MONITORING PLAN
STREAM FLOW AND HYDROLOGICAL BASELINE AND GROUNDWATER

White Pine Springs Site

Evart, Michigan

April 2019

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White Pine Springs
Evart, Michigan

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CONTENTS

TABLES

FIGURES

APPENDICES

1 INTRODUCTION

Nestlé Waters North America (NWNA) was issued Water Supply Permit 1701 (Permit 1701); Water Supply Serial Number 2016667 for Production Well PW-101; on April 2, 2018 by the Michigan Department of Environmental Quality (MDEQ). Production Well PW-101 is part of the White Pine Springs (WPS) site located in Osceola Township, Osceola County, Michigan (**Figure 1**). Permit 1701 was approved under Section 17 of the Michigan Safe Drinking Water Act (1976 Public Act 399 as amended) and allows NWNA to increase the maximum pumping rate of PW-101 from 250 to 400 gallons per minute (gpm).

General Condition #5 of Permit 1701 states that NWNA must, "…submit monitoring plans and Quality Assurance Project Plans (QAPP) to the Department for consideration and approval and required by the special conditions section of this permit." Permit 1701 further states, "The monitoring plans must include the required elements detailed in the special conditions section of this permit. The permit holder [NWNA] may propose equivalent monitoring in place of the special conditions for Department consideration and approval."

This monitoring plan has been prepared by Arcadis of Michigan LLC (Arcadis) on behalf of NWNA to meet the monitoring plan and QAPP (**Appendix A**) requirements set forth in General Condition #5 of Permit 1701. This monitoring plan pertains specifically to the Streamflow (pages 6 and 7 of Permit 1701) and Hydrological Baseline and Groundwater (pages 8 through 10 of Permit 1701) sections of the Permit, A summary of the sections in this document are provided below:

- Section 1.0 Introduction – provides an overview of the existing monitoring program.
- Section 2.0 Streamflow – provides the monitoring required under the permit, methods to complete monitoring, reporting, and variations from the permit with equivalent monitoring.
- Section 3.0 Hydrogeological Baseline and Groundwater – provides the monitoring required under the permit, methods to complete monitoring, reporting, and variations from the permit with equivalent monitoring.

1.1 Existing Monitoring Program

NWNA initiated a long-term environmental monitoring (LTM) program in June 2000 at the start of WPS site assessment. Monitoring wells and shallow drive points were installed to measure and monitor groundwater levels. Stilling wells and staff gauges were installed to measure surface water levels. Stream gauging stations were established along Chippewa Creek, Twin Creek, and their tributaries; and V-notch weirs were installed at representative springs to measure surface water flows. Precipitation data was also obtained monthly from the City of Evart (COE) Waste Water Treatment Plant (WWTP).

The monitoring network has evolved throughout the 18 years of the LTM program. **Table 1** provides a list of the monitoring points that have been removed or abandoned along with an explanation of why the point was no longer needed or could not be replaced. Note that in some instances a point was removed, and a direct replacement was installed. In these cases, the designation "R" was added to the point label.

The current monitoring network consists of the following:

- 38 monitoring wells, including nine wells instrumented with datalogging pressure transducers that record water levels once per day;
- 21 shallow groundwater drive points, including 8 instrumented with datalogging pressure transducers that record water levels once per day;
- Nine wetland points, with all instrumented with datalogging pressure transducers that record water levels once per day;
- Eight stilling wells to measure surface water levels, including three instrumented with datalogging pressure transducers that record water levels once per day;
- 14 staff gauges that are used to measure surface water levels in springs, wetlands, and streams;
- Two surveyed bridge abutments from which surface levels in Twin Creek and Chippewa Creek are measured;
- 12 gauging stations where stream flow is measured with an acoustic Doppler velocimeter (ADV) or an electromagnetic flow meter.

A summary of the monitoring network is presented in **Table 2**. The monitoring locations are presented on **Figure 2** (Long Term Monitoring Network) and **Figure 2A** (Stream Flow Monitoring Locations).

2 STREAMFLOW

Permit 1701 requires monitoring to be completed monthly at the identified streamflow locations and continuous monitoring (hourly) at SF-1 and SF-8 from June 1 through October 31. The monitoring plan will refer to the period of continuous streamflow monitoring as the Continuous Monitoring Period. The monthly monitoring will be completed along with the required hydrologic monitoring using manual measuring methods. The Continuous Monitoring Period requires hourly monitoring at locations SF-1 and SF-8. Both these locations will use electronic devices to monitor the stage of the creeks which will be converted to streamflow using rating curves. This section also discusses the reporting that will be completed and equivalent monitoring to Permit 1701 requirements.

2.1 Monitoring

Streamflow monitoring will consist of the following components:

1. Stream flow will be measured monthly at the following locations (**Figure 3A**): Twin Creek Locations (SF-1, SF-2, SF-8, SF-9, SF-10, SF-11, SF-13) and Chippewa Creek Locations (SF-16, SF-17, SF-18, and SF-19). This monitoring will be consistent with United States Geological Survey (USGS) methods for collecting stream discharge measurements (Turnipseed and Sauer, 2010; Rantz et al.1982). The monitoring shall occur monthly according to a fixed schedule (**Appendix B**). However, the monthly monitoring schedule may be modified for August and September based on antecedent precipitation. During this time period, monitoring will be rescheduled if the amount of precipitation in the 48-hour period (two calendar days) prior to monitoring has been greater than 0.2 inches.

2. Continuous streamflow monitoring at Twin Creek location SF-8 during the Continuous Monitoring Period. A pre-fabricated flume appropriately rated for the creek channel will be installed. A stilling well (SW-8A) that is constructed in accordance with USGS standards (Turnipseed, 2010) will be installed with the flume. A transducer will be housed in the stilling well that will collect stage data hourly. Data collected by the transducer will be transmitted by a telemetry system that will allow it to be assessed in the office. Monthly inspection will be conducted of the flume and areas up and downstream of the flume.
3. Continuous streamflow monitoring at Twin Creek location SF-1 during the Continuous Monitoring Period (June through October). A stilling well (SW-1A) that is constructed in accordance with USGS standards (Turnipseed, 2010) will be installed in the creek. A transducer will be housed in the stilling well that will collect stage data hourly. Data collected by the transducer will be transmitted by a telemetry system that will allow it to be assessed in the office.

2.2 Monitoring Methods

2.2.1 Streamflow Monitoring

Monthly streamflow data will be collected with either the Sontek/YSI FlowTracker ® (FlowTracker) a handheld ADV or Marsh McBirney Flo-Mate 2000 an electromagnetic flow meter (Flow Mate). The streamflow measurement procedures are explained in detail in **Appendix A** (Section 5.0) and **Appendix C**.

Stream flow measurements will be collected in accordance with USGS standards (Turnipseed, 2010) (**Appendix C**). The FlowTracker or equivalent will be used at locations SF-1, SF-2, SF-9, SF-10, SF-11, SF-13, SF-16, SF-17, and SF-18. The Flow Mate or equivalent will be used at locations SF-8 and SF-19, because the stream channels configuration is too narrow and shallow to allow for accurate use of the Flow Tracker.

2.2.2 Continuous Streamflow Monitoring at SF-1 and SF-8

Based on the stream channel configuration, gradient, and range of anticipated flow rates for the SF-8 location, a cutthroat flume has been selected as an appropriate measurement device. The flume will be constructed of aluminum and will be installed in accordance with manufacturer instructions (**Appendix D**).

The rating curve established by the flume manufacturer will be used to calculate the flow at SF-8 based on the stage measured in the accompanying stilling well. Prior to implementation, the flume will be calibrated through field testing (Flow Mate measurements and/or bucket testing) to verify the accuracy of the rating curve.

The flume will be removed each November and re-installed in May. The flume will be installed according to manufacturer instructions and field tested each year as discussed above and in the QAPP (**Appendix A** Sections 3.2.6).

Stilling wells, water level instrumentation and telemetry equipment will be installed at both stream flow monitoring locations (SF-1 and SF-8). The stilling wells will be installed by hand augering approximately one to two feet into the streambed and installing a 5-foot long, 4-inch diameter PVC screen. The screen will be placed so the that water elevation in the channel can be monitored. The screen will be affixed to a fence post driven into the streambed for stability. An equivalent stilling well construction at the SF-8 location may consist of the stilling well being part of the pre-fabricated plume. Additional casing would be added to allow room for the transducer and telemetry equipment.

The stilling wells will be equipped with In-Situ Level Troll 700 instruments or equivalent (**Appendix A** Sections 3.2.3 and 5.4). The Level Troll 700 will be set to 'depth mode' so that the stage is recorded at hourly intervals during the Continuous Monitoring Period. A battery-operated In-Situ telemetry system will be connected to the transducer so that the data can be accessed daily during the Continuous Monitoring Period. The transducers and telemetry system will be removed each November and re-installed in May.

A rating curve will be developed for the SF-1 streamflow monitoring location (**Appendix A** Section 3.4.5). The rating curve will be used to convert the stage data collected by In-Situ Level Troll 700 instrument into flows. The initial rating curve will be based on the streamflow monitoring data measured using the FlowTracker from 2016 through the installation time of stilling well at SF-1. The SF-1 rating curve will be refined over time as additional data are collected.

United States Army Corps of Engineers and MDEQ Joint Permit Application for SF-1 and SF-8 will be prepared by Arcadis on behalf of NWNA and submitted to the MDEQ Cadillac District office for approval prior to installation of these points. Since the flume is not a permanent structure, the MDEQ Cadillac District office will be contacted to ascertain if it should be included on the United States Army Corps of Engineers and MDEQ Joint Permit Application.

2.3 Streamflow Reporting

The streamflow monitoring data collected during a calendar year will be submitted yearly to the MDEQ by February 28th as part of the annual report on Streamflow and Groundwater Conditions. Annual streamflow reporting will include stage and discharge data in table format and files downloaded directly from monitoring devices and data loggers, inspection reports, field sheets, description of activities, data trends, action level exceedances, a narrative of any maintenance issues or equipment failures encountered, and discussion of response actions undertaken to address maintenance issues or equipment failures. The report will also include a tabulation of daily average pumping rates and daily precipitation during the calendar year. The format of the annual report is included in **Appendix E**.

- The first monitoring report will describe baseline conditions as defined in the Permit. Baseline conditions will be described based on data collected after approval of monitoring plans/QAPP and the historical data collected at the site beginning as early as June 2000. Permit 1701 requires the baseline report to be submitted to MDEQ before the pumping rate at well PW-101 can be increased from 250 gpm to 400 gpm. Once the pumping rate at Well PW-101 is increased above the current 250 gpm permit level, annual reports will be submitted (due February 28).

During the Continuous Monitoring Period, NWNA will calculate the daily average of the streamflow at SF-1 and SF-8. If the daily average flow at SF-1 falls below 431 gallons per minute (gpm) for 14 consecutive days or the daily average flow at SF-8 falls below 72 gpm for 14 consecutive days, the MDEQ will be notified and appropriate actions will be undertaken to meet the requirements of the Permit. In addition, if no flow is observed at locations SF-8 and SF-1 at any point in time, the MDEQ will be notified and appropriate actions will be undertaken to meet the requirements of the Permit.

If the streamflow data from SF-1 and SF-8 appear anomalous based on data review, Arcadis field staff will visit the site and attempt to assess the cause of the anomalous data. Typical causes for anomalous data are malfunctioning or damaged instruments/cables or a temporary change of condition such as a dam forming from lodged debris. In the case of damming, the observation will be noted in the field notes and an attempt will be made to remove the debris. If the debris is too large to remove or a natural obstruction exist (i.e., beaver dam), a proposed solution will be discussed with the MDEQ. In the case of malfunctioning instrument, the instrument will be reset. If, however, the instrument has been damaged or testing indicates the instrument needs servicing, the instrument will be removed and replaced with a backup instrument (**Appendix A** Section 5.4).

2.4 Variances and Equivalent Monitoring

The streamflow monitoring proposed above is equivalent to the monitoring specified in the Permit. This equivalent monitoring includes in some cases different monitoring locations, different timing of monitoring, and a different date for the submittal of the annual report. These differences are described below.

2.4.1 Monitoring Locations

The proposed monthly monitoring of stream flows (SF-1, SF-2, SF-8, SF-9, SF-10, SF-11, SF-13, SF-16, SF-17, SF-18, and SF-19) does not include former Weirs 1 through 10 as these weirs have been removed (**Table 1**). The original purpose of installing the weirs was to monitor spring discharge for Food and Drug Administration source identity. The weirs were removed either at the request of the MDEQ Fisheries Division or because erosion and significant alteration of the natural stream channel near the weirs were observed. In general, over time weirs alter the channel configurations and are obstacles to upstream migration of fish. Post removal of the weirs, the stream channels have returned to a more natural state. Water levels continue to be monitored in the stilling wells/staff gauges that accompanied the weirs (see below table and **Appendix F**) and these data are used to evaluate environmental conditions in the spring areas and are sufficient to characterize the hydrologic setting and potential effects of pumping PW-101.

Weir	Surface Water Monitoring Point (Equivalent)	Weir	Surface Water Monitoring Point (Equivalent)
1	Vent-2	6	Seep-6
2	SG-2	7	Downstream at SG-9
3	SG-3 and SW-3WCO	8	Downstream at SG-9
4	SW-14 and SW-4WCO	9	SG-9
5	SG-5 and SW-5WCO	10	SG-10

2.4.2 Monitoring Schedule

The Permit requires monthly monitoring of streamflow measurements. Currently, monitoring is not conducted in January or February. This is due to:

- Safety concerns (cold weather and snow-covered, uneven wetland areas to traverse)

- Parking issues (snow piles on edge of roads from plowing does not allow access to entry roads for monitoring resulting in additional walking to monitoring points)
- Monitoring points and streams being frozen
- Ice dams affecting flow

Due to the conditions above, NWNA proposes the use of transducer data from points installed near the spring areas to replace the requested streamflow measurements. NWNA currently has transducers recording depth to water daily at Seeps (Seep-1R, Seep-4, and Seep-5) and stilling wells in spring areas (SW-3WCO, SW-4WCO, and SW-5WCO). Data from these locations will be downloaded during the March monitoring event, evaluated for trends, and provided with the annual report.

In addition, the Permit states that streamflow monitoring is to occur at least 72 hours after a rainfall event. A review of the past three years of precipitation data (**Table 3**) show that the windows of time when monitoring could occur and meet the 72 hours post rainfall requirement is highly inconsistent and, in some cases, there are no days within a month that would meet this requirement.

Based on discussions with MDEQ, the technical intent of this requirement is to ensure that the stream low flow period is measured and not affected by recent precipitation. Based on evaluation of the site stream flow data, the “low flow period” occurs in the late summer to early fall months (i.e., August and September).

Therefore, NWNA proposes to schedule monitoring as follows:

- In January of each year NWNA will prepare and submit to MDEQ a schedule that identifies the dates that the monthly monitoring will occur.
- The March through July and October through December monitoring will be completed as a scheduled monthly event. The schedule would not be adjusted based on antecedent precipitation. However, a monitoring event typically takes two to three days to complete, so the field staff can adjust the streamflow monitoring to reduce the effect of precipitation.
- During August and September, if 0.2 inches or more of precipitation occurs in the 48-hours (two calendar days) prior to monitoring the streamflow monitoring will be rescheduled. Monitoring will continue should rainfall occur on the day of the streamflow measuring.
- The proposed scheduling procedure for streamflow monitoring described above will meet the technical intent of ensuring that the stream low flow period is measured and not affected by recent precipitation.

2.4.3 Reporting

The Permit specifies several different due dates for annual reports depending on the category or type of data. For example, the Streamflow Monitoring Data Report is due December 31, while the Hydrogeological Baseline and Groundwater Data Report is due October 1. To provide a comprehensive technical monitoring report, all reports will be submitted collectively and submitted by February 28th the year following the data collection. If any Permit threshold is exceeded during the monitoring year, the MDEQ will be notified and actions will be taken as prescribed.

The first monitoring report will describe baseline conditions as defined in the Permit. Baseline conditions will be described based on data collected after approval of monitoring plans/QAAP and the historical data collected at the site beginning as early as June 2000. Permit 1701 requires the baseline report to be submitted to MDEQ before the pumping rate at well PW-101 can be increased from 250 gpm to 400 gpm. Once the pumping rate at well PW-101 is increased above the current 250 gpm permit level, annual reports will be submitted (due February 28).

3 HYDROLOGICAL BASELINE AND GROUNDWATER

Permit 1701 requires monitoring to be completed monthly at the identified locations (monitoring wells [MW], drive points [DP], staff gauges [SG], stilling wells [SW], seeps and vents. Procedures for the installation of a nested well set and completion of the monitoring are discussed. This section also discusses the reporting that will be completed and variations to Permit 1701 with equivalent monitoring.

3.1 Nested Well Installation

The Permit states that five nested well pairs are to be used to evaluate vertical gradients and "*to the degree possible, these vertically nested wells can utilize the hydrology monitor wells required in the wetlands conditions to reduce duplication of effort*". There are currently nine pairs of nested monitoring well pairs for determining vertical gradients at the Site. The existing nested well pairs near the wetland areas show significant head differences between the shallow and deep wells with upward vertical gradients in the five areas identified in the Permit. All of the cluster well pairs are shown on **Figure 3** and **Table 4** lists the historical vertical gradient data over the last year at well clusters near the wetlands. Boring and construction well logs wells for the well clusters shown on **Figure 3** can be found in the QAPP in **Appendix A**.

To meet the Permit conditions of five nested wells pairs, NWNA proposes to use existing nested well pairs MW-101s and d, MW-104i and d, MW-1i and d, and MW-5i and d, and one new well cluster (MW-116s and d) to be installed as indicated below:

MDEQ Requested Location	Proposed Monitoring Wells
South-southeast side of Northern Ridge Springs between the springs and well PW-101	Use well pair MW-101s, d
The northeast side of Northern Boomerang Springs to monitor water levels and vertical gradients near the spring and in wetland R	Install new well pair (MW-116s and MW-116d)
White Pine Springs north of location SF-6 and south of wetland G	Use well set MW-1i and d and MW-5i and d
The northeast side of Southern Boomerang Springs.	Use well pairs MW-1i and d and MW-116s and MW-116d
The northwest side of wetland CC and southwest of Weir 9 near Decker Springs to measure water levels and vertical gradients in wetland CC and north of Decker Pond	Use well pair MW-104i and d

The new monitoring wells (MW-116s and MW-116d) will be installed by drilling a borehole using 4¼-inch inner diameter hollow-stem augers (HSA) or by roto-sonic method. During drilling, soil samples will be collected at approximate 5-foot intervals and at drill pressure changes by HSA method or continuously by the roto-sonic method for the purpose of geologic descriptions. Appropriate soil sampling intervals will be identified by the onsite geologist. The well depths are assumed to be approximately 40 and 110 feet below ground surface (bgs). **Appendix A** includes procedures with respect to well installation and development.

Each monitoring well will be given a well identification (i.e. MW-116S), followed by a single letter used to classify the position of the well screen installed in relation to the source aquifer:

- "s" – denotes "shallow" screened wells within the source aquifer
- "d" – denotes "deep" screened wells within the source aquifer
- The newly installed monitoring wells will be surveyed by a registered surveyor (**Appendix A** Section 3.3). The survey will provide latitude and longitude in decimal degrees with the horizontal datum in NAD 83 SPC Michigan south zone (international feet) and the vertical datum in NAVD 88 (U.S. feet).

3.2 Monitoring Activities

The groundwater monitoring activities will consist of the following components (**Figure 3**):

1. The measurement of groundwater levels monthly[1] in the following monitoring wells:
    - MW-1d, MW-1i, MW-1u, MW-2i, MW-3i, MW-4u, MW-5d, MW-5i, MW-6i, MW-7i, MW-8i, MW-9i, MW-10i, MW-11s, MW-12i, MW-12s, MW-13i, MW-101s, MW-101d, MW-101L, MW-102i, MW-102d, MW-103i, MW-103d, MW-104i, MW-104d, MW-105s, MW-105d, MW-105L, MW-106d, MW-107i, MW-107d, MW-110d, MW-111d, MW-112i, MW-113d, MW-114i, MW-115i, and newly installed wells (MW-116s and MW-116d).
2. The measurement of groundwater levels monthly[1] in the following drive points:
    - DP-1, DP-2, DP-3, DP-4, DP-5, DP-11, DP-12, DP-14, DP-15, DP-16, DP-17, DP-18, DP-19, DP-20, SW-1-DP, SW-2-DP, SW-3-DP, SW-6-DP, SW-8-DP, SW-10-DP, SW-11-DP, SW-14-DP, Seep-1R, Seep-2, Seep-3, Seep-4, Seep-5, Seep-6, Vent-1R, Vent-2
3. The measurement of surface-water levels monthly[1] at staff gages and stilling wells.

- The staff gauges that will be monitored are:
    - SG-2, SG-3, SG-5, SG-9, DP-G-SG, DP-H-SG, SG-10R, SG-16, SG-18, SG-19, SG-201, SG-202, SG-203R, SG-204

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[1] Monthly groundwater level and surface water level monitoring will occur in the same monitoring event as surface water discharge monitoring. Based on the Permit condition described in stream flow monitoring, LTM events may be rescheduled in August and September if greater than 0.2 inches of precipitation occurs in the area in the 48-hours (2 calendar days) before the scheduled monitoring event. Rescheduling due to precipitation may result in less than or greater than monthly monitoring during those months.

- The stilling wells that will be monitored are:
  - SW-1, SW-2, SW-3 WCO, SW-4 WCO, SW-5 WCO, SW-8, SW-9, SW-14 (note that new stilling wells [SW-1A and SW-8A] will replace the existing SW-1 and SW-8)
- Surface water levels will also be monitored from the bridge abutments at SG-17R, and SW-13R.

4. The Wetland monitoring plan includes monitoring water levels at 11 wetlands (A, B, C, D, E, G, H, Q, R, CC, and DD). The monitoring at these wetlands will consist of existing points SW-8-DP/WT-A-1, DP-4/WT-E, WT-A-2, WT-G, WT-H, WT-CC-1, WT-CC-2, WT-R-1, WT-R-2, WT-R-4, and WT-R-5, and six additional locations proposed in the wetland monitoring plan. Transducers will be employed in each of these points to monitor daily water levels from mid- May through mid-November. These points will be included in the monitoring plan.

3.3 Monitoring Methods

3.3.1 Monitoring Wells and Drive Points Water Levels

Monitoring wells and drive points are fixed points that are used to measure groundwater levels. Groundwater levels from monitoring wells and drive points will be determined by measuring the depth to groundwater from a surveyed reference point on the top of the well casing, indicated by a drawn mark. An electronic water level tape will be used to measure the depth to water in accordance with United States Environmental Protection Agency (USEPA) recommended procedure (USEPA, 2016). This protocol is summarized in the Arcadis Technical Guidance Instructions (**Appendix A** Section 3.4.2 and **Appendix G**). The groundwater elevation at each monitoring point is determined by subtracting the depth to water from the elevation of the top of well casing reference point.

3.3.2 Surface Water Levels

Staff gauges and stilling wells are fixed points that are used to measure surface water elevations of streams, ponds or springs. Staff gauges typically consist of a graduated placard where the reading is taken at the surface water level. The water elevation is calculated by taking a water level reading and subtracting it from the value at the top of the staff gauge ruler (surveyed elevation). This subtraction gives the distance from the top of the staff gauge ruler to the water. This distance is then subtracted from the surveyed elevation from the top of the staff gauge ruler. The stilling wells are like the groundwater monitoring points discussed above in that the depth to water is measured inside the monitoring point from a surveyed reference.

Locations SG-17R and SW-13R are surveyed reference point markings on bridges over Chippewa and Twin creeks, respectively. The surface water elevation is determined by measuring the distance from the mark on the bridge to the water surface. That distance is then subtracted from the elevation of the mark, giving the surface water elevation.

Further discussion of the field methodologies used to measure surface water elevations are provided in the QAPP (**Appendix A** Section 3.4.3 and **Appendix G**).

3.3.3 Transducers

Transducers will be used to monitor water levels in drive points (WT locations) as part of the Permit Conditions - Wetlands requirements. The transducers will be set to record depth to water measurements at a daily frequency. Data is downloaded from the transducers at each monitoring event using the Mesa-2 (field tablet) or equivalent computer. Data collected is stored in the project file. The QAPP (**Appendix A**) details the use of transducers in Section 3.4.4.

Since the transducers are to record data during the growing season, they will be installed each April and removed in November. Transducer removal during the winter months will protect the transducers from possible damage since the water in these monitoring points typically freezes.

3.3.4 Maintenance Activities

Maintenance activities will be completed as needed during monitoring events. The activities have been discussed throughout the monitoring plan and in detail in the QAPP (**Appendix A** Section 5.0 and **Appendix G**). Maintenance activities include:

- Sending the FlowTracker® instrument to the manufacturer for annual maintenance
- Changing malfunctioning transducers, as needed
- Assessing water level meter yearly to determine any elongation
- Assessing flume condition
- Other as-needed maintenance as identified in the field
- Resurveying of shallow SW, DP, and SG locations to account for elevation changes that may occur (i.e., frost heave, animal interferences)
- Replacing monitoring points that have been damaged

MDEQ will be notified of any maintenance activities during monthly and/or annual reporting.

3.3.5 Precipitation Data

Precipitation data are recorded daily by the COE WWTP which is located approximately 3.25 miles south-southeast of the Site. Data are obtained from the COE WWTP after each monitoring event and monthly (**Appendix A** Section 3.4.7). Summarized precipitation data will be provided to MDEQ in the monthly reports and in the annual report.

3.4 Hydrological Baseline and Groundwater Reporting

3.4.1 Baseline/Annual Reports

- The groundwater monitoring results will be submitted in print and electronic format on an annual basis as part of the of the annual report on Streamflow and Groundwater Conditions. The annual report shall contain data collected during the previous calendar year. The report will include an analysis of water level trends and vertical gradient trends and will identify any areas where additional monitoring points are needed or locations that could be revised. The monthly water level monitoring data will be provided in print and in an electronic Excel data table format. These tables will include the location name, latitude and longitude in decimal degrees, screen length, top of screen, bottom of screen, date collected, water level elevation above mean sea level (MSL), water level depth below ground level, and any other comments relevant to the data quality or monitoring events. The format of the Annual Report is included in **Appendix E**.

- The annual report will also contain an evaluation of the validity and effectiveness of the groundwater model developed by S.S. Papadopulos & Associates (SSPA) and an assessment of the recharge rates used in the groundwater model. The model evaluations are described in **Appendix H**. In addition, should the data not support the existing groundwater model, the conceptual model shall be reviewed and recommended changes along with a schedule for completion shall be submitted in writing to the MDEQ for approval along with the annual report.
- The first monitoring report will describe baseline conditions as defined in the Permit. Baseline conditions will be described based on data collected after approval of monitoring plans/QAPP and the historical data collected at the site beginning as early as June 2000. Permit 1701 requires the baseline report to be submitted to MDEQ before the pumping rate at well PW-101 can be increased above 250 gpm to 400 gpm. Once the pumping rate well PW-101 is increased above the current 250 gpm permit level, annual reports will be submitted (due February 28).

3.4.2 Monthly Reporting

- Monthly reporting will consist of updating the groundwater elevation table with the newly collected data. The table will then be submitted to the MDEQ in electronic format, within seven calendar days of data collection.

3.5 Variances and Equivalent Monitoring

The groundwater activities proposed above are equivalent to the monitoring specified in the Permit, although some locations differ from the monitoring locations described in the Permit. These differences relate primarily to the number of locations where surface-water levels are to be measured monthly.

3.5.1 Monitoring Locations

The "Hydrological and Groundwater" section of Permit 1701 identifies the points to be included in the monitoring plan. This monitoring plan modifies the Permit required points to those described in Section 3.2. The points included in the monitoring plan includes the current points monitored, the new stilling wells (SW-1A and SW-8A), new well set (MW-116s and MW-116d), and proposed wetland monitoring points (to be determined). The Permit required points were modified because several groundwater and surface water monitoring points listed in the Permit no longer exist at the site as they were abandoned for various reasons over time. Monitoring points listed in the Permit that no longer exist at the site are listed on **Table 1**. The table also includes date of discontinued use, reasoning why the point was removed, and equivalent data provided by other monitoring locations.

3.5.2 Schedule

As stated in Section 2.4.2, Permit 1701 requires monthly monitoring of specific monitoring points, however, due to safety concerns and conditions that may affect data quality (frozen monitoring points), NWNA has offered equivalent monitoring for the months of January and February. NWNA proposes the use of transducer data from points upgradient of Production Well PW-101 and from locations between the production well and springs. The transducers which record data daily are:

Monitoring Point	Location
MW-3i	Between Production Well PW-101 and White Pine Springs
MW-9i	Between Production Well PW-101 and Chippewa Springs
MW-104d	Between Production Well PW-101 and Decker Springs
MW-111d	Between Wetlands A and E
MW-114i	Up-gradient location

Data from these locations will be downloaded during the March monitoring event, evaluated for trends, and provided as part of the March monthly data submittal.

In addition, the monitoring conducted in August and September may be adjusted based on antecedent precipitation. The monitoring will be rescheduled if 0.2 inches or more of precipitation occurs in the 48-hours (two calendar days) prior to the scheduled monitoring event.

3.5.3 Reporting

The Permit specifies several different due dates for annual reports depending on the category or type of data. For example, the Streamflow Monitoring Data Report is due December 31, while the Hydrogeological Baseline and Groundwater Data Report is due October 1. To provide a comprehensive technical monitoring report, all reports will be submitted collectively and submitted by February 28th the year following the data collection. If any Permit threshold is exceeded throughout the monitoring year, the MDEQ will be notified and actions will be taken as prescribed. This approach will provide a complete comprehensive scientific study to the MDEQ annually.

The first annual monitoring report (due February 28th) will describe baseline conditions as defined in the Permit. The Permit requires a minimum of one round of monitoring after approval of monitoring plans/QAPP to inform on baseline conditions prior to increasing the pumping rate of PW-101 above 250 gpm. As an increase in the pumping rate will not occur until after submittal of the first annual monitoring report, this monitoring plan proposes that all monitoring rounds completed prior to the end of December in the first year of monitoring be used to inform on baseline conditions.

4 REFERENCES

Arcadis (2019). Quality Assurance Project Plan (Appendix A)

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United States Environmental Protection Agency. (2016, November 3). *Level and Well Depth Measurement: SESD Operating Procedure*. Region 4 Athens, Georgia. Retrieved from https://www.epa.gov/sites/production/files/2017-07/documents/groundwater_level_and_well_depth_measurement105_af.r3.pdf

TABLES

Table 1

Summary of Abandoned Monitoring Points and Discussion of Equivalent Monitoring
NWNA White Pine Springs Site

Monitoring Point ID	Date Abandoned/ Last Monitored*	Discussion
MW-4i	8/12/2003*	MW-4i monitored the intermediate zone of the spring aquifer approximately 1,500 feet SW of the production well PW-101. It was an artesian well that was abandoned because the check valve in the well began leaking. We evaluated the need to replace this well but determined that wells MW-1i and MW-3i (both screened in intermediate zone of spring aquifer), which are located within a few hundred feet to the northeast (towards production well) and east, respectively, provide data that appropriately define groundwater levels in this area.
MW-108i	11/14/2016	MW-108i monitored the intermediate zone of the spring aquifer. This well was damaged and subsequently abandoned. Well MW-108i was located between the production well and Seep-6. We have determined that Wells MW-101i and MW-101d, screened in the intermediate and deep zones of the spring aquifer to the east of MW-108i, provide sufficient data to evaluate water levels in the vicinity of MW-108i.
Seep-1	5/15/2017	Seep-1 monitored the spring seep area located about 1,500 feet south of the production well. This point settled at an angle (or was potentially struck by an animal) so it was removed and replaced by Seep-1R. Seep-1R is located within a couple of feet of Seep-1.
DP-6, DP-7, DP-8	2/19/2009*, 4/24/2009*, 4/24/2009*	These points monitored shallow groundwater elevations on the west side of Twin Creek almost 3,000 feet from the production well. These points are not located on either NWNA or SHC properties and there were issues with accessing these points long-term. They were removed from monitoring after a wind storm in 2009 made the location inaccessible due to fallen trees. After the storm we evaluated the need to replace these points and determined that they points were not useful for understanding effects of pumping as they were located too far from the production well and located on opposite side of the wide creek valley (Wetland R). Closer monitoring points to the production well in Wetland R exist to evaluate effects of pumping. For example, well DP-5 is located between these points and production well PW-101 (closer to pumping).
SW-4, SW-5, SW-7, SW-12	8/7/2001*	These points were used to monitor surface water elevations in Twin Creek and its tributaries in Wetland R along the SHC southwestern property boundary. These points were abandoned to reduce redundant monitoring points at the site. Existing points DP-1 and DP-2 (and new location DP-17 [WT-R-4]) are located between these points and the production well PW-101. In addition, surface water and stream flow measurements are collected upstream (SW-1 and SW-11) and downstream (SW-9/SF-9) on Twin Creek, and upstream on the tributary that flows through White Pine Springs at SW-14.
SW-4-DP, SW-5-DP, SW-7-DP, SW-12-DP	8/7/2001*	These points were used to monitor the groundwater elevation of the shallow groundwater near Twin Creek on the SHC southwestern property boundary. They were abandoned to reduce the number of redundant monitoring points. Points SW-6dp and SW-14dp monitor the shallow groundwater near these abandoned locations and closer to the production well.
SW-10, SW-10R	8/8/2002*, 4/20/2005*	SW-10 was a surface water elevation monitoring point in Twin Creek. This point was removed and replaced by SW-10R. SW-10R was later removed by vandals. This point was not replaced because there are surface water monitoring points located upstream and downstream of the former SW-10 location. SW-13R is located downstream near mouth of Twin Creek and SW-9 is located upstream. In addition, surface water elevations are also collected at the SF-103 location located downstream of the former SW-10 location.
SW-11R	3/18/2014*	SW-11R was a surface water elevation monitoring point on Twin Creek. It was a replacement for SW-11 and was subsequently removed by vandals. Streamflow measurements occur at adjacent location SF-11 and stream depths are measured during each gaging event.
SW-15, SW-15-DP	5/15/2002*	SW-15 was a surface water elevation monitoring point, while SW-15dp monitored the shallow groundwater near the creek. These points were abandoned in an effort to reduce redundant monitoring points. Points SW-14/SW-14-DP are located a short distance up-stream (closer to the production well PW-101) and monitor both the surface water elevation and the shallow groundwater level.

Table 1

Summary of Abandoned Monitoring Points and Discussion of Equivalent Monitoring
NWNA White Pine Springs Site

Monitoring Point ID	Date Abandoned/ Last Monitored*	Discussion
SW-3	1/23/2009*	SW-3 was a surface water elevation monitoring point on a tributary of Twin Creek. This point was abandoned in an effort to reduce redundant monitoring points. New location DP-17 [WT-R-4] is located between former SW-3 and production well PW-101. In addition, surface water elevation and stream flows are monitored at downstream location SW-9/SF-9.
SW-6	10/29/2008*	SW-6 was a surface water elevation monitoring point on a tributary of Twin Creek. This point was abandoned to reduce redundant monitoring points. This location was unreliable for understand effects of pumping as water level significantly influenced by beaver and fallen trees.
SW-13	4/30/2003*	SW-13 was a surface water elevation monitoring point on Twin Creek. The point was a surveyed point on a bridge. This point was replaced with SW-13R (also a surveyed point on the bridge) after construction of a new bridge.
SG-7, SG-8, SG-200	9/23/2004*	Each of these locations were surface water elevation monitoring points. These three points were all located in the small creek feeding into Decker Ponds from the north. The points were removed because water level data from location SG-9, which is located downstream of these abandoned points, provide sufficient data to characterize water levels in this tributary.
SG-10	12/14/2017*	SW-10 was a surface water elevation monitoring point. It was damaged by a fallen tree. It has been replaced by SG-10R.
SG-20	4/30/2003*	SG-20 was a surface water elevation monitoring point. It was located near the mouth of Chippewa Creek over two miles East of the production well. It was abandoned as nearby property owners objected to monitoring at this location. Flows in Chippewa Creek are adequately and appropriately monitored at several other upstream surface water monitoring locations on Chippewa Creek and closer to the production well.
SG-203	5/8/2018	SG-203 was a surface water elevation monitoring point. It was removed when the stream channel changed after the weir was removed, leaving the point out of the stream channel. The point was replaced by SG-203R.
SG-204	10/10/2016*	SG-204 is a surface water elevation monitoring point in the Chippewa Creek watershed. The point is still present and is a part of the monitoring system. This point was set in the pond north of the former hatchery building. This point, however, is no longer located within the pond due to leakage of the existing dam which has lowered the level of the pond. If water levels in the pond rise in the future, data will be collected at this point.
Weir 1	5/15/2017*	Weir-1 was a stream flow monitoring point. There were issues with maintenance of this point (underflow) and after evaluation we determined this point was no longer needed as there are other nearby monitoring points. Surface water elevation is monitored at Vent-2, located near the former Weir-1 location. Stream flows are monitored at downstream locations.

Table 1

Summary of Abandoned Monitoring Points and Discussion of Equivalent Monitoring
NWNA White Pine Springs Site

Monitoring Point ID	Date Abandoned/ Last Monitored*	Discussion
Weir 2	3/19/2014	Weir-2 was a stream flow monitoring point located on small channel tributary of Twin Creek. This point was approved by MDEQ (Fisheries Division). It was removed, however due to flow around the weir. Surface water elevation is monitored at nearby SG-2. In addition, surface water elevation and streamflow are monitored at downstream Twin Creek location SW-9/SF-9.
Weir 3	10/20/2010	Weir-3 was a stream flow monitoring point located on small channel tributary of Twin Creek. This point was abandoned at the request of MDEQ (Fisheries Division). Because there are monitoring points located further downstream we determined that replacement of this point was not necessary. Surface water elevation is monitored at SG-3. In addition, surface water elevation and streamflow are monitored at downstream Twin Creek location SW-9/SF-9.
Weir 5	4/21/2010	Weir-5 was a stream flow monitoring point located on small channel tributary of Chippewa Creek. This point was abandoned at the request of MDEQ (Fisheries Division). Because there are monitoring points located further downstream we determined that replacement of this point was not necessary. SG-5 and SW-5wco monitor surface water elevation near to where Weir-5 was located. In addition, surface water elevation and streamflow are monitored at downstream Chippewa Creek location SG-16/SF-16 (after SHC dams).
Weir 6	4/23/2009	Weir-6 was a stream flow monitoring point located on small channel tributary of Twin Creek. This point was abandoned at the request of MDEQ (Fisheries Division). Because there are monitoring points located further downstream we determined that replacement of this point was not necessary. Seep-6 is located near the former Weir-6 location which monitors surface water elevation near the seep. In addition, location SW-1/SF-1 monitors surface water elevation and streamflow in a downstream Twin Creek tributary.
Weir 7, Weir 8	9/22/2004	Each of these locations (Weirs-7 through 9) were used to monitor stream flow in a small stream that enters the Decker Ponds from the north. These points were abandoned at the request of MDEQ (Fisheries Division). Monitoring of surface water conditions near this tributary continue as follows: (1) Location SG-9 monitors surface water elevation of stream; (2) Locations SG-201 and SG-202 monitor surface water elevation of first two Decker Ponds; (3) Surface water elevation and streamflow are monitored downstream Chippewa Creek at location SG-16/SF-16, which is after the Decker ponds.
Weir 9	3/18/2014	
Weir 10	4/9/2018	Weir-5 was a stream flow monitoring point located on small channel tributary of Chippewa Creek. This point was abandoned at the request of MDEQ (Fisheries Division). Because there are monitoring points located further downstream we determined that replacement of this point was not necessary. SG-10R monitors surface water elevation at the former weir location. In addition, SW-8/SF-8 monitors surface water elevation and streamflow downstream of Weir-10.

Table 2

Current Monitoring Network
NWNA White Pine Springs Site

Monitoring Well ID	Discussion
MW-1u and MW-4u	Monitor wells screened in perched aquifer north of springs.
MW-11s, MW-12s, MW-101s, and MW-105s	Monitor wells screened in shallow portion of source aquifer
MW-1i, MW-2i, MW-3i, MW-5i, MW-6i, MW-7i, MW-8i, MW-9i, MW-10i, MW-12i, MW-13i, MW-102i, MW-103i, MW-104i, MW-107i, MW-108i, MW-112i. MW-114i, and MW-115i	Monitor wells screened in intermediate portion of source aquifer
MW-1d, MW-5d, MW-101d, MW-102d, MW-103d, MW-104d, MW-105d, MW-106d, MW-107d, MW-110d, MW-111d, and MW-113d	Monitor wells screened in deep portion of source aquifer
MW-101L and MW-105L	Monitor wells screened below a dense fine-grained unit at the base of the source aquifer
Drive Point ID	**Discussion**
SW-1-dp, SW-2-dp	Shallow aquifer below eastern tributary of Twin Creek
SW-11-dp, SW-3-dp, SW-10-dp	Shallow aquifer near channel of Twin Creek (at 110th Avenue, 8 Mile Road, and 100th Avenue)
SW-6-dp, SW-14-dp	Shallow aquifer in White Pine Springs
SW-8-dp (WT-A-1)	Wetland A
DP-1, DP-2, DP-3	Shallow aquifer adjacent to White Pine Springs
DP-4 (WT-E)	Wetland E
DP-5	Shallow aquifer at Northern Boomerang Springs
DP-11 (WT-H)	Wetland H
DP-12 (WT-G)	Wetland G
DP-14 (WT-A-2)	Wetland A
DP-15 (WT-CC-1), DP-16 (WT-CC-2)	Wetland CC
DP-17 (WT-R-4), DP-18 (WT-R-5), DP-19 (WT-R-2), DP-20 (WT-R-1)	Wetland R
Seeps and Vents ID	**Discussion**
Seep-1r, Seep-2, Seep-3, Seep-4, Vents 1 and Vent 2	White Pine Springs
Seep-5	Chippewa Springs
Seep-6	Northern Ridge Springs

Table 2

Current Monitoring Network
NWNA White Pine Springs Site

Surface Water ID	Discussion
SW-1, SW-2	Eastern tributary of Twin Creek
SW-3. SW-9, SW-13r,	Twin Creek
SG-2, SG-3, SW-3-wco. SW-4-wco, SW-14	Streams in White Pine Springs area
SG-9	Stream in Wetland CC (Decker Springs area)
SG-5, SW-8, SW-5-wco, SG-10, SG-203	Streams in headwaters of Chippewa Creek
SG-16, SG-17r	Chippewa Creek
SG-18, SG-19	Tributaries to Chippewa Creek
SG-201, SG-202	Decker Ponds
SG-204	Pond at 95th Avenue
DP-11- SG (WT-H-SG)	Wetland H
DP-12-SG (WT-G-SG)	Wetland G
Twin Creek Streamflow Monitoring Location	**Discussion**
SF-1 and SF-2	Tributary of Twin Creek downstream from source in spring area. Location SF-1 has been identified by MDEQ as point to monitor during the Stipulated Period. Location SF-2 is downstream from location SF-1.
SF-11	Twin Creek location upstream of confluence with SF-1 and 2 tributary.
SF-9, SF-10, and SF-13	Twin Creek at 8 Mile Road (SF-9), 100th Avenue (SF-10), and near mouth (SF-13). Note USGS has install monitoring location at SF-9.
Chippewa Creek Streamflow Monitoring Location	**Discussion**
SF-8	Tributary of Chipewa Creek in spring area. Location SF-9 has been identified by MDEQ as point to monitor during the Stipulated Period. Location SF-8 will be equipped with a flume.
SF-16	Chipewa Creek downstream of Decker Ponds.
SF-17	Chipewa Creek downstream of Decker Ponds. Note USGS has install monitoring location at SF-13.
SF-18	Tributary that enters Chipewa Creek downstream of location SF-16.
SF-19	Tributary that enters Chipewa Creek downstream of location SF-17.

