Response to Michigan Department of Environmental Quality Comments dated February 15, 2019 on the Back Forty Project Mining Permit Amendment Application

Project I.D.: 17A021.19

Aquila Resources Inc.
Stephenson, Michigan

March 1, 2019

AQUILA RESOURCES

Foth

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Prepared for

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Stephenson, Michigan

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March 1, 2019

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Attachments

Mining Plan, Volume I:

Comment #1:
Figure 4.1: When does mine pit excavation begin in the project timeline? How do the phases of development of the pit (Figure 4.2) correlate with the project timeline?

Response to Comment #1:
Excavation of topsoil and overburden within the mine pit footprint will begin at the start of mine construction (at the start of Mine Year -2 in the project timeline shown on Figure 4-1 of the Mining Permit Amendment Application [MPAA]). Waste rock excavation within the mine pit footprint is anticipated to begin at the start of Mine Year -1 in order to provide the necessary construction materials for initial development of mine facilities such as the Tailings Management Facility (TMF). Ore excavation is anticipated to begin at the end of mine construction (at the beginning of mine operations) at the start of Mine Year 0.

The mine pit phases shown on Figure 4-2 of the MPAA do not directly correlate with the project timeline shown on Figure 4-1 of the MPAA. The mine pit phases shown on Figure 4-2 are intended to illustrate the general sequence of mine pit development. However, in response to this comment, this correlation is provided below:

- Excavation of topsoil, overburden, and waste rock that takes place during mine construction (during Mine Years -2 and -1 in the project timeline shown on Figure 4-1 of the MPAA) will be focused on a shallow, eastern portion of the Mine Pit that is outlined as Mine Pit Phase 1A on Figure 4-2 of the MPAA.

- Excavation of topsoil, overburden, and waste rock within the general footprint of Mine Pit Phase 1B is anticipated to begin after mine construction (after the start of Mine Year 0 in the project timeline shown on Figure 4-1).

Comment #2:
Figure 4.3 is difficult to read. Please provide a more readable copy.

Response to Comment #2:
An updated copy of Figure 4-3 is provided in Attachment 2.

Comment #3:
Section 4.1.3: Has the amended mine plan changed the variation in the estimated number of employees over the life of mine? R425.203 (b)

Response to Comment #3:
No, the variation in the estimated number of employees has not materially changed from the range presented in the Mining Permit Application (MPA, 2015a) of 208 to 250 employees during operations and approximately 500 employees during construction.

Comment #4:
Section 4.8: Michigan Department of Natural Resources (DNR) shall be copied on the mussel relocation plan and plans for mussel relocation activities. Special Permit Condition (SPC) B12.

Response to Comment #4:
Aquila acknowledges this comment and will provide a copy of the mussel relocation plan/plans to the Michigan Department of Natural Resources (MDNR).

Comment #5:
Section 4.5.1: Clarify how the plan for tailings transport meets the requirement of SPC E8 and E9.

Response to Comment #5:
The tailings transport systems will be equipped with secondary containment systems extending from the pump boxes in the Processing Plant to the inside of the crest of the TMF. The secondary containment will comprise a system of lined ditches and/or double containment pipelines leading to a series of lined (dump ponds) containment ponds. The secondary containment systems will be designed to suit the pipeline grade and the presence of roads and other infrastructure.

Reclamation Plan, Volume I:

Comment #6:
Section 8.0 of Appendix C references the need for borrow pit areas within the project site for predicted overburden shortfall. Proposed borrow pits were not included in the reclamation plan. If there are plans for borrow pits within the project site, the locations and reclamation of these sites are required to be included in the reclamation plan.

Response to Comment #6:
The predicted overburden shortfall of 0.27 million cubic meters (Mm^3) that is mentioned in Appendix C is relatively insignificant compared to the total overburden generated by the project, and is attributable to the reclamation of the backfilled mine pit and TMF slopes at mine closure. This predicted shortfall in overburden will be diverted from the footprints of the former waste rock facilities (WRF), ore storage (OS), and process plants during restoration/reclamation of those areas to their original states. The predicted overburden shortfall of 0.27 Mm^3 equates to an overburden excavation depth of approximately 6 inches if stripped evenly from the combined areas of the former WRFs, OS, and process plant during reclamation. No formal borrow pits will exist within the project site postclosure and any plans for diversion of minimal quantities of overburden within the project site during reclamation will be submitted to the Michigan Department of Environmental Quality (MDEQ) for approval prior to reclamation. Any outstanding shortfall in overburden quantities required for reclamation of the project site that is not approved by the MDEQ to be diverted from within the project site will be purchased from the open market and imported from off-site.

