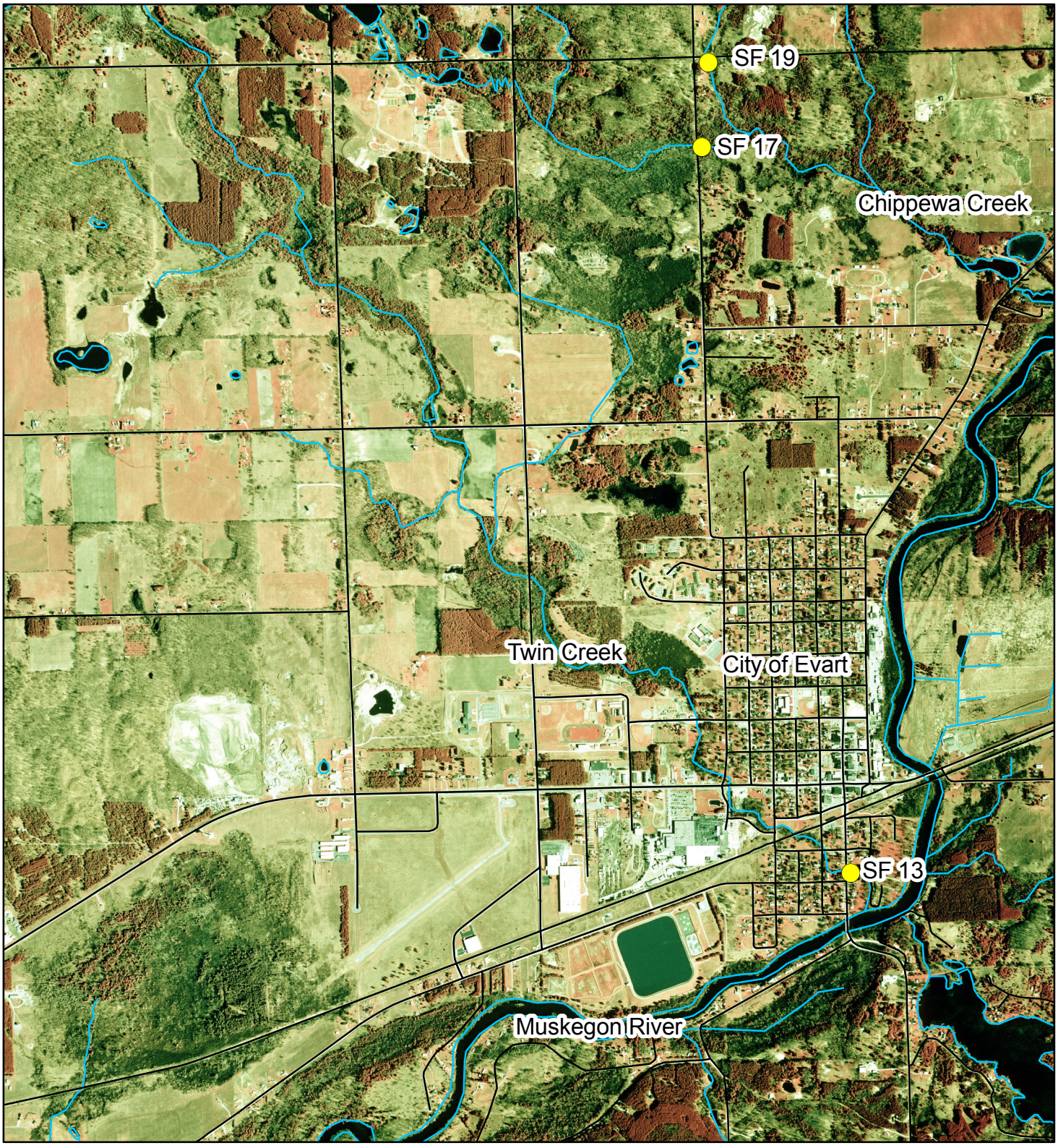
References

Nestle Waters North America (NWNA). March 2015. Memorandum: Streamflow measurement protocol for City of Evart and White Pine Springs.

Table 1. August 2015 streamflow measurements in Twin and Chippewa Creeks.