Table 3

Evart Daily Precipitation Evaluation
NWNA Whitw Pine Springs Site

Year	Month	Daily Precipitation (inches)																															Monthly Total Precipitation (inches)	Days Meeting Criteria
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31		
2015	JAN		0.2	0.5	0.05	0.18	0.02	0.23	0.11	0.01	0.01	0	0	0	0	0	0	0.06	0.01	0.09	0.07	0	0.02	0	0.02	0	0	0	0.12	0	0	0.55	**2.25**	**3**
	FEB	0	0.14	0.15	0	0	0	0.01	0.07	0.03	0	0.01	0.04	0	0	0	0.02	0.03	0	0.01	0.04	0.01	0	0.22	0.05	0	0	0	0				**0.83**	**1**
	MAR	0	0.19	2.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.35	0	0	0	0	0	0.34	0.03	**3.00**	**20**
	APR	0.05	0	0	0.15	0	0	0.36	0.69	1.43	0	0	0.14	0	0	0	0	0	0	0.68	0.2	0.06	0	0	0	0	0	0	0	0	0		**3.76**	**9**
	MAY	0	0	0.14	0	0	0	0	0.64	0.36	0.63	0.07	0	0	0.84	0	0	0	0	0	0	0	0	0	0.43		0.62	0.01	0	0.64	0.5	0	**4.88**	**9**
	JUN	0	0	0	0	0	0	0.06	0	0	0	2.03	0.01	0.87	0.01	0	0	0	0	0	0	0.24	0	0	0	1.34	0	0	0	0.03	0		**4.59**	**7**
	JUL	0	0	0	0	0.87		0	0	0	0	0	0	1.14	0	0	0.24	0.14	0	0	0.32	0	0	0	0	0	0	0	0	0	0	0.09	**2.8**	**12**
	AUG	0	1.07	0	0	0	0	0.52	0	0.04	0	0	0.11	0	0.08	0	0	1.58	0.05	0.15	0	0	0	0.38	0.04	0.01	0	0	0.12	0	0	0	**4.15**	**1**
	SEP	0	1.05	0.37	0.03	0	0.6		0.03	0	0	0	0	0	0	0	0	0	0.63	0	0	0	0	0	0	0	0	0	1.04	0	0		**3.75**	**13**
	OCT	0	0	0.26	0.04	0.02	0	0	0.72	0	0	0	0.11	0	0	0.06	0	0.01	0	0.06	0	0	0	0.24	0.16	0	0	0.64	0.17	0.02	0.05	0.56	**3.12**	**1**
	NOV	0	0	0	0	0.48	0	0	0	0	0	0.46	0.17	0.02	0	0		0.21	0.11	0	0.03	0.15	0.04	0	0	1.31			0	0.03	0.3		**3.31**	**3**
	DEC	0.01	0	0	0	0	0	0	0	0	0.01	0.01	0.27	1.49	0	0.01	0.03	0.01	0.01	0	0.24	0.01	0.28	0.11			0.45	0	0.98	0.1	0	0.01	**4.03**	**5**
2016	JAN		0	0.03	0	0	0	0	0.3	0.39	0.03	0.16	0	0.11	0	0.01	0	0.03	0	0.03	0	0	0	0	0	0.23	0	0.04	0	0	0	0.32	**1.68**	**3**
	FEB	0	0.95	0	0.03	0	0	0	0	0	0	0	0.04	0	0.07	0	0.03	0	0	0.12	0	0	0	0	0.33	0	0	0	0	0.22			**1.79**	**6**
	MAR	0	0	0	0.18	0	0	0	0.07	0	0	0	0	0.59	0	0.91	0.01	0	0	0	0	0	0.29	0.65	0.17	0	0	0.99	0	0	1.51	0	**5.37**	**3**
	APR	0.07	0	0.09	0	0.54	0.1	0	0	0.02	0.16	0	0	0	0	0	0	0	0	0	0.23	0.06	0	0	0.1	0.2	0	0.3	0.08	0	0.19		**2.14**	**6**
	MAY	0	0	1.28	0.12	0	0	0	0	0	0	0	0	0.34	0.09	0	0	0	0	0	0	0	0	0	0.16	0.45	0.06	0.12	0	0	0	0.29	**2.91**	**11**
	JUN	0	0	0	0.78	0	0.4	0	0	0	0.33	0	0.06	0	0.35	0.2	0	0	0	0	0	0.01	0	0	0	0	0.74	0	0	0	0.47		**3.34**	**3**
	JUL	0	0	0	0	0	0	0.42	0.85	0	0	0.02	0.39	0.02	0	0	0	0	0	0	0.39	0	0	0.28	0.3	0	0.07	0	0.06	0	0	0	**2.8**	**6**
	AUG	0	0	0	0	0	0	0	0	0	0	0.01	1.49	0.06	0	0.22	0.07	0.04	0	0	0.19	0.1	0	0.01	0	0	0.25	0.13	0	0	0	0	**2.57**	**11**
	SEP	0	0	0	0		0.09	1.32	0.02	0.02	0.16	0	0.1	0	0	0	0.35	0	0	0.02	0.24	0.02	0.03	0	0	0.16	0.16	0.12	0	0.19	0.58		**3.58**	**4**
	OCT	0.73	0.03	0	0.28	0.04	0.36	0.01	0	0	0	0.02	0.2	0	0	0.55	0.04	0	0	0	0	0	0	0	0	0.37	0.55	0	0	0.02	0	0.03	**3.23**	**5**
	NOV	0.07	0.12	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0.13	0	0	0	0.04	0.39	0	0	0.01	0.15	0.74	0	0.04		**1.71**	**8**
	DEC	0	0	0	0.32	0	0	0.03	0	0.01	0.17	0.58	0	0.03	0	0	0.73	0.02	0	0	0	0	0.44		0	0.33		0	0	0.05	0.03	0	**2.74**	**1**
2017	JAN	0.09		0.04	0.01	0	0	0.01	0	0.63	0.31	0.16	0	0	0	0	1.02	0	0	0.07	0	0.01	0.02	0.24	0.08	0.41	0.03	0.15	0	0	0.23	0.05	**3.56**	**1**
	FEB	0	0	0	0.01	0	0.05	0.1	0.04	0	0	0.12	0.03	0	0	0	0	0	0	0	0	0	0	1.86	0.04	0	0	0	0.45				**2.7**	**7**
	MAR	0.51	0.05	0.04	0	0	0	0	0	0	0	0	0.3	0.02	0	0	0	0.14	0	0	0	0	0	0.33	0	0.33	0.13	0	0	0.63	0.19	0	**2.67**	**7**
	APR	0	0.13	1.37	0.02	0.47	0	0	0	0.25	0.32	0	0.04	0	0.34	0.39	0.01	0	0	0.55	0.06	0	0	0	0	0.04	0.05	0	0	0.53	0.95		**5.52**	**0**
	MAY	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0.32	0	0.15	0	0	0.13	0.02	0.12	0.06	0	0	0	0	0		0	0	**0.95**	**12**
	JUN	0	0	0.63	0	0	0	0	0	0	0	0.33	0	0.15	1.23	0	0.13	0.25	0.01	0	0	1.2	2.46	0	0.01	0	0	0	0.58	0	0		**6.98**	**5**
	JUL	0	0	0	0	0	0.28	0	0	0.03	0	0.07	0.49	0	0	0	0	0	0	0	0	0.11	0.1	0	0	0.64	0.36	0	0	0	0	0.22	**2.3**	**10**
	AUG	0	0	0.93	0.01	0	0.07	0	0	0	0.2	0.01	0	0	0.05	0	0.62	0.06	0	0	0	0.83	0	0	0	0	0	0.35	0	0	0	0	**3.13**	**3**
	SEP	0	0.13	0.61		0.18	0.06	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0		**1.21**	**18**
	OCT	0	0	0.88	0	0.08	0.06	0.42	0	0	0.88	0	0	0.04	0.85	0.03	0	0	0	0	0	0	2.35	2.04	0.25	0	0.08	0.03	0.02	0.06	0.09	0	**8.16**	**4**
	NOV	0.21	0	0.01	0.24	0	0	0	0.16	0.05	0	0	0	0	0.8	0	0	0.71	0.23	0.01	0	0	0.01			0.01	0	0	0.01	0.06	0		**2.51**	**1**
	DEC	0	0	0.26	0.01	0	0.05	0.01	0.28	0	0.05	0.07	0.48	0.07	0.28	0.12	0	0.07	0	0	0	0	0.13	0	0			0.09	0.04	0.02			**2.03**	**1**
2018	JAN		0.03	0.01	0	0	0	0.07	0	0.03	0.35	0.52	0	0	0.19	0.01	0	0	0	0	0	0.55	0.45	0	0	0	0	0	0.07	0	0.02	0	**2.3**	**4**
	FEB	0.03	0.05	0.63	0	0.05	0	0	0.08	0	0.34	0	0	0	0	0	0	0	0	2.75	0.17	0	0	0	0.18	0	0	0	0				**4.28**	**6**
	MAR	0	0	0	0	0.37	0.04	0.01	0	0	0	0.07	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0.42	0	0.06	0	0.27	0	**1.26**	**14**
	APR	0	0.17	0.31	0	0.3	0	0	0	0	0	0.19	0.31	1.41	0.68	0.2	0.07	0	0	0	0	0	0	0.12	0.04	0	0	0	0	0	0		**3.8**	**9**
	MAY	0.08	0.75	0.74	0	0	0.02	0	0	0.61	0.06	0.23	0	0	0.3	0	0	0	0.75	0	0.06	0.07	0	0	0	0	0.93	0	0	0	1.13	0	**5.73**	**1**
	JUN	0	0.17	0.09	0	0	0	0	0.12	0	0	0	0	0	0	0.08	0	0.36	0.01	0	0	0	0	0	0	0	0	0	0	0	0		**0.83**	**13**
	JUL	0	0	0	0	0	0	0	0	0	0	0	1.13	0.12	0	0	0	0	0	0.10	0.45	0.03	0	0	0	0	0	0	0	0	0	0	**1.83**	**20**
	AUG	2.07	0	0	0	0	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	1.16	0	0	0	0.07	0	1.13	0.47	0.98	0	0.2	0.12	**6.35**	**11**
	SEP	0.45	0.72	0.5	0	0.82	0	0	0	0	0	0	0	0	0	0	0	0	0	0.32	0	0	0	0	0.21	0.03	0.12	0	0.01	0.04	0.02		**3.24**	**11**
	OCT	0.32	0.78	1.01	0.13	0.45	0	0	0.81	0	0.45	0.03	0	0	0	0	0	0	0	0	0.21	0.13	0.07	0	0	0	0	0	0	0	0.21	0.33	**4.93**	**9**
	NOV	0	0	0	0.37	0.44	0.73	0	0	0	0.19	0.03	0	0	0	0	0.09	0.1	0	0	0	0	0	0	0.18	0	0.06	0.02	0	0	0	0	**2.21**	**5**
	DEC	0.87	0.07	0.01	0	0	0.03	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0.11	0	0	0	0	0	0	0.09	0	0	0	0.89	**2.10**	**9**

Table 4
Groundwater Elevation Summary
NWNA White Pine Springs Site

Well ID	Latitude	Longitude	Screened Interval (ft bgs)	Boring/well construction Logs	Groundwater Elevations (ft amsl)										
					3/16/2017	4/10/2017	5/15/2017	6/12/2017	7/11/2017	8/14/2017	9/12/2017	10/11/2017	11/14/2017	12/14/2017	3/13/2018
MW-1d	-85.294239	43.9359204	103.50-108.50	yes/yes	1098.67	1098.74	1098.91	1098.81	1098.71	1098.56	1098.44	1098.34	1098.58	1098.73	1098.81
MW-1i	-85.294227	43.9359366	33.50-38.50	yes/yes	1096.89	1096.95	1097.12	1097.02	1096.91	1096.77	1096.66	1096.58	1096.78	1096.93	1097
MW-5d	-85.291969	43.9359873	153.00-158.00	yes/yes	1099.63	1099.73	1099.87	1099.71	1099.62	1099.42	1099.29	1099.19	1099.53	1099.65	1099.73
MW-5i	-85.29195	43.9359613	90.00-100.00	yes/yes	1098.33	1098.46	1098.58	1098.44	1098.29	1098.16	1098.04	1097.93	1098.16	1098.33	1098.42
MW-101d	-85.296582	43.9400605	150.00-160.00	yes/yes	1122.45	1122.35	1123.07	1122.9	1122.72	1122.83	1122.58	1122.19	1122.85	1122.68	1122.97
MW-101s	-85.293775	43.9401151	65.00-75.00	yes/yes	1114.5	1114.48	1114.88	1114.88	1114.78	1114.61	1114.43	1114.24	1114.43	1114.55	1114.7
MW-104d	-85.286742	43.9388974	175.00-185.00	yes/yes	1110.99	1110.92	1111.4	1111.2	1111.11	1111.1	1110.94	1110.57	1110.88	1111.03	1111.29
MW-104i	-85.286737	43.9389251	120.00-130.00	yes/yes	1110.96	1110.88	1111.36	1111.2	1111.12	1111.08	1110.94	1110.56	1110.88	1111.04	1111.28

Well ID	Vertical Hydraulic Gradient										
	3/16/2017	4/10/2017	5/15/2017	6/12/2017	7/11/2017	8/14/2017	9/12/2017	10/11/2017	11/14/2017	12/14/2017	3/13/2018
MW-1d MW-1i	-0.0252	-0.0253	-0.0253	-0.0253	-0.0254	-0.0253	-0.0252	-0.0249	-0.0254	-0.0254	-0.0256
MW-5d MW-5i	-0.0216	-0.0211	-0.0214	-0.0211	-0.0221	-0.0209	-0.0208	-0.0209	-0.0228	-0.0219	-0.0218
MW-101d MW-101s	-0.0936	-0.0927	-0.0964	-0.0944	-0.0935	-0.0968	-0.0960	-0.0936	-0.0992	-0.0957	-0.0974
MW-104d MW-104i	-0.0005	-0.0007	-0.0007	0.0000	0.0002	-0.0004	0.0000	-0.0002	0.0000	0.0002	-0.0002

Notes:
ft amsl - feet above mean sea level
ft bgs - feet below ground surface

1. Vertical hydraulic gradients are calculated for data collected from March 2017 through March 2018.
Positive values indicate flow direction is down and negative values indicate flow direction is up.

FIGURES

CITY: LANSING DIV: ENV DB: D.AKENS PIC:S.INSALACO PM:B.RUST TM:L.EENIGENBURG TR: PROJECT NUMBER: USA71817 COORDINATE SYSTEM: NAD 1983 StatePlane Michigan South FIPS 2113 Feet
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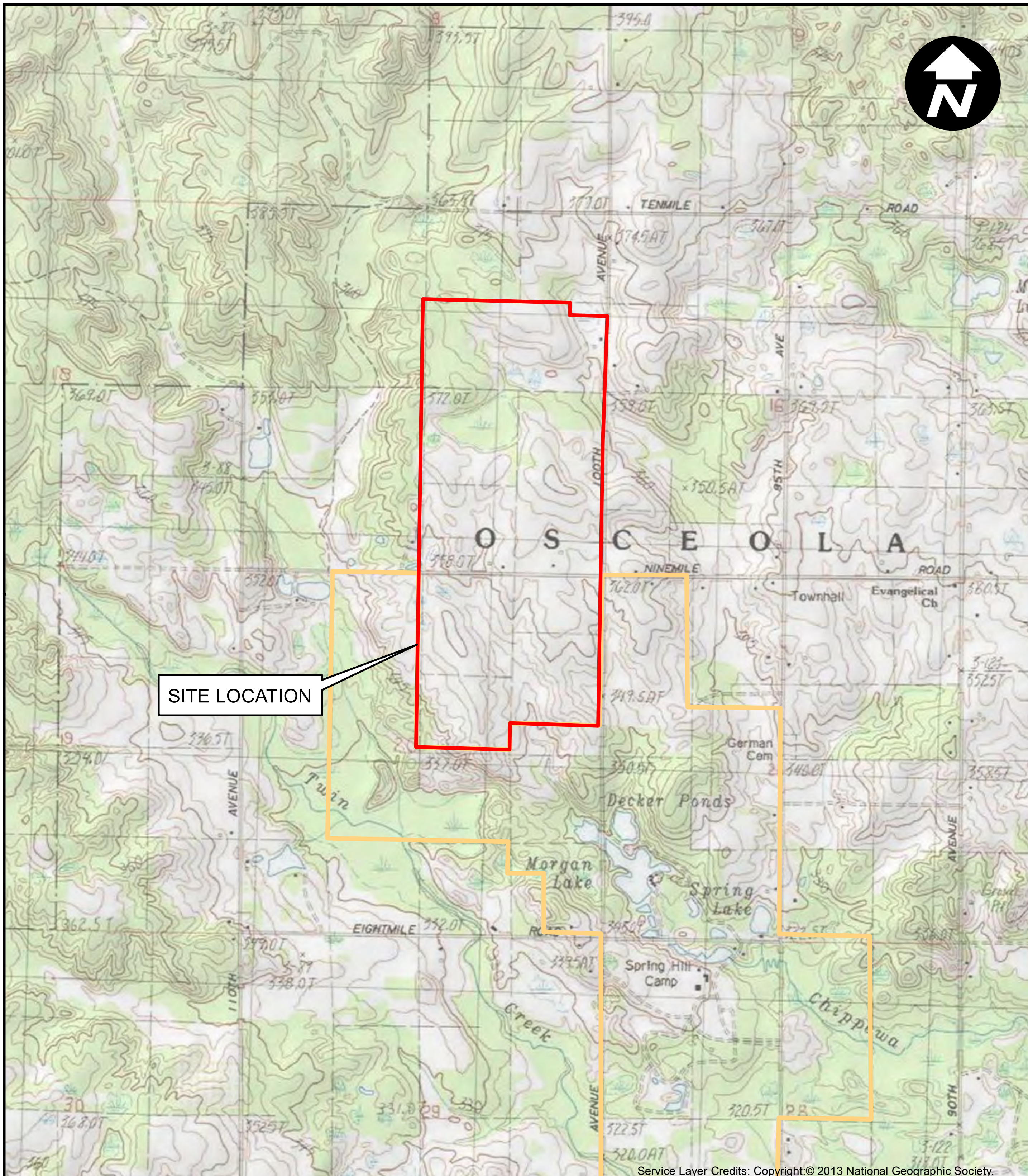


USGS 7.5' TOPOGRAPHIC MAP AREA SHOWN NAMED, "EVART"

0 2,000 4,000
Feet

Legend

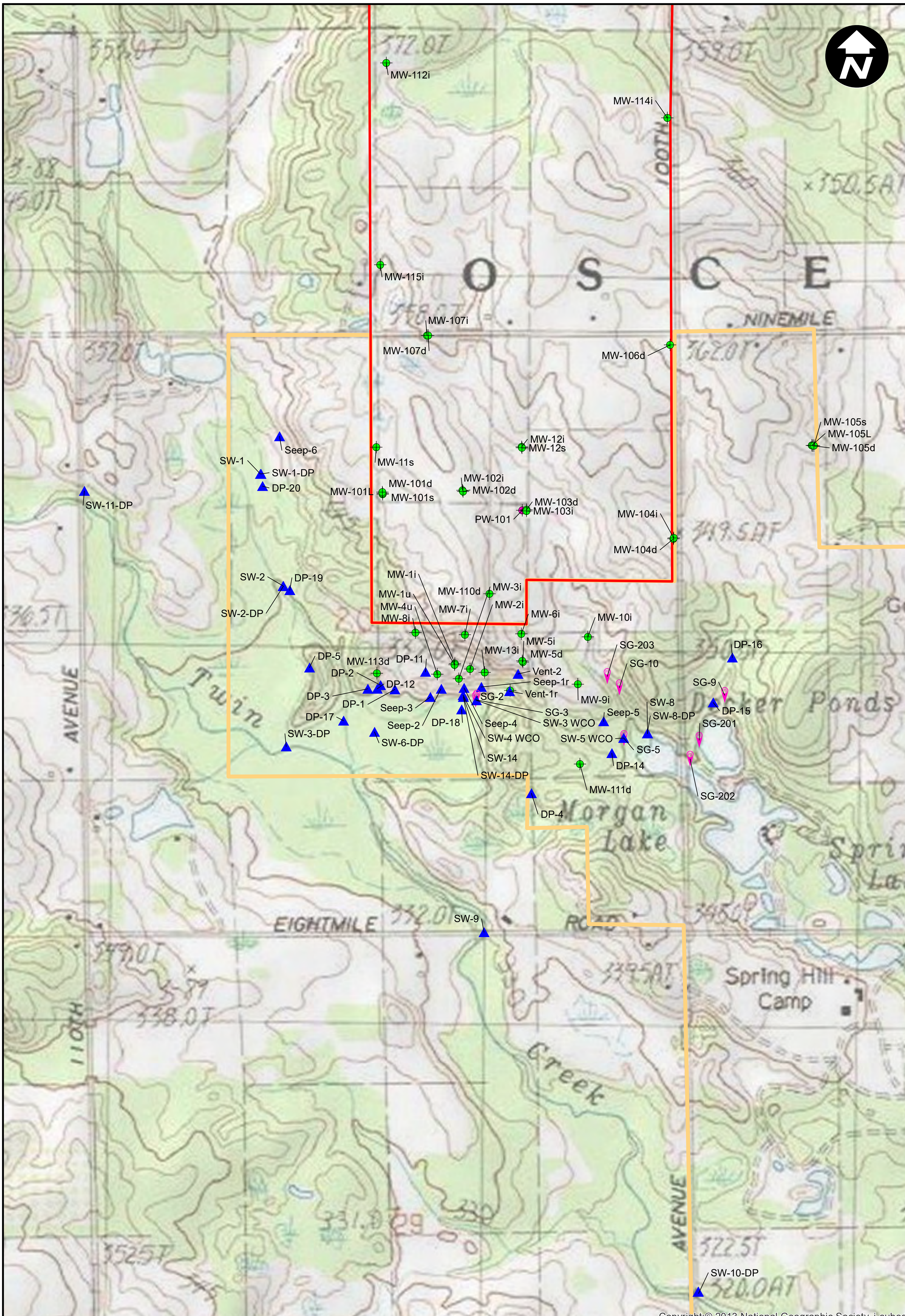
- Nestle Property
- SHC Property

NESTLE WATERS NORTH AMERICA
WHITE PINE SPRING SITE

SITE LOCATION MAP

ARCADIS Design & Consultancy for natural and built assets

FIGURE
1



Legend

- ▲ Drive Point
- Monitoring Well
- Production Well
- Staff Gage
- Nestle Property
- SHC Property

0 800 1,600
SCALE IN FEET

NESTLE WATERS NORTH AMERICA
WHITE PINE SPRING SITE

LONG TERM MONITORING NETWORK

ARCADIS Design & Consultancy for natural and built assets

FIGURE 2

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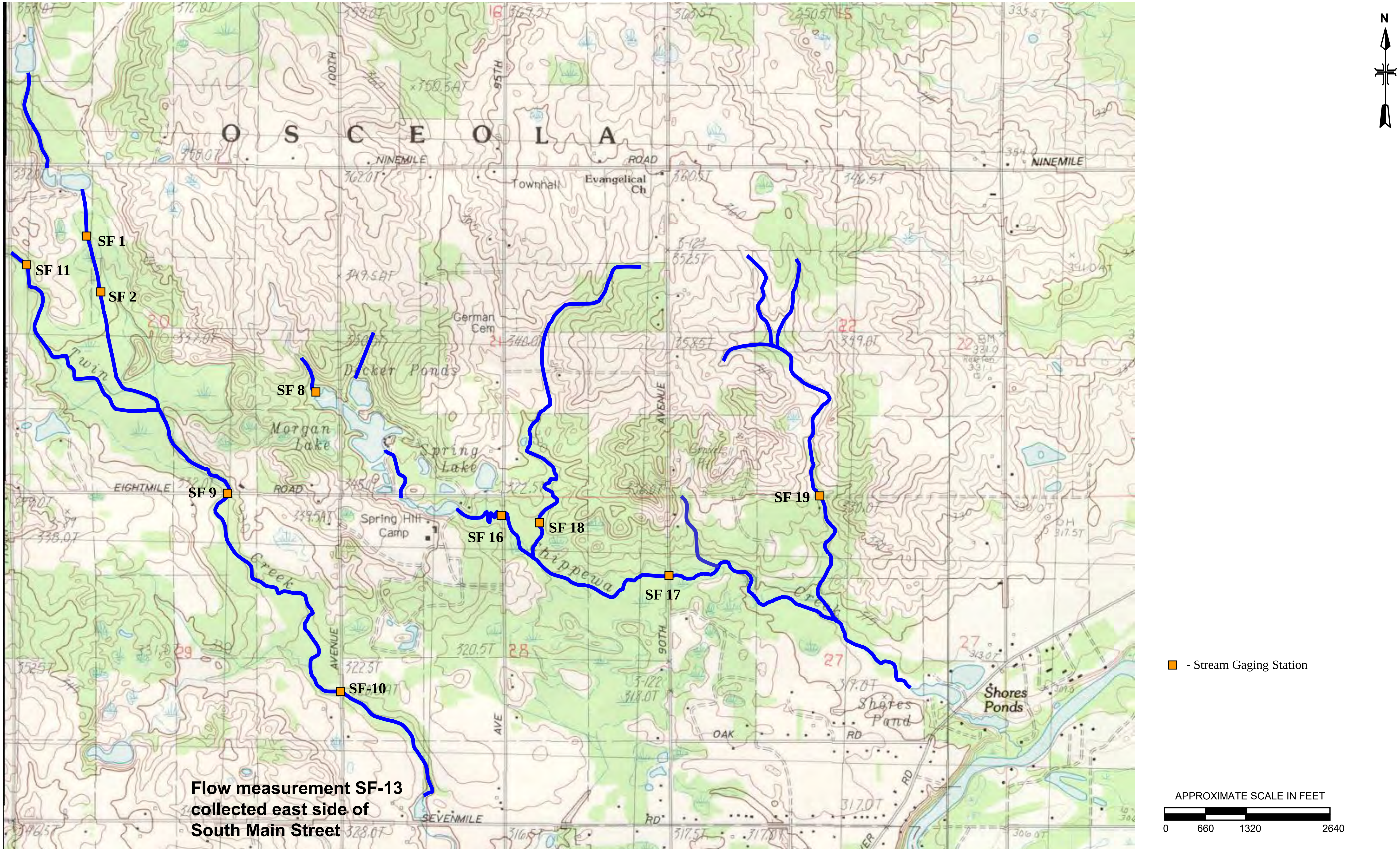

SOURCE: USGS, Evart, MI Quadrangle (1983)

Updated 2-6-03 J/projects/4065031/monitoring locations.ppt

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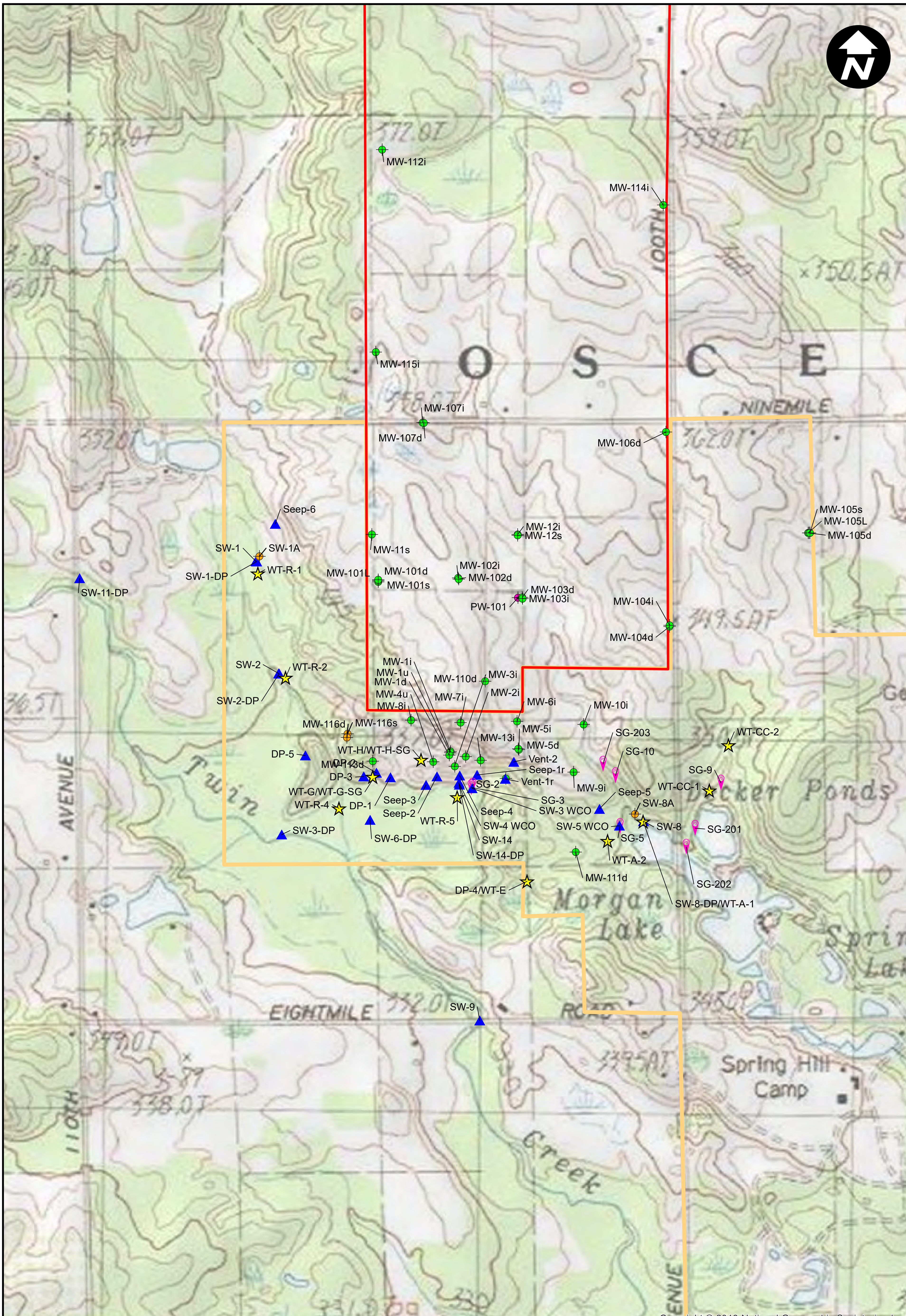
NESTLE WATERS NORTH AMERICA
WHITE PINE SPRINGS SITE

STREAM FLOW MONITORING LOCATIONS

FIGURE 2A



Legend

- New Locations
- Newly Installed Monitoring Well
- Drive Point
- Monitoring Well
- Production Well
- Staff Gage
- Nestle Property
- SHC Property

0 800 1,600

SCALE IN FEET

NESTLE WATERS NORTH AMERICA
WHITE PINE SPRING SITE

PERMIT MONITORING NETWORK

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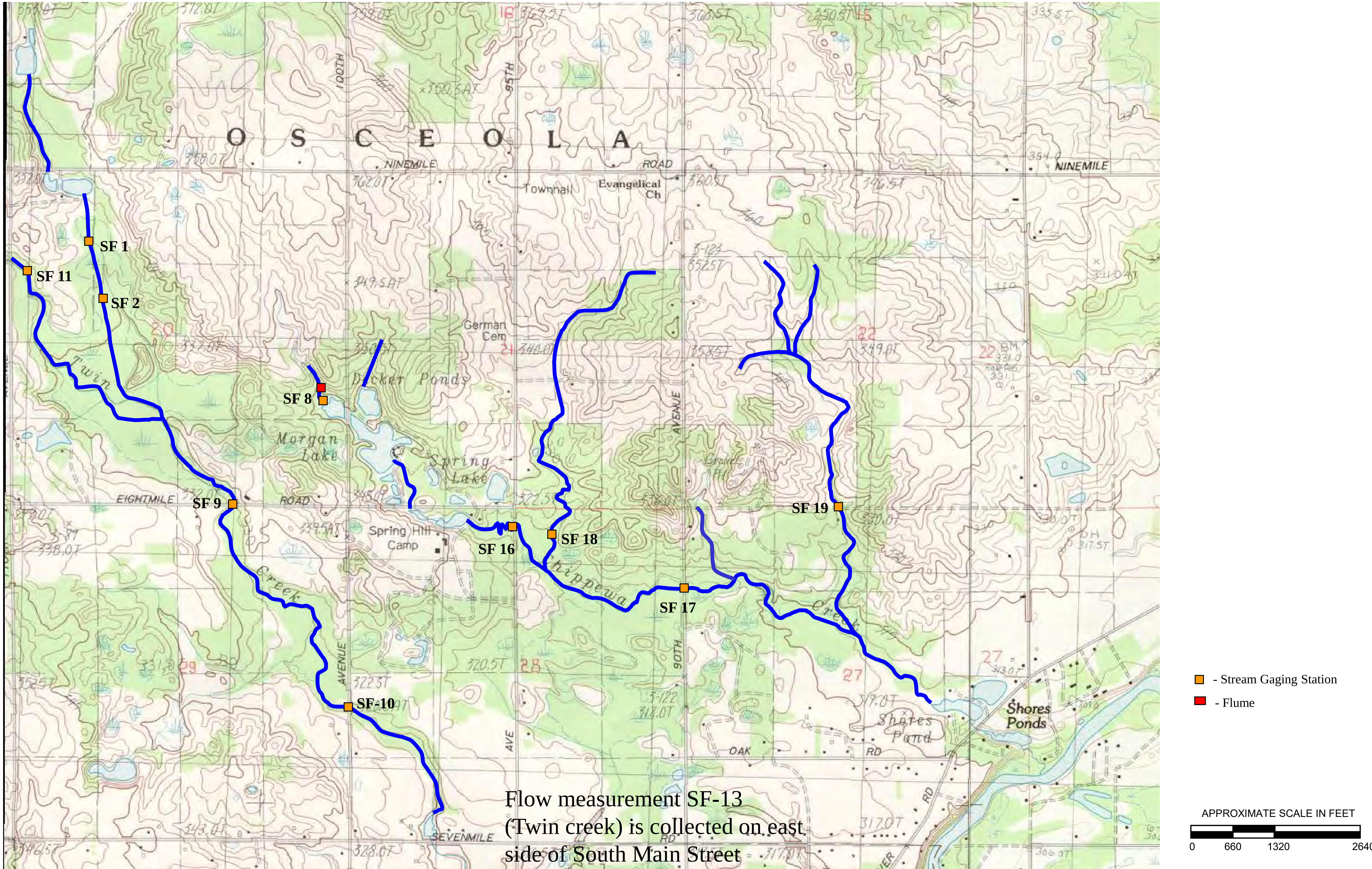
FIGURE

3

Z:\GISProjects_ENV\NoviBrighton_MI\4065010\NESTLE\Permit_Mon_Net_fig3_2019.mxd PLOTTED: 4/9/2019 8:10:49 AM BY: akens



SOURCE: USGS, Evart, MI Quadrangle (1983)

Updated 2-6-03 J/projects/4065031/monitoring locations.ppt

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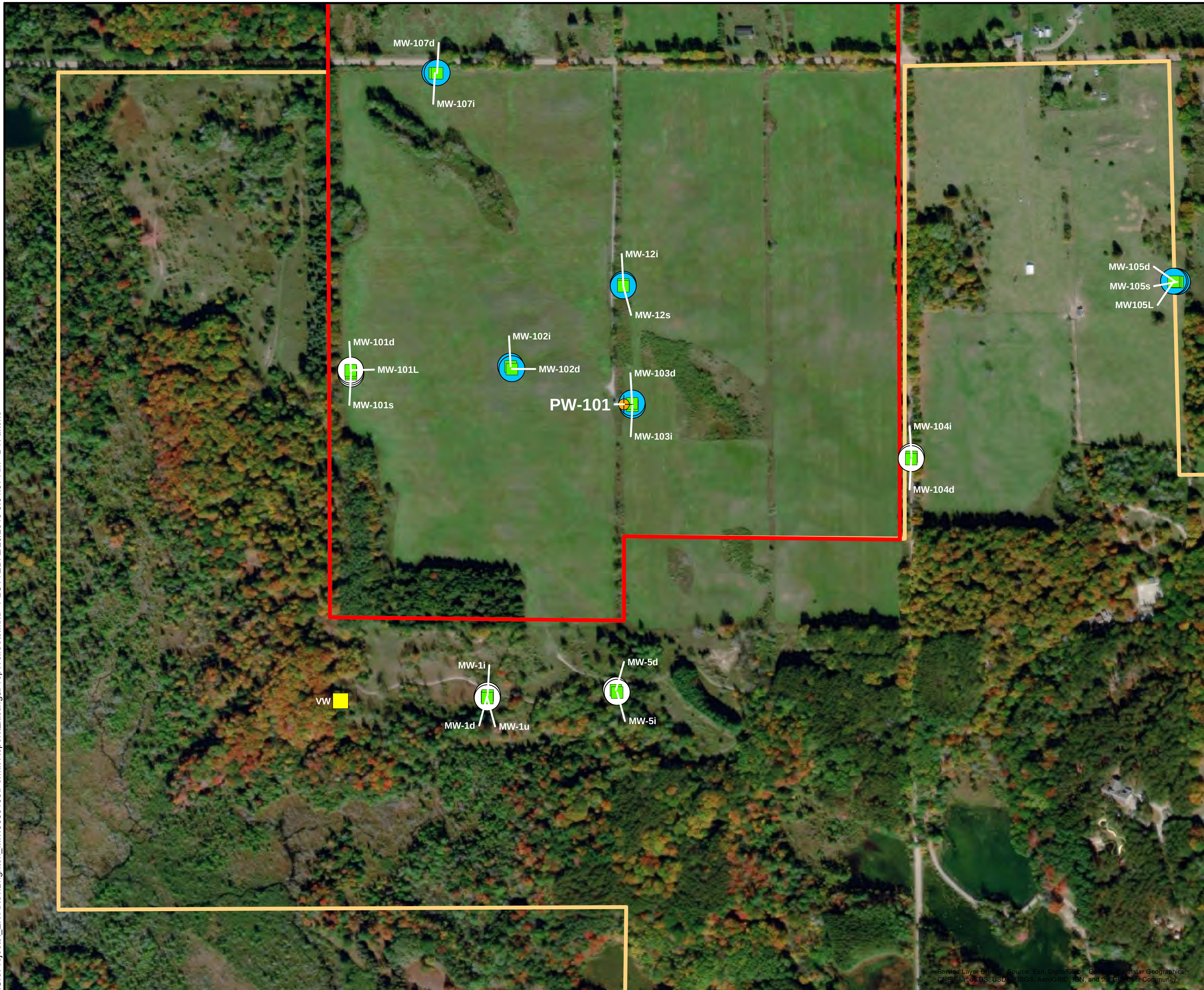
NESTLE WATERS NORTH AMERICA
WHITE PINE SPRINGS SITE

PERMIT STREAM FLOW MONITORING LOCATIONS

FIGURE 3A



Legend

- PRODUCTION WELL
- MONITORING WELLS
- LOCATIONS TO ADDRESS MDEQ VERTICAL LOCATIONS
- ADDITIONAL LOCATIONS WITH WELL SETS
- PROPOSED VERTICAL WELL SET
- NESTLE PROPERTY
- SHC PROPERTY

NOTES:

U = DENOTES "UPPER" WELLS SCREENED IN SHALLOW UPPER SATURATED ZONE (PERCHED) ABOVE CLAY LAYER - SEPARATED FROM SOURCE AQUIFER
s = DENOTES "SHALLOW" WELLS SCREENED WITHIN SOURCE AQUIFER
i = DENOTES "INTERMEDIATE" WELLS SCREENED WITHIN SOURCE AQUIFER
d = DENOTES "DEEP" WELLS SCREENED WITHIN SOURCE AQUIFER
L = DENOTES "LOWER" WELLS SCREENED BELOW A DENSE FINE-GRAINED UNIT AT BASE OF SOURCE AQUIFER.

0 450 900
SCALE IN FEET

NESTLE WATERS NORTH AMERICA
WHITE PINE SPRING SITE

EXISTING AND PROPOSED WELL SETS

ARCADIS Design & Consultancy for natural and built assets

FIGURE
4

CITY: Novi DIV: ENV DB: TRY PIC: PM: TM: TR: PROJECT NUMBER: COORDINATE SYSTEM: Oblique Mercator (Hotine)
Z:\GISProjects_ENV\NoviBrighton_MI\40650100\Permit Report\Existing&PropWellSets.mxd PLOTTED: 2/26/2019 9:54:57 AM BY: akens

APPENDIX A

Quality Assurance Project Plan

ARCADIS Design & Consultancy for natural and built assets

Nestlé Waters NORTH AMERICA

QUALITY ASSURANCE PROJECT PLAN

Streamflow and Hydrological Baseline and Groundwater

White Pine Springs Site

Evart, Michigan

April 2019

QUALITY ASSURANCE PROJECT PLAN

Streamflow and Hydrologic Baseline and Groundwater
White Pine Springs
Evart, MI

Mike Pozniak, PG
Senior Geologist

Greg Foote, CPG
Principal Hydrogeologist/Project Manager

Prepared for:

NORTH AMERICA

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Prepared by:

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Lansing, Michigan 48933

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Our Ref.:

040645121.0000.00002

Date:

April 2019

CONTENTS

TABLES

FIGURES

APPENDICES

ACRONYMS AND ABBREVIATIONS

ADV	Acoustic Doppler Velocimeter
BBP	blood-borne pathogen
bgs	below ground surface
BS	Bachelor of Science
COE	City of Evart
CPR	cardiopulmonary resuscitation
DP	Drive Point
FA	first aid
gpm	gallons per minute
ID	inner diameter
LTM	long-term monitoring program
MDEQ	Michigan Department of Environmental Quality
MS	Master of Science
MW	Monitoring Well
NWNA	Nestle Waters North America
PM	Project Manager
PVC	polyvinyl chloride
PW	Production Well
QC	quality control
QAPP	Quality Assurance Project Plan
SG	Staff Gauge
SNR	signal to noise ratio
SW	Stilling Well
TGI	Technical Guidance Instructions
TOC	top of casing
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WPS	White Pine Springs
WWTP	Wastewater Treatment Plant

1 INTRODUCTION

Nestlé Waters North America (NWNA) was issued Water Supply Permit 1701 (Permit 1701); Water Supply Serial Number 2016667 for Production Well PW-101; on April 2, 2018 by the Michigan Department of Environmental Quality (MDEQ). Production Well PW-101 is part of the White Pine Springs (WPS) site located in Osceola Township, Osceola County, Michigan (**Figure 1**). Permit 1701 was approved under Section 17 of the Michigan Safe Drinking Water Act (1976 Public Act 399 as amended) and allows NWNA to increase the maximum pumping rate at PW-101 from 250 to 400 gallons per minute (gpm).

General Condition #5 of Permit 1701 states that NWNA must, "…submit monitoring plans and Quality Assurance Project Plans (QAPP) to the Department for consideration and approval and required by the special conditions section of this permit." Permit 1701 further states, "The monitoring plans must include the required elements detailed in the special conditions section of this permit. The permit holder [NWNA] may propose equivalent monitoring in place of the special conditions for Department consideration and approval."

This QAPP has been prepared by Arcadis of Michigan LLC (Arcadis) on behalf of NWNA to meet the requirements set forth in General Condition #5 of Permit 1701. This QAPP pertains specifically to the Streamflow (pages 6 and 7 of Permit 1701) and Hydrological Baseline and Groundwater (pages 8 through 10 of Permit 1701) sections of the Permit. This QAPP provides procedures for data collection, data validation, and administration activities to be performed before, during, and after field monitoring activities at the WPS site. These procedures provide methods for consistent and accurate data collection including:

- monitoring point installation,
- preventative maintenance, equipment calibration,
- field measurement and monitoring, data management,
- training.

1.1 Title and Approval Page

Site Name:	White Pine Springs
Site Location:	Evart, Michigan
Document Title:	Quality Assurance Project Plan Hydrologic Monitoring
Lead Organization:	
Preparer's Name and Organizational Affiliation:	Greg Foote, Arcadis
Preparer's Contact Information:	300 S Washington SQ, Suite 315 Lansing, MI 48933 517-324-5042 greg.foote@arcadis.com
Preparation Date:	April 2019
Arcadis Project Manager	Signature Greg Foote, Arcadis
Arcadis Quality Manager	Signature Mike Pozniak, Arcadis

1.2 Distribution List

QAPP Recipients	Title	Organization	Telephone Number	E-mail Address
Arlene Anderson Vincent	Natural Resource Manager	NWNA	231-823-8451	arlene.anderson-vincent@waters.nestle.com
Leah Clark	Geologist	MDEQ	517-284-5566	clarkl13@michigan.gov
Jill Van Dyke	Geologic Specialist	MDEQ	517-284-5565	vandykej1@michigan.gov
Matt Gamble	Water Unit Supervisor	MDEQ	517-897-1508	gamblej1@michigan.gov
Greg Foote	Project Manager	Arcadis	517-324-5042	greg.foote@arcadis.com
Mike Pozniak	Quality Manager	Arcadis	517-324-5054	mike.pozniak@arcadis.com
Amanda Robinson	Task Manager	Arcadis	248-994-2287	amanda.robinson@arcadis.com
Kaitlyn Voet	Field Lead	Arcadis	248-809-4013	kaitlyn.voet@arcadis.com

Note:

Copies of this QAPP will be distributed to the individuals listed above and will be made available to other key personnel who will be assigned to work on the project. Those named above will be responsible for distributing this QAPP and related documents to others in their organization. The copies will include this QAPP and any subsequent revisions and addenda.

1.3 Project Personnel Sign-Off Sheet

Name	Project Title/ Role	Education/ Experience	Specialized Training/ Certifications for Project Title/Role	Signature/Date
Greg Foote	Project Manager	Bachelor of Science (BS) Geology, Minor Mathematics Master of Science (MS) Geology 28+ years of experience	- -	
Mike Pozniak	Quality Manger	Associate of Applied Science Civil Engineering Technology BS Geology MS Geology 30+ years of experience	- -	
Amanda Robinson	Task Manger	BS Environmental Geosciences, Geophysics Specialization MS Environmental Geosciences, Environmental Toxicology Specialization 4+ years of experience	First Aid (FA)/Cardiopulmonary Resuscitation (CPR)/Blood Borne Pathogens (BBP)	
Kaitlyn Voet	Field Lead	BS Geological Engineering 2+ years of experience	FA/CPR/BBP	

Note:

The project personnel sign-off table above documents key project personnel who have read the applicable sections of and will perform required activities in accordance with this QAPP.

*Staff listed above are the primary project personnel. Staff will be added as appropriate through duration of the project.

1.4 Communications Pathways

Communication Drivers	Responsible Entity	Name	Phone Number	Procedure (e.g., Timing, Pathways)
Manage all project phases	Arcadis	Greg Foote	517-324-5042	Will serve as the Arcadis liaison to the MDEQ and NWNA.
Field work implementation	Arcadis	Greg Foote Mike Pozniak	517-324-5042 517-324-5054	Arcadis will inform MDEQ and client about upcoming field work. The information will be documented using phone logs or email.
Coordinate field program	Arcadis	Mike Pozniak Amanda Robinson	517-324-5054 248-994-2287	To be notified by field personnel of field-related questions on problems by phone or email by the close of business the next business day.
Reporting of issues	Arcadis	Greg Foote	517-324-5042	Report any serious issues to the MDEQ and NWNA, and other concerned parties within 24 hours by telephone or email.
Approval of amendments to the QAPP	Arcadis	Mike Pozniak	517-324-5054	Obtain initial approval from the Arcadis Project manager (PM) and submit document amendments within 10 business days to the MDEQ and NWNA for approval.
Real time modifications to QAPP	Arcadis	Mike Pozniak Amanda Robinson	517-324-5054 248-994-2287	To be notified by Arcadis Field Lead or Field Staff of any changes to QAPP made in the field and reasons by phone or email within two business days. Will promptly notify the Arcadis PM of any such changes

2 MONITORING PROGRAM

NWNA initiated the White Pine Springs Long-Term Monitoring (LTM) program at the start of hydrologic investigations for the spring source in June 2000. One of the primary purposes of the LTM program was to document the natural variability in the hydrologic system before pumping occurred. After production well PW-101 was permitted in 2009 and groundwater withdrawal began, the LTM program continues to evaluate the hydrologic system. In addition, climatic data (precipitation) is obtained from the City of Evart (COE) Wastewater Treatment Plant (WWTP).

Data are collected from a network of monitoring locations that were constructed as part of the long-term monitoring (LTM) program. The current monitoring network consists of:

- 38 monitoring wells;
- 21 shallow groundwater drive points;
- Nine wetland points;
- Eight stilling wells to measure surface water levels;
- 14 staff gauges that are used to measure surface water levels in springs, wetlands, and streams;
- Two surveyed bridge abutments from which surface levels in Twin Creek and Chippewa Creek are measured;
- 12 gauging stations where streamflow is manually measured with an acoustic Doppler velocimeter (ADV) or an electromagnetic flow meter.

Field protocols and quality assurance processes were developed and implemented at the start of the WPS LTM program. These protocols and procedures have been modified (as needed) throughout the LTM program. An example of modifying the protocols and procedures would be the introduction of new equipment. The protocols and procedures will continue to be followed for the Permit 1701 required monitoring as documented in this QAPP.

As required by Permit 1701 and identified in the Streamflow and Hydrological Baseline and Groundwater or the Wetland Monitoring Plans (Arcadis, 2019 and Environmental Consulting & Technology, INC. [ECT], 2019), the following monitoring points will be added:

- Well set (MW-116s and MW-116d) to be installed at the northeast side of Northern Boomerang Springs to monitor water levels and the vertical gradients near the springs and in wetland R.
- Stilling wells at SW-1A (Twin Creek) and SW-8A (Chippewa Creek).
- Flume at SF-8 (Chippewa Creek).
- Drive points at 11 wetlands (A, B, C, D, E, G, H, Q, R, CC, and DD). The monitoring at these wetlands will consist of existing points SW-8-DP/WT-A-1, DP-4/WT-E, WT-A-2, WT-G, WT-H, WT-CC-1, WT-CC-2, WT-R-1, WT-R-2, WT-R-4, and WT-R-5, and six additional locations proposed in the wetland monitoring plan (ECT, 2019). Transducers will be employed in each of these points to monitor daily water levels from mid-May through mid-November.

Table 1 identifies the points that will be monitored in accordance with Permit 1701, while **Figures 2** and **2A** illustrate the locations.

The Streamflow section of Permit 1701 identifies a period of continuous streamflow monitoring (June 1 through October 31) at locations SF-1 and SF-8. Stage will be measured hourly at these two locations during this period with rating curves used to estimate flow. The QAPP refers to the period of continuous streamflow monitoring as the Continuous Monitoring Period.

3 PERMIT TASKS

3.1 Installation of Monitoring Points

Existing monitoring points have been installed over the past 18 years by professionally-trained geologist and/or licensed professionals. Permit 1701 requires the installation of additional monitoring points (monitoring wells, flume/stilling well, stilling well [Arcadis, 2019] and drive points [ECT, 2019]). Installation and construction methods of new monitoring points are discussed in the following sections. When a new subsurface monitoring point (monitoring well or drive point) is installed, the drilling methods, soil descriptions, and well construction details will be recorded on boring and well construction logs (**Appendix A**). Other monitoring point installations will be documented in the field notes. The construction details for the new monitoring points will be provided in the baseline report.

3.1.1 Monitoring Wells

Two new monitoring wells (MW-116s and MW-116d) will be installed by a licensed Michigan driller and logged by an Arcadis geologist following *Technical Guidance Instructions (TGI)- Monitoring Well Installation* (**Appendix B**). A borehole will be advanced with a drill rig equipped with 4¼-inch inner diameter (ID) hollow-stem augers or other appropriate drilling technologies such as roto-sonic. During drilling, soil samples will be collected at periodic intervals (or continuously in the case of roto-sonic) for the purpose of geologic descriptions. Appropriate soil sampling intervals will be identified in the field by the onsite geologist. For wells installed using the roto-sonic method, a continuous core is collected and described by the onsite geologist. Geologic descriptions will be written following the *TGI – Soil Descriptions,* (**Appendix B**).

Monitoring wells will be constructed using two-inch inner diameter, Schedule 40 polyvinyl chloride (PVC) well materials, with 0.010-slot, five-foot long well screens. The annulus of each monitoring well borehole will be filled with filter sand pack to at least five feet above the well screen. At least two feet of activated bentonite pellets will be placed in the annulus above the sand pack, and the remaining annulus will be filled with bentonite slurry grout to approximately two feet below ground surface (bgs). The monitoring wells will be then completed at the ground surface with protective casings anchored in concrete collars. Each monitoring well will be developed using a combination of one or more of the following methods: air lifting, surging, and pumping (*Technical Guidance Instruction – Monitoring well development,* **Appendix B**). During well development, water quality parameters including turbidity, pH, conductivity, dissolved oxygen, and temperature will be measured and recorded. Well development will be terminated when the water quality parameters stabilize.

The new monitoring wells will be given a well identification (i.e. MW-116s), followed by a single letter used to classify the position of the well screen installed in relation to the source aquifer:

- “s” – denotes “shallow” screened wells within the source aquifer
- “d” – denotes “deep” screened wells within the source aquifer and

3.1.2 Drive Points

Drive points will be installed in 11 identified wetlands (A, B, C, D, E, G, H, Q, R, CC, and DD). Existing monitoring points (SW-8-DP/WT-A-1, DP-4/WT-E, WT-A-2, WT-G, WT-H, WT-CC-1, WT-CC-2, WT-R-1, WT-R-2, WT-R-4, and WT-R-5) will be used to monitor some of the identified wetlands but six additional drive points will need to be installed (ECT, 2019). The new drive points will be located by ECT along their investigative transects.

Drive points will be installed in hand-augered boreholes to a depth of approximately two to six feet bgs. The points will be installed by a trained field geologist. The drive points will be constructed of two-inch ID PVC. Screens lengths and depths will be determined in the field after consultation with ECT so that the points monitor water levels in the wetlands. After installing the drive point, the hand augered borehole naturally collapses around the drive point. No sand pack or sealing materials will be used since points are located in a wetland. The points will be developed by bailing.

3.1.3 Stilling Wells

Two stilling wells (SW-1A and SW-8A) will be installed to aid in determining streamflow during the identified Continuous Monitoring Period (see Section 3.4.3). Stilling well SW-1A will be installed in a tributary of Twin Creek located west of Production Well PW-101 while SW-8A will be installed in the headwaters of Chippewa Creek, south of the Production Well PW-101.

Stilling well SW-1A will be installed in a hand-augured borehole within the stream channel to a depth of one to two feet below the streambed. It will be constructed of two-inch ID PVC well screen open to the surface water body. After installing the stilling well, the hand augered borehole naturally collapses around the stilling well. No sand pack or sealing materials will be used. A fence post will be driven into the streambed and attached to the stilling well for stability.

The stilling well at location SW-8A will be installed as discussed above or be integrated in the flume installed at that location.

3.1.4 Flumes

A flume will be installed at stream gauging location SF-8 (Twin Creek) in accordance with United States Geological Survey (USGS) standards (Turnipseed and Saur, 2010; Rantz et al, 1982; and Use of Flumes in Measuring Discharge at Gaging Stations, United States Department of the Interior Geological Survey, 1965). A flume is used to measure the flow of water in an open channel (i.e. a stream channel, by converging the flow into a predetermined sized channel (throat) and using a stage measurement to determine flow).

Due to the flat gradient at SF-8, a rectangular Cutthroat flume (vertical sidewalls like that of the Parshall flume) will be installed into the stream channel. The Cutthroat flume has a flat floor and lacks an extended throat. This flat floor from inlet to outlet of the flume, makes the Cutthroat flume ideal for installation in low gradient stream channels. Further discussion of the installation of the Cutthroat flume is presented in Section 3.4.6.

3.2 Elevation Survey

Each of the newly installed monitoring locations (MW-116s, MW-116d, SW-1A, SW-8A, and six drive points) will be surveyed by a licensed surveyor. The surveyor will determine the latitude and longitude of each point in decimal degrees. In addition, the reference point on the top of casing (TOC) and the ground elevations will be obtained in reference to North American Vertical Datum 1988.

To ensure accurate reference elevations and to account for possible changes in elevation of shallow monitoring points, drive points, stilling wells, and staff gauges will be resurveyed as needed. Elevational changes in the shallow points may be due to shifting of the point, settling, frost heave, or animal activities. If a point is damaged, needs to be replaced, or elevation data appears to have shifted the point will be resurveyed.

3.3 Permit-Required Monitoring

The following sections describe the collection of groundwater, surface water, streamflow and climatic data. Field procedures utilized for permit-required monitoring are outlined in **Appendix C.**

3.3.1 Schedule

In January of each year, Arcadis will prepare a schedule that proposes dates at which each monthly monitoring event (March through December) will occur. The schedule will be provided to the MDEQ and property owners that have monitoring points on their property. The proposed dates, except for August and September, will be conducted as scheduled. The schedule will not be adjusted based on antecedent precipitation. A monitoring event typically takes two to three-days to complete which will allow some movement of streamflow measuring to avoid precipitation events, if possible.

During August and September, the monitoring event will be re-scheduled if 0.2 inches or more of precipitation occurs in the 48-hours (two calendar days) prior to a proposed monitoring event. Monitoring will continue should rainfall occur on the day of the streamflow measuring. The MDEQ representative(s) will be notified by email should the schedule change.