Comment #7:
Understanding that the final engineered design of the Waste Water Treatment Plant (WWTP) will be submitted to the Department of Environmental Quality (DEQ) for approval prior to construction of the WWTP, what water treatment technologies are anticipated to be necessary for operations and closure? It is not clear whether the financial assurance estimates take into account the cost to treat water from the Tailings Management Facility (TMF) at initiation of Phase 3 of reclamation at a point in operations when the TMF contains the largest volume, and the cost to treat water after commissioning of the Closure WWTP.

Response to Comment #7:
Treatment technologies that are anticipated to be necessary at the wastewater treatment plant (WWTP) are similar to those presented in the MPA and National Pollutant Discharge Elimination System (NPDES) Permit Application (Foth, 2015b) and will include:

- pH adjustment and chemical precipitation of metals
- flocculation and clarification
- filtration
- mercury polishing

Membrane filtration that was previously proposed in the MPA has been replaced with filtration and mercury polishing to avoid the generation of concentrate solution.

The Closure WWTP is anticipated to consist of a scaled-down version of the operations WWTP and, therefore, similar treatment technologies are anticipated.

The financial assurance estimate includes an allowance of $10.3M for postclosure monitoring and maintenance for the Life of Mine (LOM) operating period, which includes an allowance of $2.6M for 25 years of postclosure water treatment. This cost item is labeled as ‘Closure WWTP’ in the financial assurance cost estimate provided in Appendix H of the MPAA, and it accounts for the costs of the Operations WWTP at the onset of Phase 3 of reclamation. During this phase, the TMF and Contact Water Basin (CWB) will be dewatered prior to commissioning of the Closure WWTP. The $2.6M allowance for postclosure water treatment was based on the water treatment unit cost in the project cost model and conservatively addresses the treatment costs for average annual postclosure TMF seepage rates predicted in Section 11.4.2 in Appendix C of the MPAA. The costs to treat the final major flux of water during the first year of Phase 3 reclamation is estimated to be $422,000. As seepage subsides in Year 2 and Year 3 of Phase 3 reclamation, the annual water treatment costs decrease to $140,000 and $56,000, respectively. In summary, the $2.6 allowance for postclosure water treatment in the financial assurance cost estimate for the LOM operation period accounts for the treatment of the final major flux of water from the TMF and CWB at the onset of Phase 3 of reclamation and 25 years of postclosure water treatment. This includes operation of the Closure WWTP following decommissioning of the Operations WWTP.

Comment #8:
Section 6.1: Describe the maintenance that will be required during Reclamation Phase 4? How do the financial assurance estimates take into account these activities?

Response to Comment #8:
The type of maintenance activities that will take place during Reclamation Phase 4 are activities related to maintenance and repair of areas where erosion may take place after vegetation has been established. These are low cost activities that are covered in the Financial Assurance estimate for the LOM operating period provided in the MPAA. This includes a $10.3M allowance (Table 9-2 in MPAA) for Postclosure Monitoring and Maintenance. The estimate accounts for maintenance items scheduled to take place during Phase 4 Reclamation (as listed in Appendix H-2 of the MPAA):

- Maintenance Inspections
- Maintenance of Revegetated Areas
- Maintenance of Access Roads
- Maintenance of Open Pit Cover
- Maintenance of TMF Cover

These cost items comprise $2.4M of the total Postclosure Monitoring and Maintenance estimate of $10.3M.

Comment #9:
What is the soil erosion and sedimentation control (SESC) plan for reclamation activities?

Response to Comment #9:
The reclamation plan will employ the same SESC practices as described in the MPAA (Foth, 2018a, Appendix E). Appendix E contains the SESC plans for construction, progressive reclamation during construction, and operations. SESC plans will be reported annually as part of the annual report and will form the basis for the SESC plan for final reclamation. The final reclamation plan and related SECS details will be provided as part of the required annual report related to planned reclamation activities.