	Discharge cfs		
Date	**SF13 Twin Creek**	**SF17 Chippewa Creek**	**SF19 Chippewa Creek**
8/4/15	8.40	3.87	0.38
8/11/15	7.30	4.24	0.46
8/18/15	9.69	4.46	0.45
8/26/15	7.23	4.21	0.48

cfs – cubic feet per second



Legend

- Streamflow Monitoring Locations

N

0 0.125 0.25 0.5 0.75 1 Miles

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PROJECT	NWNA White Pine Springs
TITLE	Streamflow Monitoring Locations
FIGURE	1 of 1

Memo

To: Field Personnel Measuring Streamflows for NWNA at the City of Evart Spring Site (COE) and the White Pine Springs Site (WPS)

From: Arlene Anderson-Vincent, Senior Natural Resource Specialist – Nestle Waters North America Inc. (NWNA

Date: March 2, 2015

Re: Streamflow Measurement Protocol for COE and WPS

This streamflow measurement protocol sets forth the procedures that should ordinarily be followed in conducting streamflow measurements at NWNA's City of Evart spring site (COE) and at NWNA's White Pine Springs site (WPS). All streamflow measurements at a given site (COE or WPS) should be made on the same day. If the measurements at all streamflow measurement locations at a given site cannot be completed within one day (*e.g.*, due to equipment failure), then streamflows should be measured on consecutive days.

FLOW METERS

The SonTek Flow Tracker® (Flow Tracker) and the Marsh McBirney Flo-Mate™ 2000 (Flo-Mate) are the flow meters that are used by NWNA consultants to measure stream velocity at its monitoring sites in Michigan. When possible, given the nature of the stream at the location being measured and the prevailing conditions, the Flow Tracker should be used. The Flow Tracker is an Acoustic Doppler Velocimeter (ADV) and relies on suspended sediment within the water column to measure water velocities. Some streams may not have sufficient sediment load, or sufficient water depth, to accurately measure stream velocities using a Flow Tracker. In situations where the Flow Tracker is unable to consistently gather sufficient stream velocity data, the Flow-Mate should be used.

The Flow Tracker and Flo-Mate meters are based on different technologies to measure stream velocities. Operators of these flow meters should be familiar with the operation manual for each meter, including how to set up the proper duration of flow measurement within each stream interval and the recognition of error codes.

FLOW METER FIELD CALIBRATION

Flow meter calibration is required for both the Flow Tracker and the Flo-Mate prior to use. The Flow Tracker must be calibrated at each stream measurement location. Calibration of the Flow Tracker is conducted through a meter-initialization process that is run prior to beginning measurements at a given streamflow measurement location. The Flow Tracker initialization process includes a ping test that is conducted for 20 seconds to determine if enough sediment is suspended within the water column for determining flow velocity. The ping test may provide a warning, such as low Signal to Noise Ratio (low SNR), or high angle of velocity, if there is not enough suspended sediment. There are other warnings as well. If the initial ping test results in

any warnings, especially low SNR or high angle of velocity, the ping test should be re-run. Should subsequent ping tests result in warnings, the Flo-Mate should be used at that streamflow measurement location.

The Flo-Mate must be calibrated at each spring site before use at that site, but need not ordinarily be calibrated at each stream measurement location at the site. Prior to calibration of the Flo-Mate at a site, a five-gallon bucket should be filled with stream water. The wading rod with the attached streamflow sensor should subsequently be placed in a vertical position (*i.e*., not leaning to one side) within the bucket of water and the depth of the sensor should be set to 60% of the total depth of water within the bucket. The Flo-Mate and water should remain still for a period of time until water is no longer observed to be moving within the bucket. The Flo-Mate should be turned on and a velocity readout of no more than 0.02 feet per second (fps) should consistently be observed. If the velocity readout is greater than 0.02 fps, the Flo-Mate should be subjected to the zero-adjust sequence. The "Recall" and "Store" buttons should be pressed simultaneously followed by pressing the "Down Arrow" button two times to initiate the zero-adjust sequence. Following the zero-adjust sequence, the velocity readout for the water within the bucket should be no more than 0.02 fps. If the velocity readout is greater than 0.02 fps after the first zero-adjust sequence, repeat the procedure and re-measure velocity within the bucket. The Flo-Mate is properly calibrated once flow within the bucket as shown on the Flo-Mate is no more than 0.02 fps.

MEASUREMENT OF VELOCITY

One of the following two methods will be used to measure stream velocity and subsequently estimate discharge at each streamflow measurement location at the COE site and the WPS site:

- Sixth-tenths-depth method
- Two-point method

Regardless of the method that is used, the cross-sectional interval spacing for any stream measurement location should not be such that more than 10% of the total stream discharge at that streamflow measurement location flows through any one of the intervals at the time of the measurement. The interval widths at most of the streamflow measurement locations range between 0.25 feet and 0.5 feet. When possible, it is preferred that intervals be narrow enough so that no more than approximately 5% of the total stream discharge at the streamflow measurement location flows through any one interval. However, a measurement interval should never be less than the width of the flow meter sensor.

The duration of the velocity measurement in any stream interval, at any depth, shall be 40 seconds for any meter that is used, unless otherwise specified.