3.3.2 Groundwater Levels

Groundwater levels from monitoring wells and drive points are determined by measuring the depth to groundwater from a surveyed reference point on the TOC, indicated by a designated mark. The water elevation at each monitoring point is determined by subtracting the depth to water from the elevation of the reference point, as described in technical guidance instructions *TGI- NWNA Manual Water-Level Measurement and Decontamination Procedures*, (**Appendix B**).

An electronic water level tape is used to measure the depth to water in accordance with United States Environmental Protection Agency (USEPA) recommended procedure (USEPA, 2016) and the *Groundwater Technical Procedures of the U.S. Geological Survey* (Cunningham and Schalk, 2011).

3.3.3 Surface Water Levels

Surface water levels from staff gauges are determined by directly reading the water level on the staff gauge tape ruler then calculating the water elevation by subtracting the water level reading from the reading at the top of staff gauge tape ruler (surveyed elevation). This subtraction gives the distance from the top of the staff gauge tape ruler to the water. This distance is then subtracted from the surveyed elevation of the top of the staff gauge **(Appendix B**).

Surface water levels from stilling wells are determined by measuring the depth to water from a surveyed reference point on the TOC, indicated by a designated mark. The water elevation at each monitoring point is determined by subtracting the depth to water from the elevation of the reference point, as described in technical guidance instructions *TGI- NWNA Manual Water-Level Measurement and Decontamination Procedures*, (**Appendix B**).

Surface water levels at two locations, SG-17R (Chippewa Creek) and SW-13R (Twin Creek), are determined by measuring the depth to water from surveyed marks on permanent bridges. Since the bridge bevels after the surveyed point, a straight edge will be extended from the surveyed point to allow an accurate measurement to be collected. That distance is then subtracted from the elevation of the mark, giving the surface water elevation.

3.3.4 Transducer Data

During the Continuous Monitoring Period, hourly streamflow determinations will be made at locations SF-1 (Twin Creek) and SF-8 (Chippewa Creek). At SF-1, a stilling well (SW-1A) will be installed and equipped with a transducer to record stage hourly. A rating curve developed for the stream will then be used to convert the stage to flow. At SF-8, a flume (Flume 8) and stilling well (SW-8A) will be installed in the stream. A transducer will be installed in the stilling well to monitor stage at hourly intervals. A rating curve developed for the flume will be used to convert stage to flow.

Stilling wells (SW-1A and SW-8A) at locations SF-1 (Twin Creek) and SF-8 (Chippewa Creek) will be equipped with transducers that will be set to automatically record hourly data during the Continuous Monitoring Period (June through October). Outside the Continuous Monitoring Period (November through May) the instruments will be removed to reduce the risk of wear, damage, or theft. Manual measurements will be collected during each monitoring event.

The transducers will be connected to a telemetry system (Tube 300R) or equivalent. The Tube 300R is a 1.92-inch diameter by 18.9-inch long stainless-steel cylinder equipped with a lithium battery and an internal barometric pressure sensor (In-Situ, 2016). The collected data will be transmitted through cellular network technology and uploaded to HydroVu (online database) twice a day during the Continuous Monitoring Period (June through October). Outside the Continuous Monitoring Period (November through May) these telemetry devices will be removed to reduce the risk of wear, damage, or theft.

In addition, the transducers installed as part of the wetlands monitoring (ECT, 2019) will be set to automatically record daily data during the growing season (mid-May through mid-November). During the monthly monitoring events, Arcadis will collect manual depth to water measurements at the drive points as described in Section 3.4.2 and will download the data from the transducers. The depth to water measurements will be used to determine the water elevations at each point. The transducer data will be assessed in the field to determine if the transducer is working properly (recording data). Vented transducer reading (at time of manual measurement) will be compared to the manual measurement with the transducer being reset if the difference is greater than 0.02 feet. Non-vented transducers will be corrected in the office for barometric pressure using measurements collected from an on-site barometer. The manual and transducer data for these points will be provided to ECT for their wetland evaluation.

3.3.5 Streamflow Measurement

The locations identified for the monthly streamflow assessment are provided in the table below:

Twin Creek Watershed	Chippewa Creek Watershed
SF-1 and SF-2 (tributary)	SF-8 (headwaters)
SF-9, SF-10, SF-11, and SF-13 (main channel)	SF-16 and SF-17 (main channel)
	SF-18 and SF-19 (tributaries)

Each of the locations identified above are marked so that measurements are collected at the same location during each monitoring event. The locations of streamflow measurements are:

- Stakes marking both sides of the stream (SF-1, SF-2, SF-8, SF-16, and SF-19).
- Culvert (circular metal) on downstream side of bridge (SF-9, SF-10, and SF-11).
- Box culverts (SF-13 and SF-17) or wooden bridge (SF-18) with graduated markings on downstream side.

Streamflow measurements will be collected manually on a monthly basis, except August and September when the schedule may vary based on precipitation events (Section 3.4.1).

Instruments for measuring velocities will include: Sontek/YSI FlowTracker ® (FlowTracker), a handheld ADV or a Marsh McBirney Flo-Mate 2000 electromagnetic flow meter (Flo-Mate) or equivalents. When using the FlowTracker in the field, the set up and procedures noted in the quick start guide (SonTek/YSI Inc., n.d.) and technical manual (SonTek/YSI Inc., 2009) will be followed and will be noted in the field book. The setup of the Flo-Mate will be completed in accordance with the instruction manual (Marsh-McBirney, 1990).

Stream discharge (flow) is the product of its velocity, the depth of the water of the stream, and the width of the stream channel. The flow measurements will be obtained following *TGI - NWNA Stream Flow Monitoring Procedures* (**Appendix B**). The TGI was developed in accordance with USGS streamflow protocol and recommended procedures (Turnipseed and Sauer, 2010; Rantz et al.1982).

Prior to beginning streamflow monitoring, quality control (QC) checks will be completed for both instruments. This includes the beam check for the FlowTracker and the zeroing process for the Flow-Mate.

Once at a stream monitoring location, the tagline will be setup (if needed), the stream will be checked for debris (obstructions), and the general depth of the stream will be determined. Any debris in the stream will be removed and documented in the field notes. The stream will be allowed to equilibrate from the debris removal before streamflow measuring begins. The depth of the stream is used to determine the streamflow measuring method to be completed. The one-point method (60% depth) is followed for collecting stream velocities when the maximum depth of the stream is less than 1.5 feet, whereas the two-point method (20% and 80% depths) is followed when the stream depth is greater than 1.5 feet. At this point the FlowTracker is then calibrated.

Since the stream channel consists of varying depths across the streamflow measuring transect, the width of the stream is divided into equal spaced intervals (usually 0.25-, 0.5-, or 1-foot at WPS). The use of intervals across the stream channel allows:

- The varying depths of the channel to be integrated into the flow calculation as the depth at each measuring station is determined using the wading rod.
- That no interval accounts for more than 10% of the total streamflow. Ideally no interval should account for more than 5% of the total streamflow.

The FlowTracker generates a file summarizing the instrument calibration, data collected at each station, and total streamflow for the monitoring location. Additionally, Arcadis staff manually enters the data collected at each stream gauging location (spacing, depth, and measured velocity) into an Excel spreadsheet using the field tablet or equivalent computer to calculate the streamflow. The Excel spreadsheet calculation is used to determine the streamflow when using the Flow-Mate and is used as a QC measure for the FlowTracker internal calculation. See the *TGI-NWNA Stream Flow Monitoring Procedures* in **Appendix B** for further details.

3.3.6 SW-1A and SW-8A Rating Curves

A stage-discharge rating curve will be developed by Arcadis for the SF-1 (Twin Creek) streamflow monitoring location. The rating curve will provide a method of converting the stream stage data (SW-1A) collected by the transducer into a flow rate. Arcadis will use the historic data (2016-2018) from this location to develop a rating curve (FlowTracker data files (SF-1) and manual stage measurements [SW-1]). The rating curve developed for the flume will be used to convert stream stage data (SW-8A) into a flow rate.

Streams are dynamic which may result in refinement of the rating curve over time. Changes to the stream are caused by erosion or deposition of the streambed materials, seasonal vegetative growth, debris, or ice. For example, erosion in a stream increases a cross-sectional area for the water, resulting in the stream to have a greater discharge with no change in flow. Thus, monthly flows and depth measurements at a streamflow location will be evaluated to determine if the rating curve needs to be refined or replaced.

3.3.7 Cutthroat Flume

Arcadis will install a rectangular Cutthroat flume at gauging station SF-8 (Twin Creek). The Cutthroat flume will be installed by digging into the stream channel and placing the flume (centered in the channel) within the prepared location with the shorter section of the flume set upstream, in accordance with the *Cutthroat Flume User's Manual* (**Appendix D**). The floor of the flume must be level horizontally in both directions (use of a level on the floor of the flume for accuracy). The flume must be braced in position with soil packed around the flume to prevent water from bypassing. Since concrete will not be used to install the flume the bracing must be left in place. The flume will be installed high enough to avoid operation under submerged flow conditions and to allow for open flow conditions. Any additional manufacturer instructions that are implemented during flume installation will be described in the field book.

Additionally, a stilling well will be installed near the flume per USGS guidance or constructed into the flume. The flume will allow flow to be estimated by the stage at the stilling well. A rating curve provided by the flume manufacturer and will be used to convert stage measurements in the stilling well to flow. This stilling well will be equipped with transducer to monitor stage, see Section 3.4.3.

3.3.8 Precipitation Data

Precipitation data are recorded daily at the COE WWTP which is located approximately 3.25 miles south-southeast of the Site. Hard copies summarizing the daily precipitation data for each month are obtained by Arcadis from the COE WWTP. During August and September, Arcadis will evaluate information from COE WWTP, local weather forecasts and the Michigan State Enviroweather station in McBain, Michigan (Approximately 20 miles north of Evart) in scheduling a monitoring event.

3.4 Data Management

Field activities and measurements are recorded in WPS dedicated fields book(s). Upon return to the office, data collected and/or recorded (i.e. photographs, field notes, transducer data, streamflow data, etc.) in the field are uploaded to the project file on an Arcadis server. The field book pages for each event are scanned and saved to the project file.

The data are added into Excel spreadsheets that contain historical data collected at WPS within a week of the field event. The data then undergoes a Quality Assurance/Quality Control verification and validation process (Section 6.0). Plots are generated from the data from each monitoring location to evaluate trends and check for outliers.

4 TRAINING

Staff working at the WPS site will meet with the Quality and Task managers yearly or more frequently as needed. At the meeting each staff will be provided a copy of the monitoring plan (Arcadis, 2019) to review. The monitoring plan (including the QAPP) will be discussed with each employee so that staff understands the what, why and how each aspect of the monitoring that will be conducted.

New staff will be trained in use of the flow meters before collecting measurements in the field. The training will start with reading the TGI, flow meter manual(s), and watching training videos. After this initial training, staff will be taken to a stream near the Arcadis office to become familiar with the instrumentation. Staff will then be integrated into the field where they will work with experienced staff. They will begin collecting streamflow measurements after demonstrating proficiency in the process and with the equipment.

Staff training will be documented.

5 USE OF FIELD EQUIPMENT

Equipment calibration, data comparison, well maintenance and security procedures, are described below and outlined in **Appendix E**. All calibration, maintenance and inspection activities will be recorded in the field book, procedures for documentation are outlined in QP306 and QP307 (**Appendix B**).

5.1 Monitoring Points

The condition of WPS site monitoring points will be inspected monthly for damages. Obstruction and/or debris interfering with measurement collection will be removed by field staff and documented. Identification labels and TOC marks will be reapplied as needed. All existing monitoring points have been surveyed; drive points, stilling wells and staff gauges will be resurveyed as needed, to detect settling of the wells.

5.2 Stream Gauging Locations

Stream gauging locations are inspected monthly for obstructions. If any obstructions to the streamflow are observed, they will be documented and removed by field staff. Marks identifying reference points on monitoring wells, drive points, stilling wells, and bridges and streamflow incremental station markings on bridges will be re-established as needed to maintain visibility.

5.3 Water Level Meter

Water levels are measured at the same point each time (surveyed reference point at the TOC which is indicated with a clearly defined mark). Each water level is measured a minimum of two times to validate measurement. If a discrepancy or anomaly is noted between the two measurements, a third measurement is taken and noted in the field book. In the winter it is important to check measurements as moisture and ice may interfere with accurate measurement of water levels. If necessary, prior to water level measurement, the probe of the water level meter is wiped with a paper towel to make sure no moisture is building up on the probe.

The serial number of the water level meter used will be noted in the field book. A back up water level meter will be brought to each monitoring event. The meters will be decontaminated before and after each event, and throughout the monitoring event (**Appendix B**).

Water level meters are inspected monthly for damages, and batteries are replaced as needed. Annually the water level meter tapes undergo a routine inspection and calibration against an undamaged tape. This is completed to detect possible elongation of the tape over time.

5.4 Transducers, Tube 300R, and Telemetry System

The transducer data will be compared to manual measurements in the field for accuracy. If manual field measurements and transducer measurements vary by greater than 0.02 feet, the transducer will be reset using the manual measurement as a reference depth. The desiccant will be inspected and replaced as needed. Every winter (mid-November to mid-May), the transducers will be removed, cleaned and sent in to undergo factory maintenance and calibration (In-Situ, 2013). The batteries within the Tube 300R last approximately five years. Battery life of the instrument will be noted annually and will be replaced approximately every five years (In-Situ, 2016).

The transducer, Tube 300R and telemetry systems will be inspected monthly for anomalies in the data. The cables will be inspected for damages monthly and trees will be trimmed back as needed to avoid cellular network interference.

5.5 FlowTracker

The FlowTracker is inspected prior to each field event by field staff. A software program (BeamCheck) is conducted prior to beginning each monitoring event to check the basic system operation.

An automated QC test (the user will be prompted to run this test before beginning streamflow measurements at each location) is conducted prior to beginning streamflow measurements at each gauging location to ensure sufficient noise to signal ratio (SNR) and to determine if any errors are correlated with the cross section. The internal memory, temperature and internal clock are checked daily for accuracy. As needed batteries are replaced, software is updated, and the probe is cleaned (SonTek/YSI Inc., 2007). Annually the FlowTracker is sent to the manufacturer for a full inspection of the instrument. A replacement FlowTracker will be supplied by the manufacturer if needed during the inspection, or if sent to the manufacturer for repairs. See the *TGI-NWNA Stream Flow Monitoring Procedures* (**Appendix B**).

5.6 Flo-Mate

The Flo-Mate will be inspected prior to each monitoring event by field staff. The batteries will be changed as needed. A field calibration will be completed and noted in the field book prior to collection of streamflow measurements during monitoring events (Marsh-McBirney Inc., 1990). See the T*GI-NWNA Stream Flow Monitoring Procedures* (**Appendix B**).

5.7 Flume

The flume and the channel the flume is installed in will be inspected prior to each monitoring event. Vegetation and debris upstream and downstream of the flume will be removed. The channel will be assessed to determine if bypassing of water upstream of the flume and scouring downstream is occurring. The flow through the flume should not exhibit turbulence, surging, or a poor velocity profile. The flume should be level horizontally from either direction, and if not, the flume will be re-leveled. The flume will be scrubbed and cleaned to remove surface buildup or algal deposits as needed, as discussed in the user's manual (Openchannelflow, n.d.). Any maintenance activities will be noted in the field book.

6 DATA VERIFICATION AND VALIDATION PROCEDURES

This section summarizes the field quality assurance procedures and data analysis/reporting techniques.

6.1 Field Quality Assurance Procedures

To ensure accurate collection of data in the field, data collection methods were developed and are utilized to minimize collecting inaccurate data. A list of field procedures is provided below:

- Written Field Procedure Protocols – To reduce inaccurate data collection standardized data collection methods, TGIs (**Appendix B**) and Field Procedures (**Appendix C**), are provided to and discussed with each field staff member.
- Water Level Measurement Collection: At each monitoring location, the measurement (reading) is taken at least twice.
- The transducer data will be assessed after downloading to the field tablet to determine if transducer is working properly (recording data). Vented transducer reading (at time of manual measurement) will be compared to the manual measurement with the transducer being reset if the difference is greater than 0.02 feet. Non-vented transducers will be corrected in the office for barometric pressure using measurements collected from an on-site barometer.
- Data Transcription Errors – Water level and streamflow measurements must be repeated verbally between the field staff recording the data and the field staff obtaining the measurement to reduce transcription errors in the field.
- Dedicated Field Book – All field notes are recorded into a dedicated site field book that is scanned and stored electronically after each monitoring event.
- Recent Data Comparison – Each field staff member will compare each measurement to the previous measurement from that monitoring point, found within the previous field events notes within the field book. If the measurement seems anomalous (relatively, compared to previous LTM values), the measurement will be retaken. When a value is re-checked, it will be documented in the field book.
- Electronic Data Entry – The FlowTracker keeps an electronic record of the streamflow data. The field staff must enter in starting edge of the stream measurement, interval width and depth of stream. The FlowTracker records the velocity measured at each interval. The FlowTracker has built-in quality control measures (Smart QC). Before each streamflow a beam-check is completed to check the noise level, SNR, peak location, and peak shape; and it will inform if the check was passed or failed. Should the check fail, the procedure is to rerun the check. Measurement errors and warnings are noted within the instrument (i.e. SNR, standard error of velocity, boundary adjustment, number of spikes filtered from data, velocity angle, etc.). These parameters are automatically reviewed during each measurement.
- Additionally, a tablet is used in the data acquisition process to ensure accurate data transcription. While in the field, the streamflow measurements (interval width, depth of stream at interval, and measured velocity at appropriate depth) are entered into a standardized Excel template in the tablet. The template calculates the total stream discharge, which is compared to the stream discharge calculated by the FlowTracker.

6.2 Data Analysis/Reporting Techniques

The data will be processed and analyzed within a week of the field event. Data are to be reviewed for reasonableness, equipment malfunction, data outliers, etc.

- Electronic Data Entry – The FlowTracker and tablet are both used in the data acquisition process. Streamflow measurements (FlowTracker and Flow-Mate) are entered in the field into a standardized excel template in the tablet. The Excel files and FlowTracker files are directly uploaded onto the project folder. The FlowTracker Data file is opened within the FlowTracker Desktop Application and is converted into a PDF format. This document provides a discharge measurement summary. The following is included in the summary: file information, site details, FlowTracker operator, system information, units, total discharge, measurement results, measurement uncertainty, incremental stream velocity, depth, and discharge, quality control, and automatic quality control test. The document is to be reviewed for any outliers. Then the recorded depths and velocities are checked between the FlowTracker PDF document and Excel (tablet) document to identify possible transcription errors.
- Manual Data Entry – Water levels recorded in the field book and stream discharge measurements from the FlowTracker and Flow-Mate are to be manually entered into their respective databases. The data manager manually enters the values while simultaneously examining the field book. Documented observations such as weather conditions (strong winds, precipitation), removed obstructions, etc., are to be recorded in the database with the measurements. Review of the field book immediately after it is returned from the field enables the data manager to effectively get answers to questions identified within the field notes from the field staff.
- Comparison to Identify Data Trends – Graphs of the data are created to evaluate trends. Data points are flagged if they appear erroneous and do not adhere to previously observed trends. Flagged measurements are not marked as erroneous but are re-checked for accuracy during the following LTM event. The flagged values will also be checked if they could be related to a weather event or other factors.
- Transducer data are compared to manual data measurements collected and data outliers are identified. This is completed to identify if there is any equipment malfunction in the field and to assure data entry procedures.
- Examination of Environmental Factors – If a data point has been identified as an outlier, environmental conditions are investigated to evaluate if an explanation for the difference in measurement exist. Examples of environmental conditions are localized amounts of precipitation, evapotranspiration, or flow restrictions such as water management practices at nearby dams or other obstructions to inflow/outflow channels.
- Manual Checks on Data Tables – For quality assurance the data measurements are reviewed within tables and graphs for accuracy through a peer review and project management review prior to data distribution.

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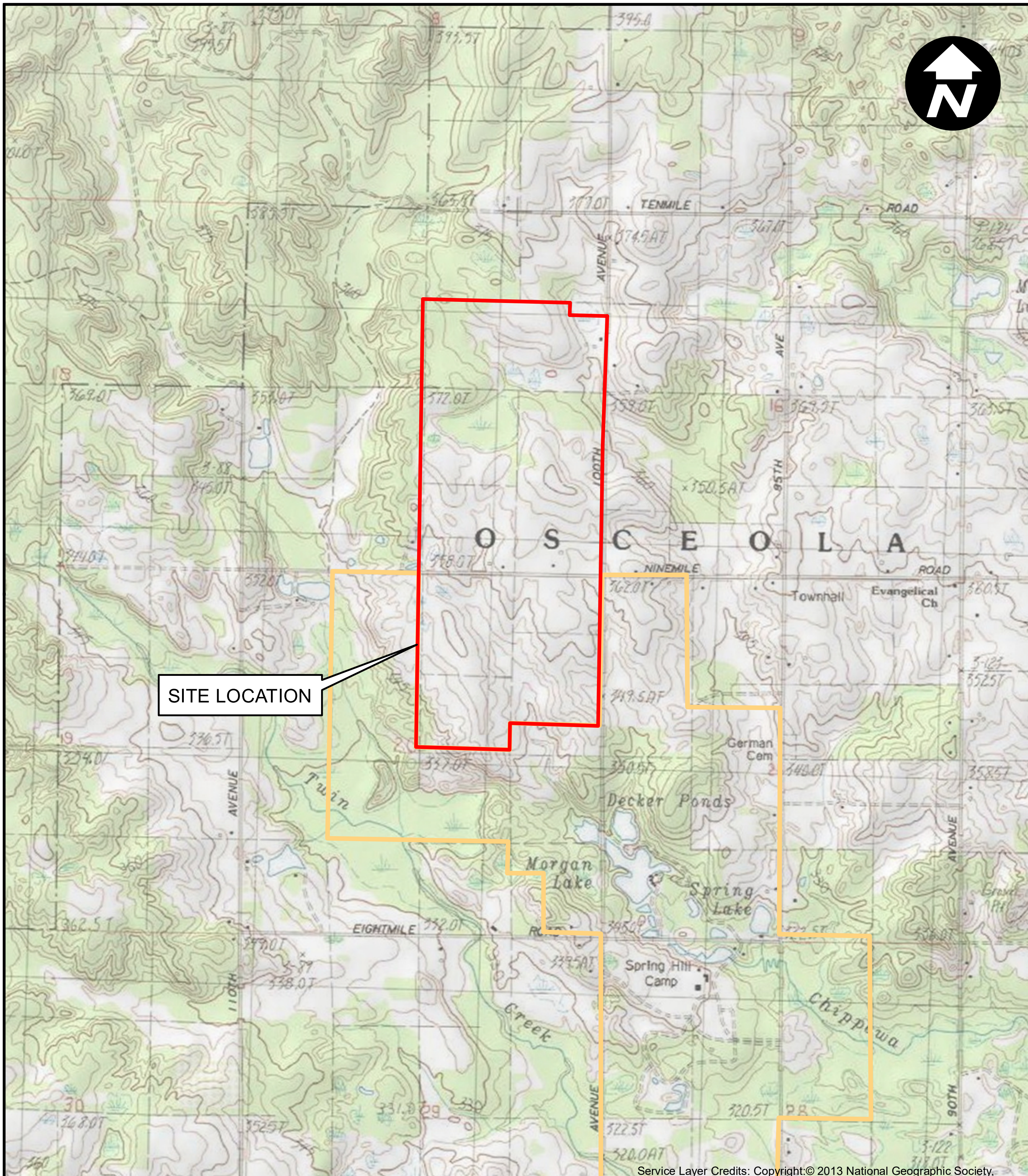
TABLES

Table 1

Permit Monitoring Network
Quality Assurance Project Plan
NWNA White Pine Springs Site

Monitoring Well ID	Transducer
MW-1u and MW-4u	
MW-11s, MW-12s, MW-101s, and MW-105s	
MW-1i, MW-2i, MW-3i, MW-5i, MW-6i, MW-7i, MW-8i, MW-9i, MW-10i, MW-12i, MW-13i, MW-102i, MW-103i, MW-104i, MW-107i, MW-108i, MW-112i. MW-114i, MW-115i, and MW-116i	
MW-1d, MW-5d, MW-101d, MW-102d, MW-103d, MW-104d, MW-105d, MW-106d, MW-107d, MW-110d, MW-111d, MW-113d, and MW-116d	
MW-101L and MW-105L	
Drive Point ID	
SW-1-dp, SW-2-dp, SW-3-dp, SW-6-dp, SW-8-dp, SW-10-dp, SW-11-dp, and SW-14-dp	SW-8-dp/WT-A-1
DP-1, DP-2, DP-3, DP-4, and DP-5	DP-4/WT-E
Seep-1r, Seep-2, Seep-3, Seep-4, Seep-5, and Seep-6	
Vent 1r and Vent 2	
Wetland ID Point	
SW-8DP/WT-A-1, DP-4/WT-E, WT-A-2, WT-G, WT-H, WT-CC-1, WT-CC-2, WT-R-1, WT-R-2, WT-R-4, WT-R-5, and six additional locations proposed in the wetland monitoring plan	SW-8DP/WT-A-1, DP-4/WT-E, WT-A-2, WT-G, WT-H, WT-CC-1, WT-CC-2, WT-R-1, WT-R-2, WT-R-4, WT-R-5, and six additional locations proposed in the wetland monitoring plan
Surface Water ID	
SW-1, SW-2, SW-3, SW-8, SW-9, SW-13r, SW-14	
SW-3-wco. SW-4-wco, SW-5-wco	
SG-2, SG-3, SG-5, SG-9, SG-10, SG-16, SG-17r, SG-18, SG-19, SG-201, SG-202, SG-203, and SG-204	
DP-11-sg and DP-12-sg	
SW-1A and SW-8A (Stipulated Period)	SW-1A and SW-8A (Stipulated Period)
Twin Creek Streamflow Monitoring Location	
SF-1, SF-2, SF-9, SF-10, SF-11, and SF-13	
Chippewa Creek Streamflow Monitoring Location	
SF-8, SF-16, SF-17, SF-18, and SF-19	

FIGURES



USGS 7.5' TOPOGRAPHIC MAP AREA SHOWN NAMED, "EVART"

0 2,000 4,000

Feet

Legend

Nestle Property

SHC Property

NESTLE WATERS NORTH AMERICA
WHITE PINE SPRING SITE

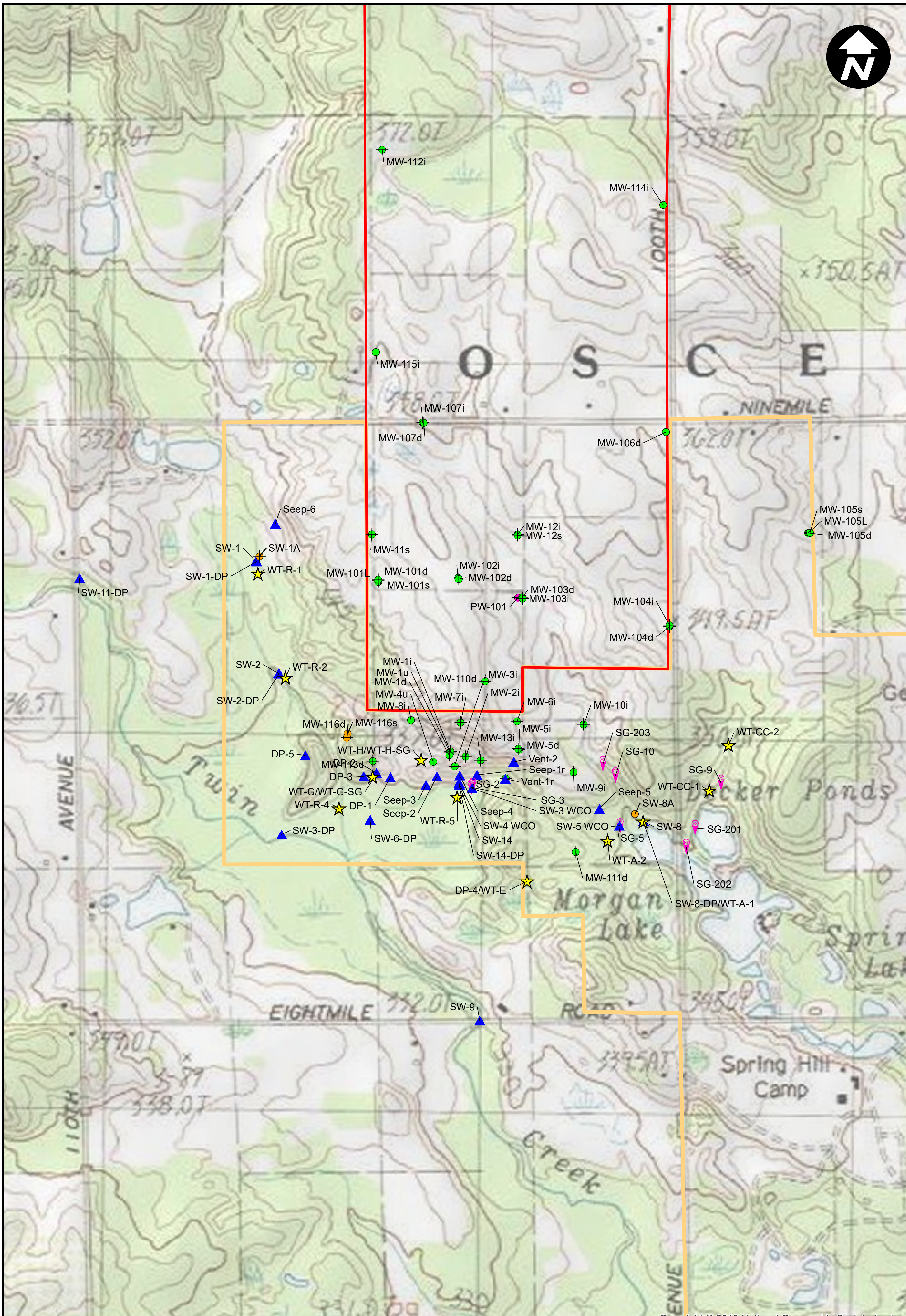
SITE LOCATION MAP

ARCADIS Design & Consultancy for natural and built assets

FIGURE

1

CITY: LANSING DIV: ENV DB: D.AKENS PIC:S.INSALACO PM:B.RUST TM:L.EENIGENBURG TR: PROJECT NUMBER: USA71817 COORDINATE SYSTEM: NAD 1983 StatePlane Michigan South FIPS 2113 Feet
Z:\GISProjects_ENV\NoviBrighton_MI\4065010\NESTLE\SiteLocation.mxd PLOTTED: 2/6/2019 9:46:59 AM BY: akens



Legend

- New Locations
- Newly Installed Monitoring Well
- Drive Point
- Monitoring Well
- Production Well
- Staff Gage
- Nestle Property
- SHC Property

0 800 1,600

SCALE IN FEET

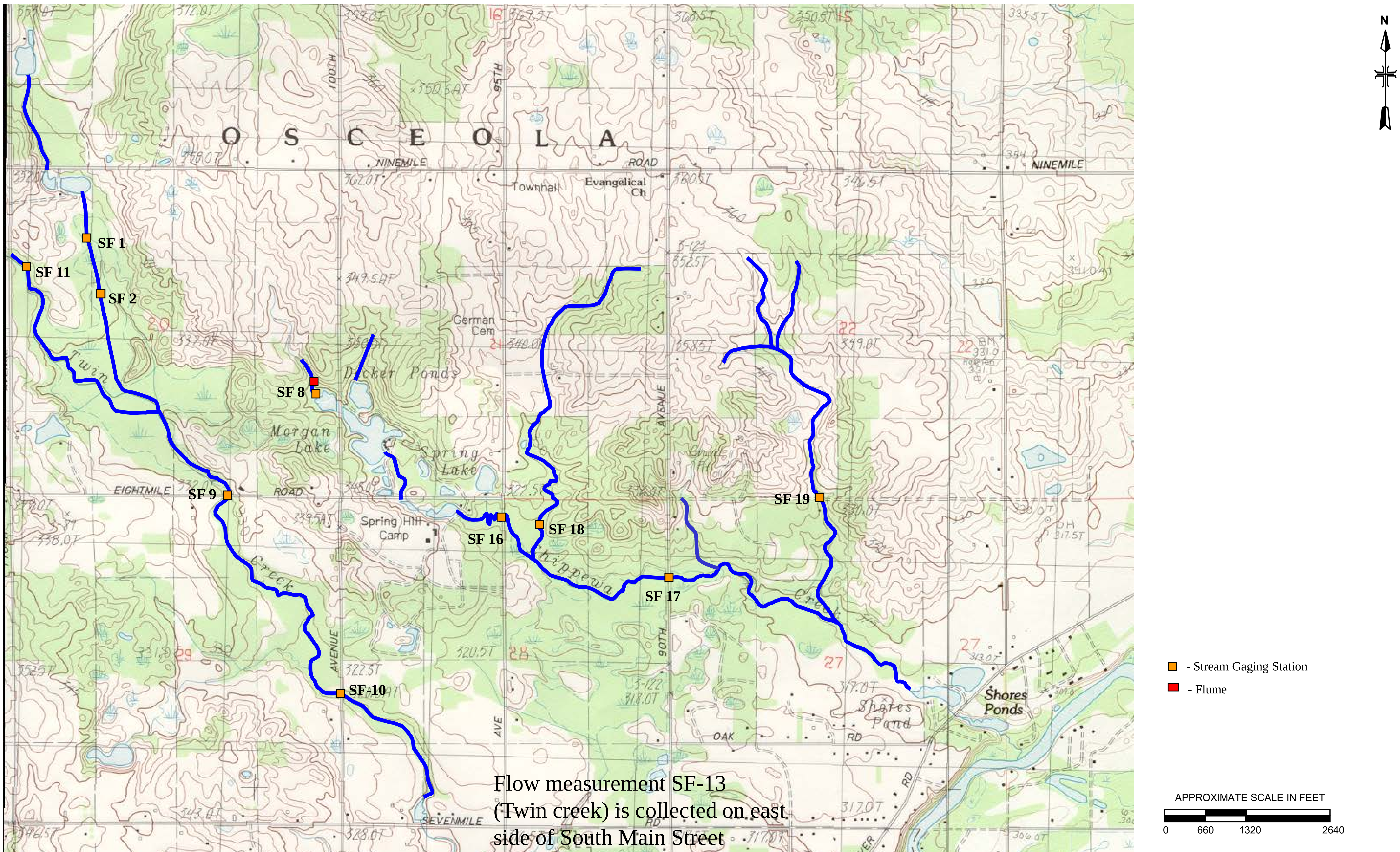
NESTLE WATERS NORTH AMERICA
WHITE PINE SPRING SITE

LONG TERM MONITORING NETWORK

ARCADIS Design & Consultancy for natural and built assets

FIGURE **2**

Z:\GISProjects_ENV\NoviBrighton_MI\40650100\NESTLE\Longterm_Mon_Net_fig2_2019.mxd PLOTTED: 4/9/2019 8:12:34 AM BY: akens



SOURCE: USGS, Evart, MI Quadrangle (1983)

Updated 2-6-03 J/projects/4065031/monitoring locations.ppt

ARCADIS Design & Consultancy for natural and built assets

NESTLE WATERS NORTH AMERICA
WHITE PINE SPRINGS SITE

PERMIT STREAM FLOW MONITORING LOCATIONS

FIGURE 2A

APPENDIX A

Boring and Construction Logs

ARCADIS Design & Consultancy for natural and built assets

Soil Boring Log

Boring No.: ______

Sheet : 1 of

Project Name: ______ Date Started: ______ Logger: ______

Project Number ______ Date Completed: ______ Editor: ______

Project Location ______ Weather Conditions: ______

Depth (feet)	Blow Counts	Sample ID & Time	Recovery (in.)	PID (ppm)	USCS Class.	Description	Construction Details

Drilling Co.: ______

Driller: ______

Drilling Method: ______

Drilling Fluid: ______

Remarks: ______

Sampling Method: ______

Sampling Interval: ______

Water Level Start: ______

Water Level Finish: ______

Converted to Well: ☐ Yes ☐ No

Surface Elev: ______

North Coor: ______

East Coor: ______

ARCADIS Design & Consultancy for natural and built assets

Soil Boring Log

Boring No.: ____________

Sheet : 2 of

Project Name: ____________ Date Started: ____________ Logger: ____________

Project Number ____________ Date Completed: ____________ Editor: ____________

Project Location ____________ Weather Conditions: ____________

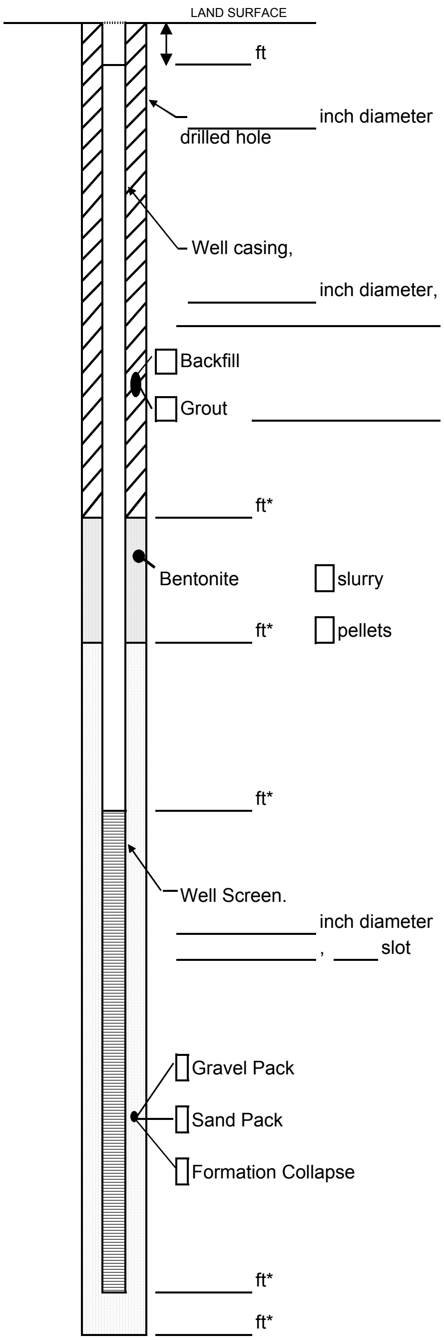
Depth (feet)	Blow Counts	Sample ID & Time	Recovery (in.)	PID (ppm)	USCS Class.	Description	Construction Details

Remarks:

ARCADIS

Well Construction Log

(Unconsolidated)



Measuring Point is
Top of Well Casing
Unless Otherwise Noted.

* Depth Below Land Surface

Project ______________ Well ______

Town/City ______________

County -- ______________ State ______

Permit No. -- ______________

Land-Surface Elevation and Datum:

-- ______________ feet ☐ Surveyed ☐ Estimated

Installation Date(s) ______________

Drilling Method ______________

Drilling Contractor ______________

Drilling Fluid ______________

____

Development Technique(s) and Date(s)

____

____

____

Fluid Loss During Drilling ______________ gallons

Water Removed During Development ______ gallons

Static Depth to Water ______________ feet below M.P.

Pumping Depth to Water ______________ feet below M.P.

Pumping Duration ________ hours

Yield ________ gpm Date ______

Specific Capacity ________ gpm/ft

Well Purpose Monitoring

____

____

Remarks ______________

____

____

____

____

Prepared by ______________

APPENDIX B

Arcadis Technical Guidance Documents (TGIs)

STATEMENT OF POLICY:

The Arcadis Environment Business Line (ENV) uses measuring and test equipment in the course of its activities. Equipment used by ENV and their subcontractors must be in the condition required for the performance of specified activities. A procedure for performing and documenting calibration and for the preventive maintenance of measuring and test equipment will be followed to provide necessary controls.

1. Purpose

The objective of this Quality Procedure (QP) is to provide a standard procedure for the calibration and control of measuring and test equipment, including establishing the correct equipment type, range, accuracy, and precision to meet data collection needs. Equipment must be uniquely identified, calibrated against recognized standards that are clearly identified and documented, and maintained to provide reliable performance and to meet ENV quality requirements.

2. Responsibilities

Certified Project Manager – responsible for implementation of this procedure.

Field Supervisor – responsible for field equipment and for communicating calibration and maintenance procedures for equipment used by ENV staff. Similar requirements for field equipment calibration and maintenance should also be communicated to subcontractors using field equipment. Subcontractors are responsible for following those requirements and are subject to performance audits.

Quality Consultant – responsible for providing quality assurance and quality control guidance to the CPM in implementing this procedure.

Project Team Members – project team members are responsible for verifying calibration status prior to using the equipment, and for operating equipment by approved procedures, documenting information, and reporting equipment malfunctions.

3. Terms and Definitions

Accuracy – a qualitative evaluation of the agreement between an individual value (or the central tendency of a set of values) and the correct value or the accepted reference value.

Calibration – the process of evaluating and standardizing an instrument by determining the deviation from a known standard.

Measuring and Test Equipment – devices or systems used to calibrate, measure, gauge, test, or inspect in order to acquire data.

Precision – a qualitative evaluation of measurement data used to describe the dispersion of a set of numbers with respect to its central tendency.

4. Related Forms

Not applicable.

DESCRIPTION OF PROCEDURE:

Measuring and test equipment will be controlled by a calibration and preventive maintenance program. Instruments that measure a quantity or whose performance must meet stated criteria will be subject to calibration. Calibration of equipment may be performed internally using reference equipment and standards, or externally by agencies or manufacturers. Two types of calibration are presented in this procedure:

- Operational calibration, which is routinely performed as part of instrument usage.
- Periodic calibration, which is performed at prescribed intervals for equipment such as water-level indicators, pressure recording devices, and thermometers. In general, equipment that can be calibrated periodically is relatively stable in performance.

Preventive maintenance is an organized and documented program of equipment cleaning, lubricating, reconditioning, adjusting, and/or testing intended to maintain proper performance, prevent equipment from failing during use, and maintain reliability.

1. Calibration Procedures

Documented procedures must be used for calibrating measuring and test equipment and reference equipment. Procedures such as those published by ASTM International (formerly known as the American Society for Testing and Materials), U.S. Environmental Protection Agency (USEPA), or procedures provided by manufacturers will be used whenever possible.

Where pre-established procedures are not available, procedures will be developed. Factors such as the type of equipment, stability characteristics of the equipment, required accuracy and precision, and the effect of error on the quantities measured must be taken into account. Calibration procedures must include:

- Type of equipment to be calibrated
- Reference equipment and standards to be used
- Calibration method and specific procedure

- Acceptance tolerances
- Frequency of calibration
- Data recording form.

2. Equipment Identification

Measuring and test equipment owned by Arcadis must be uniquely identified using the manufacturer's serial number, a calibration system identification number, or an inventory control tag number. This identification must be attached to the equipment. In addition to the identification number, equipment requiring periodic calibration must bear a label indicating when the next calibration is due. Equipment that is rented or leased for the purposes of measuring and testing must also be uniquely identified.

Personnel are responsible for verifying calibration status from due date labels or instrument records prior to using the equipment. Measuring and test equipment that is not properly calibrated must not be used.

3. Calibration Frequency

Measuring and test equipment and reference equipment will be calibrated at prescribed intervals and/or as part of operational use. The calibration frequency will depend on the type of equipment, inherent stability, manufacturer's recommendations, intended use, effect of error on the measurement process, and experience. Calibration frequencies may be defined in project-specific plans or in calibration procedures. The CPM or Field Supervisor is responsible for specifying the procedures to be followed to meet project data quality objectives.

Scheduled periodic calibration may not be performed for infrequently used equipment; such equipment will be calibrated on an "as needed" basis prior to use, and then at the required frequencies for the duration of its use.

Field equipment will require an operational check per the applicable procedure and or the equipment manual prior to use, and then again at the end of the working day. Pre-use calibration should be completed under conditions of anticipated use (e.g., temperature, humidity, and atmospheric pressure) if these parameters may influence results.

4. Reference Equipment and Standards

Whenever possible, equipment must be calibrated using reference equipment (i.e., physical standards) and chemical and radioactive standards having known relationships to nationally recognized standards (e.g., National Institute of Standards and Technology [NIST]) or accepted values of natural physical constants. If national standards or constants do not exist, the basis for the calibration must be documented.

Physical standards may include calibration weights, certified thermometers, standard measurement tapes, gauge blocks, and reference gauges. These are generally used for periodic calibrations. Physical standards must be used only for calibration.

Chemical and radioactive standards may include reagents, solvents, and gases. These may be Standard Reference Materials (SRM) provided by NIST or USEPA, or they may be vendor-certified materials traceable to NIST or USEPA SRMs. Chemical and radioactive standards will primarily be used for operational calibrations.

The date of receipt and expiration date must be clearly labeled on the container of each standard. If calibration standards are transferred to additional containers, these containers must be labeled with the name of the standard, the lot number, and the shelf life. Calibration standards that exceed shelf life must not be used and must be discarded.

If equipment is sent to the manufacturer or calibration laboratory for calibration, adequate documentation must be maintained to establish the calibration method, reference standard source, or traceability to recognized standards.

5. Calibration Failure

Equipment failing calibration or becoming inoperable during use will be removed from service and segregated to prevent inadvertent use, or tagged to indicate it is out of service. The equipment must be repaired and properly recalibrated; equipment that cannot be repaired will be replaced.

The results of activities involving equipment that has failed recalibration will be evaluated by the CPM. If the results are adversely affected, the findings of the evaluation will be documented and appropriate personnel will be notified.

Periodic calibration of measuring and test equipment does not replace the user’s responsibility for verifying proper function of equipment. If an equipment malfunction is suspected, the device must be tagged or removed from service, and recalibrated. If it fails recalibration, it must be repaired or replaced.

6. Documentation of Calibration

Records must be maintained for each piece of calibrated measuring and test equipment and each piece of reference equipment. The records must indicate that established calibration procedures have been followed, and that the accuracy of reference chemical and radioactive standards has been verified.

Records for periodically calibrated equipment must include the following minimum information:

- Type and identification number of equipment
- Calibration frequency and acceptance tolerances

- Calibration dates
- Name of individual and organization performing the calibration
- Reference equipment and/or standards used for calibration
- Calibration data
- Certificates or statements of calibration provided by manufacturers and external organizations
- Documentation of calibration acceptance or failure, and of repair of failed equipment.

For equipment requiring calibration, information should be maintained in a project or equipment database regarding the calibration and maintenance history for that equipment. Equipment that does not have a calibration sticker or that has an expired calibration sticker should be tagged inoperable and sent for calibration. The equipment information file should contain periodic calibration files, as well as equipment calibration and maintenance records, calibration data forms, and/or certification of calibration provided by manufacturers or external organizations, and notice of equipment calibration failure.

Measuring and test equipment used for field investigations will typically be calibrated as part of operational use. For this equipment, records of the calibrations or checks will be documented as part of the test data (e.g., in the field notebook or on a Field Activity Log). Equipment-specific forms may also be developed. These records should include information similar to that required for periodically calibrated equipment. Documentation related to malfunctioning equipment or equipment that fails calibration should also be included in the individual equipment file.

Calibration files for equipment requiring periodic calibration should be sent with equipment that is transferred to allow a continuously updated record to be maintained. Recalibration of sensitive equipment should be performed following the transfer.

When measuring and test equipment is rented or leased, procurement documents must specify that a current certificate of calibration must accompany the equipment. This certificate must be maintained with the project documentation calibration records.

7. Operational Checks

Certain equipment may require periodic operability tests or checks to verify that operating systems are within the allowed range. These tests are in addition to formal calibration. Like calibrations, these tests will be performed at specified frequencies, or as part of operational use using reference equipment and standards.

If an instrument fails an operability test, and corrective action cannot bring the instrument into tolerance, it must be removed from service and segregated to prevent inadvertent use, or tagged to indicate it is out of service. Such equipment will be repaired and/or recalibrated.

Operability tests will generally be performed in conjunction with data acquisition. Information recorded must include:

- Type and identification number of equipment (e.g., model and serial numbers)
- Test date
- Name of individual and organization performing the test
- Reference equipment and standards used
- Test data
- Documentation of acceptance or failure.

Documentation may be in the field notebook or on a Field Activity Log.

8. Preventive Maintenance

Preventive maintenance is an organized program of equipment cleaning, lubricating, reconditioning, adjusting, and/or testing intended to maintain proper performance, prevent equipment from failing during use, and maintain reliability. Specific maintenance details may be supplied in project-specific plans. A typical preventive maintenance program includes:

- A listing of the equipment that is included in the program
- The frequency of maintenance (manufacturer's recommendations or previous experience with the equipment)
- Service contracts
- Identification of spare parts
- Items to be checked and specific protocols to be followed
- Documentation of maintenance.

Maintenance records of measuring and test equipment must be maintained at the location that is the host for the equipment. Documentation of subcontractor and Arcadis equipment that is used for an individual project will be included in the project files. Records for multi-project equipment will be maintained by the location that controls the equipment.

Measuring and test equipment must be controlled through the use of sign-out/sign-in records or other suitable method. Equipment that is returned from field use must be free of contamination, packaged in a manner suitable for storage, and returned to its designated area. Support personnel should be notified of performance problems with equipment.

— END OF PROCEDURE —

STATEMENT OF POLICY:

It is Arcadis Environment Business Line (ENV) policy that field activities must be documented to facilitate the interpretation of data; show compliance with project plans, work plans, and contract terms; and to serve as evidentiary records. Documentation reflecting activities performed must be legible, organized, and complete. Applicable regulatory and client requirements should be considered when documenting field activities. Project-specific requirements for documentation typically should be described in the Work Plan, Field Sampling Plan (FSP), and/or in the Quality Assurance Project Plan (QAPP).

1. Purpose

The purpose of this Quality Procedure (QP) is to provide a standard procedure for the documentation of fieldwork activities. This documentation pertains to site-related projects, but is not limited to the collection of samples, subsurface information, and oversight of construction activities. Field documentation must include, at a minimum, project title and number, date and times of activities, the identification of the employee performing the work, and the specifics of the work being performed.

2. Responsibilities

Certified Project Manager (CPM) – is responsible for the project-related administration of this QP.

Quality Consultant – is responsible for providing quality assurance and quality control guidance to the CPM in implementing this procedure. Note that for federal projects, there are specific requirements and qualifications for the QA Officer assigned to the project.

Project Team Members – who are assigned to document field activities, are responsible for compliance with this procedure.

3. Terms and Definitions

Field Sampling Plan (FSP) – A document that describes the procedures and protocols necessary to complete field sampling and data collection activities.

Work Plan – A document that describes proposed project activities.