Contingency Plan, Volume I:

Comment #10:
Section 4.3.5 of the Mining Plan indicates that explosives will be stored and handled on site, which is different from the original Mining Permit Application (MPA) Mining Plan. This was not addressed in the list of amendments to the Contingency Plan, Section 8. Provide a stand-alone updated contingency plan document to include all applicable items listed in R425.205 and Section L of the Mining Permit, including assessment of risk and response measures. A copy of the updated contingency plan is required to be submitted to the emergency management coordinator having jurisdiction over the affected area.

Response to Comment #10:
An updated Contingency Plan is being prepared in response to this comment and will be provided to MDEQ and the appropriate emergency management coordinator as soon it is completed.

Cut-off Wall Design and Menominee River Bank Stability Assessment, Volume I, Appendix B:

Comment #11:
Sect. 4.3, Hydrogeological Seepage Model: Is this the same model as referenced in the June 2016 Response? Was this groundwater model submitted as part of the wetland permit for the Back Forty Project?

Response to Comment #11:
Yes, it is the same model as referenced in the June 2016 Response (Foth, 2016). Yes, the same groundwater model was used as part of the Wetland Permit Application for the Back Forty Project.

Comment #12:
Section 3.1 Design Criteria: The minimum factor of safety for slope stability is Industry standard for dams is generally 1.5. Where does the factor of safety (FOS) falls below 1.5 on the embankment and what would be the impacts of a slope failure in those locations?

Response to Comment #12:
The industry standard of 1.5 is specific to the long-term stability of dams. (For dams, a lower factor of safety of 1.3 applies for short-term stability (i.e., during construction) and 1.1 is normally applied for initial pseudo-static analysis for earthquake loadings.) These factors of safety apply to dams; they are not intended to be applied to either cut slopes (as in the open pit) or to natural earth slopes such as the Menominee River bank. In any case, the factors of safety for potential deep-seated failures involving the river bank and the proposed cut-off wall (Figure C-2 to Appendix C to MPAA Appendix B) are all higher than 1.5. Likewise, the factors of safety of the proposed open pit cut slopes adjacent to the cut-off wall (Figure C-1 to Appendix C to Appendix B) are also higher than 1.5.

The terrace adjacent to the river bank was formed by erosion and re-deposition of the glacio-fluvial sand sediments that occurred shortly after deglaciation, which occurred about 10,000 years ago. The upper glacio-fluvial sand layer has been characterized as cohesionless frictional material with an angle of internal friction of about 33 degrees. These materials could be subject to surficial gravelling. The consequences of a surficial gravelling failure would be very minor. It could involve a minor retrogression of the river bank but could not affect the proposed cut-off wall or the mine open pit. Observations of the river bank in historical air photos (Appendix B to MPAA Appendix B) indicate that the river bank has experienced little or no movement since 1938.

Comment #13:
Provide additional information from the SLOPE/W and SEEP/W models and input parameters. What were the water surfaces assumed on each side of the berm in each model? What flood/operating conditions do those represent? Provide a description of what scenario the pseudo-static model was designed to capture and what the reduced FOS means as it relates to stability of the embankment. Section 4.4 Stability of Overburden Soil – Table 1: The harmonic mean k values for each of the four soil materials was used. Section 2.3, Hydrogeology, gives a range of k values for each of the soils, with the worst case being higher than the harmonic mean. While this may not make a huge difference in the SLOPE/W model, was sensitivity analyses conducted to evaluate the impacts of using the higher conductivity values for the soils to capture that "worst case scenario" rather than the average by using harmonic mean values?

Response to Comment #13:
The river bank stability analyses results shown on Figure C-2 (in Appendix C to MPAA Appendix B) include a parametric study of three river water levels:

1. A "dry river" condition with a water level at the base of the river.
2. A 100-year flood condition with the river water level at 211.7 m.
3. A 1,000-year flood with the river water level at Elev. 212.4 m.

The water level on the open pit side of the cut-off wall was lowered to represent a dewatered open pit condition with the seepage exiting at the top of the weathered bedrock. The cut-off wall was assumed to be 1.0 meter (m) wide with a permeability of 1 x 10^{-8} m/sec. This resulted in a relatively flat phreatic surface sloping slightly from the river towards the cut-off wall. A higher permeability for the overburden sand would have resulted in a flatter phreatic surface with a somewhat higher water level on the river side of the cut-off wall. The water level in the river bank would not change however; it would still be the same as the assumed water level in the river. Thus, an increased permeability would only slightly reduce the factors of safety for the overall deep-seated failures involving the river bank and the cut-off wall.