When measuring stream velocity, do not stand directly behind or in front of the sensor. Stand far enough downstream and to the side of the sensor so not to affect the measurement, and keep the sensor pointed directly into the flow and the wading rod in a vertical position.

Six-Tenths-Depth Method

The six-tenths-depth method is used at a streamflow measurement location when stream depth is less than 1.5 feet throughout all of the cross-sectional intervals within the streamflow measurement location. The following steps assume that the flow meter has been calibrated as specified above.

1. At the center of each interval, or at the established permanent marker for that interval, the operator shall record the depth of water (in tenths of feet) to the top of the sediment.

2. Prior to measuring stream velocity, the wading rod must be set to 60% of the total water depth using the depth gage located at the top of the wading rod. For detailed instructions on properly operating top-set wading rods for streamflow measurements, refer to the operator's manual that accompanies the flow meter.

3. Stream velocity is measured in each interval throughout the stream cross section at the streamflow measurement location. Velocity measurements using the Flow Tracker may be initiated once the flow around the sensor appears to have settled following adjustment of sensor depth. With respect to the Flo-Mate, since it continually repeats velocity measurements over the full programmed time interval once that amount of time has been programmed into the meter prior the commencement of measurements at the site, the operator must wait for the end of the 40-second period that is ongoing at the point when the operator has set the sensor to the 60% depth and the streamflow around the sensor has stabilized. Then, the subsequent 40-second time interval should be used for the measurement of stream velocity for that cross-sectional interval.

4. Velocity and depth data should be entered into the appropriate location in the Excel spreadsheet prior to collecting data from the next cross-sectional interval in the streamflow monitoring location.

5. The spreadsheet data should be field-reviewed for data-entry errors upon completion of all velocity measurements at each streamflow measurement location before moving on to the next location.

6. The spreadsheet should also be examined before leaving the streamflow measurement location to determine whether more than 10% of the total discharge flowed through any single cross-sectional interval during the velocity measurements. If total discharge exceeded 10% in any of the intervals, the operators should collect additional stream velocity data adjacent to and within the interval where the exceedance occurred. The operators should subdivide the affected intervals(s) and each of the intervals adjacent to the affected interval(s) into equal sub-intervals and collect velocity data at the midpoint of each of the sub-intervals. (Where there are permanent markers, the additional velocity measurements should be collected at the midpoint between the affected markers.) If additional measurements are taken because of an exceedance in any of the interval(s), additional cells must be established in the affected spreadsheet for the purpose of entering the additional data.

Two-Point Method

The two-point method should be used at a streamflow measurement location if stream depth is greater than 1.5 feet anywhere within any cross-sectional interval at that streamflow measurement location.

1. At the center of each interval, or at the established permanent marker for that interval, the operator shall record the depth of water (in tenths of feet) to the top of the sediment.

2. Stream velocity will be measured in each cross-sectional interval at 20% and at 80% of the depth below the surface. The 20% and 80% depths will be determined following entry of total water depth in the Excel spreadsheet. At each interval, the operator will

first set the sensor at the 20% depth and measure velocity, and then set the sensor to the 80% depth and measure velocity.

3. Velocity measurements using the Flow Tracker may be initiated once the flow around the sensor appears to have settled following adjustment of sensor depth. With respect to the Flo-Mate, since it continually repeats velocity measurements over the full programmed time interval once that amount of time has been programmed into the meter prior to the commencement of measurements at the site, the operator must wait for the end of the 40-second period that is ongoing at the point when the operator has set the sensor to the appropriate depth and the streamflow around the sensor has stabilized. Then, the subsequent 40-second time interval should be used for the velocity measurement at that depth.

4. Velocity and depth data should be entered into the appropriate location in the Excel spreadsheet prior to collecting data from the next cross-sectional interval in the streamflow monitoring location.

5. The spreadsheet data should be field reviewed for data-entry errors upon completion of all velocity measurements at each streamflow measurement location before moving on to the next location.

6. The spreadsheet should also be examined before leaving the streamflow measurement location to determine whether more than 10% of the total discharge flowed through any single cross-sectional interval during the velocity measurements. If total discharge exceeded 10% in any of the intervals, the operators should collect additional stream velocity data adjacent to and within the interval where the exceedance occurred. The operators should subdivide the affected intervals(s) and each of the intervals adjacent to the affected interval(s) into equal sub-intervals and collect velocity data at the midpoint of each of the sub-intervals. (Where there are permanent markers, the additional velocity measurements should be collected at the midpoint between the affected markers.) If additional measurements are taken because of an exceedance in any of the interval(s), additional cells must be established in the affected spreadsheet for the purpose of entering the additional data.