Quality Assurance Project Plan (QAPP) – A document that prescribes the quality assurance/quality control (QA/QC) procedures to be followed. Uniform Federal Policy (UFP) QAPPs are now frequently required for environmental projects by most federal regulatory agencies. A UFP QAPP includes Worksheets used to document the entire project plan developed following the systematic planning process. For more details on the UFP QAPP see http://www.epa.gov/fedfac/documents/qualityassurance.htm. Note that if the project QAPP is written following the UFP format, it will also contain a description of the sampling rationale and sampling locations as well as QA/QC requirements. The UFP QAPP format is designed to capture the entire systematic planning process. If a UFP QAPP is written for a project, a separate FSP is generally not required unless specified by the particular client or contract.

Standard Operating Procedure (SOP) and Technical Guidance Instruction (TGI) – Documents that describe a procedure and or protocol necessary to conduct a specific activity.

4. Related Forms

Forms used for documenting field activities may be included as attachments to the FSP or the QAPP and may include the following examples:

- Chain-of-custody (COC) form
- Sample data log
- Field modification form
- Sample receipt form
- Corrective action form
- Field activity log
- Calibration log
- Analysis request and chain-of-custody record
- Daily quality control reports
- Purge log
- Soil boring log.

Examples of SOPs and TGIs with field forms and check-lists can be found in the Arcadis Procedure Library at: https://arcadiso365.sharepoint.com/TEAMS/US_envsoplibrary/SitePages/Home.aspx.

DESCRIPTION OF PROCEDURE:

1. General Requirements

1.1 Documentation Format

Documentation of field activities provides an accurate and comprehensive record of the work performed sufficient for a technical peer to reconstruct the day's activities and confirm that necessary client, regulatory, contract, and work plan requirements were met. General requirements include:

- Use of field books (preferably bound) as the primary source for information collection and recording. Field books should be dedicated to the project and appropriately labeled.
- Use of personal digital assistant (PDA) to document select field sampling and data collection activities using Arcadis' electronic data gathering system (EDGE); examples include subsurface data, well/piezometer

installation, groundwater sampling, and water-level measurements. Use of PDAs with EDGE is optional but encouraged.

- Use of a Field Activity Log is suggested to formally document activities and events as a supplement to bound field books. The Field Activity Log can be a standard or project-specific form or a bound field book. Preprinted standard forms are available for many activities and should be used whenever possible. These forms will provide prompts and request additional information that may be useful and/or needed. Project-specific field forms may be generated or existing forms may be modified to meet specific project needs. Client-supplied forms may be substituted, as required.
- Appropriate header information is documented on the first page of notes for each day of fieldwork, including project title, project number, date, time, author, and relevant setting information such as weather conditions, topography, surface water conditions, observed site activities/uses, and other persons in field team. In addition, include on every page of notes the page number and date. Project-specific information depends on the nature of work being performed and should be discussed by the project team prior to commencing fieldwork. As appropriate, dedicated field logs/journals or forms should be used. When Field Activity Log Forms are used, information fields that are not applicable should be noted as such with the symbol "N/A" or other appropriate notation.
- Field documentation entries shall be made using indelible ink.
- Data entries shall be legible. A single line should be drawn through incorrect entries and the corrected entry written next to the original strikeout. Strikeouts are to be initialed and dated by the originator.
- Units of measurement shall be specified. The level of accuracy shall be indicated (e.g., observed estimate, quantified census from direct count, and electronic data collection).
- Field records are to be maintained in project files unless otherwise specified by a client or stipulated by a contract.
- Unless addressed specifically by a client or stipulated by a contract, site photographs should be taken to document the general setting and landscape as well as site-specific issues/resources of interest. Photo locations and the compass direction of view should be recorded in the notes with the photo number.

1.2 Documentation Entries

A chronology of field events should be recorded. General entry requirements include:

- Visitors to the site, including owner and regulatory agency representatives
- Summary of pertinent project communications with the client, regulators, or other site visitors during the fieldwork
- Other contractors or entities working on site
- A description of the day's field activities, generally in chronological sequence or in order of significance, using military time notation (e.g., 9:00 a.m. as 0900, and 5:00 p.m. as 1700)
- If applicable, calibration of measuring and test equipment and identification of the calibration standard(s) (use a Calibration Log, if available, with cross-reference entered into the field book)
- Field equipment identification, including information such as the type, manufacturer, model number, or other specific information

- If applicable sampling activities are being performed, weather information such as temperature, wind speed and direction, precipitation, time of measurement, and units
- Documentation of safety meeting (e.g., tailgates and tailboards) topics and attendees
- Verification of subsurface utility clearance in accordance with ENV ivision policy
- Safety and/or monitoring equipment readings, including time of measurements and units
- If applicable, specific forms used for collection of data are referenced in the field notebook
- Subcontractor progress and/or problems encountered
- Changes in the scope of work
- Other unusual events.

2. Specific Requirements

2.1 Sample Collection

Sample collection data are documented in a bound field book, PDA, and/or on a Field Activity Log. Where both are being used, information contained in one is cross-referenced to the other. Entries such as the following examples should be consistent with the requirements in the project-specific Work Plan, FSP, and QAPP:

- Sample identification number, location taken, depth interval, sample media, sample preservative, collection time, and date
- Sample collection method and protocol
- Physical description of the sample (using a standard classification system for soil)
- If a composite sample, include the number, location(s), and depth(s) of grab samples incorporated in the composite
- Quality-related samples (e.g., field duplicates, trip blanks, equipment rinse, blanks matrix spikes, and matrix spike duplicates)
- Container description and sample volume
- Pertinent technical data, such as pH, conductivity, temperature, and head-space readings
- Pertinent technical comments
- Identification of personnel collecting the sample.

2.2 Sample Labeling

Sample labels must be prepared and attached to sample containers. Labels are either provided by the laboratory performing the analyses or are generated internally. Labels should be indelible and securely attached to the container. The information to be provided may include:

- Sample identification number
- Sample date, initials or name of who collected the sample, and collection time
- Physical description of the sample (e.g., water, solid, gas, or other physical medium)
- Analytical parameters and method(s)

- Preservatives, if present
- Sample location and depth, if applicable
- Client.

Although this information is typically written out, it can also be recorded in an electronic tracking system if a bar code is used.

2.3 Analysis Request and Chain-of-Custody Record

A critical component of data collection is the documentation that the samples were obtained from specific locations and received by the laboratory or archive without alteration. Evidence of collection, shipment, laboratory receipt, and laboratory custody until disposal or archive must be properly documented. Documentation will be accomplished through a COC record that documents each sample and identifies the individuals responsible for sample collection, shipment, and receipt. A sample is considered in custody if at least one of the following criteria is met:

- The sample is in a person's actual possession
- The sample is in unobstructed view, after being in the person’s actual possession
- The sample is locked and only accessible by the custodian after having been in the person’s actual possession
- The sample is in a secured area, restricted to authorized personnel (e.g., laboratory).

An example COC form to be used by ENV personnel in collecting and shipping samples can be found on the corporate Intranet. A laboratory typically will not accept samples for analysis without a correctly prepared COC form. The COC must be signed by each individual who has the sample in his/her custody. Each sample shipped to a laboratory for analyses must be documented on the COC. Information on this form correlates with other supporting documentation, including the field log book, sample labels, and sample collection logs.

The COC documents the elapsed time and the custodians of the sample from the time of its collection. The individuals who have physically handled the sample(s) or witnessed initial sample collection and packaging (sample team member) must be identified on the form. A sample team member relinquishes the sample by signing the COC. Individuals who either relinquish or receive samples must include their complete names, company affiliation, and the date and time the sample(s) were relinquished. The times that the samples are relinquished and received by the next custodian should coincide, with the exception of transfer by commercial carriers. These carriers will not be required to sign the COC.

If a sample is to be stored for a period of time (e.g., overnight), measures are taken to secure the sample container in a manner that only provides access to the custodian of record. If samples are relinquished to a commercial carrier (i.e., UPS or Federal Express), the carrier waybill number is recorded, and a copy of the waybill is attached to the COC. These documents are maintained with other field documentation. The original COC is sealed inside a zip-top plastic bag and placed inside the shipping container with the samples.

If corrections are made to the COC, the corrections should be made (single line through the error, initial, and date) by the originator of the change, and, if necessary, an explanation of the change should be provided. The documentation should be of a level of detail that clearly documents the change to a third-party reviewer.

Guidance for choosing a laboratory and completing analyses requests and COC can be found in QP 2.09-Subcontracting Laboratory Services and on the corporate Intranet for the Arcadis Laboratory Program (ALP) and should also be described in the project-specific planning documents (i.e., Work Plan, FSP. or QAPP).

2.4 Subsurface Logs

Test pits, soil borings, monitoring wells or rock coreholes wells, and piezometer installations are to be recorded in bound field books or PDA and may be supplemented with prepared forms. Personnel completing the log are to supply the following information:

- Administrative and technical information included in the header.
- Types of equipment used (e.g., drill rig type, drilling tools used [including diameter and length], or backhoe model).
- Subcontractor/driller used.
- Descriptions of subsurface materials encountered and the number and type of samples collected, if any.
- Subsurface exploration depth and units of measure.
- For drilling, length of recovery.
- Sample type and sample number for geotechnical or analytical samples collected. These data are to be also entered on the sample collection log (if used) and the sample label.
- Classification standard protocol used, if any (e.g., ASTM International Standard Penetration Test).
- Narrative description of the soil, sediment, or bedrock (using standard classification system) and other pertinent information.
- Additional data, such as background and sample vapor/gas readings, observation of sheens, non-aqueous-phase liquid, depth to water (if encountered), presence of (but generally not description of) odors, changes in drilling conditions, and other pertinent information.
- Description of the materials used to seal the boring, unless it is completed as a well or piezometer.

2.5 Monitoring Well/Piezometer Installation

In addition to requirements in Section 2.4, subsequent well or piezometer development activities may involve transcription of field data from the field book onto a computer-based boring log. The field notebook or PDA is to be used to identify the chronology and major events of the installation activity, and the computer-based boring log is to be used to correlate the geologic strata to the major elements of the monitoring well construction. Information to be collected and recorded must meet the regulatory and client requirements and may include the following:

- Location identity
- Screen and riser type, length, diameter, and location

- Diameter
- Total depth
- Sump location and depth and diameter
- Materials of construction (e.g., stainless steel, polyvinyl chloride, or other material)
- Seal type(s) and or depth(s)
- Sand or gravel pack type, including materials (e.g., silica) and gradation
- Depth to water before and after installation.

2.6 Air Sampling Logs

At a minimum, air sampling documentation should include:

- Start and finish time of sampling
- Sampling location
- Sampling method/media
- Volume sampled.

2.7 Construction, Demolition, Abandonment, and Related Activities

Monitoring and documentation of construction and comparable activities shall be documented in bound field books and/or on appropriate company forms and should include similar information as specified above, including information such as:

- Project name and number
- Owner or client name
- Contractor or subcontractors performing the work
- Contractor or subcontractor superintendent(s) and personnel (as available) on site
- Chronological sequence and description of work activities performed, including workday start and completion times
- Reference to contract sections, work plans, or specifications describing work being performed
- Reference to relevant permit conditions and regulatory requirements and/or reference to regulatory guidance documents controlling work approach
- Listing of all trades performing work by contractor and subcontractor
- Hours worked per trade
- Work hours per day per shift, if applicable
- Equipment on site (e.g., description, model number, size, and type) and hours of use
- Listing of equipment on site being left idle
- Description and quantity of materials used or incorporated, with reference to contract or specification item number, if feasible; include simple sketch of excavation with approximate dimension, if applicable
- Calculations with dimensions for quantities of material used or incorporated

- Delineation of the work area and access routes (e.g., fencing, flagging, or staking), confirmation that activities occurred within the work area or description of work occurring outside the delineated work area and justification (as needed), and characterization of impacts outside the designated work area
- Documentation of compliance with speed limits, dust control, erosion control best management practices, and other basic elements of construction activities as dictated by project work plans and applicable permits and regulatory criteria.

2.8 Daily Safety Meeting

A Daily Safety Meeting is to be conducted and documented each workday prior to the initiation of field activities, with on-site ENV personnel, contractors, subcontractors, and visitors if possible. Safety topics discussed are entered on the Daily Safety Meeting Form (available on the corporate Intranet). Topics discussed should include site-specific conditions, procedures to be followed that day, and protective equipment. A printed listing of the attendees at the meeting and their signatures should be included. Other required data are:

- Identification of the individual conducting the meeting and his/her signature
- Identification of the project supervisor and project manager.

2.9 Calibration

Documentation of the calibration and calibration results shall be made for field equipment requiring calibration measuring and test equipment calibration data are recorded in the field book or on the Field Activity Log. Calibration data include the following:

- Unique identification of instrument being calibrated, including type, model, and serial number
- Date and time of calibration
- Standards used in the calibration, including standard identity, concentration, lot number, and manufacturer of the standard
- Instrument reading with respect to each calibration standard
- Comments, as necessary, regarding instrument performance.

2.10 Photographs and Videos

When the client allows, photographs and videos may be used to help document pre-, active, and post-field activities. In sensitive areas (e.g., secured or confidential), the client must be contacted to evaluate security procedures concerning use of photographs or videos. Photographic and video documentation should include project title, project number, date, time, and description of conditions. The time should also be documented if time is important to a sequence of photographs.

Photographs are documented by numbering digital photographs and identifying the number and subject on the Field Activity Log. Individual prints may be marked with a stamp or preprinted self-adhesive labels, or by writing the project number and sequential number of each photograph and referencing the numbers in the field book, the Field Activity Log, or a dedicated photo log. Videos used for field documentation are to be identified by project title, project number, and description.

2.11 Subcontractor Preparedness Checklist

Prior to starting work, a review is to be made and documented of a subcontractor's preparedness to perform specified activities. This review may be documented on the Field Activities Log or on checklists that may be developed according to requirements for subcontracted work activities. Particular emphasis should be on site-specific issues that may require special consideration such as health and safety, access, and unique settings. These should be discussed in advance with the CPM and the client in developing and implementing the Scope of Work.

— END OF PROCEDURE —

ARCADIS Design & Consultancy for natural and built assets

TECHNICAL GUIDANCE INSTRUCTION - MONITORING WELL DEVELOPMENT

Rev: #0

Rev Date: April 24, 2017

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
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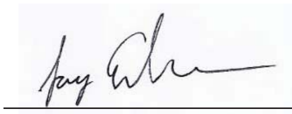
APPROVAL SIGNATURES

Prepared by:	 Jay Erickson	4/24/2017 Date:
Technical Expert Reviewed by:	 Marc Killingstad	4/24/2017 Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

This Technical Guidance Instruction (TGI) covers the development of screened wells used for obtaining representative groundwater information and samples from granular aquifers (i.e., monitoring wells). Note that this TGI only applies to monitoring well development and not remediation (injection/extraction) well development.

The purposes of Monitoring Well Development are:

1. Repair damage to the borehole wall from drilling that can include clogging, smearing or compaction of aquifer materials;
2. Remove fine grained sediment from the formation and filter pack that may result in high turbidity levels in groundwater samples;
3. To re-sort formation and filter pack material adjacent to the well screen;

4. To recover any drilling fluids (if used) that may affect the permeability of the formation and filter pack or alter the water quality around the well; and
5. To optimize the well efficiency and hydraulic communication between the well screen and the formation.

Successful monitoring well development is dependent on the following:

1. Hydrostratigraphy – Permeable formations containing primarily sand and gravel are more easily developed due to lower percentages of silt and clay material. Water in permeable formations can be moved in and out of the screen and/or through the formation easier than in less permeable deposits
2. Well Diameter – Development tooling including brushes, surge blocks, pumps and jetting tools are more readily available for wells 4 inches in diameter and greater.
3. Well Design – Wells with filter packs and screens designed to match the formation through the analysis of formation sieve samples are easier to develop. An important aspect to well design is to minimize the size of the annular space between the formation and well screen. Adequate room must be allowed for the proper installation of well materials, but not too large as to prevent/reduce communication with the surrounding formation.
4. Drilling Methods – Different drilling methods result in varying amount of borehole damage and, therefore, impact the degree to which development will be successful.

Well development methods for monitoring wells include the following:

1. Bailing – use of a bailer to remove water and sediment from the well casing. This technique does little to remove fines from the filter pack and may lead to bridging of sediment since the flow in only in one direction, toward the well screen.
2. Pumping/overpumping – use of a pump to remove water and sediment from the well casing, overpumping involves pumping the well at a rate that exceeds the design capacity of the well. Similar to bailing, this technique does little to remove fines from the filter pack and may lead to bridging of sediment since the flow in only in one direction, toward the well screen. Small diameter monitoring wells have the additional constraint on pump size and flow rates.
3. Backwashing (rawhiding) – consists of starting and stopping a pump intermittently to produce rapid pressure changes in a well. This method can produce better results than pumping alone since the procedure involves movement of the water in and out of the screen and formation. However, in many cases the surging action is not rigorous enough to fully develop the well.
4. Surging/swabbing – use of a mechanical surge block or swabbing tool to operate like a piston with an up and down motion. The downstroke causes a backwash action that breaks up bridged sediment and the upstroke pulls the dislodged sediment into the well. This method works well for small and large diameter wells. Care should be taken on the downstroke so as not to force fines back into the formation, frequent pumping/purging during surging help to keep fines out of the well. Double surge blocks are recommended.
5. Jetting – use of a tool fitted with nozzles that direct streams of water horizontally into well screens at high velocity. Due to the size of the tooling, this method is better suited for wells 4 inch in diameter and larger. The method is also more effective with wire-wrapped/continuous slot screens due to the

increased open area. Jetting requires specialized equipment and concurrent pumping to prevent reintroducing fines into the filter pack. Additionally, jetting requires subsequent surging to remove fines dislodged in the filter pack and formation.

For most situations, gentle surging coupled with bailing or pumping to remove dislodged materials is recommended.

Well development for properly designed and constructed monitoring wells may begin after the annular seal materials have been installed and allowed to cure, since these wells are designed to retain 90-99% of the filter pack material. This cure time is typically at least 24 to 48 hours after the sealing materials have been installed.

This TGI is meant to provide a general guide for proper monitoring well development. A site-specific field implementation plan for well installation and development detailing the specific methods and tools should be developed to provide site-specific instruction and guidance.

3 PERSONNEL QUALIFICATIONS

Monitoring well development activities will be performed by persons who have been trained in proper well development procedures under the guidance of an experienced field geologist, engineer, or technician.

4 EQUIPMENT LIST

Required equipment depends on the selected method and should be detailed in the site-specific field implementation plan. However, the following are typically required.

- Health and safety equipment, as required by the site Health and Safety Plan (HASP):
- Cleaning equipment
- Field notebook and/or personal digital assistant (PDA)
- Monitoring well keys
- Water level indicator
- Field parameter meter (YSI)
- Well Development Logs
- Well construction logs/diagrams
- Weighted tape (measure depth)
- Turbidity meter
- Camera
- Watch/timing device.

5 CAUTIONS

Where surging is performed to assist in removing fine-grained material from the sand pack, surging must be performed in a gentle manner. Excessive suction could promote fine-grained sediment entry into the outside of the sand pack from the formation.

Avoid using development fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

In some cases, it may be necessary to add potable water to a well to allow surging and development, especially for new monitoring wells installed in low permeability formations. Before adding potable water to a well, the Certified Project Manager (CPM) and/or Project Hydrogeologist must be notified and the CPM shall make the decision regarding the appropriateness and applicability of adding potable water to a well during well development procedures. If potable water is to be added to a well as part of development, the potable water source should be sampled and analyzed for constituents of concern, and the results evaluated by the CPM prior to adding the potable water to the well. If potable water is added to a well for development purposes, at the end of development the well will be purged dry to remove the potable water, or if the well no longer goes dry then the well will be purged to remove at least three times the volume of potable water that was added.

6 HEALTH AND SAFETY CONSIDERATIONS

Field activities associated with monitoring well development will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

7 PROCEDURE

As indicated above, for most monitoring wells, gentle surging coupled with bailing or pumping to remove dislodged sediment is recommended.

1 Ensure sufficient time has passed to allow for proper curing of the well seal.

2 Don appropriate PPE (as required by the site-specific HASP).

3 Place plastic sheeting around the well.

4 Clean all equipment entering each monitoring well, except for new, disposable materials that have not been previously used.

5 Open the well cover while standing upwind of the well, remove well cap. Insert PID probe approximately 4 to 6 inches into the casing or the well headspace and cover with gloved hand. Record the PID reading in the field notebook. If the well headspace reading is less than 5 PID units, proceed; if the headspace reading is greater than 5 PID units, screen the air within the breathing zone. If the PID reading in the breathing zone is below 5 PID units, proceed. If the PID reading is above 5 PID units, move upwind from well for 5 minutes to allow the volatiles to dissipate. Repeat the breathing zone test. If the reading is still above 5 PID units, don the appropriate respiratory protection in accordance with the requirements of the HASP. Record all PID readings.

6 Obtain an initial measurement of the depth to water and the total well depth from the reference point at the top of the well casing. Record these measurements in the field log book. It is recommended to use a weighted tape for the total well depth measurement.

7 The depth to the bottom of the well should be sounded and then compared to the completion form or construction diagram for the well. Any discrepancies should be reported immediately to the CPM and/or Project Hydrogeologist. If sand or sediment is present inside the well, it should first be removed by bailing. Do not insert bailers, pumps, or surge blocks into the well if obstructions, parting of the casing, or other damage to the well is suspected. Instead report the conditions to the CPM and/or Project Hydrogeologist and obtain approval to continue or cease well development activities.

8 Lower a double surge block into the screened portion of the well. Starting from the bottom of the screen using 2 foot throws, gently raise and lower the surge block to force water in and out of the screen slots and sand pack. Continue surging for 15 to 30 minutes.

9 Lower a bottom-loading bailer, submersible pump, or inertia pump tubing with check valve to the bottom of the well and gently bounce on the bottom of the well to collect/remove accumulated sediment, if any. Remove and empty the bailer, if used. Repeat until the bailed/pumped water is free of excessive sediment and contact at the bottom of the well feels solid. Alternatively, measurement of the well depth with a weighted tape can be used to verify that sediment and/or silt has been removed to the extent practicable, based on a comparison with the well installation log or previous measurement of total well depth.

10 After surging the well for a minimum of two cycles and removing excess accumulated sediment from the bottom of the well, re-measure the depth-to-water and the total well depth from the reference point at the top of the well casing. Record these measurements in the field log book.

11 Remove formation water by pumping/bailing. Where pumping is used, measure and record the pre-pumping water level. Operate the pump at a relatively constant rate. Measure the pumping rate using a calibrated container and stop watch, and record the pumping rate in the field log book. Measure and record the water level in the well at least once every 5 minutes during pumping. Note any relevant observations in terms of water color, visual level of turbidity, sheen, odors, etc. Pump or bail until termination criteria specified in the Site-Specific Field Implementation plan are reached. Note: the project-specific field implementation plan may also specify a maximum turbidity requirement for completion of development. Unless otherwise specified the maximum turbidity should be 50 NTUs or less. Record the total volume of water purged from the well.

12 While developing, take periodic water level measurements (at least one every five minutes) to determine if drawdown is occurring and record the measurements on the Well Development Log.

13 While developing, calculate the rate at which water is being removed from the well. Record the volume on the Well Development Log.

14 While developing, water is also periodically collected directly from the well or bailer discharge and readings taken of the indicator parameters: pH, specific conductance, and temperature. Development is considered complete when the indicator parameters have stabilized (i.e., three consecutive pH, specific conductance, and temperature readings are within tolerances specified in the project work plans or within 10% if not otherwise specified), the extracted water is clear and free

of fine sediment and most importantly, when acceptable volume of water has been removed and/or a sufficient amount of surging has been performed.

15 In certain instances, for slow recharging wells, the parameters may not stabilize. In this case, well development is considered complete when minimal amounts of fine-grained sediments are recovered and acceptable volume of water has been removed.

16 If the well goes dry, stop pumping or bailing. Note the time that the well went dry. After allowing the well to recover, note the time and depth to water. Resume pumping or bailing when sufficient water has recharged the well.

17 Contain all development water in appropriate containers.

18 When complete, secure the lid back on the well.

19 Place disposable materials in plastic bags for appropriate disposal and decontaminate reusable, downhole pump components and/or bailer

8 WASTE MANAGEMENT

Materials generated during monitoring well installation and development will be placed in appropriate labeled containers and disposed of as described in the Work Plan/Field Implementation Plan or Field Sampling Plan.

9 DATA RECORDING AND MANAGEMENT

All well development activities should be documented on appropriate log forms as well as in a proper field notebook and/or PDA. Additionally, all documents (and photographs) should be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site; times of arrival and departure; significant weather conditions; timing of well development activities; development method(s); observations of purge water color, turbidity, odor, sheen, etc.; purge rate; and water levels before, during, and after pumping.

10 QUALITY ASSURANCE

All reused, non-disposable, downhole well development equipment should be cleaned in accordance with the procedures outlined in the project documents.

11 REFERENCES

American Society for Testing Materials (ASTM), Designation D5521-05. *Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

ARCADIS Design & Consultancy for natural and built assets

TGI - MONITORING WELL INSTALLATION

Rev #: 0

Rev Date: April 24, 2017

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	4/24/2017	All	Re-written as a TGI	Marc Killingstad Peter C. Frederick

APPROVAL SIGNATURES

Prepared by:	Jay Erickson	Date: 4/20/17
Technical Expert Reviewed by:	Marc Killingstad	Date: 4/24/17

1 INTRODUCTION

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2 SCOPE AND APPLICATION

This Technical Guidance Instruction (TGI) describes methods used to install groundwater monitoring wells in granular aquifers. It is assumed that the monitoring well has been properly designed, including sizing of the filter pack and screen, the length of the screen, total depth of the well, material strength and compatibility and surface completion. Typical monitoring wells are constructed of manufactured screen and engineered filter pack and are generally suitable for formations with granular materials having a grain size distribution with up to 50% passing a #200 sieve and up to 20% clay-sized material. Monitoring wells installed in formations finer than this may not be able to produce turbidity free water.

The monitoring well installation procedures set forth herein are consistent with the approach and methods presented in the American Society of Testing and Materials (ASTM) D5092 – *Standard Practice for Design and Installation of Groundwater Monitoring Wells* (ASTM D5092). As such, following this TGI in combination with proper well design (see appropriate TGI), well development (see appropriate TGI), groundwater sampling procedures (see appropriate TGI), and well maintenance and rehabilitation (see appropriate TGI), will result in a monitoring well suitable for: (1) collection of groundwater samples representative of the surrounding formation and free of artificial turbidity; (2) measurement of accurate groundwater levels; and (3) hydraulic conductivity testing of formation sediments immediately adjacent to the open interval of the well (e.g., slug testing).

Monitoring well boreholes in unconsolidated (overburden) materials are typically drilled using the hollow-stem auger drilling method. Other drilling methods that are also suitable for installing overburden monitoring wells, and are sometimes necessary due to site-specific geologic conditions or project objectives, include: drive-and-wash, spun casing, Rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary with core barrel or roller bit. Direct-push techniques (e.g., Geoprobe or cone penetrometer) and driven well points may also be used in some cases within the overburden. Monitoring wells to be installed within consolidated materials such as fractured bedrock are commonly drilled using water-rotary (coring or tri-cone roller bit), air rotary or Rotasonic methods. For guidance when installing monitoring wells in consolidated materials, please refer to the appropriate document. The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling/well depths, site or regional geologic knowledge, type of monitoring to be conducted using the installed well, project objectives, and cost.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). No polyvinyl chloride (PVC) glue/cement will be used in constructing or retrofitting monitoring wells that will be used for water-quality monitoring. No coated bentonite pellets will be used in the well drilling or construction process. Specifications of materials to be installed in the borehole will be obtained prior to mobilizing onsite; these materials generally include:

- Well casing (length, material, and diameter);
- Well screen (length, material, diameter, and slot size);
- Bentonite (type, as applicable, chips, non-coated and granular bentonite are acceptable);
- Filter pack (filter pack type and fine sand seal type, as applicable); and
- Grout (type, as applicable).

Well materials will be inspected and, if needed, cleaned or replaced prior to installation.

3 PERSONNEL QUALIFICATIONS

Monitoring well installation activities will be performed by persons who have been trained in proper well installation procedures under the guidance of an experienced field geologist, engineer, or technician. Where field sampling is performed for soil or bedrock characterization, field personnel will have undergone in-field training in soil or bedrock description methods, as described in the appropriate Standard Operating Procedures (SOPs) and/or TGIs for those activities.

4 EQUIPMENT LIST

The following materials will be available during soil boring and monitoring well installation activities, as required:

- Site Plan with proposed soil boring/well locations;

- Work Plan (or equivalent), Field Sampling Plan (FSP), and site-specific Health and Safety Plan (HASP);
- Personal protective equipment (PPE), as required by the HASP;
- Traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area, if such are not provided by drillers;
- Appropriate soil sampling equipment (e.g., stainless steel spatulas, knife);
- Soil and/or bedrock logging equipment as specified in the appropriate project documents;
- Appropriate sample containers and labels;
- Drum labels as required for investigation derived waste handling;
- Chain-of-custody forms;
- Insulated coolers with ice, when collecting samples requiring preservation by chilling;
- Photoionization detector (PID) or flame ionization detector (FID);
- Ziplock style bags;
- Water level or oil/water interface meter;
- Locks and keys for securing the well after installation;
- Decontamination equipment (bucket, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels);
- Engineer's tape/measuring wheel;
- Weighted tape;
- Disposable bailers;
- Digital camera (or phone with camera)
- Field notebook or Personal Digital Assistant (PDA); and
- Appropriate field forms, consider including a photo of the well head and a Google Earth map showing the well location.

Prior to mobilizing to the site, Arcadis personnel will contact the drilling subcontractor or in-house driller (as appropriate) to confirm that appropriate sampling and well installation equipment will be provided. Specifications of the sampling and well installation equipment are expected to vary by project, and so communication with the driller is necessary to ensure that the materials provided will meet the project objectives. Equipment/materials typically provided by the driller could include:

- Drilling equipment required by the ASTM standard guidance document D1586, when performing split-spoon sampling;
- Disposable plastic liners (when drilling with direct-push equipment);
- Drums for investigation derived waste;

- Drilling and sampling equipment decontamination materials;
- Decontamination pad materials, if required; and
- Well construction materials.

5 CAUTIONS

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service. See appropriate guidance for proper utility clearance protocol.

Prior to beginning field work, contact the project technical team to ensure that all field logistics (e.g., access issues, health and safety issues, communication network, schedules, etc.) and task objectives are clearly understood by all team members.

Some regulatory agencies require a minimum annular space between the well or permanent casing and the borehole wall. When specified, the minimum clearance is typically 2 inches on all sides (e.g., a 2-inch diameter well requires a 6-inch diameter borehole). In addition, some regulatory agencies have specific requirements regarding grout mixtures. Determine whether the oversight agency has any such requirements prior to finalizing the drilling and well installation plan.

If dense non-aqueous phase liquids (DNAPL) are known or expected to exist at the site, refer to the project specific documents for additional details regarding drilling and well installation to reduce the potential for inadvertent DNAPL remobilization.

Similarly, if light non-aqueous phase liquids (LNAPLs) are known or expected to be present as “perched” layers above the water table, refer to the DNAPL Contingency Plan. Follow the general provisions and concepts in the DNAPL contingency plan during drilling above the water table at known or expected LNAPL sites.

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

Similarly, consider the compatibility between the well materials and the surrounding environment. For example, PVC well materials are not preferred when DNAPL is present. In addition, some groundwater conditions leach metals from stainless steel or are corrosive to metal well materials. If questions arise, contact the CPM and/or project technical lead to discuss.

Water used for drilling and sampling of soil or bedrock, decontamination of drilling/sampling equipment, or grouting boreholes upon completion will be of a quality acceptable for project objectives. Testing of water supply should be considered.

Specifications of materials used for backfilling the borehole will be obtained, reviewed and approved to meet project quality objectives. Bentonite is not recommended where DNAPLs are likely to be present or in groundwater with high salinity. In these situations, neat cement grout is preferred.

As noted above, coated bentonite pellets will not be used in monitoring well construction, as the coating could impact the water quality in the completed well.

Heat of hydration during neat cement grout curing must be considered to avoid damage to PVC well materials. The annular space for a typical monitoring well is small enough that heat of hydration should not create excessive temperature increases which may damage PVC well material. However, washouts in the borehole can lead to thick accumulations of grout which can produce enough heat during curing to weaken and potentially damage PVC casing. If heat of hydration is a concern, contact the project technical lead to address the issue.

6 HEALTH AND SAFETY CONSIDERATIONS

Field activities associated with monitoring well installation will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

7 PROCEDURE

The procedures for installing groundwater monitoring wells are presented below:

Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods

1. Prior to monitoring well installation, determine the expected volumes of filter pack and seal materials including bentonite (if applicable) and grout (neat cement or cement-bentonite).
2. Locate boring/well location, establish work zone, and set up sampling equipment decontamination area.
3. Advance boring to desired depth. Collect soil and/or bedrock samples at appropriate interval as specified in the Work Plan (or equivalent) and/or FSP. Collect, document, and store samples for laboratory analysis as specified in the Work Plan and/or FSP. Decontaminate equipment between samples in accordance with the Work Plan (or equivalent) and/or FSP. A common sampling method that produces high-quality soil samples with relatively little soil disturbance is described in ASTM D1586 – *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils* (ASTM D1586). Split-spoon samples are obtained during drilling using hollow-stem auger, drive-and-wash, spun casing, and fluid/mud rotary. Rotasonic drilling produces soil cores that, for the most part, are relatively undisturbed, but note that when drilling in consolidated or finer-grained sediment the vibratory action during core barrel advancement may create secondary fractures or breaks. Dual-rotary removes cuttings by compressed air or water/mud and allow only a general assessment of geology.
4. Describe each soil sample as outlined in the appropriate project records. Record descriptions in the field notebook and/or personal digital assistant (PDA). It is also beneficial to photo document the samples. It should be noted that PDA logs must be electronically backed up and transferred to a location accessible to other project team members as soon as feasible to retain and protect the field data. During soil boring advancement, document all drilling events in field notebook, including blow counts (number of blows required to advance split-spoon sampler in 6-inch increments) and work stoppages. Blow counts will not be available if Rotasonic, dual-rotary, or direct-push methods are used.

5. If it is necessary to install a monitor well into a permeable zone below a confining layer, particularly if the deeper zone is believed to have water quality that differs significantly from the zone above the confining layer, then a telescopic well construction should be considered. In this case, the borehole is advanced approximately 3 to 5 feet into the top of the confining layer, and a permanent casing (typically PVC, black steel or stainless steel) is installed into the socket drilled into the top of the confining layer. The casing is then grouted in place. The preferred methods of grouting telescoping casings include: pressure-injection grouting using an inflatable packer installed temporarily into the base of the casing, such that grout is injected out the bottom of the casing until it is observed at ground surface outside the casing; displacement-method grouting (also known as the Halliburton method), which entails filling the casing with grout and displacing the grout out the bottom of the casing by pushing a drillable plug, typically made of wood to the bottom of the casing, following by tremie grouting the remainder of the annulus outside the casing; or tremie grouting the annulus surrounding the casing using a tremie pipe installed to the base of the borehole. In all three cases, the casing is grouted to the ground surface, and the grout is allowed to set prior to drilling deeper through the casing. Site-specific criteria and work plans should be created for the completion of non-standard monitoring wells, including telescopic wells.
6. Before installing a screened, it is important to confirm that the borehole has been advanced into the targeted saturated zone. This is particularly important for wells installed to monitor the water table and/or the shallow saturated zone, as the capillary fringe may cause soils above the water table to appear saturated. If one or more previously installed monitoring wells exist nearby, use the depth to water at such well(s) to estimate the water-table depth at the new borehole location.

   To verify that the borehole has been advanced into the saturated zone, it is necessary to measure the water level in the borehole. For boreholes drilled without using water (e.g., hollow-stem auger, cable-tool, air rotary, air hammer), verify the presence of groundwater (and /or LNAPL, if applicable) in the borehole using an electronic water level probe, oil-water interface probe, or a new or decontaminated bailer. For boreholes drilled using water (e.g., drive and wash, spun-casing with roller-bit wash, Rotasonic, or water rotary with core or roller bit), monitor the water level in the borehole as it re-equilibrates to the static level. In low-permeability units like clay, fine-grained glacial tills, shale and other bedrock formations, it may be necessary to wait overnight to allow the water level to equilibrate. Document depth to water in the borehole on the appropriate field forms and field notebook. If there are questions concerning the depth of the well/screen interval, consult with the project technical lead prior to finalizing well depth/screen interval. To the extent practicable, ensure that the depth of the well below the apparent water table is deep enough so that the installed well can monitor groundwater year-round, accounting for seasonal water-table fluctuations. When in doubt, err on the side of slightly deeper well installation.
7. Upon completing the borehole to the desired depth, if a screened well construction is desired, install the monitoring well by lowering the screen and casing assembly with sump through the augers or casing. Monitoring wells typically will be constructed of 2-inch-diameter (although sometimes 4-inch), flush-threaded PVC or stainless steel slotted or wire wrapped well screen and blank riser casing. Smaller diameters may be used if wells are installed using direct-push methodology or if multiple wells are to be installed in a single borehole. The screen length will be specified in the Work Plan (or equivalent) or FSP based on regulatory requirements and specific monitoring objectives. Monitoring well screens are usually 5 to 10 feet long, but may be up to 25 feet long in very low permeability, thick

geologic formations. The screen length will depend on the purpose for the well and the objectives of the groundwater investigation and will (in most cases) be determined prior to the field mobilization.

The slot size and filter pack gradation should be predetermined in the Work Plan (or equivalent) or FSP and based on site-specific grain-size analysis (sieve analysis) or other geologic considerations or monitoring objectives. Typically, slot sizes for monitoring wells will range from 0.010 inches to 0.020 inches while the filter pack will be 20-40, Morie No. 0, or equivalent. In very fine-grained formations where sample turbidity needs to be minimized, it may be preferred to use a 0.006-inch slot size and 30-65, Morie No. 00, or equivalent filter pack. Alternatively, where monitoring wells are installed in coarse-grained deposits and higher well yield is required, a 0.020-inch slot size and 10-20, Morie No. 1, or equivalent filter pack may be preferred. If the screen slot size and filter pack have not been based on site-specific grain-size analysis, consider collecting soil samples during well installation so future wells can be properly designed.

A blank sump may be attached below the well screen if the well is being installed for DNAPL recovery/monitoring purposes. If so, the annular space around the sump may be backfilled with neat cement grout using a tremie to the bottom of the well screen prior to placing the filter pack around the screen. A blank riser will extend from the top of the screen to approximately 2.5 feet above grade or, if necessary, just below grade where conditions warrant a flush-mounted monitoring well. For wells greater than 50 feet deep, centralizers may be desired to assist in centering the monitoring well in the borehole during construction.

8. When the monitoring well assembly has been set in place and the grout has been placed around the sump (if any), place a washed silica filter pack in the annular space from the bottom of the boring to a height of 1 to 2 feet above the top of the well screen (following specifications in the Work Plan) using a tremie. The filter pack is placed and drilling equipment extracted in increments until the top of the sand pack is at the appropriate depth. Verify that the expected volume of filter pack matches with the actual amount installed. There can be differences due to irregularities in the borehole. Washout of the borehole will result in the need for greater than calculated well materials. If a difference of more than 10% is noted, consult with the project technical team. The filter pack will be consistent with the screen slot size and the soil particle size in the screened interval, as specified in the Work Plan (or equivalent) or FSP. The well should be gently surged to prevent filter pack material bridging and to settled the filter pack prior to well seal installation.

9. A hydrated bentonite seal (a minimum of 2 feet thick) will then be placed in the annular space above the sand pack (alternatively, in some cases a fine sand seal may be installed instead of bentonite—follow the specifications in the Work Plan). If non-hydrated bentonite is used, the bentonite should be permitted to hydrate in place for a minimum of 30 minutes before proceeding. *No coated bentonite pellets will be used in monitoring well drilling or construction*. Potable water may be added to hydrate the bentonite if the seal is above the water table. Monitor the placement of the sand pack and bentonite with a weighted tape measure.

10. During the extraction of the augers or casing, a cement/bentonite or neat cement grout will be placed in the annular space from the bentonite seal to a depth approximately 2 ft. below groundwater surface (bgs) or as specified in the Work Plan (or equivalent). As with the filter pack, it is recommended that seal material be placed with a tremie pipe. Ensure that seal materials are mixed at the proper ratios with water following manufacturer’s recommendations.

11. Install the monitoring well completion as specified Work Plan (or equivalent). Typical completions are a locking, steel protective casing (extended at least 1.5 feet below grade and 2 feet above grade) over the riser casing and secure with a neat cement seal. Alternatively, for flush-mount completions, place a steel curb box with a bolt-down lid over the riser casing and secure with a neat cement seal. In either case, the cement seal will extend approximately 1.5 to 2.0 feet below grade and laterally at least 1 foot in all directions from the protective casing, and should slope gently away to promote drainage away from the well.
12. Monitoring wells should be labeled using indelible ink or paint with the appropriate designation on both the inner and outer well casings or inside of the curb box lid.
13. When an above-grade completion is used, the riser will be sealed using an expandable locking plug and the top of the well will be vented by drilling a small-diameter (1/8 inch) hole near the top of the well casing or through the locking plug, or by cutting a vertical slot in the top of the well casing. When a flush-mount installation is used, the riser will be sealed using an unvented, expandable locking plug.
14. During well installation, record construction details and actual measurements relayed by the drilling contractor and tabulate materials used (e.g., screen and riser footages; bags of bentonite, cement, and sand) in the field notebook as well as appropriate field forms.
15. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section 7 below.

Direct-Push Method

The direct-push drilling method may also be used to complete soil borings and install monitoring wells. Examples of this technique include the Diedrich ESP vibratory probe system, GeoProbe®, or AMS Power Probe® dual-tube system. Environmental probe systems typically use a hydraulically operated percussion hammer. Depending on the equipment used, the hammer delivers 140- to 350-foot pounds of energy with each blow. The hammer provides the force needed to penetrate very stiff to medium dense soil formations. The hammer simultaneously advances an outer steel casing that contains a dual-tube liner for sampling soil. The outside diameter (OD) of the outer casing ranges from 1.75 to 2.4 inches and the OD of the inner sampling tube ranges from 1.1 to 1.8 inches. The outer casing isolates shallow layers and permits the unit to continue to probe at depth. The double-rod system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, the inside diameter (ID) of the steel casing provides clearance for the installation of small-diameter (e.g., 0.75- to 1-inch ID) micro-wells. The procedures for installing monitoring wells in soil using the direct-push method are described below.

1. Locate boring/well location, establish work zone, and set up sample equipment decontamination area.
2. Advance soil boring to designated depth, collecting samples at intervals specified in the Work Plan (or equivalent). Samples will be collected using dedicated, disposable, plastic liners. Describe samples in accordance with the procedures outlined in Step 3 above. Collect samples for laboratory analysis as specified in the Work Plan (or equivalent) and/or FSP.
3. Upon advancing the borehole to the desired depth, install the micro-well through the inner drill casing. The micro-well will consist of approximately 1-inch ID PVC or stainless steel slotted screen and blank riser. The sand pack, bentonite seal, and cement/bentonite grout will be installed as described, where applicable, in Steps 9 through 11 above.

4. Install protective steel casing or flush-mount, as appropriate, as described in Step 12 above. During well installation, record construction details and tabulate materials used in field notebook as well as appropriate field forms.
5. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section 8 below.

Driven Well Point Installation

Well points will be installed by pushing or driving using a drilling rig or direct-push rig, or hand-driven where possible. The well point construction materials will consist of a 1- to 2-inch-diameter threaded steel casing with either 0.010- or 0.020-inch slotted stainless steel screen. The screen length will vary depending on the hydrogeologic conditions of the site. The casings will be joined together with threaded couplings and the terminal end will consist of a steel well point. Because they are driven or pushed to the desired depth, well points do not have annular backfill materials such as sand pack or grout.

8 WASTE MANAGEMENT

Investigation-derived wastes (IDW), including soil cuttings and excess drilling fluids (if used), decontamination liquids, and disposable materials (well material packages, PPE, etc.), will be placed in clearly labeled, appropriate containers, or managed as otherwise specified in the Work Plan (or equivalent), FSP, and/or IDW management guidance document.

9 DATA RECORDING AND MANAGEMENT

Drilling activities should be documented on appropriate field/log forms as well as in a proper field notebook and/or PDA. Additionally, all documents (and photographs) should be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of well installation activities, soil descriptions, well construction specifications (screen and riser material and diameter, sump length, screen length and slot size, riser length, sand pack type), and quantities of materials used. In addition, the locations of newly-installed wells will be documented photographically or in a site sketch. If appropriate, a measuring wheel or engineer’s tape will be used to determine approximate distances between important site features.

The well location, ground surface elevation, and inner and outer casing elevations will be surveyed using the method specified in the site Work Plan (or equivalent). Generally, a local baseline control will be set up. This local baseline control can then be tied into the appropriate vertical and horizontal datum, such as the National Geodetic Vertical Datum of 1929 or 1988 and the State Plane Coordinate System. At a minimum, the elevation of the top of the inner casing used for water-level measurements should be measured to the nearest 0.01 foot. Elevations will be established in relation to the National Geodetic Vertical Datum of 1929. A permanent mark will be placed on top of the inner casing to mark the point for water-level measurements.

10 QUALITY ASSURANCE

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the appropriate SOP. Well materials will also be cleaned prior to well installation.

11 REFERENCES

American Society for Testing Materials (ASTM) D5092 - *Standard Practice for Design and Installation of Ground Water Monitoring Wells*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

American Society of Testing and Materials (ASTM) D1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

TGI - SOIL DESCRIPTION

Rev: #2

Rev Date: February 16, 2018

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	May 20, 2008	17	Original SOP	Joe Quinnan Joel Hunt
1	September 2016	15	Updated to TGI	Nick Welty Patrick Curry
2	February 16, 2018	15	Updated descriptions, attachments and references in text	Nick Welty Patrick Curry

APPROVAL SIGNATURES

Prepared by:		June 30, 2017
	Patrick Curry, PG	Date:
Technical Expert Reviewed by:		June 30, 2017
	Nicklaus Welty, PG	Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

This Arcadis Technical Guidance Instruction (TGI) describes proper soil description procedures. This TGI should be followed for unconsolidated material unless there is an established client-required specific procedure or regulatory-required specific procedure. In cases where there is a required specific procedure, it should be followed and should be referenced and/or provided as an appendix to reports that include soil classifications and/or boring logs. When following a required non-Arcadis procedure, additional information required by this TGI should be included in field notes with client approval.

This TGI has been developed to emphasize field observation and documentation of details required to:

- make hydrostratigraphic interpretations guided by depositional environment/geologic settings;
- provide information needed to understand the distribution of constituents of concern; properly design wells, piezometers, and/or additional field investigations; and develop appropriate remedial strategies.

This TGI incorporates elements from various standard systems such as ASTM D2488-06, Unified Soil Classification System, Burmister and Wentworth. However, none of these standard systems focus specifically on contaminant hydrogeology and remedial design. Therefore, although each of these systems contain valuable guidance and information related to correct descriptions, strict application of these systems can omit information critical to our clients and the projects that we perform.

This TGI does not address details of health and safety; drilling method selection; boring log preparation; sample collection; or laboratory analysis. Refer to other Arcadis procedure, guidance, and instructional documents, the project work plans including the quality assurance project plan, sampling plan, and health and safety plan (HASP), as appropriate.

3 PERSONNEL QUALIFICATIONS

Soil descriptions should only be performed by Arcadis personnel or authorized sub-contractors with a degree in geology or a geology-related discipline. Field personnel will complete training on the Arcadis soil description TGI in the office and/or in the field under the guidance of an experienced field geologist with at least 2 years of prior experience applying the Arcadis soil description method.

4 EQUIPMENT LIST

The following equipment should be taken to the field to facilitate soil descriptions:

- field book, field forms or PDA to record soil descriptions;
- field book for supplemental notes;
- this TGI for Soil Descriptions and any project-specific procedure, guidance, and/or instructional documents (if required);
- field card showing Wentworth scale;
- Munsell® soil color chart;
- tape measure divided into tenths of a foot;
- stainless steel knife or spatula;
- hand lens;
- water squirt bottle;
- jar with lid;
- personal protective equipment (PPE), as required by the HASP; and
- digital camera

5 CAUTIONS

Drilling and drilling-related hazards including subsurface utilities are discussed in other procedure documents and site-specific HASPs and are not discussed herein.

Soil samples may contain hazardous substances that can result in exposure to persons describing soils. Routes for exposure may include dermal contact, inhalation and ingestion. Refer to the project specific HASP for guidance in these situations.

6 HEALTH AND SAFETY CONSIDERATIONS

Field activities associated with soil sampling and description will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities. Know what hazardous substances may be present in the soil and understand their hazards. Always avoid the temptation to touch soils with bare hands, detect odors by placing soils close to your nose, or tasting soils.

7 PROCEDURE

1. Select the appropriate sampling method to obtain representative samples in accordance with the selected sub-surface exploration method, e.g. split-spoon or Shelby sample for hollow-stem drilling, acetate sleeves for direct push, bagged core for sonic drilling, etc.
2. Proceed with field activities in required sequence. Although completion of soil descriptions is often not the first activity after opening sampler, identification of stratigraphic changes is often necessary to select appropriate intervals for field screening and/or selection of laboratory samples.
3. Set up boring log field sheet.
   - Drillers in both the US and Canada generally work in feet due to equipment specifications. Use the Arcadis standard boring log form (**Attachment A**).
   - The preferred boring log includes a graphic log of the principal soil component to support quick visual evaluation of grain size. The purpose of the graphic log is to quickly assess relative soil permeability. Note, for poorly sorted soils (e.g. glacial till), the principal component may not correlate to permeability of the sample. In this case, the geologist should use best judgement to graph overall soil type consistent with relative soil permeability. For example, for a dense sand/silt/clay till, the graphic log would reflect the silt/clay, rather than sand.
   - Record depths along the left-hand side at a standard scale to aid in the use of this tool. See an example completed boring log (**Attachment B**).
4. Examine each soil core (this is different than examining each sample selected for laboratory analysis), and record the following for each stratum:
   - depth interval;
   - principal component with descriptors, as appropriate;
   - amount and identification of minor component(s) with descriptors as appropriate;
   - moisture;
   - consistency/density;
   - color; and
   - additional description or comments (recorded as notes).
5. At the end of the boring, record the amount of drilling fluid used (if applicable) and the total depth logged.

The above is described more fully below.

DEPTH

To measure and record the depth below ground surface (bgs) of top and bottom of each stratum, the following information should be recorded.