The open pit stability analyses results shown on Figure C-1 (in Appendix C to MPAA Appendix B) considered only the 1,000-year flood with the river water level at Elev. 212.4 m. A higher permeability for the overburden sand would have resulted in a somewhat higher water level on the river side of the cut-off wall. However, the water level at the seepage exit point on the open pit face would be practically unchanged. Thus, an increased permeability would have practically no impact on the factors of safety for the open pit overburden.

Comment #14:
Phreatic surface is assumed from the SEEP/W seepage model for the SLOPE/W slope stability model. While this is appropriate, what are the SEEP/W model input parameters and results to ensure that the phreatic surfaces are reasonable? What is the expected seepage through the foundation? Critical exit gradients of 0.33 to 0.25 are generally acceptable and result in factors of safety for seepage through the foundation of 3 to 4. Where do the critical exit gradients occur, and what the results are at those locations?

Response to Comment #14:
As discussed above in response 13, the SEEP/W modeling resulted in a flat phreatic surface sloping slightly from the river towards the cut-off wall and the open pit. The flow was from the river towards the open pit, so there were no exit gradients into the river. The exit gradients on the open pit side are observably flat and within the Lower Overburden (Figure C-1). The calculated exit gradients varied between 0.11 and 0.36. As discussed in Section 3.5 of Appendix B, a blanket drain consisting of geotextile and riprap will be provided at the toe of the overburden to prevent “piping.” With such blanket drains, higher exit gradients are acceptable.

Design of Tailings Management Facility, Waste Rock Facilities, Ore Storage Areas, and Overburden Stockpile, Volume I, Appendix C:

Comment #15:
Part 632, R409(i)(F) requires a cover to be employed to isolate the reactive materials from precipitation and air as soon as practicable. While it may not be practicable to cover the waste rock and ore during operations, especially with an operations period of only 7 years, provide plans for covering these materials should production be idled.

Response to Comment #15:
Ore on the ore pad represents a mined resource. If the decision were made to idle production, it is expected that the ore would be milled first before shutting down the Processing Plant.

It is not practicable to cover the waste rock facilities while they are actively being used, particularly since the LOM plan is to relocate the waste rock back into the open pit at permanent closure. If production was idled, Aquila would continue to monitor and collect the leachate at the base of the TMF, North Waste Rock Facility (NWRF) and the South Waste Rock Facility (SWRF) and to treat it as necessary.

Water Management, Volume I, Appendix D:

Comment #16:
Will the contact water roadside ditches be paved or lined?

Response to Comment #16:
The roadside ditches outside of the TMF and WRF will be constructed of low-permeability compacted soils or pavement that are relatively impervious and adequate to safely convey any collected storm water from contact water roads to the CWB. Ditches surrounding the TMF and WRFs will be double lined.

Comment #17:
How was the groundwater level of the site taken into account in the design of the Contact Water Basin (CWB) and South Waste Rock Facility (SWRF)? How will soil and foundation conditions be verified during construction of the storage facilities?

Response to Comment #17:
The groundwater levels were taken into account in the design of the CWB and SWRF. A summary of groundwater levels from boreholes and test pits in the areas of the CWB and SWRF are provided in the MPA and MPAA. Measured groundwater levels were considered in establishing the design base grades for the CWB and SWRF, which are near or above the measured water levels.

Soil and groundwater conditions will continue to be investigated and monitored as part of final design studies. Final design details for the CWB and SWRF will be submitted to the MDEQ prior to mine construction. If final design analysis suggests that establishing the base grades above the maximum measured water levels is not practicable, the final design will include provisions for monitoring soil and groundwater conditions during construction. The final design will address the need for possible local temporary dewatering and/or underdrain systems at the base of the facilities, as identified in Appendix D of the MPAA.

Comment #18:
What is the plan for snow storage in the contact area?

Response to Comment #18:
Snow is planned to be stored in unused portions of the process plant area, namely in and around unused ore stockpiles and the laydown area (refer to Figure 2-2 of the MPAA).

Comment #19:
Fig. 1: The emergency overflow structures are not shown in contact water management area.