DATA ENTRY AND DISCHARGE ESTIMATION

As specified above in the descriptions of the velocity measurement methods, all collected streamflow and depth data is entered into an Excel spreadsheet. The operators should use a handheld Personal Data Assistant (PDA), electronic tablet, or laptop computer that is suitable for outdoor use in wet environments.

Individual Excel spreadsheet templates have been prepared for each streamflow measurement location. The following data shall be collected as part of the streamflow measurements at each location:

- Date
- Equipment used
- Names of operators
- Starting time of measurement
- Ending time of measurement
- Water level elevation of nearest staff gage
- Total depth of each cross-sectional interval
- Stream velocity in each interval at the required depth(s).

These data should be saved using a file name system that includes the name of the streamflow measurement location and the date of measurement. To properly save the data, open the template and perform a "save as" operation. Rename the location-specific template followed by the date the measurements are recorded (e.g., SG-102 1-1-2015).

Six-Tenths-Depth Method Discharge Estimate

Discharge using the Six-Tenths-Depth Method is computed as the product of the area of the cross-sectional interval and the measured velocity. This method uses the subdivisions of the stream into cross-sectional intervals at the streamflow measurement location (sometimes also referred to as segments, partial areas, sections, subareas, verticals, stations, profiles, panels, or ensembles), and the velocity in each interval at 60% of the total depth. The total discharge is the summation of the products of the areas of the intervals and their respective velocities and is expressed below by the following equation:

$$Q = \sum_{i=1}^{n} a_i \, v_i$$

where Q = total discharge in cubic feet per second,
a_i = cross-section interval area, in square feet, for the *i*th interval of the *n* intervals into which the cross section is subdivided, and
v_i = the corresponding 60% velocity, in feet per second, of the flow of the *i*th interval.

Two-Point Method Discharge Estimate

Discharge using the Two-Point Method is computed as the product of the area of the cross-sectional interval and the average measured velocity. This method uses the subdivisions of the stream into cross-sectional intervals at the streamflow measurement location, and the average velocity at 20% and at 80% of the total depth within each interval. Average velocity is determined for each interval as the average of the 20% velocity and the 80% velocity. The total discharge is the summation of the products of the areas of the intervals and their respective average velocities and is expressed below by the following equation:

$$Q = \sum_{i=1}^{n} a_i \, \bar{v}_i$$

where Q = total discharge in cubic feet per second,
a_i = cross-section area, in square feet, for the *i*th interval of the *n* intervals into which the cross section is divided, and
$\bar{v}_i$ = the corresponding average velocity, in feet per second, of the flow of the *i*th interval.

CITY OF EVART INFORMATION

City of Evart Spring Site Equipment and Methodology

Streamflow Measurement Location	Preferred Meter	Preferred Method

SF101 (Twin Creek)	Flow Tracker ADV	Two-Point (20% and 80%)
SF103 (Twin Creek)	Flow Tracker ADV	Sixth-Tenths (60%) when depth≤1.5 ft. at all intervals Two-Point when depth>1.5 ft. at any interval
SF106 (Twin Creek)	Flow Tracker ADV	Sixth-Tenths (60%) when depth≤1.5 ft. at all intervals Two-Point when depth>1.5 ft. at any interval

WHITE PINE SPRINGS INFORMATION

White Pine Springs Site Equipment and Methodology

Site	Meter	Method
SF1 (Twin Creek)	Flow Tracker ADV Flo-Mate if repeated error readings on Flow Tracker	Sixth-Tenths (60%),
SF2 (Twin Creek)	Flow Tracker ADV Flo-Mate if repeated error readings on Flow Tracker	Sixth-Tenths (60%),
SF8 (Chippewa – above100th)	Flo-Mate	Sixth-Tenths (60%)
SF9 (Twin Creek 8 Mile)	Flow Tracker ADV	Sixth-Tenths (60%)
SF10 (Twin Creek 100th Ave)	Flow Tracker ADV	Sixth-Tenths (60%)
SF11 (Twin Creek 110th Ave)	Flow Tracker ADV	Sixth-Tenths (60%)
SF13	Flow Tracker ADV	Sixth-Tenths (60%) when depth≤1.5ft. at all intervals Two-Point when depth>1.5ft. at any interval
SF16 (Chippewa – raceway)	Flow Tracker ADV	Sixth-Tenths (60%)
SF17 (Chippewa – 90th Ave)	Flow Tracker ADV	Sixth-Tenths (60%)
SF18 (Chippewa-W of 8 Mile)	Flow Tracker ADV Flo-Mate if repeated error readings on Flow Tracker	Sixth-Tenths (60%),
SF19 (Chippewa)	Flow Tracker ADV Flo-Mate if repeated error readings on Flow Tracker	Sixth-Tenths (60%),