1. Measured depth to the top and bottom of sampled interval. Use starting depth of sample based upon measured tool length information and the length of sample interval.
2. Length of sample recovered, not including slough (material that has fallen into hole from previous interval), expressed as fraction with length of recovered sample as numerator over length of sampled interval as denominator (e.g. 14/24 for 14 inches recovered from 24-inch sampling interval that had 2 inches of slough discarded).
3. Thickness of each stratum measured sequentially from the top of recovery to the bottom of recovery.
4. Any observations of sample condition or drilling activity that would help identify whether there was loss from the top of the sampling interval, loss from the bottom of the sampling interval, or compression of the sampling interval. Examples: 14/24, gravel in nose of spoon; or 10/18 bottom 6 inches of spoon empty.

DETERMINATION OF COMPONENTS

Obtain a representative sample of soil from a single stratum. If multiple strata are present in a single sample interval, each stratum should be described separately. More specifically, if the sample is from a 2-foot long split-spoon where strata of coarse sand, fine sand and clay are present, then the resultant description should be of the three individual strata unless a combined description can clearly describe the interbedded nature of the three strata. Example: Fine Sand with interbedded lenses of Silt and Clay, ranging between 1 and 3 inches thick.

Identify principal component and express volume estimates for minor components on logs using the following standard modifiers.

Modifier	Percent of Total Sample (by volume)
and	36 - 50
some	21 - 35
little	10 - 20
trace	<10

Determination of components is based on using the Udden-Wentworth particle size classification (see below) and measurement of the average grain size diameter. Each size grade or class differs from the next larger grade or class by a constant ratio of ½. Due to visual limitations, the finer classifications of Wentworth's scale cannot be distinguished in the field and the subgroups are not included. Visual determinations in the field should be made carefully by comparing the sample to the Soil Description Field Guide (**Attachment C**) that shows Udden-Wentworth scale or by measuring with a ruler. Use of field sieves is encouraged to assist in estimating percentage of coarse grain sizes. Settling test or wash method (Appendix X4 of ASTM D2488) is encouraged for determining presence and estimating percentage of clay and silt. Note that "gravel" is not an Udden-Wentworth size class.

Udden-Wenworth Scale Modified Arcadis, 2008			
Size Class	Millimeters	Inches	Standard Sieve #
Boulder	256 – 4096	10.08+	
Large cobble	128 - 256	5.04 -10.08	
Small cobble	64 - 128	2.52 – 5.04	
Very large pebble	32 – 64	0.16 - 2.52	
Large pebble	16 – 32	0.63 – 1.26	
Medium pebble	8 – 16	0.31 – 0.63	
Small pebble	4 – 8	0.16 – 0.31	No. 5 +
Granule	2 – 4	0.08 – 0.16	No.5 – No.10
Very coarse sand	1 -2	0.04 – 0.08	No.10 – No.18
Coarse sand	½ - 1	0.02 – 0.04	No.18 - No.35
Medium sand	¼ - ½	0.01 – 0.02	No.35 - No.60
Fine sand	1/8 -¼	0.005 – 0.1	No.60 - No.120
Very fine sand	1/16 – 1/8	0.002 – 0.005	No. 120 – No. 230
Silt (subgroups not included)	1/256 – 1/16	0.0002 – 0.002	Not applicable (analyze by pipette or hydrometer)
Clay (subgroups not included	1/2048 – 1/256	.00002 – 0.0002	

Identify components as follows. Remove particles greater than very large pebbles (64-mm diameter) from the soil sample. Record the volume estimate of the greater than very large pebbles. Examine the sample fraction of very large pebbles and smaller particles and estimate the volume percentage of the pebbles, granules, sand, silt and clay. Use the jar method, visual method, and/or wash method (Appendix X4 of ASTM D2488) to estimate the volume percentages of each category.

Determination of actual dry weight of each Udden-Wentworth fraction requires laboratory grain-size analysis using sieve sizes corresponding to Udden-Wentworth fractions and is highly recommended to determine grain-size distributions for each hydrostratigraphic unit.

Lab or field sieve analysis is advisable to characterize the variability and facies trends within each hydrostratigraphic unit. Field sieve-analysis can be performed on selected samples to estimate dry weight fraction of each category using ASTM D2488 Standard Practice for Classification of Soils for Engineering Purposes as guidance, but replace required sieve sizes with the following Udden-Wentworth set: U.S. Standard sieve mesh sizes 6; 12; 20; 40; 70; 140; and 270 to retain pebbles; granules; very coarse sand; coarse sand; medium sand; fine sand; and very fine sand, respectively.

PRINCIPAL COMPONENT

The principal component is the size fraction or range of size fractions containing the majority of the volume. Examples: the principal component in a sample that contained 55% pebbles would be “Pebbles”; or the principal component in a sample that was 20% fine sand, 30% medium sand and 25% coarse sand would be “Sand, fine to coarse” or for a sample that was 40% silt and 45% clay the principal component would be “Clay and Silt”. Shade the boxes on the graphic log (**Attachment A**) up to and including the box with the principal component. The purpose of the graphical log is to provide a relative estimate of permeability. As noted above, for poorly sorted soils such as glacial till, the principal component may not correlate to permeability of the sample. In this case, the geologist should use best judgement to graph overall soil type consistent with relative soil permeability.

Include appropriate descriptors with the principal component. These descriptors vary for different particle sizes as follows.

Angularity – Describe the angularity for very coarse sand and larger particles in accordance with the table below (ASTM D-2488-06). Figures showing examples of angularity are available in ASTM D-2488-06 and the Arcadis Soil Description Field Guide.

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces.
Sub-angular	Particles are similar to angular description but have rounded edges.
Sub-rounded	Particles have nearly plane sides but have well-rounded corners and edges.
Rounded	Particles have smoothly curved sides and no edges.

Plasticity – Describe the plasticity for silt and clay based on observations made during the following test method (ASTM D-2488-06).

- As in the dilatancy test below, select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.
- Shape the test specimen into an elongated pat and roll by hand on a smooth surface or between the palms into a thread about 1/8 inch (3 mm) in diameter. If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation. Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 inch. The thread will crumble when the soil is near the plastic limit.

Description	Criteria
Non-plastic	A 1/8-inch (3 mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled, and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Dilatancy – Describe the dilatancy for silt and silt-sand mixtures using the following field test method (ASTM D-2488-06).

- From the specimen select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material adding water if necessary, until it has a soft, but not sticky, consistency.
- Smooth the ball in the palm of one hand with a small spatula.
- Shake horizontally, striking the side of the hand vigorously with the other hand several times.
- Note the reaction of water appearing on the surface of the soil.
- Squeeze the sample by closing the hand or pinching the soil between the fingers, and not the reaction as none, slow, or rapid in accordance with the table below. The reaction is the speed with which water appears while shaking and disappears while squeezing.

Description	Criteria
None	No visible change in the specimen.
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

Note that silt and silt-sand mixtures will be non-plastic and display dilatancy. Clay mixtures will have some degree of plasticity but do not typically react to dilatancy testing. Therefore, the tests outlined above can be used to differentiate between silt dominated and clay dominated soils.

MINOR COMPONENT(S)

The minor component(s) are the size fraction(s) containing less than 50% volume. Example: the identified components are estimated to be 60% medium sand to granules, 25% silt and clay; 15 % pebbles – there are two identified minor components: silt and clay; and pebbles.

Include a standard modifier to indicate percentage of minor components (see Table on Page 6) and the same descriptors that would be used for a principal component. Plasticity should be provided as a descriptor for clay and clay mixtures. Dilatancy should be provided for silt and silt mixtures. Angularity should be provided as a descriptor for pebbles and coarse sand. For the example above, the minor constituents with modifiers could be: some silt and clay, low plasticity; little medium to large pebbles, sub-round.

SORTING

Sorting is the opposite of grading, which is a commonly used term in the USCS or ASTM methods to describe the uniformity of the particle size distribution in a sample. Well-sorted samples are poorly graded and poorly sorted samples are well graded. Arcadis prefers the use of sorting for particle size distributions and grading to describe particle size distribution trends in the vertical profile of a sample or hydrostratigraphic unit because of the relationship between sorting and the energy of the depositional process. For soils with sand-sized or larger particles, sorting should be determined as follows:

Well sorted – the range of particle sizes is limited (e.g. the sample is comprised of predominantly one or two grain sizes).

Poorly sorted – a wide range of particle sizes are present.

You can also use sieve analysis to estimate sorting from a sedimentological perspective; sorting is the statistical equivalent of standard deviation. Smaller standard deviations correspond to higher degree of sorting (see Remediation Hydraulics, 2008).

MOISTURE

Moisture content should be described for every sample since increases or decreases in water content is critical information. Moisture should be described in accordance with the table below (percentages should not be used unless determined in the laboratory).

Description	Criteria
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet (Saturated)	Visible free water, soil is usually below the water table.

CONSISTENCY or DENSITY

This can be determined by standard penetration test (SPT) blow counts (ASTM D-1586) or field tests in accordance with the tables below. When drilling with hollow-stem augers and split-spoon sampling, the SPT blow counts and N-value is used to estimate density. The N-value is the blows per foot for the 6" to 18" interval. Example: for 24-inch spoon, recorded blows per 6-inch interval are: 4/6/9/22. Since the second interval is 6" to12", the third interval is 12" to 18", the N value is 6+9, or 15. Fifty blow counts for less than 6 inches is considered refusal. In recent years, more common drilling methods include rotary-sonic or direct push. When blow counts are not available, density is determined using a thumb test. Note however, the thumb test only applies to fine-grained soils.

Fine-grained soil – Consistency

Description	Criteria
Very soft	N-value < 2 or easily penetrated several inches by thumb.
Soft	N-value 2-4 or easily penetrated one inch by thumb.
Medium stiff	N-value 9-15 or indented about ¼ inch by thumb with great effort.
Very stiff	N-value 16-30 or readily indented by thumb nail.
Hard	N-value > than 30 or indented by thumbnail with difficulty

Coarse-grained soil – Density

Description	Criteria
Very loose	N-value 1- 4
Loose	N-value 5-10
Medium dense	N-value 11-30
Dense	N-value 31- 50
Very dense	N-value >50

COLOR

Color should be described using simple basic terminology and modifiers based on the Munsell system. Munsell alpha-numeric codes are required for all samples. If the sample contains layers or patches of varying colors this should be noted and all representative colors should be described. The colors should be described for moist samples. If the sample is dry it should be wetted prior to comparing the sample to the Munsell chart.

ADDITIONAL COMMENTS (NOTES)

Additional comments should be made where observed and should be presented as notes with reference to a specific depth interval(s) to which they apply. Some of the significant information that may be observed includes the following.

- Odor - You should not make an effort to smell samples by placing near your nose since this can result in unnecessary exposure to hazardous materials. However, odors should be noted if they are detected during the normal sampling procedures. Odors should be based upon descriptors such as those used in NIOSH “Pocket Guide to Chemical Hazards”, e.g. “pungent” or “sweet” and should not indicate specific chemicals such as “phenol-like” odor or “BTEX” odor.
- Structure
- Bedding planes (laminated, banded, geologic contacts).
- Presence of roots, root holes, organic material, man-made materials, minerals, etc.
- Mineralogy
- Cementation
- NAPL presence/characteristics, including sheen (based on client-specific guidance).
- Reaction with HCl - typically only used for special soil conditions, such as caliche environments.
- Origin, if known (Lacustrine; Fill; etc.).

EXAMPLE DESCRIPTIONS

51.4 to 54.0’ CLAY, some silt, medium to high plasticity; trace small to large pebbles, sub-round to sub-angular up to 2” diameter; moist, stiff, dark grayish brown (10 YR 4/2) NOTE: Lacustrine; laminated 0.1 to 0.2” thick, laminations brownish yellow (10 YR 4/3).

32.5 to 38.0’ SAND, medium to very coarse, sub-round to sub-angular; little granule and pebble, trace silt; poorly sorted, wet, grayish brown (10 YR 5/2).

Unlike the first example where a density of cohesive soils could be estimated, this rotary-sonic sand and pebble sample was disturbed during drilling (due to vibrations in a loose sand and pebble matrix) so no density description could be provided. Neither sample had noticeable odor so odor comments were not included.

The standard generic description order is presented below.

- Depth
- Principal Components
  - Angularity for very coarse sand and larger particles
  - Plasticity for silt and clay
  - Dilatancy for silt and silt-sand mixtures
- Minor Components
- Sorting
- Moisture
- Consistency or Density
- Color
- Additional Comments

8 WASTE MANAGEMENT

Project-specific requirements should be identified and followed. The following procedures, or similar waste management procedures are generally required.

Water generated during cleaning procedures will be collected and contained onsite in appropriate containers for future analysis and appropriate disposal. PPE (such as gloves, disposable clothing, and other disposable equipment) resulting from personnel cleaning procedures and soil sampling/handling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums or a covered roll-off box for appropriate disposal.

Soil materials will be placed in sealed 55-gallon steel drums or covered roll-off boxes and stored in a secured area. Once full, the material will be analyzed to determine the appropriate disposal method.

9 DATA RECORDING AND MANAGEMENT

Upon collection of soil samples, the soil sample should be logged on a standard boring log and/or in the field log book depending on Data Quality Objectives (DQOs) for the task/project. The preferred standard boring log is presented below and is included as **Attachment A**.

The general scheme for soil logging entries is presented above; however, depending on task/project DQOs, specific logging entries that are not applicable to task/project goals may be omitted at the project manager's discretion. In any case, use of a consistent logging procedure is required.

Completed logs and/or logbook will be maintained in the task/project field records file. Digital photographs of typical soil types observed at the site and any unusual features should be obtained whenever possible. All photographs should include a ruler or common object for scale. Photo location, depth and orientation must be recorded in the daily log or log book and a label showing this information in the photo is useful.

10 QUALITY ASSURANCE

Soil descriptions should be completed only by appropriately trained personnel. Descriptions should be reviewed by an experienced field geologist for content, format and consistency. Edited boring logs should be reviewed by the original author to assure that content has not changed.

11 REFERENCES

Arcadis Soil Description Field Guide, 2008.

Munsell® Color Chart – available from Forestry Suppliers, Inc.- Item 77341 "Munsell® Color Soil Color Charts.

Field Gauge Card that Shows Udden-Wentworth scale – available from Forestry Suppliers, Inc. – Item 77332 "Sand Grain Sizing Folder."

ASTM D-1586, Test Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM D-2488-00, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

United States Bureau of Reclamation. Engineering Geology Field Manual. United States Department of Interior, Bureau of Reclamation. http://www.usbr.gov/pmts/geology/fieldmap.htm.

Petrology of Sedimentary Rocks, Robert L. Folk, 1980, p. 1-48.

NIOSH Pocket Guide to Chemical Hazards.

Remediation Hydraulics, Fred C. Payne, Joseph A. Quinnan, and Scott T. Potter, 2008, p 59-63.

ATTACHMENT A

Arcadis Standard Soil Boring Log Form

SOIL BORING LOG

Boring/Well ____________ Project ______________________________ Page ____ of ____

Site Location ______________________________ Drilling Started ______________

Total Depth Drilled ________ Feet Hole Diameter ________ inches Drilling Completed ______________

Type of Sample or Coring Device ____________ Length and Diameter of Coring Device ______________ Sampling Interval ____________ feet

Drilling Method ____________ Drilling Fluid Used ____________

Drilling Contractor ______________________________ Driller ______________

Prepared By ______________________________ Helper ______________

Core Recovery (feet)	PID Reading (ppm)	Sample Depth (ft bgs)	MUD		SAND					GRAVEL				**Udden-Wentworth Description:** principal components, (angularity, plasticity, dilatency); minor components, (angularity, plasticity, dilatency); sorting, moisture content, consistency/density, color, additional comments
			clay	silt	very fine	fine	medium	coarse	very coarse	granular	pebble	cobble	boulder	

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SOIL BORING LOG (CONT'D)

Boring/Well ______________________ Prepared By ______________________ Page ____ of ____

			MUD		SAND					GRAVEL				
Core Recovery (feet)	PID Reading (ppm)	Sample Depth (ft bgs)	clay	silt	very fine	fine	medium	coarse	very coarse	granular	pebble	cobble	boulder	Udden-Wentworth Description: principal components, (angularity, plasticity, dilatency); minor components, (angularity, plasticity, dilatency); sorting, moisture content, consistency/density, color, addtl. Comments

ATTACHMENT B

Example of Completed Arcadis Soil Boring Log

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SOIL BORING LOG

Boring/Well: SB-01 | Project: Example | Page 1 of 1

Site Location: Anytown, North America | Drilling Started: 6/26/17

Total Depth Drilled: 20 Feet | Hole Diameter: 4.5 inches | Drilling Completed: 6/26/17

Type of Sample or Coring Device: Continuous | Length and Diameter of Coring Device: 5', 2.25" macrocore | Sampling Interval: 5 feet

Drilling Method: Geoprobe | Drilling Fluid Used: NA

Drilling Contractor: Fibertec | Driller: Ryan Brown

Prepared By: A. DeGrandis | Helper: Grant Berger

Core Recovery (feet)	PID Reading (ppm)	Sample Depth (ft bgs)	MUD: clay	MUD: silt	SAND: very fine	SAND: fine	SAND: medium	SAND: coarse	SAND: very coarse	GRAVEL: granular	GRAVEL: pebble	GRAVEL: cobble	GRAVEL: boulder	Udden-Wentworth Description: principal components, (angularity, plasticity, dilatency); minor components, (angularity, plasticity, dilatency); sorting, moisture content, consistency/density, color, additional comments
	0.3	1	X	X	X	X	X							(0.0-4.0) SAND, fine to medium, sub-rounded;
	0.1	2	X	X	X	X	X							little granules to small pebbles, sub-rounded
60"	0.0	3	X	X	X	X	X							to sub-angular; trace silt; poorly sorted, dry
(HA)	0.0	4	X	X	X	X	X							to moist, dark grayish brown (10YR 4/2).
↓	1.4	5	X	X										NOTE: Ablation till.
	1.7	6	X	X										
	0.9	7	X	X										(4.0-10.0) SILT, non-plastic, rapid dilatancy;
52"	1.2	8	X	X										dry to moist, soft to medium stiff,
	0.6	9	X	X										gray (10YR 5/1).
↓	0.2	10	X	X										
	0.0	11	X	X	X	X								(10.0-15.5) SAND, fine, sub-rounded; trace
	0.0	12	X	X	X	X								silt; well sorted, moist to wet, pale
60"	0.1	13	X	X	X	X								brown (10YR 6/3).
	0.0	14	X	X	X	X								
↓	0.0	15	X	X	X	X								NOTE: Wet at 12.0'
	0.2	16	X	X	X	X								
	0.0	17	X											(15.5-20.0) CLAY, high plasticity, no dilatancy;
58"	0.0	18	X											little silt; moist, soft to medium stiff,
	0.0	19	X											light gray (10YR 7/1) to dark gray (10YR 4/1).
↓	0.0	20	X											NOTE: Lacustrine, minor 0.1-0.25" lamination.
														End of boring - 20.0'

ATTACHMENT C

Arcadis Soil Description Field Guide

ON THE ORIGINAL DRAWING.
USE TO VERIFY FIGURE
REPRODUCTION SCALE

SOIL DESCRIPTION FIELD GUIDE (JUNE 30, 2017; REV. 2.0)

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FINE-GRAINED SOILS

Description	Criteria
	Descriptor - Plasticity
Nonplastic	A 1/8-inch (3mm) thread cannot be rolled at any moisture content.
Low	Thread can barely be rolled, and lump cannot be formed when drier than plastic limit.
Medium	Takes considerable time and rolling to reach plastic limit. Thread cannot be rolled after reaching plastic limit. Lump crumbles when drier than plastic limit.
High	Thread is easy to roll and quickly reaches plastic limit. Thread can be rerolled several times after reaching plastic limit. Lump can be formed without crumbling when drier than plastic limit.
	Descriptor - Dilatancy
No Dilatancy	No visible change when shaken or squeezed.
Slow	Water appears slowly on the surface of soil during shaking and does not disappear or disappears slowly when squeezed.
Rapid	Water appears quickly on surface of soil during shaking and disappears quickly when squeezed.
Minor Components with Descriptors	
	Moisture
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet	Visible free water; soil is usually below the water table. (Saturated)
	Consistency
Very soft	N-value < 2 or easily penetrated several inches by thumb.
Soft	N-value 2-4 or easily penetrated 1 inch by thumb.
Medium stiff	N-value 5-8 or indented about 1/2 inch by thumb with great effort.
Stiff	N-value 9-15 or indented about 1/4 inch by thumb with great effort.
Very stiff	N-value 16-30 or readily indented by thumb nail.
Hard	N-value > than 30 or indented by thumbnail with difficulty.
Color using Munsell	
Geologic Origin (if known)	
Other	

EXAMPLE OF SOIL DESCRIPTION AND PHOTO

10-15 feet CLAY, medium to high plasticity; trace silt; trace small to very large pebbles, subround to subangular up to 2" diameter; moist, stiff, dark grayish brown (10YR 4/2). NOTE: Lacustrine; laminated 0.1 to 0.2" thick, laminations brownish yellow (10YR 4/3).

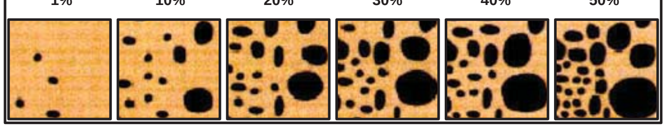
DESCRIPTION ORDER

Depth Interval
Principal Components with Descriptors
Minor Components with Descriptors
Sorting
Field Moisture Condition
Density/Consistency
Color using Munsell
Geologic Origin (if known)
Other descriptions as NOTES:
- Odor
- Stratigraphy
- Structure
- Sphericity
- Cementation
- Reaction to acid

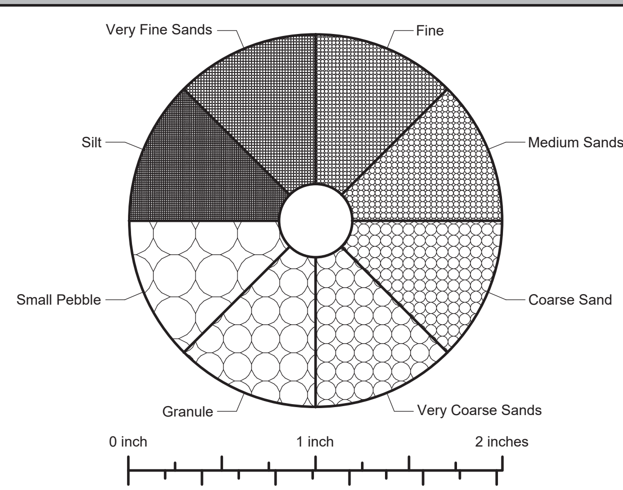
UDDEN-WENTWORTH SCALE

Fraction	Sieve Size	Grain Size	Approximate Scale
Boulder		256 - 4096 mm	Larger than volleyball
Large Cobble		128 - 256 mm	Softball to volleyball
Small Cobble		64 - 128 mm	Pool ball to softball
Very Large Pebble		32 - 64 mm	Pinball to pool ball
Large Pebble		16 - 32 mm	Dime size to pinball
Medium Pebble		8 - 16 mm	Pencil eraser to dime size
Small Pebble	No. 5+	4 - 8 mm	Pea size to pencil eraser
Granule	No. 10 - 5	2 - 4 mm	Rock salt to pea size
Very Coarse Sand	No. 18 - 10	1 - 2 mm	See field gauge card
Coarse Sand	No. 35 -18	0.5 - 1 mm	See field gauge card
Medium Sand	No. 60 - 35	0.25 - 0.5 mm	See field gauge card
Fine Sand	No. 120 - 60	0.125 - 0.25 mm	See field gauge card
Very Fine Sand	No. 230 - 120	0.0625 - 0.125 mm	See field gauge card
Silt and Clay. See SOP for description of fines	Not Applicable	<0.0625 mm	Analyze by pipette or hydrometer

PARTICLE PERCENT COMPOSITION ESTIMATION



GRAPH FOR DETERMINING SIZE OF PARTICLES



MINOR COMPONENTS % MODIFIERS

Modifier	Percent of Total Sample (by volume)
and	36 - 50
some	21 - 35
little	10 - 20
trace	<10

FOR COARSE-GRAINED SOILS

Description	Criteria
	Descriptor - Angularity
Angular	Particles have sharp edges and relatively planar sides withunpolished surfaces.
Subangular	Particles are similar to angular but have rounded edges.
Subround	Particles have nearly planar sides but have well-roundedcorners and edges.
Round	Particles have smoothly curved sides and no edges.
Minor Components with Descriptors	
	Sorting Cu= d60/d10
Well Sorted	Near uniform grain-size distribution Cu= 1 to 3.
Poorly Sorted	Wide range of grain size Cu= 4 to 6.
	Moisture
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet	Visible free water; soil is usually below the water table. (Saturated)
	Density
Very loose	N-value 1 - 4
Loose	N-value 5 - 10
Medium Dense	N-value 11 - 30
Dense	N-value 31 - 50
Very dense	N-value >50
Color using Munsell	
Geologic Origin (if known)	
Other	
	Cementation
Weak Cementation	Crumbles or breaks with handling or little finger pressure.
Moderate Cementation	Crumbles or breaks with considerable finger pressure.
Strong Cementation	Will not crumble with finger pressure.
	Reaction with Dilute HCl Solution (10%)
No Reaction	No visible reaction.
Weak Reaction	Some reaction, with bubbles forming slowly.
Strong Reaction	Violent reaction, with bubbles forming immediately.

EXAMPLE OF SOIL DESCRIPTION AND PHOTO

10 -15 feet SAND, medium to very coarse; little granules to medium pebbles, subround to subangular; trace silt; poorly sorted, wet, grayish brown (10YR5/2).

ON THE ORIGINAL DRAWING. USE TO VERIFY FIGURE REPRODUCTION SCALE

SOIL DESCRIPTION FIELD GUIDE (JUNE 30, 2017; REV. 2.0)

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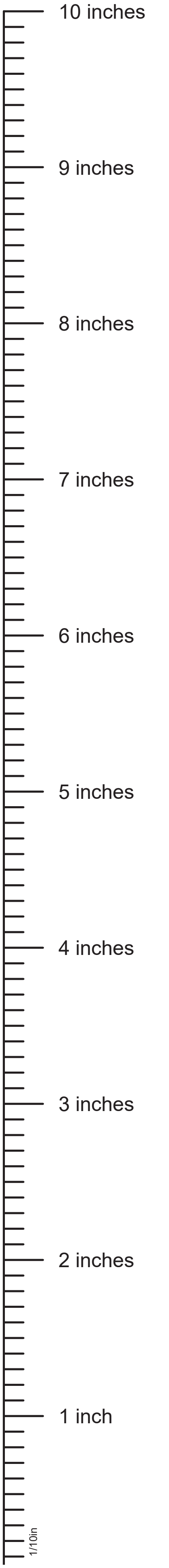
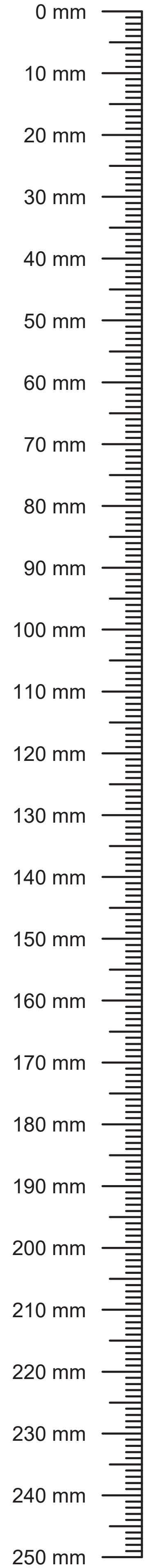




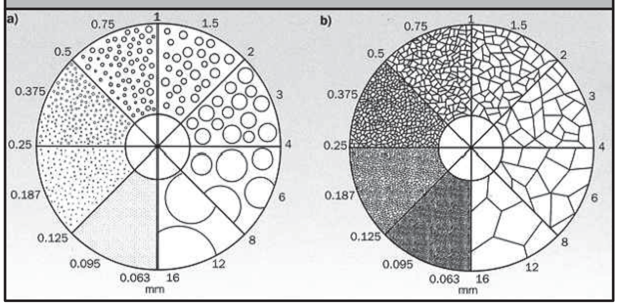
VARIATIONS IN SOIL STRATIGRAPHY

Term	Thickness of Configuration
Parting	0 - to 1/16-inch thickness.
Seam	1/16 - to 1/2-inch thickness.
Layer	1/2 - to 12-inch thickness.
Stratum	> 12-inch thickness.
Pocket	Small erratic deposit, usually less than 1 foot in size.
Varved Clay	Alternating seams or layers of sand, silt, and clay (laminated).
Occasional	≤ 1 foot thick.
Frequent	> 1 foot thick.

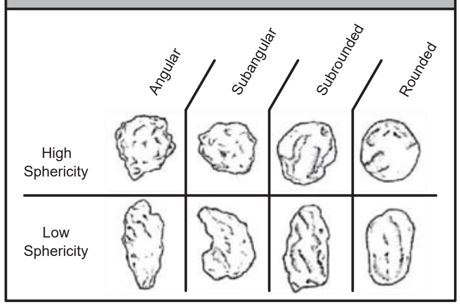
SOIL STRUCTURE DESCRIPTIONS

Term	Description
Homogeneous	Same color and appearance throughout.
Laminated	Alternating layers < 1/4 inch thick.
Stratified	Alternating layers ≥ 1/4 inch thick.
Lensed	Inclusions of small pockets of different materials, such as lenses of sand scattered through a mass of clay; note thickness.
Blocky	Cohesive soil can be broken down into small angular lumps, which resist further breakdown.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear to be polished or glossy, sometimes striated.

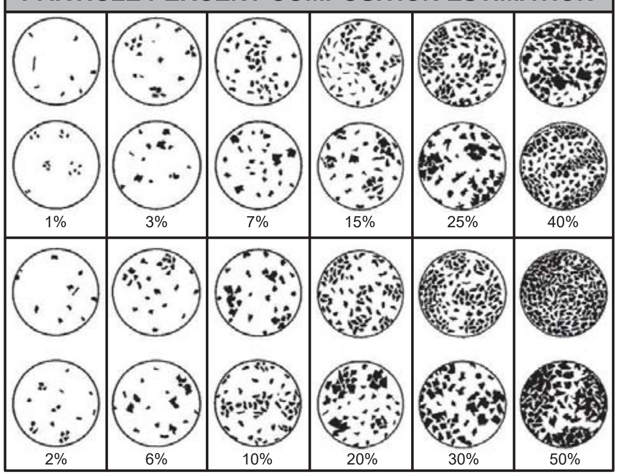
GRAPH FOR DETERMINING SIZE OF PARTICLES



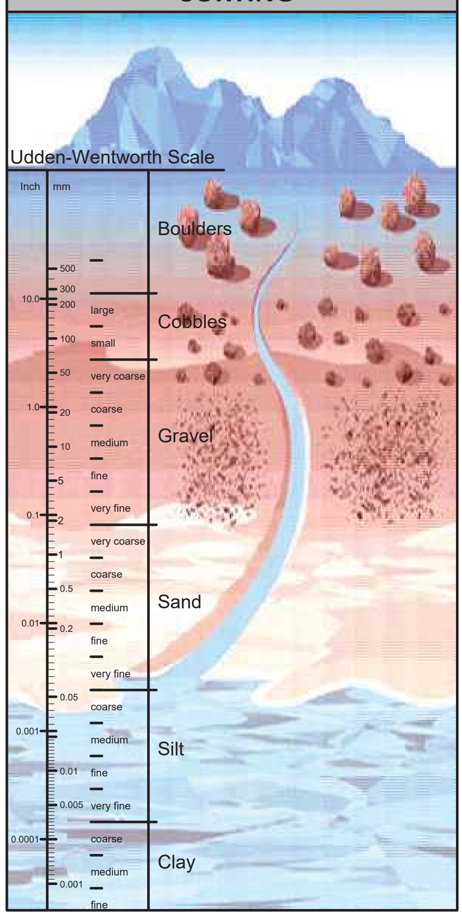
ANGULARITY CHART



PARTICLE PERCENT COMPOSITION ESTIMATION



SORTING



SETTLING TABLE (SILT/CLAY)

Diameter of Particle (mm)	<0.625	<0.031	<0.016	<0.008	<0.004	<0.002	<0.0005
Depth of Withdrawal (cm)	10	10	10	10	5	5	3
Time of Withdrawal	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec
Temperature (Celsius)							
20	00:00:29	00:01:55	00:07:40	00:30:40	00:61:19	04:05:00	37:21:00
21	00:00:28	00:01:52	00:07:29	00:29:58	00:59:50	04:00:00	
22	00:00:27	00:01:50	00:07:18	00:29:13	00:58:22	03:54:00	
23	00:00:27	00:01:47	00:07:08	00:28:34	00:57:05	03:48:00	
24	00:00:26	00:01:45	00:06:58	00:27:52	00:55:41	03:43:00	33:56:00
25	00:00:25	00:01:42	00:06:48	00:27:14	00:54:25	03:38:00	
26	00:00:25	00:01:40	00:06:39	00:26:38	00:53:12	03:33:00	
27	00:00:24	00:01:38	00:06:31	00:26:02	00:52:02	03:28:00	
28	00:00:24	00:01:35	00:06:22	00:25:28	00:50:52	03:24:00	31:00:00
29	00:00:23	00:01:33	00:06:13	00:24:53	00:49:42	03:10:00	
30	00:00:23	00:01:31	00:06:06	00:24:22	00:48:42	03:05:00	

TGI – NWNA STREAM FLOW MONITORING PROCEDURE

Rev: #0

Rev Date: 02/05/2019

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	February 5, 2019	All	Updated and re-written as TGI	Greg Foote

APPROVAL SIGNATURES

Prepared by:	Amanda M. Robinson	02/05/2019 Date:
Technical Expert Reviewed by:	Mike Pozniak	02/05/2019 Date:

1 INTRODUCTION

This document inclusively applies to all NWNA (Nestle Water North America) sites located in Michigan. Procedures and methods are outlined in this document and are to be used and observed by Arcadis staff when performing tasks under the scope of this document.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of these procedures. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the activities performed under this document.

The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for project work. In turn, project staff are required to consult with the CPM if or when there is a required deviation or omission from work performed as compared to what is described herein, that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

The objective of this Technical Guidance Instruction (TGI) is to describe procedures to collect stream flow measurements in accordance with United States Geological Survey (USGS) streamflow monitoring protocols (Turnipseed and Sauer, 2010), stream depth, and localized conditions within each monitoring location. Stream flow measurements may be collected using a Sontek/YSI FlowTracker ® (Flow Tracker) or Marsh McBirney Flo-Mate™ 2000 (Flo-Mate). This TGI describes the equipment, field procedures, materials and documentation procedures to measure and record stream flow data using the aforementioned equipment. This TGI was revised following procedures documented for NWNA sites in *Streamflow Monitoring Protocol for Michigan Streams Memo* from Advanced Ecological Management (AEM) dated January 25, 2015.

Stream flow measurements will be collected primarily using a Flow Tracker. The Flow Tracker is an Acoustic Doppler Velocimeter (ADV) and is the preferred instrument for use to by the Michigan Department of Environmental Quality (MDEQ) and USGS for conducting stream velocity measurements in most wadable streams as a means for estimating stream discharge. The instrument relies on acoustic doppler technology for data collection, a short pulse at a known frequency is transmitted and sound is reflected off particulate matter within the stream column and are reflected to the acoustic receivers collecting 2D flow, for a sample volume four inches from center of the transmitter.

There are some limitations with the Flow Tracker with specific stream characteristics that cause the Flow Tracker to be unable to consistently gather sufficient stream velocity data (i.e. shallow and narrow streams, low signal to noise ratios of less than 4 dB). In these conditions the Marsh McBirney Flo-Mate™ 2000 (Flo-Mate) may be used. The instrument relies on an electromagnetic sensor for data collection. The voltage is measured, and linear velocity value is generated.

Stream flow measurements for each site should be measured on the same day. If measurement of all streams for each site is not possible within one day, then stream flows should be measured on consecutive days.

3 PERSONNEL QUALIFICATIONS

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The HASP and other documents will identify other training requirements or access control requirements.

4 EQUIPMENT LIST

The following field equipment is required for stream flow measurements:

- HASP and appropriate field forms
- User Manual’s. *The operator must have and be familiar with the operation, technical and/or instruction manual(s) for both flow meters.*
- Appropriate personal protective equipment (PPE) as specified in the HASP
- Site specific flow meters
    - Flow Tracker and protective case
    - Flo-Mate and protective case
- Tool box for repairs/replacement (flat head and Philips screwdrivers)
- Top-setting wading rod (wading rod)
- 16-AA batteries for the Flow Tracker (4-D batteries for the Flo-Mate)
- 100-foot measuring tape in 10ths of feet (or sufficient length for the maximum width of streams)
- Five-gallon bucket
- Waders and boots
- Summary table of previous stream flow measurement or field book
- Field notebook and/or smart device (phone or tablet)
- Indelible ink pen

Note: All equipment and materials are dedicated to the NWNA sites and cannot be used on sites with environmental contamination.

5 CAUTIONS

- Use caution when handling and transport flow meters and related equipment. The flow meter(s) must be placed in their protective case(s) to prevent damage during transport.
- Do not overtighten the flow meter sensor probe, as this could damage the sensor.
- The flow meter system(s) should not be opened without specific instructions from the manufacturer.

- Avoid placing sample volume (typically four inches from the center of the transmitting device) of the Flow Tracker from an obstruction or boundary.
- Remove batteries from Flow Tracker when not in use to conserve battery life.

6 HEALTH AND SAFETY CONSIDERATIONS

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Appropriate personal protective equipment (PPE) will be worn during these activities. Field personnel will thoroughly review client-specific health and safety requirements, as necessary.

7 PROCEDURE

Calibration/diagnostic inspection procedures and stream flow measurement procedures for each flow meter are described in the sections below. Stream cross sections are established for identified stream gauging locations prior to equipment use. Cross sections are recommended to be within a straight channel with uniform flow, without impacts of eddies and/or turbulence. At each stream gauging location, a graduated tagline, fixed marker, or measuring tape is strung across the stream ideally perpendicular to flow. A minimum or 20 measurements are recommended (or 22 including the leading and ending edge).

Flow Tracker:

Equipment Check

The following procedures should be performed before the start monitoring event to ensure the software and equipment are performing properly:

- Flow Tracker software should be downloaded and kept up to date on staff computer.
- Fill a five-gallon bucket with water, adding sediment if necessary.
- Connect Flow Tracker to computer, with software open.
- Perform a BeamCheck, a diagnostic to be run on the Flow Tracker. *A pulse of sound (ringing) is sent into the water. This checks the signal strength of the sampling volume and return signal and range of the receivers (boundary reflection and noise level).*
- Follow the instruction provided in **Section 6.5 of the Flow Tracker Technical Manual**.
- If anomalies are noted during the beam check contact Sontek and schedule maintenance for the equipment.

Field Diagnostics and Set-up

Field diagnostic inspections should be completed prior to beginning stream flow measurements at each location, see **Section 3.2 of the Flow Tracker Technical Manual**.

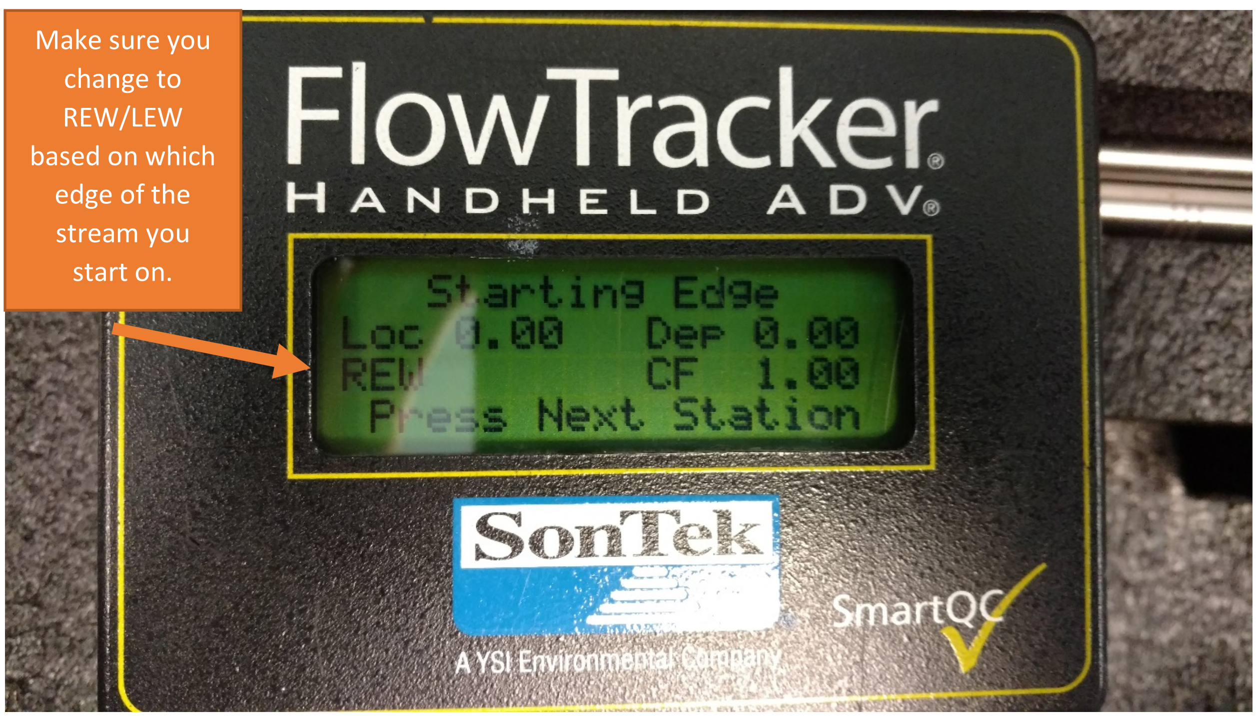
- Turn on Equipment.
- Check to make sure there is enough internal memory to store the expected data collection. *Note: when you format the recorder, it erases all files from the Flow Tracker. Make sure all data is* saved prior to reformatting.
- Check temperature data for reasonableness.
- Check the internal clock to verify correct date/time.

- Check battery life. *Note: If battery life is low, replace batteries. If the battery life is drained all the way during field measurements data will not be saved.*
- Ensure Flow Tracker is properly constructed. The meter is generally attached to a wading rod to stabilize the meter and is used as a gauge to measure water depth.
- Prior to data collection, a file name must be generated. Include stream flow identification and reference to date of collection (for example SF-1 Extension 203).
- Enter site location and Operator's name.
- An auto quality control (QC) test is prompted prior to beginning stream flow measurements. This is a meter-initialization process that is an automated version of the BeamCheck. 20 pings will be transmitted, and the test results are recorded with the locations data file. The following parameters are tested: noise level, SNR, peak shape, and peak location. If an anomaly is found, a warning will be presented to the operator, repeat the QC test as necessary. If subsequent tests result in warnings, use of the Flo-Mate for the measurement may be considered.

<u>Stream Flow Measurement Procedure</u>

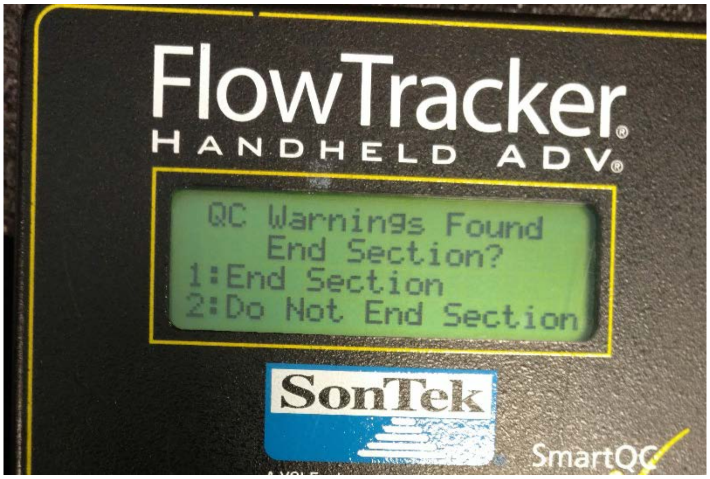
Use of the Flow Tracker with a wading rod is applicable whenever the depth is above 0.25 feet. Follow the procedures below when collecting stream flow measurements using a Flow Tracker:

- Measurements should be taken from the same side of the stream for each location. Enter edge location data (ex. REW).

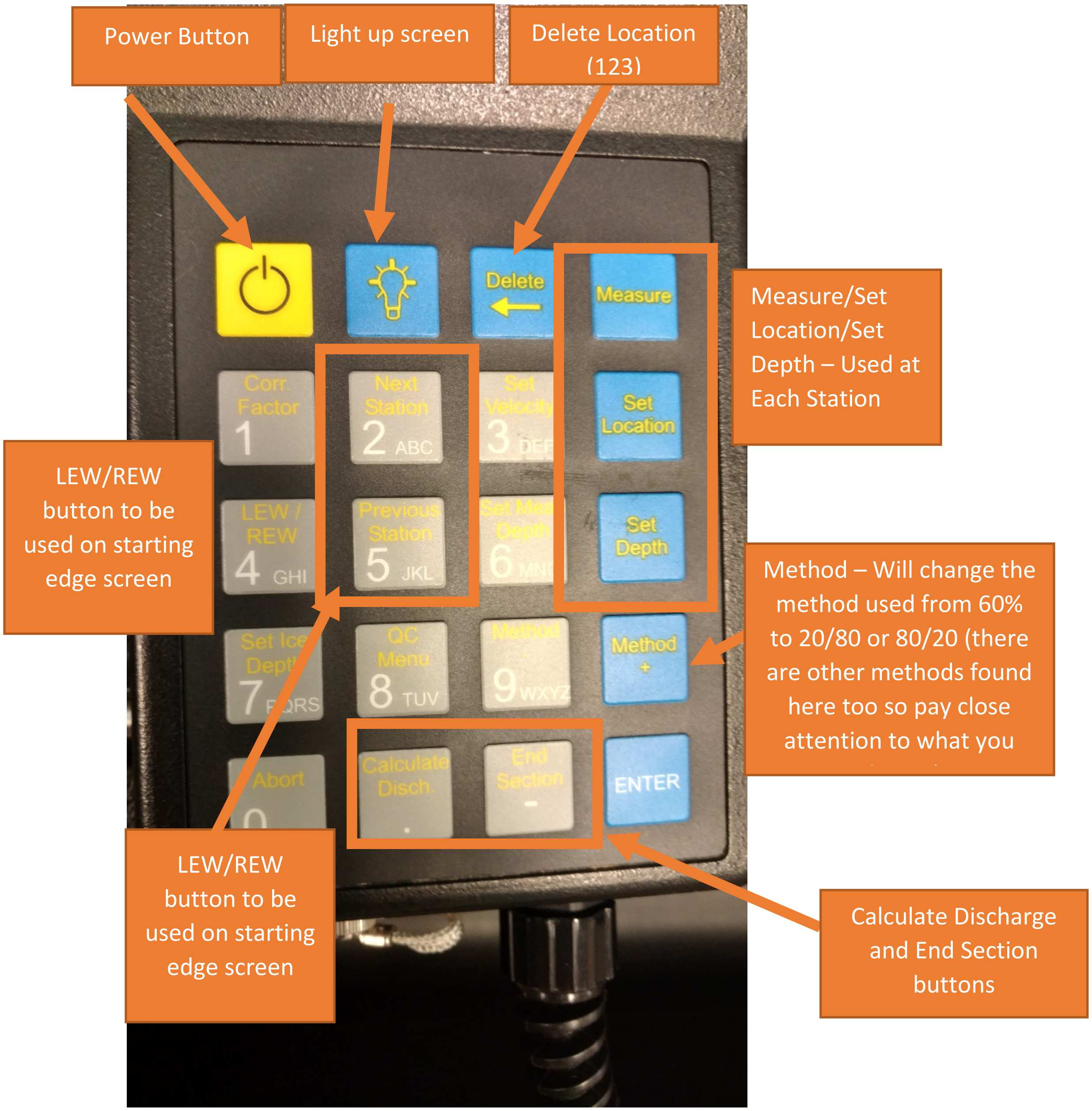


- At an established interval width marker (i.e. 0.25 or 0.5 feet), the operator records the location and the depth of water to the top of the sediment. *The established interval width should not be less than the width of the flow meter sensor.*

- The wading rod should be set to 60% (single point method) of the total water depth using the metric gauge on the wading rod for water depths less than 1.5 feet. *If greater than 1.5 feet two-point method must be followed where velocity measurements are collected at 20% and 80% of the depth, and an average of the measurements is calculated (Turnipseed and Sauer, 2010).*
  - Single-point method (0.6 depth) used at depths less than 1.5 feet.
  - Two-point method (0.2 and 0.8 depths) used at depths greater than 1.5 feet.
  - Three-point method (0.2, 0.6, and 0.8 depths) used when a non-standard profile is encountered when the two-point method is followed.
- A 40-second interval burst of velocity data is recorded at each interval marker, once per second during the burst. Mean velocity reading and quality control data are displayed at the end of each measurement and recorded. If values are outside the expected boundary limits a warning is made visible to the operator. The measurement may be repeated if necessary.
- The operator verbally states each water depth and mean velocity reading, a second field staff repeats the reading back to the operator for verification and manually records the data within an excel file saved on a smart device. *Measurements are taken with the sensor pointed directly into the flow and the wading rod in a vertical position. The operator must stand far enough behind the sensor so not to affect the measurement.*
- Repeat until all interval velocity measurements have been collected. After each velocity reading the Flow Tracker will indicate if any warnings were present (i.e. SNR, high/low velocity angle, etc.). See **Table 1-1 in Section 1.4 of the Flow Tracker Technical Manual** for a table of quality control parameters and a description of each. Repeat measurement if necessary.
- When all measurements of the stream have been collected "End Section" should be pressed to close the file.



- The Flow Tracker will inform you of QC warnings found, included if 10% of the discharge was exceeded. *It is recommended that each measurement remain below 10% of the total discharge, and 5% is preferred if possible.*
- To retrieve discharge measurements, the ending edge information is entered, and discharge data is visible. The field staff compare discharge measurements from the smart device and the Flow Tracker to ensure proper transcription of data.
- All flow readings are stored in the Flow tracker until they are deleted by the user. The user should record the discharge readings from the Flow Tracker within the field notes. An example of the Flow Tracker data file and the excel spreadsheet created for each location can be observed in **Attachment A**.