Response to Comment #19:
Although not shown on Figure 1, the design details such as emergency overflow structures for the CWB are contained in the design drawings provided in Appendix 2 of MPAA Appendix D Water Management Plan.

Comment #20:
Contact Water Management, CWB Design Procedure (Operations Phase): Reference to the LLCS1, LLCS2, LLCS3, and LLCS4 should be corrected as follows to be consistent with the design procedure:

- *Water flows associated with the TMF including water collected from the two sumps LLCS1 and LLCS2 and decant water pumped from the pond.*
- *Water from sump LLCS3 LLCS2 associated with the SWRF and sump(s) LLCS3 and LLCS4 associated with the NWRF.*

Response to Comment #20:
The corrected flow descriptions are as follows:

- Water flows associated with the TMF including water collected from sump, and decant water pumped from the pond.

- Water from sump LLCS2 associated with the SWRF and sump(s) LLCS3 and LLCS4 associated with the NWRF.

Environmental Monitoring Plan, Volume I, Appendix F:

Comment #21:
Module 1, Groundwater Monitoring Well Locations: Provide a revised Figure 1-2, Table 1-1, and Tables 1-2 to include the following:

a. *Additional leachate/compliance monitoring wells as close as practicable and downgradient of LLCS1, LLCS3, LLCS4, south of the CWB (near WL- 2b), and between the mine pit and the Menominee River (near WL-14). Proposed CW-3, CW-5, and CW-6 may be relocated for monitoring of the collection sumps.*
b. *Table 1-2: Revise to continue monthly monitoring of groundwater elevations during operations.*

Response to Comment #21:
Please see revised Figure 1-2, Table 1-1, and Table 1-2 in Attachment 21. These revised figure and tables will be included in an updated consolidated Environmental Monitoring Plan (EMP) that addressees changes derived from MDEQ's review and this response document.

Comment #22:
Module 1, Figure 1-3: Are there plans to monitor WL-40 as required by SPC K26?

Response to Comment #22:
Yes, this is covered in the Wetland Monitoring Plan under the Wetland Permit.

Comment #23:
Does the proposed regional monitoring include points in WL-14, WL-2b, WL-B1, and WL-C1?

Response to Comment #23:
Wetlands WL-14, WL-2b, WL-B1, and WL-C1 will be monitored as part of the wetland monitoring program required under the Wetland Permit.

Comment #24:
Provide the Standard Operations Procedures (SOP's) referenced in Section 3 of Module 2 of the Environmental Monitoring Plan (EMP).

Response to Comment #24:
The requested SOPs are provided in Attachment 24.

Comment #25:
Section 3.2 of Module 2: While SPC K4(e) was included in the Mining Permit based on recommendations from Water Resources Division (WRD) during the review of the original MPA, upon review of the EMP provided in the MPAA, WRD has provided the following interpretation of SPC K4(e): The 95% exceedance flow is not the equivalent of stagnant water. It is dependent

on the measured and/or estimated flow of the waterbody using specific methods for calculating flow. For example, if a waterbody is intermittent, the 95 % exceedance flow may at times reach zero cubic feet per second but at other times it might be greater than zero. If the waterbody is perennial in nature, it will almost always have some amount of flow. For purposes of sampling, if by measurement (using acceptable methods), the water is found to have a flow greater than zero cubic feet per second, the waterbody should be sampled. Alternatively, a sample could be taken regardless of flow to be conservative. WRD recommends that the language be modified in the Mining Permit (SPC K.4.e) to indicate that surface water quality samples should be taken unless flow is equal zero. Revise Module 2 to indicate that samples will be taken unless flow is stagnant, or equal to zero.

Response to Comment #25:
Aquila agrees that Mining Permit SPC K.4.e should be changed to require sampling regardless of flow. Aquila will capture this change within an updated final EMP that will be provided to MDEQ for approval within 60 days of issuing the Part 632 Amendment.

Comment #26:
Section 3.2 of Module 2: Any adjustment of parameters and/or monitoring frequency of environmental monitoring required by the Mining Permit requires OGMD approval.

Response to Comment #26:
Aquila concurs with this comment.

Comment #27:
Module 2, Table 2-2, Surface Water – For consistency with the NPDES effluent water quality monitoring, provide a revised Table 2-2 to include the following additional parameters: Barium, Beryllium, Boron, Total Chromium, Hexavalent Chromium, Total Cobalt, Lithium, Molybdenum, Strontium, Thallium, and Vanadium. See item #38 regarding detection levels.