Flo-Mate:

Field Set-up, Calibration and Stream Flow Measurement Procedure

The Flo-Mate is used in the field to collect stream velocity readings, when stream characteristics are not conducive for use of a Flow Tracker. The following procedures should be followed when using a Flo-Mate as described below:

- Clean the sensor as noted in the Flo-Mate instruction manual (Marsh McBirney, Inc, 1990).
- Connect the flow meter to the wading rod.

- Fill five-gallon bucket with stream water.
- Place wading rod with the attached stream flow sensor in a vertical position within the bucket of water, keeping it at least three inches away from the sides and bottom of the bucket. *The depth of the sensor should be at 60% of the total depth of water within the bucket*.
- Turn on Flo-Mate. Wait 10-15 minutes after you have positioned the sensor before taking any zero readings.
- Begin zero adjust readings. *Velocity readings should not be more than 0.02 feet per second (fps). If greater than 0.02 fps conduct zero-adjust sequence by pressing the "recall" and "store" buttons simultaneously followed by pressing the "down arrow" to times. Repeat as needed. See the Flo-Mate instruction manual for further guidance.*
- The Flo-Mate is properly calibrated once flow within the bucket is less than 0.02 fps.
- Begin stream velocity measurements. Allow the instrument to average the velocities over a 40 second interval. *The sensor should be facing upstream.*
- The operator verbally states each water depth and mean velocity reading, a second field staff repeats the reading back to the operator for verification and manually records the data within an excel file saved on a smart device.
- All flow readings are recorded in an excel spreadsheet on a smart device, and the discharge is recorded in the field notebook once total discharge has been calculated. See example of excel spreadsheet in **Attachment A**.

8 WASTE MANAGEMENT

Waste generated at the site shall be disposed of properly by Arcadis personnel.

9 DATA RECORDING AND MANAGEMENT

Streamflow measurements as well as all relevant observations should be documented in the field notebook, field forms and/or smart device as appropriate. When using the Flow Tracker data is saved directly to the device, including errors and anomalies noted by the instrument. The Flow Tracker generates a file summarizing the instrument calibration/diagnostic inspection and data collected at each location. Additionally, all stream velocity and depth data should be manually recorded within an excel spreadsheet within a smart device (i.e tablet) to be used as a quality control measure for both flow meters. The following information must be documented:

- Streamflow or location identification;
- Equipment used;
- Operators;
- Date;
- Starting time of measurement;
- Ending time of measurement;
- Water elevation of nearest surface water level measurement (i.e. staff gauge) and corresponding time of collection;
- Measurement intervals;
- Depth to water at each interval;

- Flow velocity at each interval.

The data should be saved using a file name system that includes the site name and data of measurement (i.e. SF-1_2-3-2019).

Once all the data has been collected and recorded, all notes/forms/data must be uploaded to the appropriate project directory on the Arcadis server, and an email should be sent to the Task Manager and/or Technical lead for notification. A summary of the work completed that day and any relevant observation noted (such as stream inspection) during the daily activities should be included with the email. The appropriate team member will review the data for accuracy and provide feedback.

10 QUALITY ASSURANCE

- As described in the detailed procedure, the flow meters will be calibrated prior to measurements to ensure software and equipment are functioning properly. The results will be recorded.
- The Flow Tracker keeps an electronic record of the stream flow data and staff will manually record the field data using a smart device to ensure accurate data transcription.
- Field notes and documents will be reviewed by the project team once the field data has been uploaded to the project file.
- Flow meters are to be checked and recalibrated annually.

11 REFERENCES

Advanced Ecological Management. (2015). Streamflow Monitoring Protocol for Michigan Streams Memorandum (January 2015).

Marsh-McBirney Inc. (1990, December). Marsh-McBirney Inc. *Flow-Mate Model 2000 Portable Flowmeter Instruction Manual.*

SonTek/YSI Inc. (2007, July). *FlowTracker Handheld ADV Technical Manual, Firmware Version 3.7, Software Version 2.30.*

SonTek/YSI Inc. *FlowTracker – Quick Start Guide, Handheld ADV for Velocity and Flow Measurements.*

Turnipseed, D.P., and Sauer, V.B. (2010). Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p.

Attachment A

Discharge Measurement Summary

Date Generated: Tue Dec 11 2018

File Information

File Name	SF17.124.WAD
Start Date and Time	2018/12/04 11:03:38

Site Details

Site Name	WPS
Operator(s)	KAITLYN

System Information

Sensor Type	FlowTracker
Serial #	P5794
CPU Firmware Version	3.9
Software Ver	2.30
Mounting Correction	0.0%

Units (English Units)

Distance	ft
Velocity	ft/s
Area	ft^2
Discharge	cfs

Discharge Uncertainty

Category	ISO	Stats
Accuracy	1.0%	1.0%
Depth	0.3%	1.5%
Velocity	0.6%	1.9%
Width	0.1%	0.1%
Method	1.7%	-
# Stations	2.2%	-
Overall	**3.0%**	**2.6%**

Summary

Averaging Int.	40	# Stations	23
Start Edge	REW	Total Width	11.000
Mean SNR	28.4 dB	Total Area	9.615
Mean Temp	36.91 °F	Mean Depth	0.874
Disch. Equation	Mid-Section	Mean Velocity	0.5059
		Total Discharge	**4.8637**

Measurement Results

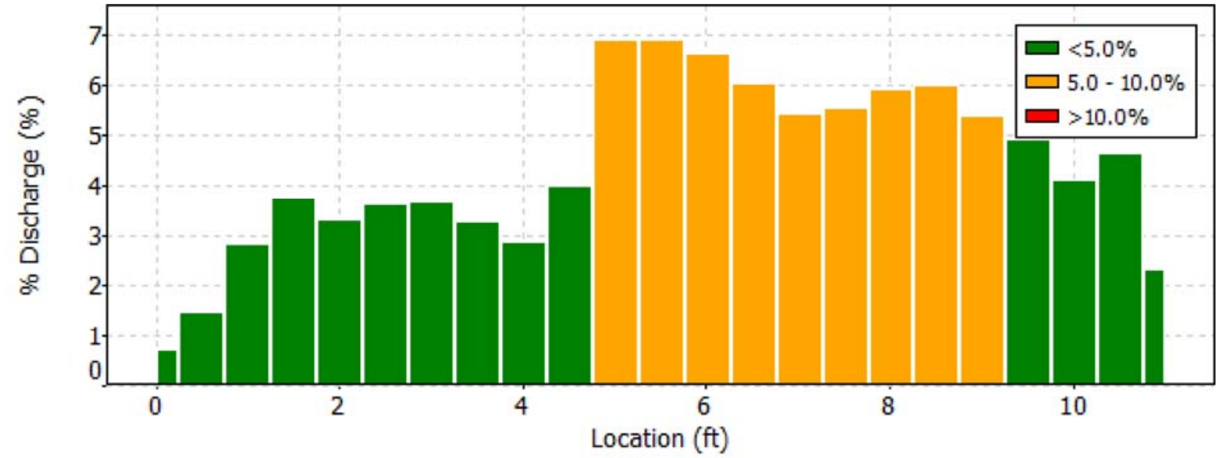
St	Clock	Loc	Method	Depth	%Dep	MeasD	Vel	CorrFact	MeanV	Area	Flow	%Q
0	11:03	0.00	None	0.580	0.0	0.0	0.0000	1.00	0.2293	0.145	0.0333	0.7
1	11:03	0.50	0.6	0.620	0.6	0.248	0.2293	1.00	0.2293	0.310	0.0711	1.5
2	11:04	1.00	0.6	0.630	0.6	0.252	0.4364	1.00	0.4364	0.315	0.1374	2.8
3	11:05	1.50	0.6	0.630	0.6	0.252	0.5778	1.00	0.5778	0.315	0.1820	3.7
4	11:06	2.00	0.6	0.680	0.6	0.272	0.4728	1.00	0.4728	0.340	0.1608	3.3
5	11:07	2.50	0.6	0.710	0.6	0.284	0.4967	1.00	0.4967	0.355	0.1763	3.6
6	11:09	3.00	0.6	0.710	0.6	0.284	0.5023	1.00	0.5023	0.355	0.1783	3.7
7	11:10	3.50	0.6	0.870	0.6	0.348	0.3635	1.00	0.3635	0.435	0.1581	3.3
8	*11:11*	*4.00*	*0.6*	*1.000*	*0.6*	*0.400*	*0.2789*	*1.00*	*0.2789*	*0.500*	*0.1394*	*2.9*
9	11:12	4.50	0.6	1.050	0.6	0.420	0.3694	1.00	0.3694	0.525	0.1939	4.0
10	11:14	5.00	0.6	1.390	0.6	0.556	0.4823	1.00	0.4823	0.695	0.3352	6.9
11	11:15	5.50	0.6	1.290	0.6	0.516	0.5210	1.00	0.5210	0.645	0.3361	6.9
12	11:17	6.00	0.6	1.060	0.6	0.424	0.6089	1.00	0.6089	0.530	0.3227	6.6
13	11:18	6.50	0.6	1.050	0.6	0.420	0.5594	1.00	0.5594	0.525	0.2936	6.0
14	11:19	7.00	0.6	1.020	0.6	0.408	0.5164	1.00	0.5164	0.510	0.2634	5.4
15	11:20	7.50	0.6	0.920	0.6	0.368	0.5840	1.00	0.5840	0.460	0.2686	5.5
16	11:21	8.00	0.6	0.900	0.6	0.360	0.6365	1.00	0.6365	0.450	0.2864	5.9
17	11:22	8.50	0.6	0.830	0.6	0.332	0.7011	1.00	0.7011	0.415	0.2910	6.0
18	11:24	9.00	0.6	0.740	0.6	0.296	0.7051	1.00	0.7051	0.370	0.2609	5.4
19	11:25	9.50	0.6	0.760	0.6	0.304	0.6283	1.00	0.6283	0.380	0.2387	4.9
20	11:26	10.00	0.6	0.820	0.6	0.328	0.4862	1.00	0.4862	0.410	0.1993	4.1
21	11:27	10.50	0.6	0.840	0.6	0.336	0.5351	1.00	0.5351	0.420	0.2247	4.6
22	11:27	11.00	None	0.840	0.0	0.0	0.0000	1.00	0.5351	0.210	0.1124	2.3

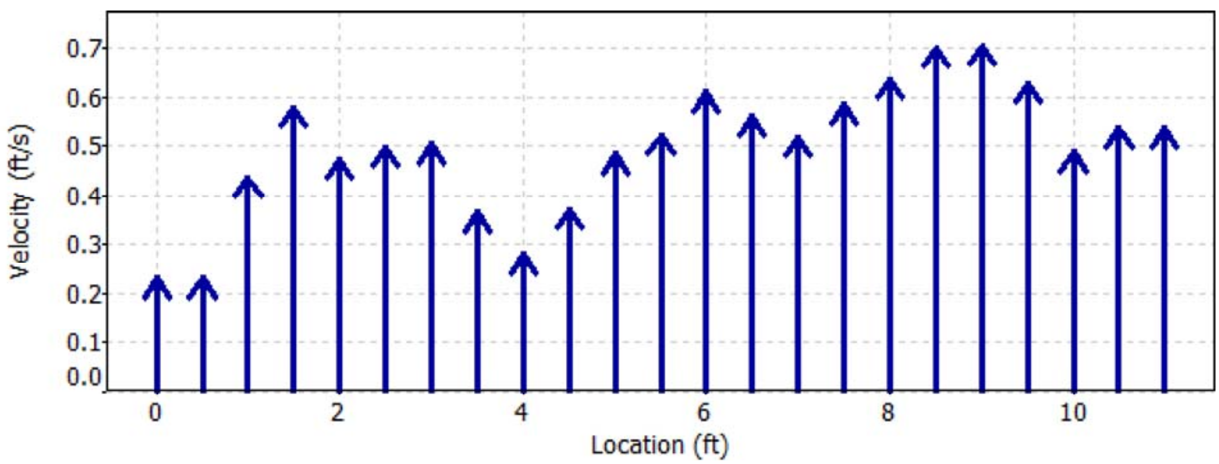
Rows in italics indicate a QC warning. See the Quality Control page of this report for more information.

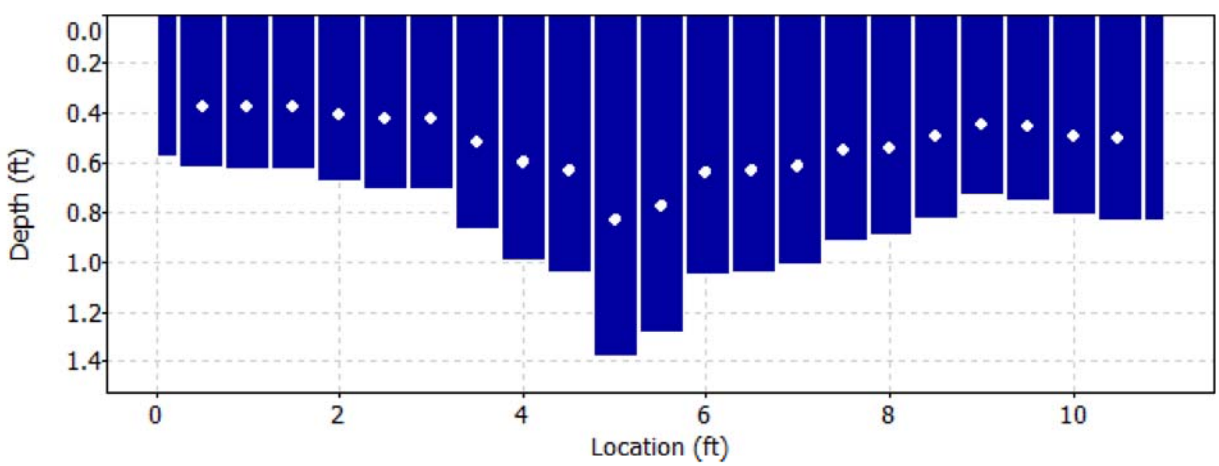
Discharge Measurement Summary

Date Generated: Tue Dec 11 2018

File Information		Site Details	
File Name	SF17.124.WAD	Site Name	WPS
Start Date and Time	2018/12/04 11:03:38	Operator(s)	KAITLYN







Discharge Measurement Summary

Date Generated: Tue Dec 11 2018

File Information

File Name	SF17.124.WAD
Start Date and Time	2018/12/04 11:03:38

Site Details

Site Name	WPS
Operator(s)	KAITLYN

Quality Control

St	Loc	%Dep	Message
8	4.00	0.6	High SNR variation during measurement: 5.2,3.9

Discharge Measurement Summary

Date Generated: Tue Dec 11 2018

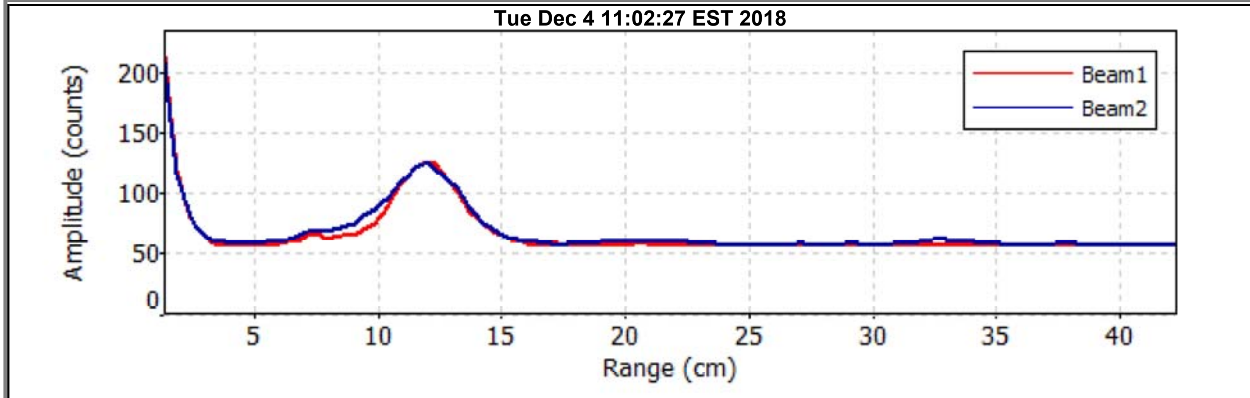
File Information

File Name	SF17.124.WAD
Start Date and Time	2018/12/04 11:03:38

Site Details

Site Name	WPS
Operator(s)	KAITLYN

Automatic Quality Control Test (BeamCheck)



- Noise level check - Pass
- SNR check - Pass
- Peak location check - Pass
- Peak shape check - Pass

STREAMFLOW NAME SF-17

Staff:	K. Voet, A. Robinson		**DTW (ft)**	**time**
Equipment:	FlowTracker	SG-17R	3.91	1045
Date:	12/4/2018			
Start Time:	1017			
End Time:	1044			

Tag Location Color	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R
Tag Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Distance Between Tags (ft)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Cumulative Distance (ft)	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50
Depth (ft)	0.62	0.63	0.63	0.68	0.71	0.71	0.87	1	1.05	1.39	1.29	1.06	1.05	1.02	0.92	0.9	0.83	0.74	0.76	0.82	0.84
Velocity (ft/sec)	0.23	0.44	0.58	0.47	0.5	0.5	0.36	0.28	0.37	0.48	0.52	0.61	0.56	0.52	0.58	0.64	0.7	0.71	0.63	0.49	0.54
Incremental Discharge (ft3/sec)	0.0713	0.1386	0.183	0.1598	0.1775	0.1775	0.1566	0.14	0.19425	0.3336	0.3354	0.3233	0.294	0.2652	0.2668	0.288	0.2905	0.2627	0.2394	0.2009	0.2268
Depth to Measurement	0.372	0.378	0.378	0.408	0.426	0.426	0.522	0.6	0.63	0.834	0.774	0.636	0.63	0.612	0.552	0.54	0.498	0.444	0.456	0.492	0.504
					rock														rocks	rocks	rocks

Wetted Horizontal Distance	**10.50**	**ft**
Total Discharge	**4.72**	**ft3/sec**
	2120.51	**GPM**

Percent Discharge through Each Interval

Tag Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
% Discharge through each interva	1.51	2.93	3.87	3.38	3.76	3.76	3.31	2.96	4.11	7.06	7.10	6.84	6.22	5.61	5.65	6.10	6.15	5.56	5.07	4.25	4.80

TGI – NWNA MANUAL WATER LEVEL MEASUREMENT AND DECONTAMINATION PROCEDURES

Rev: Rev #0

Rev Date: 02/05/2019

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	February 5, 2019	All	Updated and re-written as TGI	Mike Pozniak

APPROVAL SIGNATURES

Prepared by:		02/05/2019
	Amanda M. Robinson	Date:
Reviewed by:		02/05/2019
	Mike Pozniak	Date:

1 INTRODUCTION

This document inclusively applies to all NWNA (Nestle Water North America) sites located in Michigan. Procedures and methods are outlined in this document and are to be used and observed by Arcadis staff when performing tasks under the scope of this document.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of these procedures. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the activities performed under this document.

The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for project work. In turn, project staff are required to consult with the CPM if or when there is a required deviation or omission from work performed as compared to what is described herein, that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

The objective of this Technical Guidance Instruction (TGI) is to describe procedures to measure and record water levels (groundwater and surface water) using manual water level meters. Water levels may be measured using an electronic water level probe from established reference points (e.g. top of casing). Reference points must be surveyed to evaluate water elevations relative to mean sea level (msl). This TGI describes the equipment, field procedures, materials and documentation procedures to measure and record water levels using the aforementioned equipment.

For measuring depth to water (DTW) in monitoring wells, stilling wells, piezometers, and drive points, an electronic water level meter is used. The meter's tape is 100 feet long (length may vary) with a weighted stainless-steel probe attached to the end. The tape is graduated in 100ths of a foot with metric divisions on the reverse side. The probe relies on fluid conductivity to determine the presence of water. When the end of the probe touches water in a well/piezometer/drive point, the meter will emit an audible signal and a visual light. To produce reliable data, the electronic water level probe should be raised and lowered several times at the approximate depth where the instrument produces a tone indicating a water interface to verify consistent, repeatable results. Additionally, controls on the water level meter include a sensitivity adjustment to eliminate false readings. The meter uses one 9-volt battery for operation.

Surface water elevations can be determined from stilling wells or fixed points (bridges, walls, etc.) and measuring from an established point of reference using a water level meter. In some cases, surface water elevations will be determined from a staff gauge (a graduated scale affixed to a point of reference (pole, fence post, bridge, culvert, two-inch PVC or steel, etc.) in open water with known elevation) without the use of a water level meter.

Transducers are installed at some monitoring points, automatically measuring water levels daily. The transducers record pressure that is later converted to depth to water measurements by correcting for barometric pressure. The transducer data are electronically downloaded during the scheduled long-term monitoring (LTM) events through a tablet or equivalent computer.

For the use of pressure transducers or other automated devices for the collection of groundwater elevation data equipment manuals should be observed for operational procedures.

This TGI also includes *Decontamination Procedures* summarized below, following NWNA's *Water Level Meter Disinfection Procedure*, *NWNA-MW-SOP-04.00.01* (Nestle Waters North America, 2019).

3 PERSONNEL QUALIFICATIONS

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The HASP and other documents will identify other training requirements or access control requirements.

4 EQUIPMENT LIST

The following field equipment is required for water level measurements:

- HASP and appropriate field forms
- Appropriate personal protective equipment (PPE) as specified in the HASP
- Site-specific electronic water level indicator graduated in 0.01-foot increments. *Note: The water level meters used on or in conjunction with a NWNA groundwater withdrawal project should be dedicated for NWNA use only. Water level meters previously used on project sites with groundwater contamination should never be used at a NWNA site.*
- 9-volt battery for electronic water level meter
- Storage container. *Note: The electronic water level indicator should be stored and transported in a clean container.*
- Isopropyl alcohol (70%) or chlorine solution (200 ppm) spray bottle. *Note: no industrial scented laundry bleach will be acceptable for substitution.*
- Non-phosphate laboratory soap (Alconox or equivalent), brushes, clean buckets or clean wash tubs. *The buckets/tubs/brush are dedicated to the NWNA sites and cannot be used on sites with environmental contamination.*
- Nitrile gloves
- 100-foot measuring tape (or sufficient length for the maximum site depth requirement)
- Tools and/or keys required for opening wells
- Well construction summary table and/or well construction logs
- Summary table of previous water level measurements or field book
- Field notebook and/or smart device (phone or tablet)
- Indelible ink pen

5 CAUTIONS

Electronic water level probes can sometimes produce false-positive readings. For example, if the inside surface of the well or stilling well has condensation above the water level, then an electronic water level probe may produce a signal by contacting the side of the well rather than the true water level in the well. For accuracy, the electronic water level probe should be raised and lowered several times at the approximate depth where the instrument produces a tone indicating a water interface to verify consistent, repeatable results. Possessing and checking against a well construction summary table is vital for proper measurements and reporting.

If the depth markings on the tape or cable are worn or otherwise difficult to read, extra care must be taken in obtaining the depth readings. These tapes should be replaced.

Ensure that the type of electronic water level probe is compatible with the depth and diameter of the wells to be measured. Tapes missing length (too short) or have been repaired should be discarded because the accuracy of the tape is lost.

6 HEALTH AND SAFETY CONSIDERATIONS

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Potential hazards include pressurized wells, stinging insects that may inhabit well heads and other biologic hazards (e.g. ticks in long grass/weeds around well head). Appropriate personal protective equipment (PPE) will be worn during these activities. Open well caps slowly and keep face and body away to allow venting of any built-up pressure. Field personnel will thoroughly review client-specific health and safety requirements. It is important to note that insecticides and similar chemicals are not permitted for use while on NWNA property and/or near monitoring locations.

7 PROCEDURE

Groundwater level measurement procedures for electronic water level indicators are described in the sections below.

Water Level Measurement Procedures

The general procedures to be followed for the collection of groundwater level measurements and well depths from the monitoring wells are as follows:

- Check that the water level indicator battery is functional before leaving for site and prior to each day onsite (e.g. turn power on and check that meter sounds when probe is lowered into a bucket of water – note that water level meters will not work with distilled water).
- Record instrument make, model, serial number and (if present) Arcadis ID number in the field book.
- Identify site and monitoring point identification in field notebook along with date, time (military time), personnel and weather conditions.
- Don disposable nitrile gloves.

- Decontaminate water level indicator, any attached tape and the spool with isopropyl alcohol (see *Decontamination Procedures* below).
- Perform a well inspection (note that for some sites a well inspection form is required to be filled out along with a photo to document the conditions).
- Unlock well pro-casing (where applicable) while standing upwind from the well (note that some wells may be under pressure and precaution should be taken with opening well caps).
- Remove J-plug from monitoring point. If J-plug is tight in place (frozen, tightened, etc.), then field personnel should wait for the well to equilibrate (two minutes) after removing the J-plug before taking a water level measurement. Check previous field forms/logs for equilibration time if noted.
- Locate the measuring reference point that correlates to the survey point on the monitoring well casing. This can generally be found on the top of casing inside the well, identified by a black mark. If one is not found, create a reference point by marking the highest and/or north point on the inner casing (or outer if an inner casing is not present). All downhole measurements are to be taken from the reference point. Document the creation of any new reference point or alteration of the existing reference point.
- Turn on the water level meter and adjust sensitivity.
- Lower water level probe into well until audible and visible signals are detected. Use and install tape guide to help with accuracy and provide protection with damaging the measurement tape. If a tape guide is not available, make sure that the tape does not drag on the inner or outer casing which could fray and damage the tape.
- Measure DTW from the existing or created reference point from the top of casing [below top of casing (BTOC)] of the monitoring point to the nearest 0.01 foot.
- Hold the tape at the measuring point (tip of well casing) and state the measurement verbally. The person recording the data should repeat the measurement verbally back to the person measuring the DTW to ensure proper data collection. Repeat the measurement two more times.
- Record the final measurement in field book. Include time the measurement was taken (military time), well name, unit of measurement and type of measurement for every entry into the field book (e.g. 13:10 SW-103 4.75’ BTOC).
- Check recorded measurement against any previous measurements from the same location. Note any anomalies/discrepancies in the field book; if significant, contact the technical lead for project.
- If a transducer is installed in the monitoring point, attach field tablet or compatible computer to download data from the transducer (See respective equipment manuals for operation procedures).
- Replace J-plug on well casing, close pro-casing lid, and lock well (where applicable).
- Decontaminate (see *Decontamination Procedures* below) water level tape and probe (where applicable).

For stilling wells: If DTW measurement outside of well varies from the DTW measurement inside the well (greater than 0.01 foot. difference), the well screen may be plugged. Unplug the screen (brush screen, bail stilling well, etc.), note activities in field book, and re-measure the DTW of the stilling well.

At staff gauges: Water levels in surface water bodies are determined by first directly reading the staff gauge then calculating the water elevation. The calculation is completed by taking a reading and subtracting it from the value at the top of the staff gauge ruler (surveyed elevation). This subtraction gives the distance from the top of the staff gauge ruler to the water. This distance is then subtracted from the surveyed elevation from the reference point at the top of the staff gauge.

Total Depth Measurement Procedures

- Weighted tape or electronic water level indicator can be used to determine the total well depth.
- Follow initial procedures noted above in *Water Level Measurements*.
- Lower indicator probe (or tape) until weighted end is felt resting on the bottom of the well. Raise indicator slowly until there is no slack in the tape. Gently “feel” the bottom of the well by slowly raising and lowering the indicator: great care should be taken to avoid damaging the sensor on the probe. The operator may find it easier to allow the weight to touch bottom and then detect the ‘tug’ on the tape while lifting the weight off the well bottom.
- Because of the tape buoyancy and weight effects encountered in deep wells with long water columns, it may be difficult to determine when the tape end is touching the bottom of the well and sediment in the bottom of the well can also make it difficult to determine total depth. Care must be taken in these situations to ensure accurate measurements.
- Read and record measurement to the nearest 0.1 foot. Also note if the bottom of the well is hard or soft, relating if there is sediment present. Please refer to the note regarding total depth measurements described in *Section 5 Cautions* above.
- Follow decontamination procedure outlined below where applicable (see *Decontamination Procedures* below).

Decontamination Procedures

The purpose of following the below decontamination procedures is to prevent contamination to groundwater during the collection of manual groundwater level measurements. These procedures should be followed whenever any equipment is introduced to an environment where it comes into contact with groundwater on, or associated with any, NWNA Site. Below are the summarized points from NWNA’s *Water Level Meter Disinfection Procedure - NWNA-MW-SOP-04.00.01* (Nestle Water’s North America, 2019).

- Cleaning and sanitizing water level meters should be completed by persons wearing nitrile gloves.
- Prior to each monitoring event, remove water level meter from storage container and spray the water level sensor and at least five feet of tape above the sensor with 70% isopropyl alcohol or 200 ppm chlorine solution. Allow for appropriate contact time (30 seconds for isopropyl alcohol and two minutes for 200 ppm chlorine solution).

- Repeat disinfection procedure if water level sensor or tape comes into contact with the ground and/or any other surface not associated with groundwater monitoring.
- Store water level meter in a clean storage container (i.e., plastic bag) while transporting between monitoring locations.
- Repeat disinfection procedure prior to insertion of the water level sensor in NWNA production wells, and residential or monitoring wells located nearby a production well (within three-day time of travel to production well).
- Prior to storage of the water level meter and upon completion of the monitoring event, the sensor and measuring tape should be sanitized by spraying with 70% isopropyl alcohol or 200 ppm chlorine solution. The water level meter is to be stored in a clean storage container. *Note: if needed, the sensor, measuring tape and storage container can be cleaned with an alconox solution and rinsed. Cleaning should be followed by sanitizing with 70% isopropyl alcohol or 200 ppm chlorine solution.*
- Extra care should be taken to clean the probe after a total depth measurement. At least, the length of tape that was introduced into the water column of the well should be wiped with clean paper towel and sprayed with 70% isopropyl alcohol. All sediment or dirt needs to be removed during decontamination.

8 WASTE MANAGEMENT

Waste generated at the site shall be disposed of properly by Arcadis personnel.

9 DATA RECORDING AND MANAGEMENT

Groundwater level measurements as well as all relevant observations should be documented in the field notebook, field forms and/or smart devices as appropriate. The following information must be documented:

- Well or location identification;
- Measurement time;
- Depth to water;
- Total well depth or depth of the water body at the location, annually.

Once all the data has been collected and recorded, all notes/forms/data must be uploaded to the appropriate project directory on the Arcadis server, and an email should be sent to the Task Manager and/or Technical lead for notification. A summary of the work completed that day and any relevant observation noted (such as well inspections) during the daily activities should be included with the email. The appropriate team member will review the data for accuracy and provide feedback.

10 QUALITY ASSURANCE

- As described in the detailed procedure, the electronic water level meter will be tested prior to use to ensure accurate length demarcation on the tape or cable. The results will be recorded.
- Conduct a minimum of two measurements, more may be necessary based upon site conditions. The final measurement will be recorded, along with any anomalies or discrepancies.
- Field notes will be reviewed by the project team once the field data has been uploaded to project file.

11 REFERENCES

Cunningham, W.L., and Schalk, C.W., comps. (2011). *Groundwater technical procedures of the U.S. Geological Survey; U.S. Geological Survey Techniques and Methods1-A1, 151pp.*

United States Environmental Protection Agency. (2016, November 3). *Level and Well Depth Measurement: SESD Operating Procedure*. Region 4 Athens, Georgia. Retrieved from https://www.epa.gov/sites/production/files/2017-07/documents/groundwater_level_and_well_depth_measurement105_af.r3.pdf

Nestle Water's North America. (2019). *Water level meter disinfection procedure – NWNA-MW-SOP-04.00.01. Rev. 3.*

APPENDIX C

Field Procedures

APPENDIX C. FIELD PROCEDURES

SOP/Manual Reference Number	Title, Revision Date and/or Number[1]	Originating Organization	Equipment Type	Modified for Project Work?	Comments
01	QP306: Field Activities Documentation. November 2016	Arcadis	See SOP for specific forms	No	Describes procedure for documenting field work activities. See Appendix B.
02	QP307: Calibration and Control of Measuring and Test Equipment. November 2016.	Arcadis	See SOP for specific forms	No	Describes procedure for calibrating and documenting calibration of field measuring equipment. See Appendix B.
03	Technical Guidance Instruction – Monitoring Well Development. April 2017	Arcadis	See TGI for specific equipment needs	No	Describes the development of screened wells used for obtaining representative groundwater information and samples from monitoring wells. See Appendix B.
04	Technical Guidance Instruction – Monitoring Well Installation. April 2017	Arcadis	See TGI for specific equipment needs	No	Describes the methods used to install groundwater monitoring wells in granular aquifers. See Appendix B.
05	Technical Guidance Instruction – Soil Description. Rev #2. February 2018.	Arcadis	See TGI for specific equipment needs	No	Describes techniques for writting geologic soil descriptions. See Appendix B.

SOP/Manual Reference Number	Title, Revision Date and/or Number[1]	Originating Organization	Equipment Type	Modified for Project Work?	Comments
06	TGI-NWNA Manual Water-Level Measurement and Decontamination Procedures. February 2019.	Arcadis	Water level meter, datalogging pressure transducer	Yes	Describes the procedues to collect water level measurements. Describes the procedures to follow for disinfection. See Appendix B.
07	TGI-NWNA Stream Flow Monitoring Procedure. February 2019.	Arcadis	Flow Tracker, Marsh McBirney Flo-Mate 2000	Yes	Describes procedures for collection streamflow measurements and equipment calibration. See Appendix B.
08	Groundwater Level and Well Depth Measurement. November 3, 2016.	USEPA	Water level meter	No	Operating Procedure (USEPA, 2016)
09	Flow Tracker Handheld ADV Technical Manual Firmware Version 3.7 Software Version 2.30. March 2009.	SonTek/YSI Inc.	Flow Tracker	No	Technical Manual (SonTek/YSI Inc., 2009)
10	Flow Tracker Quick Start Guide	SonTek/YSI Inc.	Flow Tracker	No	Quick Start Guide (SonTek, n.d.)
11	Marsh-McBirney, Inc. Flo-Mate Model 2000 Portable Flowmeter Instruction Manual. December 1990.	Marsh-McBirney Inc.	Model 2000	No	Installation and Operations Manual (Marsh-McBirney Inc., 1990)
12	Level TROLL 400, 500, 700, 700H Instruments. May 2013.	In-Situ	Level Troll	No	Operator’s Manual (In-Situ, 2013)

SOP/Manual Reference Number	Title, Revision Date and/or Number[1]	Originating Organization	Equipment Type	Modified for Project Work?	Comments
13	Tube 300R Telemetry System. Rev. 004. July 2016	In-Situ	Tube 300R	No	User's Manual (In-Situ, 2016)
14	Cutthroat Flume User's Manual	Openchannelflow	Cutthroat Flume	No	User's Manual (Openchannelflow, n.d.)

[1] Copies of Technical Guidance Instructions (TGIs) and SOPs are included in **Appendix B**.

APPENDIX D

Cutthroat Flume User's Manual

CUTTHROAT FLUME

User's Manual

TABLE OF CONTENTS

INTRODUCTION TO THE CUTTHROAT FLUME

In the 1960's researchers at the Utah Water Research Laboratory at Utah State University began investigations into what would become the Cutthroat flume. The goal of the researchers was to develop a flume that overcame the limitations of the Parshall flume in flat gradient applications.

Although originally developed to measure irrigation flow, Cutthroat flumes are now used to for:

- *Cooling water discharge*
- *Dam seepage*
- *Industrial effluent*
- *Irrigation / water rights*
- *Mine discharge / dewatering*
- *Sanitary sewage (piped and treatment plant)*
- *Spring discharge*
- *Storm water*

In addition to these flow measurement applications, Cutthroat flume are frequently used in wastewater treatment plants for proportional flow splitting.

DEVELOPMENT

Prior to the development of the Cutthroat flume, flow on flat gradients presented a problem. The drop though the Parshall flume mean that the flume had to either be elevated above the floor of the channel – creating upstream ponding and overtopping issues – or using that the flume had to be used in a submerged manner (creating measurement and accuracy issues).

Funded by the U.S. Department of the Interior, Office of Water Resources Research, Drs. Skogerboe, Hyatt, Anderson, and Eggleston at the Utah Water Research Laboratory extensively researched issues related to the problem:

- *Flow conditions in flat-bodied Trapezoidal flumes (Robinson et al 1960), (Hyatt 1965)*
- *Inlet convergence ratios (Ackers and Harrison 1963)*
- *Submerged flow in open channel flow measurement structures (Skogerboe, Hyatt, Eggleston 1967)*
- *Flume discharge in flat-bodied Trapezoidal flumes (Hyatt 1965)*

Ultimately this research lead to the development of two different styles of Cutthroat flumes: Rectangular (with flat, vertical sidewalls like a Parshall flume) and Trapezoidal (with outward sloping sidewalls like a Trapezoidal flume). Of the two, the Rectangular Cutthroat flume is most commonly used.

Rectangular Cutthroat flumes are available in four different lengths (18, 36, 54, and 108-inches L) and four throat widths for each length. Trapezoidal Cutthroat flumes come in three different throat widths.

Rectangular Cutthroat flumes have a distinct advantage over similar flumes in that, for a given length, intermediate throat widths can be developed without the need to laboratory or field rate the new flume size.

Trapezoidal Cutthroat flumes have one given length and three different throat widths (V, 6-inch, and 12-inch).

For the purposes of this User's Manual, the discussion below will be for Rectangular Cutthroat flumes unless otherwise indicated.

FUNCTION

Sub-critical flumes like the Cutthroat flume operate by accelerating slow, sub-critical flow ($Fr<1$) to a supercritical state ($Fr>1$) by restricting the flow as it passes through the flume. The Cutthroat flume accomplishes this restriction by contracting the side walls of the – while keeping a constant floor elevation.

DESIGN

When viewed from above, the Cutthroat flume has an hourglass shape.

As flow enters the flume it is accelerated in the short, uniformly converging (inlet) section. Upon reaching the throat – the narrowest portion of the flume – the flow immediately expands into the diverging (outlet) section. Unlike many other flumes, the Cutthroat flume lacks an extended throat – hence the name “Cutthroat”.

The converging (inlet) section of a Cutthroat flume is 1/3 the length of the flume, with the flat sidewalls contracting at a uniform 3:1 ratio.

The diverging (outlet) section of a Cutthroat flume is 2/3 the length of the flume, with the flat sidewalls expanding at a uniform 6:1 ratio.

The floor of a Cutthroat flume is flat from inlet to outlet, making the flume well suited for low gradient installations.

This layout is the same for both Rectangular and Trapezoidal Cutthroat flumes.

STANDARDS

Like the Trapezoidal flume, the dimensions for the Cutthroat flume are not subject to a national standard, but are instead presented in various academic journals.

- *Skogerboe, G., Bennett, R., Walker, W., Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, Vol. 98, No. IR4, December 1972*
- *Bennett, R., Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972*

ACCURACY

The Cutthroat flume was developed to provide accurate flow measurement with a precision of +/-3% under free-flow conditions

This accuracy is to be expected when the ratio of flow depth (at the point of measurement) to flume length.

For greatest accuracy, the ratio of flow depth to flume length should be 0.1 and 0.4. Above 0.4 and higher approach velocities and rapid changes in the water surface introduce inaccuracies.

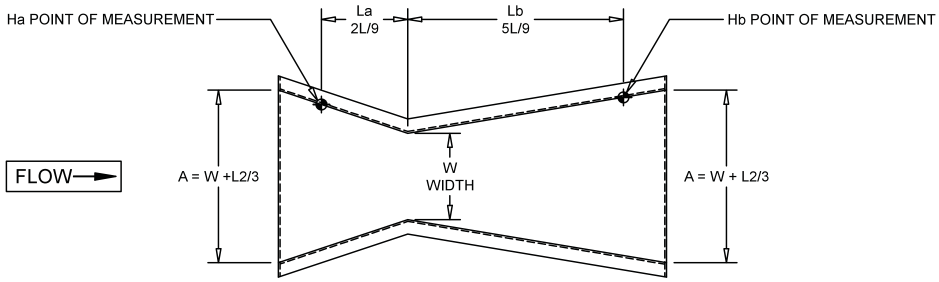
DIMENSIONS

The master dimensions for Rectangular Cutthroat flumes are found in Figure 1.

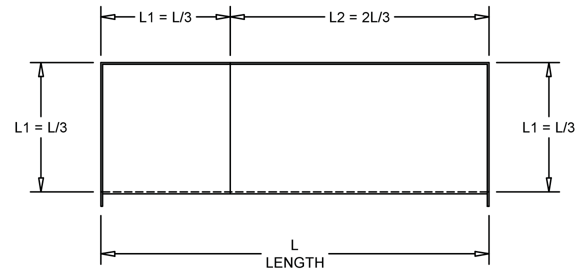
DIMENSIONAL TOLERANCES

In general, the dimensions of a Cutthroat flume must be within +/-2% of nominal.

Wider than that and the equation for the actual dimensions should be developed (assuming the deviations are constant and the throat width is between two standard sizes).



PLAN VIEW



ELEVATION VIEW

L (LENGTH)	W (WIDTH)	A	La	Lb	L1	L2
18" [45.72 CM]	1" [2.54 CM]	5" [12.7 CM]	4" [10.16 CM]	10" [25.4 CM]	6" [15.24 CM]	1' [30.48 CM]
	2" [5.08 CM]	6" [15.24 CM]	4" [10.16 CM]	10" [25.4 CM]	6" [15.24 CM]	1' [30.48 CM]
	4" [10.16 CM]	8" [20.32 CM]	4" [10.16 CM]	10" [25.4 CM]	6" [15.24 CM]	1' [30.48 CM]
	8" [20.32 CM]	1'" [30.48 CM]	4" [10.16 CM]	10" [25.4 CM]	6" [15.24 CM]	1' [30.48 CM]
36" [91.44 CM]	2" [5.08 CM]	10" [25.4 CM]	8" [20.32 CM]	1'-8" [50.8 CM]	1' [30.48 CM]	2' [60.96 CM]
	4" [10.16 CM]	1' [30.48 CM]	8" [20.32 CM]	1'-8" [50.8 CM]	1' [30.48 CM]	2' [60.96 CM]
	8" [20.32 CM]	1'-4" [40.64 CM]	8" [20.32 CM]	1'-8" [50.8 CM]	1' [30.48 CM]	2' [60.96 CM]
	1'-4" [40.64 CM]	2' [60.96 CM]	8" [20.32 CM]	1'-8" [50.8 CM]	1' [30.48 CM]	2' [60.96 CM]
54" [137.2 CM]	3" [7.62 CM]	1'-3" [38.1 CM]	1' [30.48 CM]	2'-6" [76.2 CM]	1'-6" [45.72 CM]	3' [91.44 CM]
	6" [15.24 CM]	1'-6" [45.72 CM]	1' [30.48 CM]	2'-6" [76.2 CM]	1'-6" [45.72 CM]	3' [91.44 CM]
	1' [30.48 CM]	2' [60.96 CM]	1' [30.48 CM]	2'-6" [76.2 CM]	1'-6" [45.72 CM]	3' [91.44 CM]
	2' [60.96 CM]	3' [91.44 CM]	1' [30.48 CM]	2'-6" [76.2 CM]	1'-6" [45.72 CM]	3' [91.44 CM]
108" [274.3 CM]	1' [30.48 CM]	3' [91.44 CM]	2' [60.96 CM]	5' [152.4 CM]	3' [91.44 CM]	6' [182.9 CM]
	2' [60.96 CM]	4' [121.9 CM]	2' [60.96 CM]	5' [152.4 CM]	3' [91.44 CM]	6' [182.9 CM]
	4' [121.9 CM]	6' [182.9 CM]	2' [60.96 CM]	5' [152.4 CM]	3' [91.44 CM]	6' [182.9 CM]
	6' [182.9 CM]	8' [243.8 CM]	2' [60.96 CM]	5' [152.4 CM]	3' [91.44 CM]	6' [182.9 CM]

Figure 1 – Rectangular Cutthroat Flume Master Dimensions

POINTS OF MEASUREMENT

The primary, free-flow, point of measurement, Ha, is located in the converging section of the flume a distance of 2L/9 upstream of the throat (L = flume length).

The secondary point of measurement, Hb, used to determine the submergence of a Cutthroat flume is located in near the outlet of the flume, 5L/9 downstream of the throat.

As the floor of the Cutthroat flume is flat, there is no need to adjust the Hb elevation when calculating the submergence ratio.

FLOW EQUATIONS

For free-flow conditions, the level-to-flow equation for the Cutthroat flume can be expressed as:

$$Q = KW^{1.025} H_a^{\mathrm{n}} = CH_a^{\mathrm{n}}$$

Q = free flow rate (cfs / m3/s)
K = flume discharge constant (varies by flume length / units)
C = flume discharge constant (varies by flume length / throat width / units)
W = throat width
H_a = depth at the point of measurement (feet / meters)
n = discharge exponent (depends upon throat width)

Equation 1 – Cutthroat Flume Free-Flow Equation

A unique advantage of the Cutthroat flume over other short-throated flumes is the ability to develop flow equations for intermediate throat widths. So long as the flume is of a standard length and converges / diverges as the stand ratios, the rating can be developed without the need for laboratory investigation.

Size	C (cfs)	C (m3/s)	N
18-inch x 1-inch	0.494	1479.9	2.15
18-inch x 2-inch	0.947	344.8	2.15
18-inch x 4-inch	1.975	719.2	2.15
18-inch x 8-inch	4.030	1,467	2.15
36-inch x 2-inch	0.719	181.2	1.84
36-inch x 4-inch	1.459	367.6	1.84
36-inch x 8-inch	2.970	748.3	1.84
36-inch x 16-inch	6.040	1,522	1.84
54-inch x 3-inch	0.96	209.7	1.72
54-inch x 6-inch	1.96	428.2	1.72
54-inch x 12-inch	3.980	869.5	1.72
54-inch x 24-inch	8.01	1,750	1.72
108-inch x 12-inch	3.50	632.2	1.56
108-inch x 24-inch	7.11	1,284	1.56
108-inch x 48-inch	14.49	2,618	1.56
108-inch x 72-inch	22.0	3,974	1.56

Table 1 – Rectangular Cutthroat Flume Free-Flow Discharge Values

SUBMERGED FLOW

As a Cutthroat flume becomes submerged – where downstream conditions reduce the flow out of the flume – corrections must be made to the flow equation.

In order to determine when these corrections should be made (and the degree to which the flume is submerged), the submergence ratio must be calculated.

The submergence ratio is the ratio of the downstream depth at the secondary point of measurement, Hb, to the depth at the primary point of measurement, Ha.

$$S = \frac{H_b}{H_a}$$

Equation 2 – Submergence Ratio Equation

SUBMERGENCE TRANSITION

The transition from free, unrestricted flow to submerged to one of backwater / slowed velocity discharge is known as the submergence transition (St). For Cutthroat flumes, as the flume gets large, so does the submergence transition.

18-inches L	60%
36-inches L	65%
54-inches L	70%
108-inches L	80%

Table 2 – Submergence Transitions (St) Values for Rectangular Cutthroat Flumes

Above the submergence transitions for a given flume's size, the flow must be corrected for the effects of submergence.

WHERE TO INSTALL A CUTTHROAT FLUME

When selecting a site in which to install a Cutthroat flume, there are several points to consider:

UPSTREAM OF THE FLUME

- *Flow entering a Cutthroat flume MUST be sub-critical.*
- *The Froude number (Fr) for flow entering a flume should not exceed 0.5 and should never exceed 0.99.*
    - *Surface turbulence may be encountered for Froude numbers above 0.5.*
    - *For a flume to accurately measure flow, that flow must be sub-critical (Fr<0.99).*
    - *If the approaching flow is critical (Fr = 1.0) or supercritical (Fr > 1.0), then a hydraulic jump must be formed at least 30 times the maximum anticipated head upstream of the entrance to the flume.*
- *The flow entering the flume should be smooth, tranquil, and well distributed across the channel.*
    - *ASTM D1941 indicates that 10 to 20 times the throat width will usually meet the necessary inlet conditions.*
- *If the flow is super-critical approaching the flume a hydraulic jump must be formed well upstream of the flume or upstream energy absorbers and tranquilizing racks must be used).*
- *The approaching channel should be straight so that the velocity profile is uniform. Surging, turbulent, or unbalanced flows must be conditioned before the flow enters the flume.*
- *Any bends, dips, elbows, or flow junctions upstream of the flume must be sufficiently far upstream so that the flow has is well distributed and non-turbulent.*
- *While corrections can be made for improper installations or flume settlement, they should be avoided where at all possible.*
- *Cutthroat flumes have been successfully used in applications where the flow rises up a uniform vertical column and then enters the flume.*
- *Where the channel is wider than the inlet of the flume, wing walls should be formed to smoothly direct the flow into the flume. The inlet wing walls should be of a constant radius and should end tangent to the inlet walls of the flume.*

- *When connecting to inlet piping, observations have shown that the pipe should be straight and without bends for at least 15 pipe diameters.*
- *The upstream channel should be clear of vegetative growth.*
- *Open channel (non-full pipe) flow must be present under all flow conditions.*

FLUME LOCATION

- *Cutthroat flumes must set so that the floor of the flume is level from front-to-back and from side-to-side.*
- *The shorter converging section of the flume is set upstream.*
- *When Cutthroat flumes are installed in earthen channels and furrows, care should be taken to ensure that a stable bottom elevation is present and that the elevation does not change during dry / wet seasons or low-flow periods.*
- *The flume must be centered in the flow stream.*
- *Where a Parshall flume must be set above the floor of a channel, a 1:4 (rise:run) slope should be formed into the flume. Slopes greater than this should be avoided as they can cause turbulence as the flow separates at the junction of the ramp and the inlet of the flume.*
- *All of the flow must go through the flume – there should be no bypass.*

DOWNSTREAM OF THE FLUME

- *For a Cutthroat flume to operate under free-flow conditions, the downstream channel must be of a sufficient size / configuration so that flow does not back up into the flume – slowing discharge out of the flume.*
- *When flow out of the Cutthroat flume is returning to a channel or pipe, the EPA recommends that the channel be straight and unobstructed for 5-20 throat widths – although flow spilling freely off the end of the flume can eliminate this requirement.*
- *To transition the flow out of a Cutthroat flume, wing walls should be used. These walls can be flat or perpendicular to the flume (to save space or money) or they can extend from the flume's discharge at some angle or radius sufficient to transition the flow as desired. Transitions to earthen or natural channels should be as gradual as practical to minimize downstream scour.*
- *The downstream channel should be armored (riprap) or otherwise protected so that scour does not occur.*
- *The downstream channel must be clear of vegetative growth or the collection of debris so that flow does not back up in to the flume.*

HOW TO INSTALL A CUTTHROAT FLUME

Once a site has been selected, the flume must then be installed correctly:

- *The flume should be set so that it is centered in the flow stream.*
- *The floor of the flume should be set high enough so that the flume does not operate under submerged flow conditions.*
- *The outlet of the flume should be set at or above (ideally) the invert of the outlet channel / pipe to help transition solids out of the flume.*
- *The shorter section of the flume must be set upstream.*
- *The floor must be level from front-to-back and from side-to-side (using a level on the floor - not the top - of the flume)*
- *The flume must be braced internally (plywood and lumber are typically used) during installation to ensure that distortion does not occur.*
- *The flume must not float out of its intended final position during installation.*

DIMENSIONAL BRACING

Most Cutthroat flumes ship with dimensional bracing (angle or tube) at the top of the flume. The bracing should be left on the flume until the installation has been completed.

If the flume is set in concrete, the bracing may be removed once the installation has been completed.

For installations where the flume is free-standing or otherwise not set in concrete, the bracing should be left in place.

If the bracing is removed, verify the dimensional accuracy of the flume after the removal.

CONNECTION JOINTS

Cutthroat flumes supplied with bulkheads, or transition sections must remain sealed between the joints.

While these joints may be sealed initially at the factory, a final visual inspection of all joints should be done before installation.

Where required, apply one or two continuous beads of silicone on all seating surfaces before proceeding with the installation.

HOW TO MAINTAIN A CUTTHROAT FLUME

For a Cutthroat flume to accurately measure flow, it must be periodically inspected and maintained. This inspection should be done six (6) months after installation and each following year.

The inspection should include the channel in which the flume is installed, the flow entering / exiting the flume, and the flume itself.

CHANNEL INSPECTION

- The upstream channel banks should be clear of vegetation or debris that could affect the flow profile entering the flume (upstream) or restrict flow out of the flume (downstream).
- Inspect the upstream channel to make sure that flow is not bypassing the flume.
- Inspect the downstream channel to make sure that scouring is not occurring.
- Any hydraulic jump should be at least 30 times the maximum head (Hmax) upstream of the flume.

FLOW INSPECTION

- *Flow entering the flume should be tranquil and well distributed.*
- *Turbulence, poor velocity profile, or surging should not be present.*
- *The Froude (Fr) number should, ideally, be 0.5.*
- *As the Froude number increases so does surface turbulence.*
- *Flumes accelerate sub-critical flow (Fr < 1) to a supercritical state (Fr 1>) .*
- *Flumes experiencing flows greater than unit (Fr = 1) will not accurately measure flow.*

FLUME INSPECTION

- *Flumes must be level from front-to-back and from side-to-side.*
- *Earthen installations are particularly susceptible to settling due to wet / dry and freeze / thaw cycles.*
- *Flow surfaces are to be kept clean of surface buildup or algal growth. Scrubbing or a mild detergent can be used.*
- *Galvanized flumes should be checked for corrosion.*
- *Any corrosion should be removed and then cold galvanization applied to the area.*

APPENDIX E

Field Equipment Calibration, Maintenance and Inspection

APPENDIX E. FIELD EQUIPMENT CALIBRATION, MAINTENANCE AND INSPECTION

Field Equipment	Calibration Activity	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Corrective Action	Reference[1]
Monitoring points		Clean wells, remove obstructions/debris, remark identification labels or TOC marks		Inspect for damages (well caps, locks, security, etc.) and wear	Monthly, as needed	Repairs, replacement of well parts	
	Total depth measurement				Annually	Sediment bailing, well repair, resurvey well	USEPA, 2016
	Well survey				Every other year, as needed	New elevation added to dataset	
Stream gauging location		Remove obstructions within gauging location, remark incremental stream measurements		Inspect for damages	Monthly	Move obstruction from stream	
		Staff gauge rulers cleaned		Inspect for damages	Annually, as needed	Clean, repair, remove debris	
Water level meter	Two to three manual measurements collected at each location	Battery replacement, decontamination		Inspect for damages and wear	Monthly, as needed	Repair, replace meter	USEPA, 2016
Transducer and telemetry system	Compare to manual measurements	Trim nearby trees and vegetation		Inspect for damages, dessicant life, anomolies	Monthly	Recalibrated if 0.02-foot discrepancy	
		Remove transducers every winter (mid-November to mid-May)			Annually		In-Situ, 2013
	Factory calibration	Factory maintenance, clean			Annually, as needed		

APPENDIX E. FIELD EQUIPMENT CALIBRATION, MAINTENANCE AND INSPECTION

Field Equipment	Calibration Activity	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Corrective Action	Reference[1]
Tube 300R		Replace			Approx. every five years		In-Situ, 2016
Flow Tracker	Does not require recalibration for velocity data	Battery replacement, update software, clean transducer	Beam Check, SmartQC	Inspect for damages and accuracy of temperature data and internal clock, and internal memory available	Monthly	Manufacturer Repair	*TGI-NWNA Stream Flow Monitoring Procedure* **(Appendix B)** SonTek/YSI Inc., 2009
		Send to Manufacturer		Inspect for damage and accuracy	Annually	Replacement FlowTracker	
Flo-Mate	Zero check, zero adjust	Clean sensor, battery replacement		Inspect for damage	Monthly	Repair	*TGI-NWNA Stream Flow Monitoring Procedure* **(Appendix B)** Marsh-McBirney Inc., 1990
Flume	Flow Tracker stream flow measurement, rating curve for installed level troll	Clean debris and build-up, obstruction from flume		Inspect flume for damages and level. Inspect channel for obstructions, scouring, and bypassing of water. Inpact flow for velocity changes.	Monthly	Repair, remove obstructions.	Openchannelflow, n.d.

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APPENDIX B

Monitoring Plan Summary

MONITORING PLAN

1 FLUME, STILLING WELL, AND TELEMETRY INSTALLATION

A cutthroat flume will be installed in the SF-8 area. The flume will allow flow to be estimated using a stage/discharge rating curve. The rating curve established by the flume manufacturer will be used to estimate the flow based on the stage measured in the stilling well. Prior to implementation, the flume will be calibrated through field testing (FlowTracker® ADV measurements and/or bucket testing) to verify the accuracy of the flume prior to relying on the water level measured in the stilling well to calculate flow.

Continuous monitoring at locations SF-1 and SF-8 (June through October) will require the installation of the flume at SF-8, stilling wells at both locations equipped with transducers to measure stage, and telemetry systems to make the data available to be reviewed. The stilling wells at SF-1 and SF-8 will be installed by hand augering into the streambed and installing a 4-inch diameter PVC, 5-foot long screen. The screen will be placed so the that water elevation in the channel can be monitored. The screen will be affixed to a fence post driven into the streambed for stability. An alternative stilling well at the SF-8 location may be having the stilling well built into the flume.

The stilling wells at SF-1 and SF-8 will be equipped with In-Situ Level Troll 700 instruments (or equivalent), installed so the sensor can record stage (QAPP Section 3.4.4). The Level Troll 700 will be set to 'depth mode' so that the stage is recorded. A battery-operated In-Situ telemetry system will be connected to the transducer so that the data can be accessed daily between June 1 and October 31. The telemetry system will be installed in the stilling wells, housed in a two- or four-inch diameter PVC pipe. The Level Troll 700 instruments will be set to collect stage data at hourly intervals from June 1 through October 31.

The flume, transducers, and telemetry system will be removed during the December monitoring event and re-installed during the May monitoring event each year.

2 MONITORING PLAN

Task 1 - Streamflow

Streamflow will be measured monthly at locations SF-1, SF-2, SF-8, SF-9, SF-10, SF-11, SF-13, SF-16, SF-17, SF-18, and SF-19 (**Figure 1A**). Streamflow will be measured as scheduled (see **schedule**), except in August and September when the monitoring schedule is dependent on precipitation. During this time period, if 0.2 inches of precipitation occurs 48-hours (two calendar days) prior to monitoring the streamflow monitoring will be rescheduled.

Streamflow is calculated by measuring flow velocities for small areas (usually 0.25- or 0.5-foot intervals) across the stream using a FlowTracker ® (a handheld ADV) or the Flo-Mate. Streamflow will be measured using the FlowTracker ® except at locations SF-8 and SF-19, where the Flo-Mate will be used. This changed in equipment is due to the stream channel configuration: narrow with a shallow depth.

The FlowTracker ® generates a file summarizing the instrument calibration and data collected at each location. These files will be submitted to the MDEQ. Arcadis also enters the stream data at each point into an Excel spreadsheet as a quality control procedure. The stream depth and flow velocity data are measured by one staff (Staff "A") and read aloud to a second staff member (Staff "B") who records the depth and velocity in a portable field tablet for each measured stream segment. The calculated stream flow in cubic feet per second is compared in the field between the file recorded by the FlowTracker and the Excel file in the tablet. Should the flow calculations be different, individual entries are checked for errors. The Excel spreadsheet is used to calculate flow at the locations where the Flow Mate is used. The Excel spreadsheets are stored in the project files.

Task 2 - Water Levels

The permit requires groundwater and surface water elevations to be collected on a monthly basis. At each location, the measurement (reading) will be duplicated before recording. The person obtaining the measurements then states the measurement to the recorder (second staff member), who repeats the measurement before recording it into the dedicated field book. The following sections describe water level measurement and data collection.

Groundwater Levels

Monitoring wells and drive points are used to measure groundwater levels in the spring aquifer. Nested well pairs located throughout the site are used to assess vertical hydraulic gradients. The following locations are included in the monitoring program (**Figure 1**):

- Monitoring Wells: MW-1d, MW-1i, MW-1u, MW-2i, MW-3i, MW-4u, MW-5d, MW-5i, MW-6i, MW-7i, MW-8i, MW-9i, MW-10i, MW-11s, MW-12i, MW-12s, MW-13i, MW-101s, MW-101d, MW-101L, MW-102i, MW-102d, MW-103i, MW-103d, MW-104i, MW-104d, MW-105s, MW-105d, MW-105L, MW-106d, MW-107i, MW-107d, MW-110d, MW-111d, MW-112i, MW-113d, MW-114i, MW-115i, and newly installed well set (MW-116s and MW-116d)
- Drive Points: DP-1, DP-2, DP-3, DP-4, DP-5, SW-1-DP, SW-2-DP, SW-3-DP, SW-6-DP, SW-8-DP, SW-10-DP, SW-11-DP, SW-14-DP, Vent-1R, Vent-2, Seep-1R, Seep-2, Seep-3, Seep-4, Seep-5, Seep-6

Groundwater levels from monitoring wells and drive points will be determined by measuring the depth to water from a surveyed reference point on the top of the well casing, indicated by a drawn mark. An electronic water level tape will be used to measure the depth to water. The water elevation at each monitoring point is determined by subtracting the depth to water from the elevation of the top of well casing reference point.

Surface Water and Seep Levels

Staff gauges, stilling wells, and wetland monitoring points are fixed points that are used to measure surface water elevations of streams and ponds or wetlands. Staff gauges typically consist of a graduated placard with increments that can be read from several yards away. The stilling wells, spring vent, and wetland monitoring points are like the drive points discussed above in that the depth to water is measured inside the monitoring point from a surveyed reference. Water levels in surface water bodies or wetlands are determined by first directly measuring the depth to water then calculating the water elevation. The staff gauge calculation is completed by taking a water level reading and subtracting it from the value at the top of the staff gauge ruler (surveyed elevation). This subtraction gives the distance from the top of the staff gauge ruler to the water. This distance is then subtracted from the surveyed elevation from the top of the staff gauge ruler. The following staff gauges, stilling wells, and wetland monitoring points are incorporated in the monitoring program:

- Staff Gauges: SG-2, SG-3, SG-5, SG-9, SG-10R, SG-16, SG-18, SG-19, SG-201, SG-202, SG-203R, SG-204, WT-G-SG, WT-H-SG
- Stilling Wells: SW-1, SW-2, SW-8, SW-9, SW-14, SW-3 WCO, SW-4-WCO, SW-5-WCO
- Wetland Points: SW-8DP/WT-A-1, DP-4/WT-E, WT-A-2, WT-G, WT-H, WT-CC-1, WT-CC-2, WT-R-1, WT-R-2, WT-R-4, and WT-R-5, and six additional locations proposed in the wetland monitoring plan (ECT, 2019).

Locations SG-17R and SW-13R are surveyed reference point markings on bridges over Chippewa and Twin Creeks, respectively. The surface water elevation is determined by measuring the distance from the mark on the bridge to the water surface. That distance is then subtracted from the elevation of the mark, giving the surface water elevation.

Transducer Data

The permit requires transducers to be installed in stilling wells associated with the streamflow monitoring at locations SF-1 and SF-8. Insitu Level Trolls will be installed at these two locations. The transducers will be set to record hourly from June 1 through October 31. These transducers are vented, meaning that the transducer readings are barometrically corrected. During the monthly site visits, should the manual and transducer measurements vary by greater than 0.02 feet, the transducer will be reset using the manual measurement. The transducers will be removed in December each year and reinstalled the following May.

Transducers will be used to monitor water levels in drive points (WT locations) as part of the Permit Conditions - Wetlands requirements. The transducers will be set to record depth to water measurements at a daily frequency. Data is downloaded from the transducers at each monitoring event using the Mesa-2 (field tablet) or equivalent computer. Data collected is stored in the project file. The QAPP (**Appendix A**) details the use of transducers in Section 3.4.4. Since the transducers are to record data during the growing season, they will be installed each April and removed in November. Transducer removal during the winter months will protect the transducers from possible damage since the water in these monitoring points typically freezes.

Two types of instruments (TD-Divers and Baro-Divers) are currently used to automate data collection at the WT locations. The TD-divers measure water pressure and temperature. The pressure sensor measures both air and water pressure. The Baro-Divers are used to measure air pressure, which is used to convert diver pressure readings to usable depth to water data.

Data is downloaded from the TD-Diver at each monitoring event using the Mesa-2 (field tablet) or equivalent computer. Additionally, a Baro-Diver measures atmospheric pressure daily and is used to compensate for variations within the atmospheric pressure as recorded from the TD-Divers.

Task 3 - June through October Monitoring

From June through October, streamflow will be measured hourly at locations SF-1 and SF-8. As discussed above, a telemetry system will be used to obtain hourly stage data from transducers installed in the SF-1 and SF-8 stilling wells (SW-1A and SW-8A).

If the streamflow data from SF-1 and SF-8 appears anomalous based on data review, NWNA will visit the site and attempt to assess the cause of the anomalous data. Typical causes for anomalous data are malfunctioning or damaged instruments or cables. Often, simply resetting the instrument can restore the accuracy of the instrument. If, however, the instrument has been damaged or testing indicates the instrument needs servicing, the instrument will be removed and replaced with a backup instrument. NWNA will keep a supply of backup instruments available for this purpose. NWNA may also at this time collect a manual flow measurement using the FlowTracker® instrument to further evaluate the accuracy of the readings from the instruments.

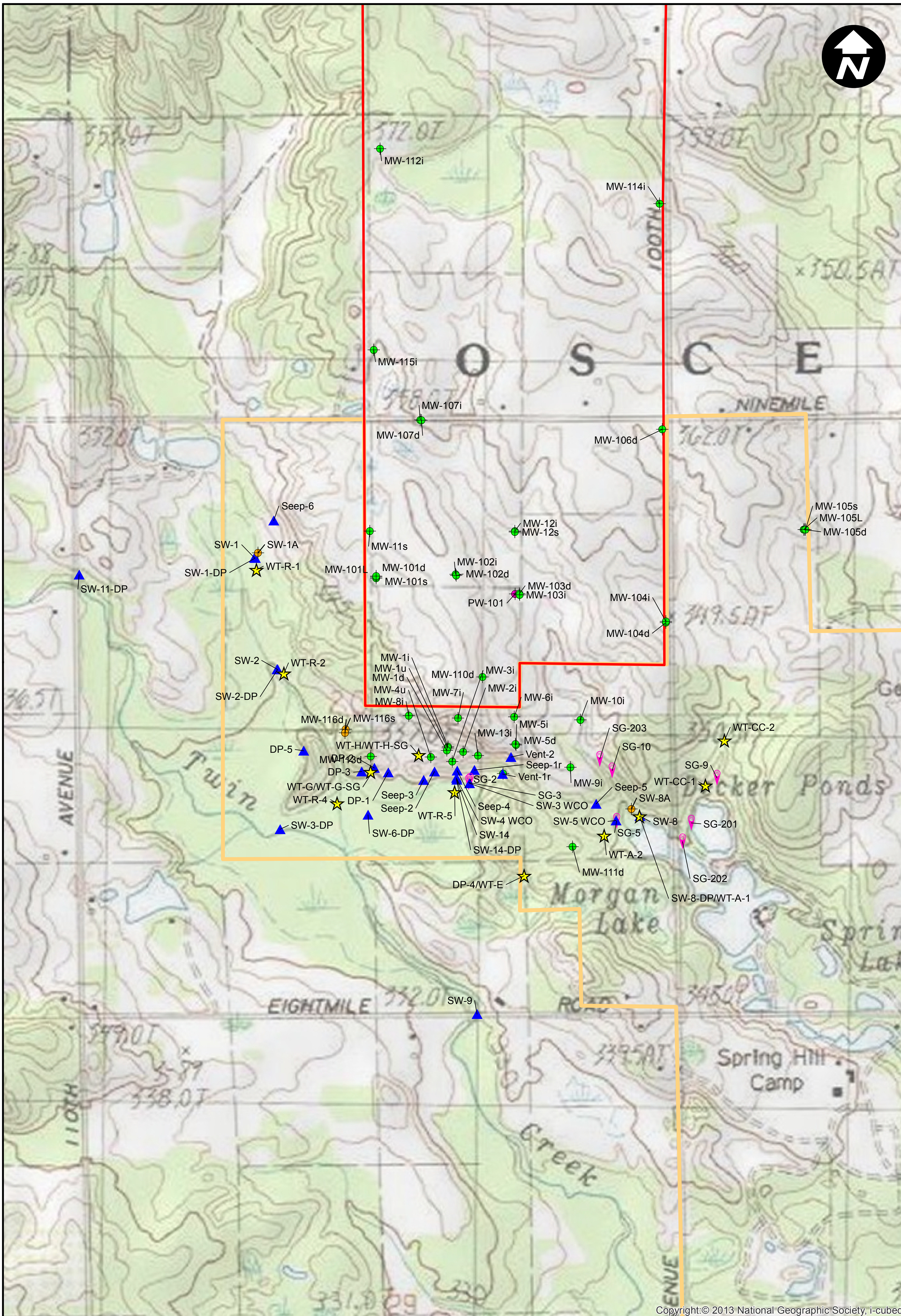
TABLES

Table 1

Permit Monitoring Network
NWNA White Pine Springs Site

Monitoring Well ID
MW-1u and MW-4u
MW-11s, MW-12s, MW-101s, and MW-105s
MW-1i, MW-2i, MW-3i, MW-5i, MW-6i, MW-7i, MW-8i, MW-9i, MW-10i, MW-12i, MW-13i, MW-102i, MW-103i, MW-104i, MW-107i, MW-108i, MW-112i. MW-114i, MW-115i, and MW-116i
MW-1d, MW-5d, MW-101d, MW-102d, MW-103d, MW-104d, MW-105d, MW-106d, MW-107d, MW-110d, MW-111d, MW-113d, and MW-116d
MW-101L and MW-105L
Drive Point ID
SW-1-dp, SW-2-dp, SW-3-dp, SW-6-dp, SW-8-dp, SW-10-dp, SW-11-dp, and SW-14-dp
DP-1, DP-2, DP-3, DP-4, DP-5,
Seep-1r, Seep-2, Seep-3, Seep-4, Seep-5, and Seep-6
Vents 1 and Vent 2
Wetland Point ID
SW-8DP/WT-A-1, DP-4/WT-E, WT-A-2, WT-G, WT-H, WT-CC-1, WT-CC-2, WT-R-1, WT-R-2, WT-R-4, WT-R-5, and six additional locations proposed in the wetland monitoring plan
Surface Water ID
SW-1, SW-2, SW-3, SW-8, SW-9, SW-13r, SW-14
SW-3-wco. SW-4-wco, SW-5-wco
SG-2, SG-3, SG-5, SG-9, SG-10, SG-16, SG-17r, SG-18, SG-19, SG-201, SG-202, SG-203, and SG-204
DP-11sg and DP-12sg
SW-1A and SW-8A (June through October)
Twin Creek Streamflow Monitoring Location
SF-1, SF-2, SF-9, SF-10, SF-11, and SF-13
Chippewa Creek Streamflow Monitoring Location
SF-8, SF-16, SF-17, SF-18, and SF-19

FIGURES



Legend

- New Locations
- Newly Installed Monitoring Well
- Drive Point
- Monitoring Well
- Production Well
- Staff Gage
- Nestle Property
- SHC Property

0 800 1,600

SCALE IN FEET

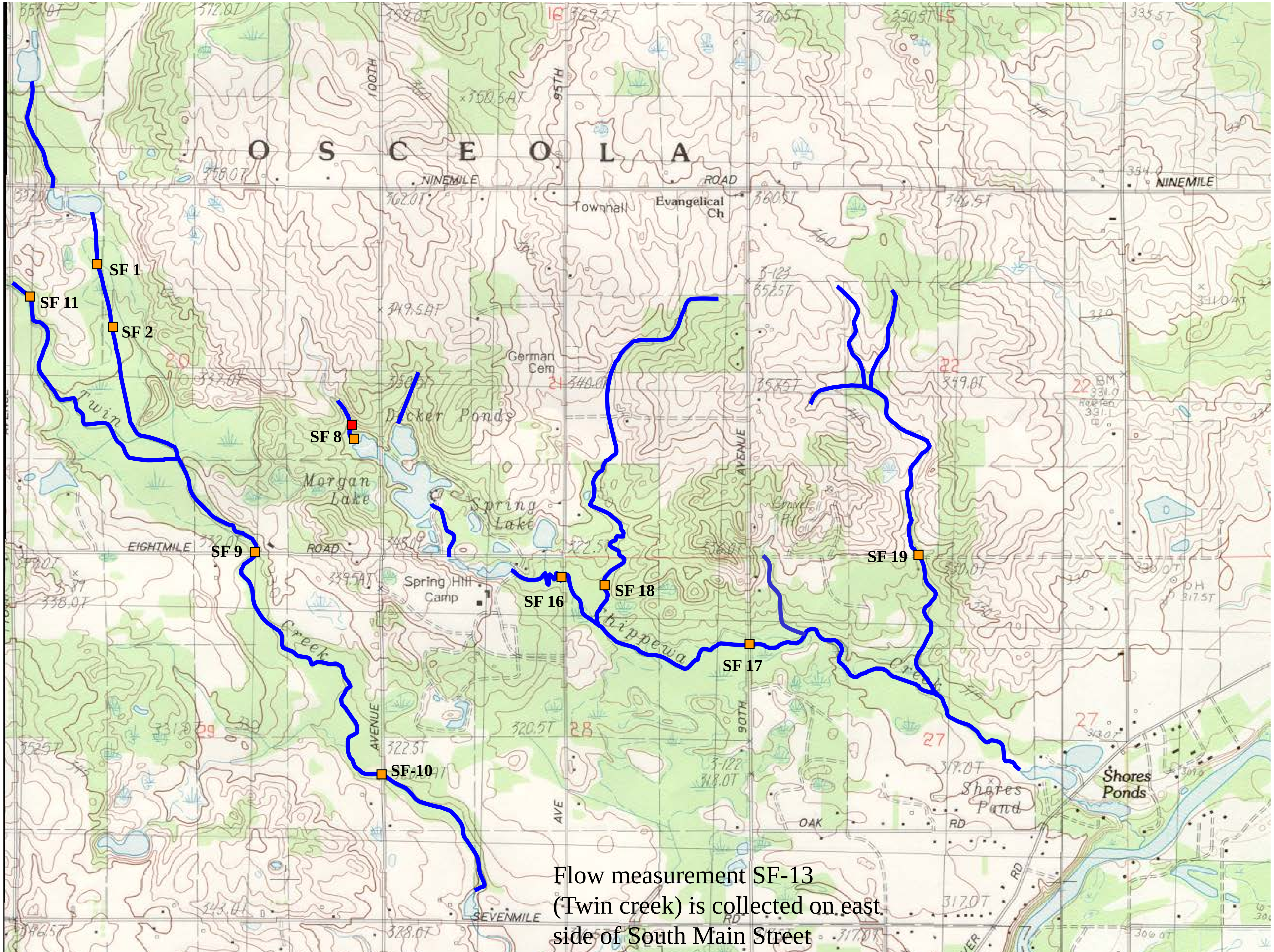
NESTLE WATERS NORTH AMERICA
WHITE PINE SPRING SITE

MONITORING NETWORK

ARCADIS Design & Consultancy for natural and built assets

FIGURE 1

Z:\GISProjects_ENV\NoviBrighton_MI\40650100\NESTLE\Mon_Net_fig1_2019.mxd PLOTTED: 4/9/2019 8:08:56 AM BY: akens



SOURCE: USGS, Evart, MI Quadrangle (1983)

N

- Stream Gaging Station
- Flume

APPROXIMATE SCALE IN FEET

0 660 1320 2640

Updated 2-6-03 J/projects/4065031/monitoring locations.ppt

ARCADIS Design & Consultancy for natural and built assets

NESTLE WATERS NORTH AMERICA
WHITE PINE SPRINGS SITE

PERMIT STREAM FLOW MONITORING LOCATIONS

FIGURE 1A

ATTACHMENT 1

2019 Monitoring Schedule

2019 Long Term Monitoring Schedule
White Pine Springs

	WPS
Jan-19	
Feb-19	
Mar-19	March 12 & 13
Apr-19	April 15 & 16
May-19	May 21 & 22
Jun-19	Jun 17-19
Jul-19	July 15 -17
Aug-19	Aug 12 & 13
Sep-19	Sept 9 - 11
Oct-19	Oct 7 & 8
Nov-19	Nov 11 & 12
Dec-19	Dec 10 &11

Notes

WPS- White Pine Springs

Monitoring during August and September

- only conducted if there is no rainfall 0.02 inches 48-hours before monitoring (two calendar days)

-monitoring event will be moved to meet precipitation parameters

APPENDIX C

Streamflow Measurement Procedure

TGI – NWNA STREAM FLOW MONITORING PROCEDURE

Rev: #0

Rev Date: 02/05/2019

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	February 5, 2019	All	Updated and re-written as TGI	Greg Foote

APPROVAL SIGNATURES

Prepared by:	[signature]	02/05/2019
	Amanda M. Robinson	Date:
Technical Expert Reviewed by:	[signature]	02/05/2019
	Mike Pozniak	Date:

1 INTRODUCTION

This document inclusively applies to all NWNA (Nestle Water North America) sites located in Michigan. Procedures and methods are outlined in this document and are to be used and observed by Arcadis staff when performing tasks under the scope of this document.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of these procedures. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the activities performed under this document.

The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for project work. In turn, project staff are required to consult with the CPM if or when there is a required deviation or omission from work performed as compared to what is described herein, that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

The objective of this Technical Guidance Instruction (TGI) is to describe procedures to collect stream flow measurements in accordance with United States Geological Survey (USGS) streamflow monitoring protocols (Turnipseed and Sauer, 2010), stream depth, and localized conditions within each monitoring location. Stream flow measurements may be collected using a Sontek/YSI FlowTracker ® (Flow Tracker) or Marsh McBirney Flo-Mate™ 2000 (Flo-Mate). This TGI describes the equipment, field procedures, materials and documentation procedures to measure and record stream flow data using the aforementioned equipment. This TGI was revised following procedures documented for NWNA sites in *Streamflow Monitoring Protocol for Michigan Streams Memo* from Advanced Ecological Management (AEM) dated January 25, 2015.

Stream flow measurements will be collected primarily using a Flow Tracker. The Flow Tracker is an Acoustic Doppler Velocimeter (ADV) and is the preferred instrument for use to by the Michigan Department of Environmental Quality (MDEQ) and USGS for conducting stream velocity measurements in most wadable streams as a means for estimating stream discharge. The instrument relies on acoustic doppler technology for data collection, a short pulse at a known frequency is transmitted and sound is reflected off particulate matter within the stream column and are reflected to the acoustic receivers collecting 2D flow, for a sample volume four inches from center of the transmitter.

There are some limitations with the Flow Tracker with specific stream characteristics that cause the Flow Tracker to be unable to consistently gather sufficient stream velocity data (i.e. shallow and narrow streams, low signal to noise ratios of less than 4 dB). In these conditions the Marsh McBirney Flo-Mate™ 2000 (Flo-Mate) may be used. The instrument relies on an electromagnetic sensor for data collection. The voltage is measured, and linear velocity value is generated.

Stream flow measurements for each site should be measured on the same day. If measurement of all streams for each site is not possible within one day, then stream flows should be measured on consecutive days.

3 PERSONNEL QUALIFICATIONS

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The HASP and other documents will identify other training requirements or access control requirements.

4 EQUIPMENT LIST

The following field equipment is required for stream flow measurements:

- HASP and appropriate field forms
- User Manual's. *The operator must have and be familiar with the operation, technical and/or instruction manual(s) for both flow meters.*
- Appropriate personal protective equipment (PPE) as specified in the HASP
- Site specific flow meters
  - Flow Tracker and protective case
  - Flo-Mate and protective case
- Tool box for repairs/replacement (flat head and Philips screwdrivers)
- Top-setting wading rod (wading rod)
- 16-AA batteries for the Flow Tracker (4-D batteries for the Flo-Mate)
- 100-foot measuring tape in 10ths of feet (or sufficient length for the maximum width of streams)
- Five-gallon bucket
- Waders and boots
- Summary table of previous stream flow measurement or field book
- Field notebook and/or smart device (phone or tablet)
- Indelible ink pen

Note: All equipment and materials are dedicated to the NWNA sites and cannot be used on sites with environmental contamination.

5 CAUTIONS

- Use caution when handling and transport flow meters and related equipment. The flow meter(s) must be placed in their protective case(s) to prevent damage during transport.
- Do not overtighten the flow meter sensor probe, as this could damage the sensor.
- The flow meter system(s) should not be opened without specific instructions from the manufacturer.

- Avoid placing sample volume (typically four inches from the center of the transmitting device) of the Flow Tracker from an obstruction or boundary.
- Remove batteries from Flow Tracker when not in use to conserve battery life.

6 HEALTH AND SAFETY CONSIDERATIONS

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Appropriate personal protective equipment (PPE) will be worn during these activities. Field personnel will thoroughly review client-specific health and safety requirements, as necessary.

7 PROCEDURE

Calibration/diagnostic inspection procedures and stream flow measurement procedures for each flow meter are described in the sections below. Stream cross sections are established for identified stream gauging locations prior to equipment use. Cross sections are recommended to be within a straight channel with uniform flow, without impacts of eddies and/or turbulence. At each stream gauging location, a graduated tagline, fixed marker, or measuring tape is strung across the stream ideally perpendicular to flow. A minimum or 20 measurements are recommended (or 22 including the leading and ending edge).

Flow Tracker:

Equipment Check

The following procedures should be performed before the start monitoring event to ensure the software and equipment are performing properly:

- Flow Tracker software should be downloaded and kept up to date on staff computer.
- Fill a five-gallon bucket with water, adding sediment if necessary.
- Connect Flow Tracker to computer, with software open.
- Perform a BeamCheck, a diagnostic to be run on the Flow Tracker. *A pulse of sound (ringing) is sent into the water. This checks the signal strength of the sampling volume and return signal and range of the receivers (boundary reflection and noise level).*
- Follow the instruction provided in **Section 6.5 of the Flow Tracker Technical Manual**.
- If anomalies are noted during the beam check contact Sontek and schedule maintenance for the equipment.

Field Diagnostics and Set-up

Field diagnostic inspections should be completed prior to beginning stream flow measurements at each location, see **Section 3.2 of the Flow Tracker Technical Manual**.

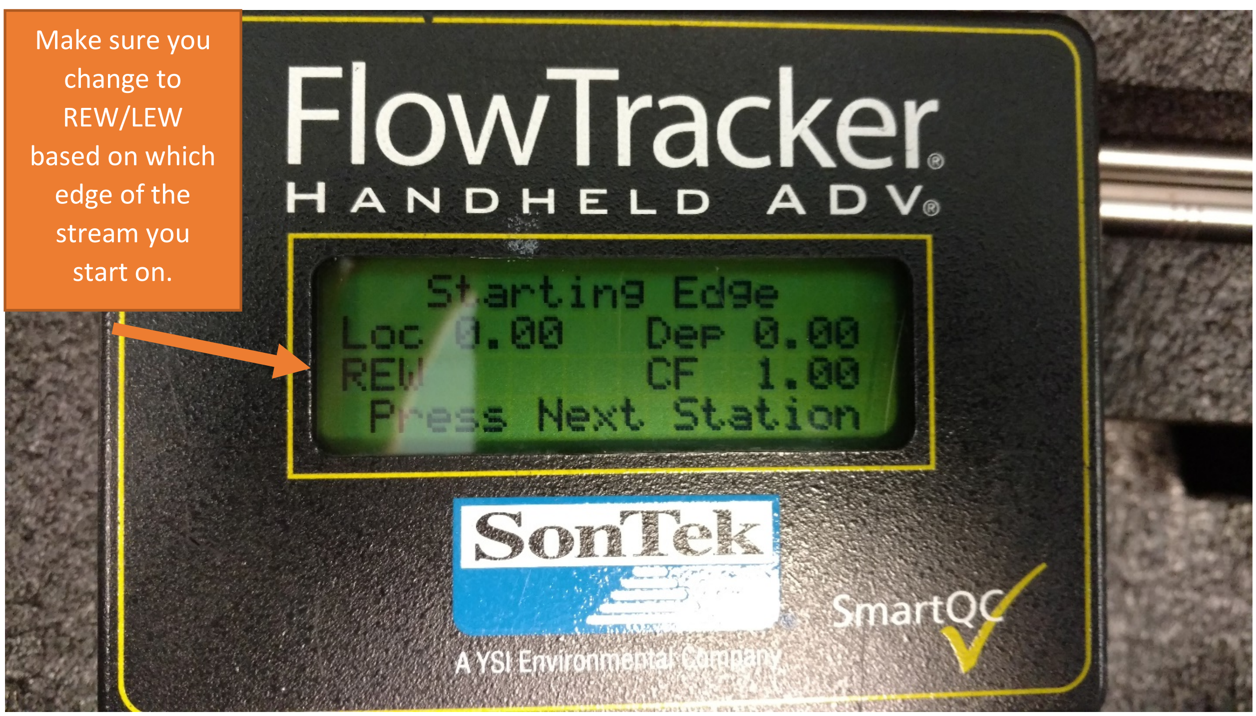
- Turn on Equipment.
- Check to make sure there is enough internal memory to store the expected data collection. *Note: when you format the recorder, it erases all files from the Flow Tracker. Make sure all data is* saved prior to reformatting.
- Check temperature data for reasonableness.
- Check the internal clock to verify correct date/time.

- Check battery life. *Note: If battery life is low, replace batteries. If the battery life is drained all the way during field measurements data will not be saved.*
- Ensure Flow Tracker is properly constructed. The meter is generally attached to a wading rod to stabilize the meter and is used as a gauge to measure water depth.
- Prior to data collection, a file name must be generated. Include stream flow identification and reference to date of collection (for example SF-1 Extension 203).
- Enter site location and Operator's name.
- An auto quality control (QC) test is prompted prior to beginning stream flow measurements. This is a meter-initialization process that is an automated version of the BeamCheck. 20 pings will be transmitted, and the test results are recorded with the locations data file. The following parameters are tested: noise level, SNR, peak shape, and peak location. If an anomaly is found, a warning will be presented to the operator, repeat the QC test as necessary. If subsequent tests result in warnings, use of the Flo-Mate for the measurement may be considered.

Stream Flow Measurement Procedure

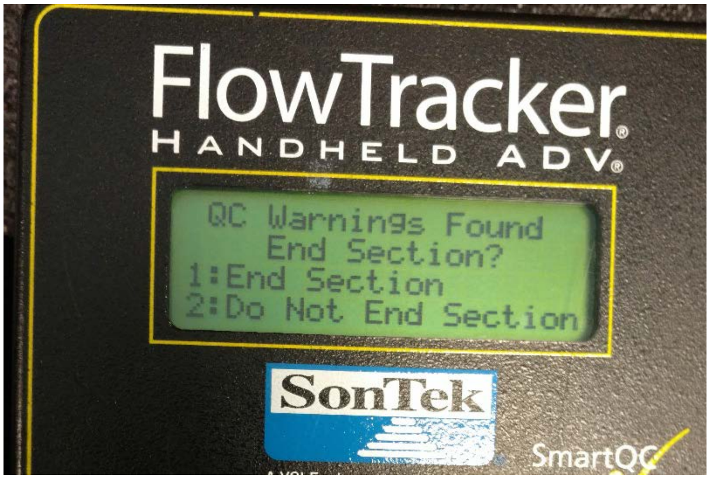
Use of the Flow Tracker with a wading rod is applicable whenever the depth is above 0.25 feet. Follow the procedures below when collecting stream flow measurements using a Flow Tracker:

- Measurements should be taken from the same side of the stream for each location. Enter edge location data (ex. REW).

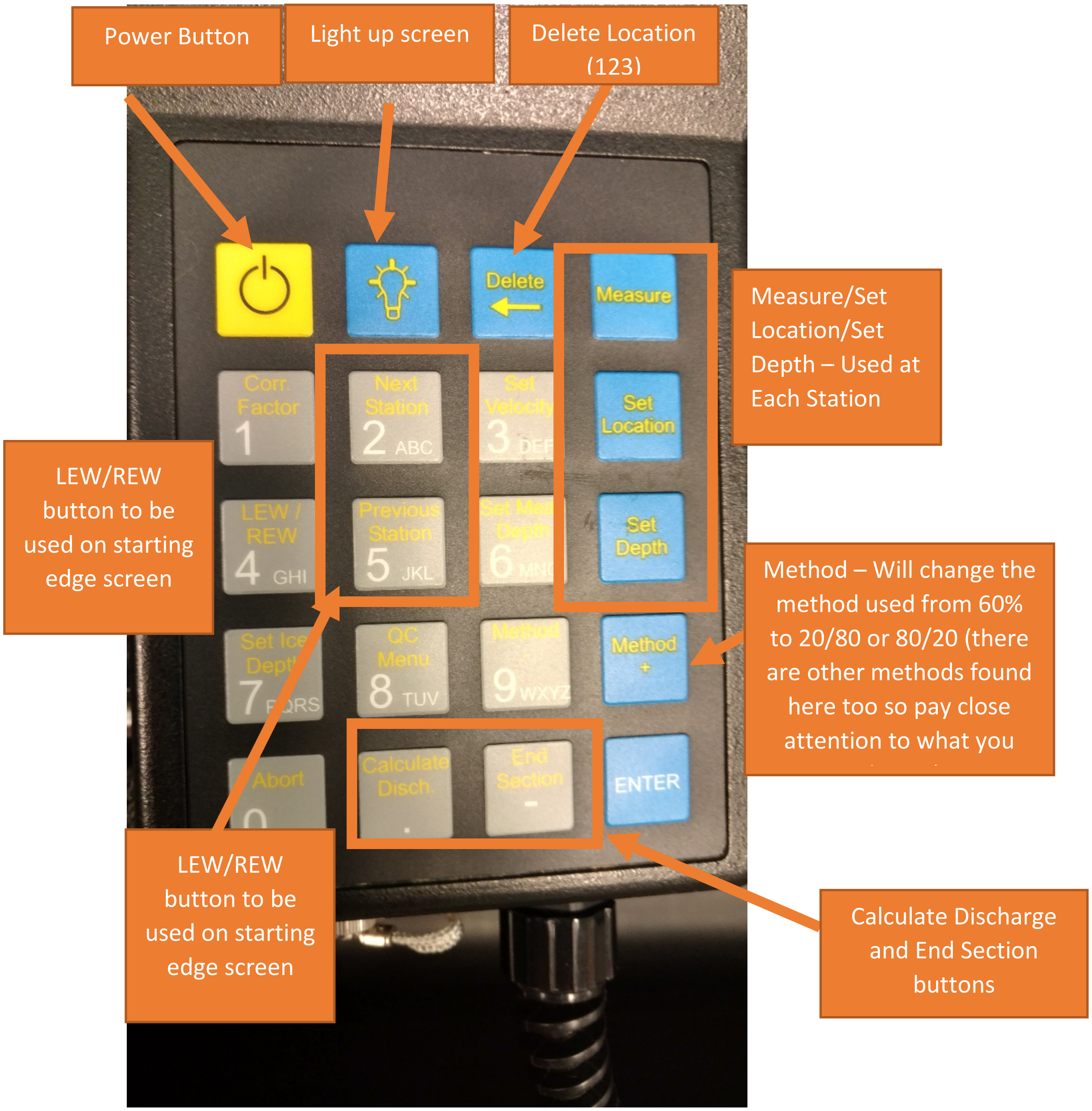


- At an established interval width marker (i.e. 0.25 or 0.5 feet), the operator records the location and the depth of water to the top of the sediment. *The established interval width should not be less than the width of the flow meter sensor.*

- The wading rod should be set to 60% (single point method) of the total water depth using the metric gauge on the wading rod for water depths less than 1.5 feet. *If greater than 1.5 feet two-point method must be followed where velocity measurements are collected at 20% and 80% of the depth, and an average of the measurements is calculated (Turnipseed and Sauer, 2010).*
    - Single-point method (0.6 depth) used at depths less than 1.5 feet.
    - Two-point method (0.2 and 0.8 depths) used at depths greater than 1.5 feet.
    - Three-point method (0.2, 0.6, and 0.8 depths) used when a non-standard profile is encountered when the two-point method is followed.
- A 40-second interval burst of velocity data is recorded at each interval marker, once per second during the burst. Mean velocity reading and quality control data are displayed at the end of each measurement and recorded. If values are outside the expected boundary limits a warning is made visible to the operator. The measurement may be repeated if necessary.
- The operator verbally states each water depth and mean velocity reading, a second field staff repeats the reading back to the operator for verification and manually records the data within an excel file saved on a smart device. *Measurements are taken with the sensor pointed directly into the flow and the wading rod in a vertical position. The operator must stand far enough behind the sensor so not to affect the measurement.*
- Repeat until all interval velocity measurements have been collected. After each velocity reading the Flow Tracker will indicate if any warnings were present (i.e. SNR, high/low velocity angle, etc.). See **Table 1-1 in Section 1.4 of the Flow Tracker Technical Manual** for a table of quality control parameters and a description of each. Repeat measurement if necessary.
- When all measurements of the stream have been collected “End Section” should be pressed to close the file.



- The Flow Tracker will inform you of QC warnings found, included if 10% of the discharge was exceeded. *It is recommended that each measurement remain below 10% of the total discharge, and 5% is preferred if possible.*
- To retrieve discharge measurements, the ending edge information is entered, and discharge data is visible. The field staff compare discharge measurements from the smart device and the Flow Tracker to ensure proper transcription of data.
- All flow readings are stored in the Flow tracker until they are deleted by the user. The user should record the discharge readings from the Flow Tracker within the field notes. An example of the Flow Tracker data file and the excel spreadsheet created for each location can be observed in **Attachment A**.



Flo-Mate:

<u>Field Set-up, Calibration and Stream Flow Measurement Procedure</u>

The Flo-Mate is used in the field to collect stream velocity readings, when stream characteristics are not conducive for use of a Flow Tracker. The following procedures should be followed when using a Flo-Mate as described below:

- Clean the sensor as noted in the Flo-Mate instruction manual (Marsh McBirney, Inc, 1990).
- Connect the flow meter to the wading rod.

- Fill five-gallon bucket with stream water.
- Place wading rod with the attached stream flow sensor in a vertical position within the bucket of water, keeping it at least three inches away from the sides and bottom of the bucket. *The depth of the sensor should be at 60% of the total depth of water within the bucket*.
- Turn on Flo-Mate. Wait 10-15 minutes after you have positioned the sensor before taking any zero readings.
- Begin zero adjust readings. *Velocity readings should not be more than 0.02 feet per second (fps). If greater than 0.02 fps conduct zero-adjust sequence by pressing the "recall" and "store" buttons simultaneously followed by pressing the "down arrow" to times. Repeat as needed. See the Flo-Mate instruction manual for further guidance.*
- The Flo-Mate is properly calibrated once flow within the bucket is less than 0.02 fps.
- Begin stream velocity measurements. Allow the instrument to average the velocities over a 40 second interval. *The sensor should be facing upstream.*
- The operator verbally states each water depth and mean velocity reading, a second field staff repeats the reading back to the operator for verification and manually records the data within an excel file saved on a smart device.
- All flow readings are recorded in an excel spreadsheet on a smart device, and the discharge is recorded in the field notebook once total discharge has been calculated. See example of excel spreadsheet in **Attachment A**.

8 WASTE MANAGEMENT

Waste generated at the site shall be disposed of properly by Arcadis personnel.

9 DATA RECORDING AND MANAGEMENT

Streamflow measurements as well as all relevant observations should be documented in the field notebook, field forms and/or smart device as appropriate. When using the Flow Tracker data is saved directly to the device, including errors and anomalies noted by the instrument. The Flow Tracker generates a file summarizing the instrument calibration/diagnostic inspection and data collected at each location. Additionally, all stream velocity and depth data should be manually recorded within an excel spreadsheet within a smart device (i.e tablet) to be used as a quality control measure for both flow meters. The following information must be documented:

- Streamflow or location identification;
- Equipment used;
- Operators;
- Date;
- Starting time of measurement;
- Ending time of measurement;
- Water elevation of nearest surface water level measurement (i.e. staff gauge) and corresponding time of collection;
- Measurement intervals;
- Depth to water at each interval;

- Flow velocity at each interval.

The data should be saved using a file name system that includes the site name and data of measurement (i.e. SF-1_2-3-2019).

Once all the data has been collected and recorded, all notes/forms/data must be uploaded to the appropriate project directory on the Arcadis server, and an email should be sent to the Task Manager and/or Technical lead for notification. A summary of the work completed that day and any relevant observation noted (such as stream inspection) during the daily activities should be included with the email. The appropriate team member will review the data for accuracy and provide feedback.

10 QUALITY ASSURANCE

- As described in the detailed procedure, the flow meters will be calibrated prior to measurements to ensure software and equipment are functioning properly. The results will be recorded.
- The Flow Tracker keeps an electronic record of the stream flow data and staff will manually record the field data using a smart device to ensure accurate data transcription.
- Field notes and documents will be reviewed by the project team once the field data has been uploaded to the project file.
- Flow meters are to be checked and recalibrated annually.

11 REFERENCES

Advanced Ecological Management. (2015). Streamflow Monitoring Protocol for Michigan Streams Memorandum (January 2015).

Marsh-McBirney Inc. (1990, December). Marsh-McBirney Inc. *Flow-Mate Model 2000 Portable Flowmeter Instruction Manual.*

SonTek/YSI Inc. (2007, July). *FlowTracker Handheld ADV Technical Manual, Firmware Version 3.7, Software Version 2.30.*

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Attachment A

Discharge Measurement Summary

Date Generated: Tue Dec 11 2018

File Information

File Name	SF17.124.WAD
Start Date and Time	2018/12/04 11:03:38

Site Details

Site Name	WPS
Operator(s)	KAITLYN

System Information

Sensor Type	FlowTracker
Serial #	P5794
CPU Firmware Version	3.9
Software Ver	2.30
Mounting Correction	0.0%

Units (English Units)

Distance	ft
Velocity	ft/s
Area	ft^2
Discharge	cfs

Discharge Uncertainty

Category	ISO	Stats
Accuracy	1.0%	1.0%
Depth	0.3%	1.5%
Velocity	0.6%	1.9%
Width	0.1%	0.1%
Method	1.7%	-
# Stations	2.2%	-
Overall	**3.0%**	**2.6%**

Summary

Averaging Int.	40	# Stations	23
Start Edge	REW	Total Width	11.000
Mean SNR	28.4 dB	Total Area	9.615
Mean Temp	36.91 °F	Mean Depth	0.874
Disch. Equation	Mid-Section	Mean Velocity	0.5059
		Total Discharge	**4.8637**

Measurement Results

St	Clock	Loc	Method	Depth	%Dep	MeasD	Vel	CorrFact	MeanV	Area	Flow	%Q
0	11:03	0.00	None	0.580	0.0	0.0	0.0000	1.00	0.2293	0.145	0.0333	0.7
1	11:03	0.50	0.6	0.620	0.6	0.248	0.2293	1.00	0.2293	0.310	0.0711	1.5
2	11:04	1.00	0.6	0.630	0.6	0.252	0.4364	1.00	0.4364	0.315	0.1374	2.8
3	11:05	1.50	0.6	0.630	0.6	0.252	0.5778	1.00	0.5778	0.315	0.1820	3.7
4	11:06	2.00	0.6	0.680	0.6	0.272	0.4728	1.00	0.4728	0.340	0.1608	3.3
5	11:07	2.50	0.6	0.710	0.6	0.284	0.4967	1.00	0.4967	0.355	0.1763	3.6
6	11:09	3.00	0.6	0.710	0.6	0.284	0.5023	1.00	0.5023	0.355	0.1783	3.7
7	11:10	3.50	0.6	0.870	0.6	0.348	0.3635	1.00	0.3635	0.435	0.1581	3.3
8	*11:11*	*4.00*	*0.6*	*1.000*	*0.6*	*0.400*	*0.2789*	*1.00*	*0.2789*	*0.500*	*0.1394*	*2.9*
9	11:12	4.50	0.6	1.050	0.6	0.420	0.3694	1.00	0.3694	0.525	0.1939	4.0
10	11:14	5.00	0.6	1.390	0.6	0.556	0.4823	1.00	0.4823	0.695	0.3352	6.9
11	11:15	5.50	0.6	1.290	0.6	0.516	0.5210	1.00	0.5210	0.645	0.3361	6.9
12	11:17	6.00	0.6	1.060	0.6	0.424	0.6089	1.00	0.6089	0.530	0.3227	6.6
13	11:18	6.50	0.6	1.050	0.6	0.420	0.5594	1.00	0.5594	0.525	0.2936	6.0
14	11:19	7.00	0.6	1.020	0.6	0.408	0.5164	1.00	0.5164	0.510	0.2634	5.4
15	11:20	7.50	0.6	0.920	0.6	0.368	0.5840	1.00	0.5840	0.460	0.2686	5.5
16	11:21	8.00	0.6	0.900	0.6	0.360	0.6365	1.00	0.6365	0.450	0.2864	5.9
17	11:22	8.50	0.6	0.830	0.6	0.332	0.7011	1.00	0.7011	0.415	0.2910	6.0
18	11:24	9.00	0.6	0.740	0.6	0.296	0.7051	1.00	0.7051	0.370	0.2609	5.4
19	11:25	9.50	0.6	0.760	0.6	0.304	0.6283	1.00	0.6283	0.380	0.2387	4.9
20	11:26	10.00	0.6	0.820	0.6	0.328	0.4862	1.00	0.4862	0.410	0.1993	4.1
21	11:27	10.50	0.6	0.840	0.6	0.336	0.5351	1.00	0.5351	0.420	0.2247	4.6
22	11:27	11.00	None	0.840	0.0	0.0	0.0000	1.00	0.5351	0.210	0.1124	2.3

Rows in italics indicate a QC warning. See the Quality Control page of this report for more information.

Discharge Measurement Summary

Date Generated: Tue Dec 11 2018

File Information	
File Name	SF17.124.WAD
Start Date and Time	2018/12/04 11:03:38

Site Details	
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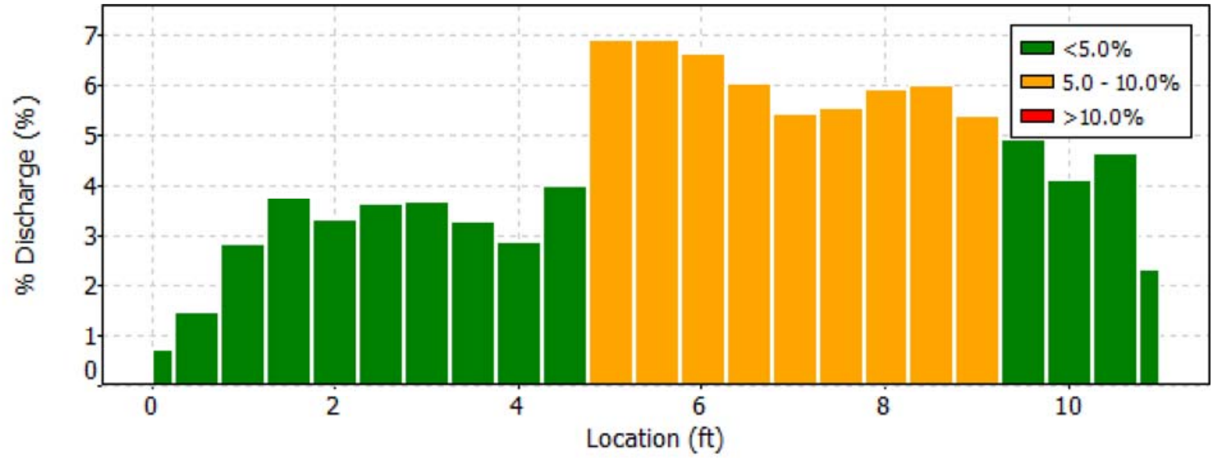

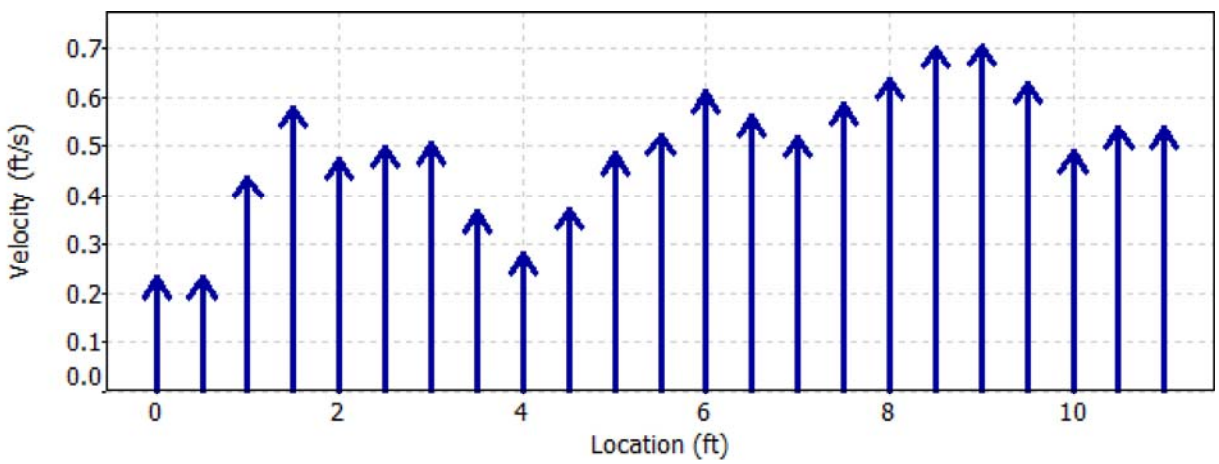

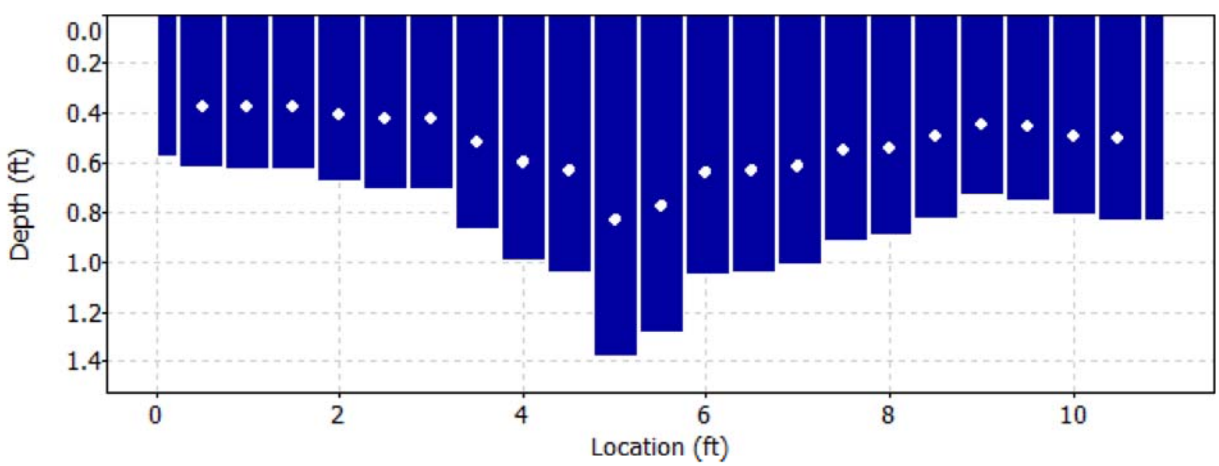

Discharge Measurement Summary

Date Generated: Tue Dec 11 2018

File Information

File Name	SF17.124.WAD
Start Date and Time	2018/12/04 11:03:38

Site Details

Site Name	WPS
Operator(s)	KAITLYN

Quality Control

St	Loc	%Dep	Message
8	4.00	0.6	High SNR variation during measurement: 5.2,3.9

Discharge Measurement Summary

Date Generated: Tue Dec 11 2018

File Information	
File Name	SF17.124.WAD
Start Date and Time	2018/12/04 11:03:38

Site Details	
Site Name	WPS
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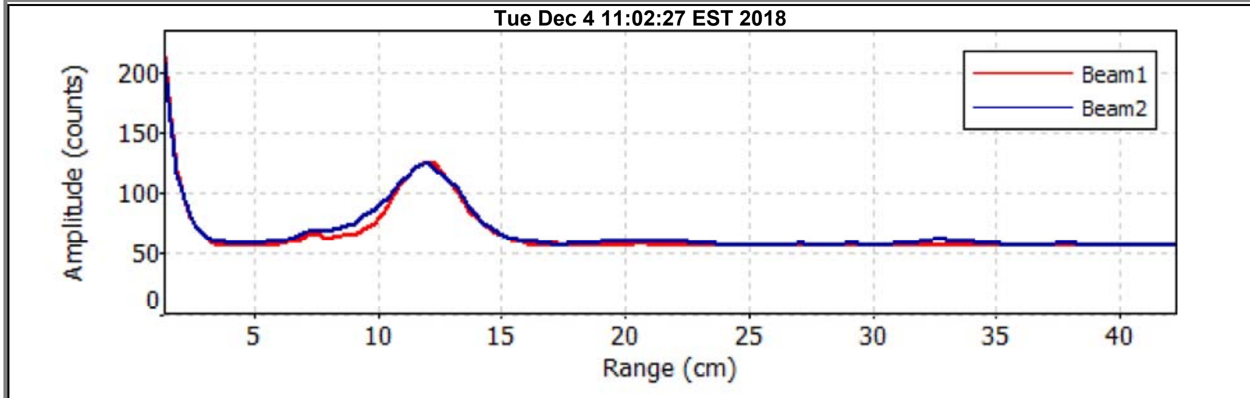
Automatic Quality Control Test (BeamCheck)



- Noise level check - Pass
- SNR check - Pass
- Peak location check - Pass
- Peak shape check - Pass

STREAMFLOW NAME SF-17

Staff: K. Voet, A. Robinson
Equipment: FlowTracker
Date: 12/4/2018
Start Time: 1017
End Time: 1044

	DTW (ft)	**time**
SG-17R	3.91	1045

Tag Location Color	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R	B	R
Tag Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Distance Between Tags (ft)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Cumulative Distance (ft)	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50
Depth (ft)	0.62	0.63	0.63	0.68	0.71	0.71	0.87	1	1.05	1.39	1.29	1.06	1.05	1.02	0.92	0.9	0.83	0.74	0.76	0.82	0.84
Velocity (ft/sec)	0.23	0.44	0.58	0.47	0.5	0.5	0.36	0.28	0.37	0.48	0.52	0.61	0.56	0.52	0.58	0.64	0.7	0.71	0.63	0.49	0.54
Incremental Discharge (ft3/sec)	0.0713	0.1386	0.183	0.1598	0.1775	0.1775	0.1566	0.14	0.19425	0.3336	0.3354	0.3233	0.294	0.2652	0.2668	0.288	0.2905	0.2627	0.2394	0.2009	0.2268
Depth to Measurement	0.372	0.378	0.378	0.408	0.426	0.426	0.522	0.6	0.63	0.834	0.774	0.636	0.63	0.612	0.552	0.54	0.498	0.444	0.456	0.492	0.504
					rock														rocks	rocks	rocks

Wetted Horizontal Distance **10.50** **ft**
Total Discharge **4.72** **ft3/sec**
2120.51 **GPM**

Percent Discharge through Each Interval

Tag Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
% Discharge through each interva	1.51	2.93	3.87	3.38	3.76	3.76	3.31	2.96	4.11	7.06	7.10	6.84	6.22	5.61	5.65	6.10	6.15	5.56	5.07	4.25	4.80

APPENDIX D

Cutthroat Flume User's Manual

CUTTHROAT FLUME

User's Manual

TABLE OF CONTENTS

INTRODUCTION TO THE CUTTHROAT FLUME

In the 1960's researchers at the Utah Water Research Laboratory at Utah State University began investigations into what would become the Cutthroat flume. The goal of the researchers was to develop a flume that overcame the limitations of the Parshall flume in flat gradient applications.

Although originally developed to measure irrigation flow, Cutthroat flumes are now used to for:

- *Cooling water discharge*
- *Dam seepage*
- *Industrial effluent*
- *Irrigation / water rights*
- *Mine discharge / dewatering*
- *Sanitary sewage (piped and treatment plant)*
- *Spring discharge*
- *Storm water*

In addition to these flow measurement applications, Cutthroat flume are frequently used in wastewater treatment plants for proportional flow splitting.

DEVELOPMENT

Prior to the development of the Cutthroat flume, flow on flat gradients presented a problem. The drop though the Parshall flume mean that the flume had to either be elevated above the floor of the channel – creating upstream ponding and overtopping issues – or using that the flume had to be used in a submerged manner (creating measurement and accuracy issues).

Funded by the U.S. Department of the Interior, Office of Water Resources Research, Drs. Skogerboe, Hyatt, Anderson, and Eggleston at the Utah Water Research Laboratory extensively researched issues related to the problem:

- *Flow conditions in flat-bodied Trapezoidal flumes (Robinson et al 1960), (Hyatt 1965)*
- *Inlet convergence ratios (Ackers and Harrison 1963)*
- *Submerged flow in open channel flow measurement structures (Skogerboe, Hyatt, Eggleston 1967)*
- *Flume discharge in flat-bodied Trapezoidal flumes (Hyatt 1965)*

Ultimately this research lead to the development of two different styles of Cutthroat flumes: Rectangular (with flat, vertical sidewalls like a Parshall flume) and Trapezoidal (with outward sloping sidewalls like a Trapezoidal flume). Of the two, the Rectangular Cutthroat flume is most commonly used.

Rectangular Cutthroat flumes are available in four different lengths (18, 36, 54, and 108-inches L) and four throat widths for each length. Trapezoidal Cutthroat flumes come in three different throat widths.

Rectangular Cutthroat flumes have a distinct advantage over similar flumes in that, for a given length, intermediate throat widths can be developed without the need to laboratory or field rate the new flume size.

Trapezoidal Cutthroat flumes have one given length and three different throat widths (V, 6-inch, and 12-inch).

For the purposes of this User's Manual, the discussion below will be for Rectangular Cutthroat flumes unless otherwise indicated.

FUNCTION

Sub-critical flumes like the Cutthroat flume operate by accelerating slow, sub-critical flow (Fr<1) to a supercritical state (Fr>1) by restricting the flow as it passes through the flume. The Cutthroat flume accomplishes this restriction by contracting the side walls of the – while keeping a constant floor elevation.

DESIGN

When viewed from above, the Cutthroat flume has an hourglass shape.

As flow enters the flume it is accelerated in the short, uniformly converging (inlet) section. Upon reaching the throat – the narrowest portion of the flume – the flow immediately expands into the diverging (outlet) section. Unlike many other flumes, the Cutthroat flume lacks an extended throat – hence the name "Cutthroat".

The converging (inlet) section of a Cutthroat flume is 1/3 the length of the flume, with the flat sidewalls contracting at a uniform 3:1 ratio.

The diverging (outlet) section of a Cutthroat flume is 2/3 the length of the flume, with the flat sidewalls expanding at a uniform 6:1 ratio.

The floor of a Cutthroat flume is flat from inlet to outlet, making the flume well suited for low gradient installations.

This layout is the same for both Rectangular and Trapezoidal Cutthroat flumes.

STANDARDS

Like the Trapezoidal flume, the dimensions for the Cutthroat flume are not subject to a national standard, but are instead presented in various academic journals.

- *Skogerboe, G., Bennett, R., Walker, W., Generalized Discharge Relations for Cutthroat Flumes, Journal of the Irrigation and Drainage Division, Vol. 98, No. IR4, December 1972*
- *Bennett, R., Cutthroat Flume Discharge Relations, Water Management Technical Paper No. 16, Colorado State University, AER71-72RSB6, March 1972*

ACCURACY

The Cutthroat flume was developed to provide accurate flow measurement with a precision of +/-3% under free-flow conditions

This accuracy is to be expected when the ratio of flow depth (at the point of measurement) to flume length.

For greatest accuracy, the ratio of flow depth to flume length should be 0.1 and 0.4. Above 0.4 and higher approach velocities and rapid changes in the water surface introduce inaccuracies.

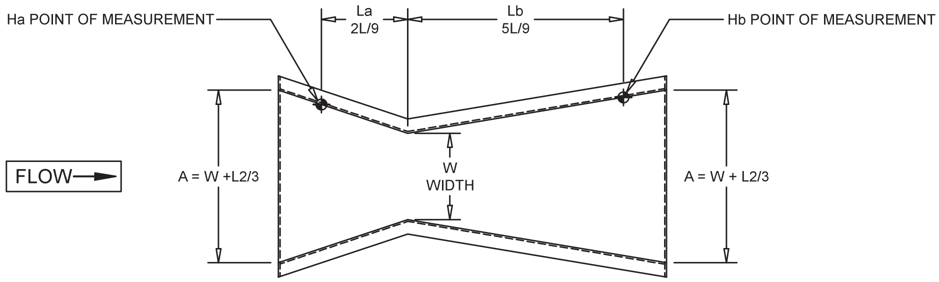
DIMENSIONS

The master dimensions for Rectangular Cutthroat flumes are found in Figure 1.

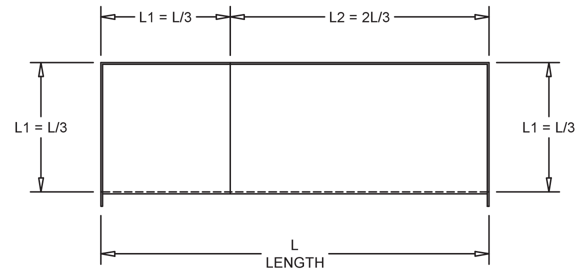
DIMENSIONAL TOLERANCES

In general, the dimensions of a Cutthroat flume must be within +/-2% of nominal.

Wider than that and the equation for the actual dimensions should be developed (assuming the deviations are constant and the throat width is between two standard sizes).



PLAN VIEW



ELEVATION VIEW

L (LENGTH)	W (WIDTH)	A	La	Lb	L1	L2
18" [45.72 CM]	1" [2.54 CM]	5" [12.7 CM]	4" [10.16 CM]	10" [25.4 CM]	6" [15.24 CM]	1' [30.48 CM]
	2" [5.08 CM]	6" [15.24 CM]	4" [10.16 CM]	10" [25.4 CM]	6" [15.24 CM]	1' [30.48 CM]
	4" [10.16 CM]	8" [20.32 CM]	4" [10.16 CM]	10" [25.4 CM]	6" [15.24 CM]	1' [30.48 CM]
	8" [20.32 CM]	1'" [30.48 CM]	4" [10.16 CM]	10" [25.4 CM]	6" [15.24 CM]	1' [30.48 CM]
36" [91.44 CM]	2" [5.08 CM]	10" [25.4 CM]	8" [20.32 CM]	1'-8" [50.8 CM]	1' [30.48 CM]	2' [60.96 CM]
	4" [10.16 CM]	1' [30.48 CM]	8" [20.32 CM]	1'-8" [50.8 CM]	1' [30.48 CM]	2' [60.96 CM]
	8" [20.32 CM]	1'-4" [40.64 CM]	8" [20.32 CM]	1'-8" [50.8 CM]	1' [30.48 CM]	2' [60.96 CM]
	1'-4" [40.64 CM]	2' [60.96 CM]	8" [20.32 CM]	1'-8" [50.8 CM]	1' [30.48 CM]	2' [60.96 CM]
54" [137.2 CM]	3" [7.62 CM]	1'-3" [38.1 CM]	1' [30.48 CM]	2'-6" [76.2 CM]	1'-6" [45.72 CM]	3' [91.44 CM]
	6" [15.24 CM]	1'-6" [45.72 CM]	1' [30.48 CM]	2'-6" [76.2 CM]	1'-6" [45.72 CM]	3' [91.44 CM]
	1' [30.48 CM]	2' [60.96 CM]	1' [30.48 CM]	2'-6" [76.2 CM]	1'-6" [45.72 CM]	3' [91.44 CM]
	2' [60.96 CM]	3' [91.44 CM]	1' [30.48 CM]	2'-6" [76.2 CM]	1'-6" [45.72 CM]	3' [91.44 CM]
108" [274.3 CM]	1' [30.48 CM]	3' [91.44 CM]	2' [60.96 CM]	5' [152.4 CM]	3' [91.44 CM]	6' [182.9 CM]
	2' [60.96 CM]	4' [121.9 CM]	2' [60.96 CM]	5' [152.4 CM]	3' [91.44 CM]	6' [182.9 CM]
	4' [121.9 CM]	6' [182.9 CM]	2' [60.96 CM]	5' [152.4 CM]	3' [91.44 CM]	6' [182.9 CM]
	6' [182.9 CM]	8' [243.8 CM]	2' [60.96 CM]	5' [152.4 CM]	3' [91.44 CM]	6' [182.9 CM]

Figure 1 – Rectangular Cutthroat Flume Master Dimensions

POINTS OF MEASUREMENT

The primary, free-flow, point of measurement, Ha, is located in the converging section of the flume a distance of 2L/9 upstream of the throat (L = flume length).

The secondary point of measurement, Hb, used to determine the submergence of a Cutthroat flume is located in near the outlet of the flume, 5L/9 downstream of the throat.

As the floor of the Cutthroat flume is flat, there is no need to adjust the Hb elevation when calculating the submergence ratio.

FLOW EQUATIONS

For free-flow conditions, the level-to-flow equation for the Cutthroat flume can be expressed as:

$$Q = KW^{1.025} H_a^{\mathrm{n}} = CH_a^{\mathrm{n}}$$

Q = free flow rate (cfs / m3/s)
K = flume discharge constant (varies by flume length / units)
C = flume discharge constant (varies by flume length / throat width / units)
W = throat width
H_a = depth at the point of measurement (feet / meters)
n = discharge exponent (depends upon throat width)

Equation 1 – Cutthroat Flume Free-Flow Equation

A unique advantage of the Cutthroat flume over other short-throated flumes is the ability to develop flow equations for intermediate throat widths. So long as the flume is of a standard length and converges / diverges as the stand ratios, the rating can be developed without the need for laboratory investigation.

Size	C (cfs)	C (m3/s)	N
18-inch x 1-inch	0.494	1479.9	2.15
18-inch x 2-inch	0.947	344.8	2.15
18-inch x 4-inch	1.975	719.2	2.15
18-inch x 8-inch	4.030	1,467	2.15
36-inch x 2-inch	0.719	181.2	1.84
36-inch x 4-inch	1.459	367.6	1.84
36-inch x 8-inch	2.970	748.3	1.84
36-inch x 16-inch	6.040	1,522	1.84
54-inch x 3-inch	0.96	209.7	1.72
54-inch x 6-inch	1.96	428.2	1.72
54-inch x 12-inch	3.980	869.5	1.72
54-inch x 24-inch	8.01	1,750	1.72
108-inch x 12-inch	3.50	632.2	1.56
108-inch x 24-inch	7.11	1,284	1.56
108-inch x 48-inch	14.49	2,618	1.56
108-inch x 72-inch	22.0	3,974	1.56

Table 1 – Rectangular Cutthroat Flume Free-Flow Discharge Values

SUBMERGED FLOW

As a Cutthroat flume becomes submerged – where downstream conditions reduce the flow out of the flume – corrections must be made to the flow equation.

In order to determine when these corrections should be made (and the degree to which the flume is submerged), the submergence ratio must be calculated.

The submergence ratio is the ratio of the downstream depth at the secondary point of measurement, Hb, to the depth at the primary point of measurement, Ha.

$$S = \frac{H_b}{H_a}$$

Equation 2 – Submergence Ratio Equation

SUBMERGENCE TRANSITION

The transition from free, unrestricted flow to submerged to one of backwater / slowed velocity discharge is known as the submergence transition (St). For Cutthroat flumes, as the flume gets large, so does the submergence transition.

18-inches L	60%
36-inches L	65%
54-inches L	70%
108-inches L	80%

Table 2 – Submergence Transitions (St) Values for Rectangular Cutthroat Flumes

Above the submergence transitions for a given flume's size, the flow must be corrected for the effects of submergence.

WHERE TO INSTALL A CUTTHROAT FLUME

When selecting a site in which to install a Cutthroat flume, there are several points to consider:

UPSTREAM OF THE FLUME

- *Flow entering a Cutthroat flume MUST be sub-critical.*
- *The Froude number (Fr) for flow entering a flume should not exceed 0.5 and should never exceed 0.99.*
    - *Surface turbulence may be encountered for Froude numbers above 0.5.*
    - *For a flume to accurately measure flow, that flow must be sub-critical (Fr<0.99).*
    - *If the approaching flow is critical (Fr = 1.0) or supercritical (Fr > 1.0), then a hydraulic jump must be formed at least 30 times the maximum anticipated head upstream of the entrance to the flume.*
- *The flow entering the flume should be smooth, tranquil, and well distributed across the channel.*
    - *ASTM D1941 indicates that 10 to 20 times the throat width will usually meet the necessary inlet conditions.*
- *If the flow is super-critical approaching the flume a hydraulic jump must be formed well upstream of the flume or upstream energy absorbers and tranquilizing racks must be used).*
- *The approaching channel should be straight so that the velocity profile is uniform. Surging, turbulent, or unbalanced flows must be conditioned before the flow enters the flume.*
- *Any bends, dips, elbows, or flow junctions upstream of the flume must be sufficiently far upstream so that the flow has is well distributed and non-turbulent.*
- *While corrections can be made for improper installations or flume settlement, they should be avoided where at all possible.*
- *Cutthroat flumes have been successfully used in applications where the flow rises up a uniform vertical column and then enters the flume.*
- *Where the channel is wider than the inlet of the flume, wing walls should be formed to smoothly direct the flow into the flume. The inlet wing walls should be of a constant radius and should end tangent to the inlet walls of the flume.*

- *When connecting to inlet piping, observations have shown that the pipe should be straight and without bends for at least 15 pipe diameters.*
- *The upstream channel should be clear of vegetative growth.*
- *Open channel (non-full pipe) flow must be present under all flow conditions.*

FLUME LOCATION

- *Cutthroat flumes must set so that the floor of the flume is level from front-to-back and from side-to-side.*
- *The shorter converging section of the flume is set upstream.*
- *When Cutthroat flumes are installed in earthen channels and furrows, care should be taken to ensure that a stable bottom elevation is present and that the elevation does not change during dry / wet seasons or low-flow periods.*
- *The flume must be centered in the flow stream.*
- *Where a Parshall flume must be set above the floor of a channel, a 1:4 (rise:run) slope should be formed into the flume. Slopes greater than this should be avoided as they can cause turbulence as the flow separates at the junction of the ramp and the inlet of the flume.*
- *All of the flow must go through the flume – there should be no bypass.*

DOWNSTREAM OF THE FLUME

- *For a Cutthroat flume to operate under free-flow conditions, the downstream channel must be of a sufficient size / configuration so that flow does not back up into the flume – slowing discharge out of the flume.*
- *When flow out of the Cutthroat flume is returning to a channel or pipe, the EPA recommends that the channel be straight and unobstructed for 5-20 throat widths – although flow spilling freely off the end of the flume can eliminate this requirement.*
- *To transition the flow out of a Cutthroat flume, wing walls should be used. These walls can be flat or perpendicular to the flume (to save space or money) or they can extend from the flume's discharge at some angle or radius sufficient to transition the flow as desired. Transitions to earthen or natural channels should be as gradual as practical to minimize downstream scour.*
- *The downstream channel should be armored (riprap) or otherwise protected so that scour does not occur.*
- *The downstream channel must be clear of vegetative growth or the collection of debris so that flow does not back up in to the flume.*

HOW TO INSTALL A CUTTHROAT FLUME

Once a site has been selected, the flume must then be installed correctly:

- *The flume should be set so that it is centered in the flow stream.*
- *The floor of the flume should be set high enough so that the flume does not operate under submerged flow conditions.*
- *The outlet of the flume should be set at or above (ideally) the invert of the outlet channel / pipe to help transition solids out of the flume.*
- *The shorter section of the flume must be set upstream.*
- *The floor must be level from front-to-back and from side-to-side (using a level on the floor - not the top - of the flume)*
- *The flume must be braced internally (plywood and lumber are typically used) during installation to ensure that distortion does not occur.*
- *The flume must not float out of its intended final position during installation.*

DIMENSIONAL BRACING

Most Cutthroat flumes ship with dimensional bracing (angle or tube) at the top of the flume. The bracing should be left on the flume until the installation has been completed.

If the flume is set in concrete, the bracing may be removed once the installation has been completed.

For installations where the flume is free-standing or otherwise not set in concrete, the bracing should be left in place.

If the bracing is removed, verify the dimensional accuracy of the flume after the removal.

CONNECTION JOINTS

Cutthroat flumes supplied with bulkheads, or transition sections must remain sealed between the joints.

While these joints may be sealed initially at the factory, a final visual inspection of all joints should be done before installation.

Where required, apply one or two continuous beads of silicone on all seating surfaces before proceeding with the installation.

HOW TO MAINTAIN A CUTTHROAT FLUME

For a Cutthroat flume to accurately measure flow, it must be periodically inspected and maintained. This inspection should be done six (6) months after installation and each following year.

The inspection should include the channel in which the flume is installed, the flow entering / exiting the flume, and the flume itself.

CHANNEL INSPECTION

- The upstream channel banks should be clear of vegetation or debris that could affect the flow profile entering the flume (upstream) or restrict flow out of the flume (downstream).
- Inspect the upstream channel to make sure that flow is not bypassing the flume.
- Inspect the downstream channel to make sure that scouring is not occurring.
- Any hydraulic jump should be at least 30 times the maximum head (Hmax) upstream of the flume.

FLOW INSPECTION

- *Flow entering the flume should be tranquil and well distributed.*
- *Turbulence, poor velocity profile, or surging should not be present.*
- *The Froude (Fr) number should, ideally, be 0.5.*
- *As the Froude number increases so does surface turbulence.*
- *Flumes accelerate sub-critical flow (Fr < 1) to a supercritical state (Fr 1>) .*
- *Flumes experiencing flows greater than unit (Fr = 1) will not accurately measure flow.*

FLUME INSPECTION

- *Flumes must be level from front-to-back and from side-to-side.*
- *Earthen installations are particularly susceptible to settling due to wet / dry and freeze / thaw cycles.*
- *Flow surfaces are to be kept clean of surface buildup or algal growth. Scrubbing or a mild detergent can be used.*
- *Galvanized flumes should be checked for corrosion.*
- *Any corrosion should be removed and then cold galvanization applied to the area.*

APPENDIX E

Format of Annual Report for Streamflow and Groundwater

TABLE OF CONTENTS

Tables

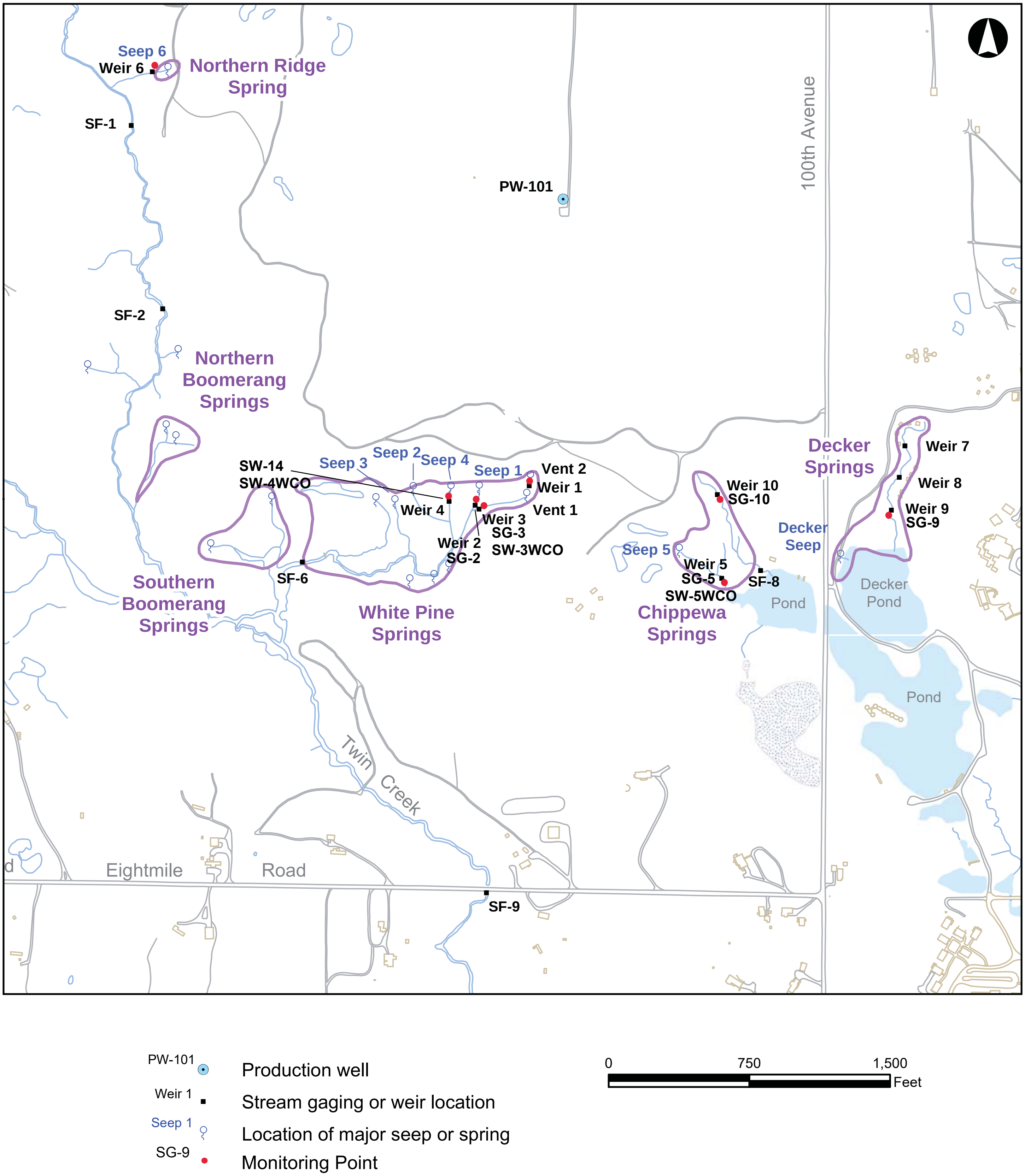
Figures

Appendices

APPENDIX F

Former Weirs and Nearby Monitoring Points

Appendix F Former Weirs and Nearby Monitoring Points



Adapted from S.S. Papadopulos & Associates, Inc. Figure

APPENDIX G

Depth to Water Measurement Procedure

TGI – NWNA MANUAL WATER LEVEL MEASUREMENT AND DECONTAMINATION PROCEDURES

Rev: Rev #0

Rev Date: 02/05/2019

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	February 5, 2019	All	Updated and re-written as TGI	Mike Pozniak

APPROVAL SIGNATURES

Prepared by:		02/05/2019
	Amanda M. Robinson	Date:
Reviewed by:		02/05/2019
	Mike Pozniak	Date:

1 INTRODUCTION

This document inclusively applies to all NWNA (Nestle Water North America) sites located in Michigan. Procedures and methods are outlined in this document and are to be used and observed by Arcadis staff when performing tasks under the scope of this document.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of these procedures. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the activities performed under this document.

The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for project work. In turn, project staff are required to consult with the CPM if or when there is a required deviation or omission from work performed as compared to what is described herein, that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

The objective of this Technical Guidance Instruction (TGI) is to describe procedures to measure and record water levels (groundwater and surface water) using manual water level meters. Water levels may be measured using an electronic water level probe from established reference points (e.g. top of casing). Reference points must be surveyed to evaluate water elevations relative to mean sea level (msl). This TGI describes the equipment, field procedures, materials and documentation procedures to measure and record water levels using the aforementioned equipment.

For measuring depth to water (DTW) in monitoring wells, stilling wells, piezometers, and drive points, an electronic water level meter is used. The meter’s tape is 100 feet long (length may vary) with a weighted stainless-steel probe attached to the end. The tape is graduated in 100ths of a foot with metric divisions on the reverse side. The probe relies on fluid conductivity to determine the presence of water. When the end of the probe touches water in a well/piezometer/drive point, the meter will emit an audible signal and a visual light. To produce reliable data, the electronic water level probe should be raised and lowered several times at the approximate depth where the instrument produces a tone indicating a water interface to verify consistent, repeatable results. Additionally, controls on the water level meter include a sensitivity adjustment to eliminate false readings. The meter uses one 9-volt battery for operation.

Surface water elevations can be determined from stilling wells or fixed points (bridges, walls, etc.) and measuring from an established point of reference using a water level meter. In some cases, surface water elevations will be determined from a staff gauge (a graduated scale affixed to a point of reference (pole, fence post, bridge, culvert, two-inch PVC or steel, etc.) in open water with known elevation) without the use of a water level meter.

Transducers are installed at some monitoring points, automatically measuring water levels daily. The transducers record pressure that is later converted to depth to water measurements by correcting for barometric pressure. The transducer data are electronically downloaded during the scheduled long-term monitoring (LTM) events through a tablet or equivalent computer.

For the use of pressure transducers or other automated devices for the collection of groundwater elevation data equipment manuals should be observed for operational procedures.

This TGI also includes *Decontamination Procedures* summarized below, following NWNA's *Water Level Meter Disinfection Procedure*, *NWNA-MW-SOP-04.00.01* (Nestle Waters North America, 2019).

3 PERSONNEL QUALIFICATIONS

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The HASP and other documents will identify other training requirements or access control requirements.

4 EQUIPMENT LIST

The following field equipment is required for water level measurements:

- HASP and appropriate field forms
- Appropriate personal protective equipment (PPE) as specified in the HASP
- Site-specific electronic water level indicator graduated in 0.01-foot increments. *Note: The water level meters used on or in conjunction with a NWNA groundwater withdrawal project should be dedicated for NWNA use only. Water level meters previously used on project sites with groundwater contamination should never be used at a NWNA site.*
- 9-volt battery for electronic water level meter
- Storage container. *Note: The electronic water level indicator should be stored and transported in a clean container.*
- Isopropyl alcohol (70%) or chlorine solution (200 ppm) spray bottle. *Note: no industrial scented laundry bleach will be acceptable for substitution.*
- Non-phosphate laboratory soap (Alconox or equivalent), brushes, clean buckets or clean wash tubs. *The buckets/tubs/brush are dedicated to the NWNA sites and cannot be used on sites with environmental contamination.*
- Nitrile gloves
- 100-foot measuring tape (or sufficient length for the maximum site depth requirement)
- Tools and/or keys required for opening wells
- Well construction summary table and/or well construction logs
- Summary table of previous water level measurements or field book
- Field notebook and/or smart device (phone or tablet)
- Indelible ink pen

5 CAUTIONS

Electronic water level probes can sometimes produce false-positive readings. For example, if the inside surface of the well or stilling well has condensation above the water level, then an electronic water level probe may produce a signal by contacting the side of the well rather than the true water level in the well. For accuracy, the electronic water level probe should be raised and lowered several times at the approximate depth where the instrument produces a tone indicating a water interface to verify consistent, repeatable results. Possessing and checking against a well construction summary table is vital for proper measurements and reporting.

If the depth markings on the tape or cable are worn or otherwise difficult to read, extra care must be taken in obtaining the depth readings. These tapes should be replaced.

Ensure that the type of electronic water level probe is compatible with the depth and diameter of the wells to be measured. Tapes missing length (too short) or have been repaired should be discarded because the accuracy of the tape is lost.

6 HEALTH AND SAFETY CONSIDERATIONS

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Potential hazards include pressurized wells, stinging insects that may inhabit well heads and other biologic hazards (e.g. ticks in long grass/weeds around well head). Appropriate personal protective equipment (PPE) will be worn during these activities. Open well caps slowly and keep face and body away to allow venting of any built-up pressure. Field personnel will thoroughly review client-specific health and safety requirements. It is important to note that insecticides and similar chemicals are not permitted for use while on NWNA property and/or near monitoring locations.

7 PROCEDURE

Groundwater level measurement procedures for electronic water level indicators are described in the sections below.

Water Level Measurement Procedures

The general procedures to be followed for the collection of groundwater level measurements and well depths from the monitoring wells are as follows:

- Check that the water level indicator battery is functional before leaving for site and prior to each day onsite (e.g. turn power on and check that meter sounds when probe is lowered into a bucket of water – note that water level meters will not work with distilled water).
- Record instrument make, model, serial number and (if present) Arcadis ID number in the field book.
- Identify site and monitoring point identification in field notebook along with date, time (military time), personnel and weather conditions.
- Don disposable nitrile gloves.

- Decontaminate water level indicator, any attached tape and the spool with isopropyl alcohol (see *Decontamination Procedures* below).
- Perform a well inspection (note that for some sites a well inspection form is required to be filled out along with a photo to document the conditions).
- Unlock well pro-casing (where applicable) while standing upwind from the well (note that some wells may be under pressure and precaution should be taken with opening well caps).
- Remove J-plug from monitoring point. If J-plug is tight in place (frozen, tightened, etc.), then field personnel should wait for the well to equilibrate (two minutes) after removing the J-plug before taking a water level measurement. Check previous field forms/logs for equilibration time if noted.
- Locate the measuring reference point that correlates to the survey point on the monitoring well casing. This can generally be found on the top of casing inside the well, identified by a black mark. If one is not found, create a reference point by marking the highest and/or north point on the inner casing (or outer if an inner casing is not present). All downhole measurements are to be taken from the reference point. Document the creation of any new reference point or alteration of the existing reference point.
- Turn on the water level meter and adjust sensitivity.
- Lower water level probe into well until audible and visible signals are detected. Use and install tape guide to help with accuracy and provide protection with damaging the measurement tape. If a tape guide is not available, make sure that the tape does not drag on the inner or outer casing which could fray and damage the tape.
- Measure DTW from the existing or created reference point from the top of casing [below top of casing (BTOC)] of the monitoring point to the nearest 0.01 foot.
- Hold the tape at the measuring point (tip of well casing) and state the measurement verbally. The person recording the data should repeat the measurement verbally back to the person measuring the DTW to ensure proper data collection. Repeat the measurement two more times.
- Record the final measurement in field book. Include time the measurement was taken (military time), well name, unit of measurement and type of measurement for every entry into the field book (e.g. 13:10 SW-103 4.75' BTOC).
- Check recorded measurement against any previous measurements from the same location. Note any anomalies/discrepancies in the field book; if significant, contact the technical lead for project.
- If a transducer is installed in the monitoring point, attach field tablet or compatible computer to download data from the transducer (See respective equipment manuals for operation procedures).
- Replace J-plug on well casing, close pro-casing lid, and lock well (where applicable).
- Decontaminate (see *Decontamination Procedures* below) water level tape and probe (where applicable).

For stilling wells: If DTW measurement outside of well varies from the DTW measurement inside the well (greater than 0.01 foot. difference), the well screen may be plugged. Unplug the screen (brush screen, bail stilling well, etc.), note activities in field book, and re-measure the DTW of the stilling well.

At staff gauges: Water levels in surface water bodies are determined by first directly reading the staff gauge then calculating the water elevation. The calculation is completed by taking a reading and subtracting it from the value at the top of the staff gauge ruler (surveyed elevation). This subtraction gives the distance from the top of the staff gauge ruler to the water. This distance is then subtracted from the surveyed elevation from the reference point at the top of the staff gauge.

Total Depth Measurement Procedures

- Weighted tape or electronic water level indicator can be used to determine the total well depth.
- Follow initial procedures noted above in *Water Level Measurements*.
- Lower indicator probe (or tape) until weighted end is felt resting on the bottom of the well. Raise indicator slowly until there is no slack in the tape. Gently “feel” the bottom of the well by slowly raising and lowering the indicator: great care should be taken to avoid damaging the sensor on the probe. The operator may find it easier to allow the weight to touch bottom and then detect the ‘tug’ on the tape while lifting the weight off the well bottom.
- Because of the tape buoyancy and weight effects encountered in deep wells with long water columns, it may be difficult to determine when the tape end is touching the bottom of the well and sediment in the bottom of the well can also make it difficult to determine total depth. Care must be taken in these situations to ensure accurate measurements.
- Read and record measurement to the nearest 0.1 foot. Also note if the bottom of the well is hard or soft, relating if there is sediment present. Please refer to the note regarding total depth measurements described in *Section 5 Cautions* above.
- Follow decontamination procedure outlined below where applicable (see *Decontamination Procedures* below).

Decontamination Procedures

The purpose of following the below decontamination procedures is to prevent contamination to groundwater during the collection of manual groundwater level measurements. These procedures should be followed whenever any equipment is introduced to an environment where it comes into contact with groundwater on, or associated with any, NWNA Site. Below are the summarized points from NWNA’s *Water Level Meter Disinfection Procedure - NWNA-MW-SOP-04.00.01* (Nestle Water’s North America, 2019).

- Cleaning and sanitizing water level meters should be completed by persons wearing nitrile gloves.
- Prior to each monitoring event, remove water level meter from storage container and spray the water level sensor and at least five feet of tape above the sensor with 70% isopropyl alcohol or 200 ppm chlorine solution. Allow for appropriate contact time (30 seconds for isopropyl alcohol and two minutes for 200 ppm chlorine solution).

- Repeat disinfection procedure if water level sensor or tape comes into contact with the ground and/or any other surface not associated with groundwater monitoring.
- Store water level meter in a clean storage container (i.e., plastic bag) while transporting between monitoring locations.
- Repeat disinfection procedure prior to insertion of the water level sensor in NWNA production wells, and residential or monitoring wells located nearby a production well (within three-day time of travel to production well).
- Prior to storage of the water level meter and upon completion of the monitoring event, the sensor and measuring tape should be sanitized by spraying with 70% isopropyl alcohol or 200 ppm chlorine solution. The water level meter is to be stored in a clean storage container. *Note: if needed, the sensor, measuring tape and storage container can be cleaned with an alconox solution and rinsed. Cleaning should be followed by sanitizing with 70% isopropyl alcohol or 200 ppm chlorine solution.*
- Extra care should be taken to clean the probe after a total depth measurement. At least, the length of tape that was introduced into the water column of the well should be wiped with clean paper towel and sprayed with 70% isopropyl alcohol. All sediment or dirt needs to be removed during decontamination.

8 WASTE MANAGEMENT

Waste generated at the site shall be disposed of properly by Arcadis personnel.

9 DATA RECORDING AND MANAGEMENT

Groundwater level measurements as well as all relevant observations should be documented in the field notebook, field forms and/or smart devices as appropriate. The following information must be documented:

- Well or location identification;
- Measurement time;
- Depth to water;
- Total well depth or depth of the water body at the location, annually.

Once all the data has been collected and recorded, all notes/forms/data must be uploaded to the appropriate project directory on the Arcadis server, and an email should be sent to the Task Manager and/or Technical lead for notification. A summary of the work completed that day and any relevant observation noted (such as well inspections) during the daily activities should be included with the email. The appropriate team member will review the data for accuracy and provide feedback.

10 QUALITY ASSURANCE

- As described in the detailed procedure, the electronic water level meter will be tested prior to use to ensure accurate length demarcation on the tape or cable. The results will be recorded.
- Conduct a minimum of two measurements, more may be necessary based upon site conditions. The final measurement will be recorded, along with any anomalies or discrepancies.
- Field notes will be reviewed by the project team once the field data has been uploaded to project file.

11 REFERENCES

Cunningham, W.L., and Schalk, C.W., comps. (2011). *Groundwater technical procedures of the U.S. Geological Survey; U.S. Geological Survey Techniques and Methods1-A1, 151pp.*

United States Environmental Protection Agency. (2016, November 3). *Level and Well Depth Measurement: SESD Operating Procedure*. Region 4 Athens, Georgia. Retrieved from https://www.epa.gov/sites/production/files/2017-07/documents/groundwater_level_and_well_depth_measurement105_af.r3.pdf

Nestle Water's North America. (2019). *Water level meter disinfection procedure – NWNA-MW-SOP-04.00.01. Rev. 3.*

APPENDIX H

SSPA Groundwater Model Assessment

Effectiveness of Groundwater Model and Recharge Re-evaluation

Permit 1701 issued for Water Supply Serial Number 2016667, Production Well PW-101, requires that the effectiveness of the groundwater model and the validity of recharge assumptions in the model shall be reviewed on an annual basis. This section describes the reviews that will be conducted.

Groundwater Model Effectiveness

The following tasks shall be conducted on an annual basis in January to evaluate the effectiveness of the groundwater model:

Task 1 – The groundwater model will be run in transient mode with monthly time steps from 2011 (the beginning of production from PW-101) through the end of the past calendar year. Average monthly pumping rates from PW-101 shall be used in this analysis. The calculated changes in groundwater levels and stream flows from January 1 through December 31 of the past calendar year from the pumping of PW-101 shall be tabulated for all monitoring locations in the approved monitoring plan for the Site.[1]

Task 2 – The groundwater level and streamflow monitoring data will be evaluated. Based on the data, a tabulation of the change in water level/stream flow at each monitoring location during the 12-month period ending in December of the past year shall be made. In addition, the average and median water level/stream flow in the past year, and in the year before the past year, shall be calculated and tabulated, as well as the changes between the two periods. In addition, spatial plots of the changes in water levels shall be prepared, and an analysis of spatial patterns shall be completed to ascertain correlation with location of PW-101. An attempt will be made to calculate that portion of the change that is related to climatic factors rather than pumping based on the spatial pattern of changes.

Task 3 – Daily climate data shall be complied for the past two years and monthly averages of precipitation, average temperature, maximum temperature and minimum temperature shall be tabulated as well as changes in these parameters over the previous two years.

Task 4 -- The changes calculated in Task 1 shall be compared with changes calculated in Task 2. Initial data exploration will consist of calculated versus observed plots, standardized residual[2] plots, and spatial plots of the residuals. The spatial distribution of residuals shall be evaluated for trends and correspondence with location of PW-101.

[1] A tabulation of stream flow changes from pumping PW-101 from 2011 through 2016 was contained on Table 7 of the report "An Addendum to the Evaluation of Groundwater and Surface Water Conditions in the Vicinity of Well PW-101, Osceola County, Michigan" dated November 2017.

[2] Residual is the change, at a given location, between a value calculated with the model and the measured change.

Task 5 – A memorandum to be included in the annual monitoring report will be prepared that describes the results of Tasks 1 through 4 with conclusions regarding the effectiveness of the groundwater model. The report will contain recommendations for changes in the Site conceptual model and the groundwater flow model if the results indicate that the model has been a poor predictor of the observed changes in groundwater levels and stream flows.

Recharge Evaluation

An assessment of the validity of the recharge rates used in the groundwater model will be made by comparing base flows measured in in Twin Creek at SF-9 and Chippewa Creek at SF-17. If the calculated base flows are within ten percent of the flow calculated with the groundwater model the recharge rate will be determined to valid. Otherwise, a recharge re-evaluation will be conducted. The U.S. Geological Survey has maintained continuous stream flow monitoring at SF-9 and SF-17 since December 2018. The daily data from these stations will be evaluated annually to determine baseflow using the methods contained in the USGS Groundwater Toolbox.[3] Based on the evaluation of the stream flow data, a water budget will be prepared for the Twin Creek and Chippewa Creek watersheds upstream of the gaging stations to determine if recharge rates in the groundwater model are consistent with stream flow and climatological data. Evapotranspiration will be estimated for purposes of the water budget from data collected at the Enviro-Weather Station at Sackett Farms in Mecosta County. The recharge rate used in the model will be determined to be valid if it is within twenty percent of the recharge rate calculated using the water budget method. Otherwise, a recharge re-evaluation will be conducted.

A memorandum to be included in the annual monitoring report will be prepared describing the recharge evaluation. If it determined that a recharge re-evaluation in needed, a workplan and schedule for this re-evaluation will be prepared.

[3] Barlow, P., W. Cunningham, T. Zhai, and M. Gray, 2015. U.S. Geological Survey groundwater toolbox, a graphical and mapping interface for analysis of hydrologic data. USGS Techniques and Methods 3-B10, 27p.