Response to Comment #27:
Table 2-2 is consistent with the proposed ambient water quality parameter list contained in the NPDES Permit Fact Sheet (see Attachment 27). As such, Aquila proposes to keep Table 2-2 as is to maintain consistency with the ambient water quality monitoring requirements contained in the NPDES Permit. Note that the parameters cited in this comment will be monitored in the effluent as noted in the comment. If the need ever arises to add these parameters to the ambient water quality parameter list, MDEQ has the authority under the Part 632 Permit to require the additional parameters.

Comment #28:
Section 4.1 of Module 4, Survey Approach: The time frame must be June 1- September 30 for MDEQ Procedure 51 (P-51) sampling. P-51 is suitable for wadeable streams and is not used to detect change (at least at small increments). It is used to determine if water bodies are meeting designated uses. Monitoring plans are needed for Menominee River stations that are not wadeable. Additional survey procedures will need to be planned and described if the goal is to detect small changes in biological community health from one year to the next.

Response to Comment #28:
Aquila agrees to conduct the surveys between June 1 and September 30 and to use MDEQ Procedure 51 (P-51) for sampling wadeable streams. Aquila will provide, within 60 days of MDEQ's issuance of the Amendment to the Part 632 Permit, an updated EMP containing the survey procedures for Menominee River, which is not wadeable. The updated EMP will be prepared per the requirement of MP 01 2016 SPC K4 and M1.

Comment #29:
Section 4.2 of Module 4, Sediment Sampling: GLEAS Procedure #64 has been renamed and is now WRD_SWAS-011. The facility should submit a sediment sampling plan for approval prior to facility operation. MDEQ Remediation and Redevelopment Division (RRD) memorandum (RRD Operational Memorandum No.4) gives some guidance on characterization of water body sediments to develop a sampling plan.

Response to Comment #29:
Aquila agrees to use WRD_SWAS-011. Consistent with MP 01 2016 SPC K4 and M1, Aquila will submit the requested sediment sampling plan to the MDEQ within 60 days of issuance of the amendment.

Comment #30:
Section 4.3 of Module 4, Community Assessment: Note P-51 is suitable for only wadeable streams and is not used to detect change (at least at small increments). Additional monitoring plans will be needed for Menominee Stations that are not wadeable and to determine if there have been changes in biological community health beyond determining if the other indigenous aquatic life and wildlife designated use is being met.

Response to Comment #30:
Aquila acknowledges that P-51 is not suitable for the Menominee River Stations. Consistent with MP 01 2016 SPC K4 and M1, Aquila will submit within 60 days of MDEQ's issuance of the Amendment an updated EMP containing the requested information.

Comment #31:
Section 4.3 of Module 4, Community Assessment: The community assessment described in this section is a general description of what they have planned, but it is not what WRD would consider a sampling plan. Examples of expected details include; how often they will complete the sampling, what literature they are using to develop the plan, what methods beyond P-51 that they will be using, what literature they will use to identify the aquatic insects, what level of identification they will be using etc. A QAPP is needed to determine if what is planned will be adequate.

Response to Comment #31:
Aquila understands and appreciates MDEQ's comments requesting more detail on the sampling for the community assessment. MDEQ is correct that what was contained in Section 4.3 is a general description of what is planned. Consistent with MP 01 2016 SPC K4 and M1, Aquila will provide the requested Quality Assurance Project Plan (QAPP) within 60 days of MDEQ's issuance of the Amendment.

Comment #32:
Section 4.3 of Module 4, Phytoplankton and Zooplankton: Methods and metrics to be used to identify and characterize community health and change are not identified. This paragraph is vague and should not be considered a plan.

Response to Comment #32:
Consistent with MP 01 2016 SPC K4 and M1, Aquila will provide to MDEQ within 60 days of MDEQ's issuance of the Amendment, an updated EMP and QAPP that addresses information noted in the comment.

Comment #33:
Section 4.5 of Module 4, Fish Tissue Sampling: Procedure #31 has been reformatted and is now Procedure #4. Here is a link to the revised procedure: https://www.michigan.gov/documents/deq/wrd-swas-proc31_445628_7.pdf

Response to Comment #33:
Aquila agrees to use the recommended reformatted procedure. Consistent with MP 01 2016 SPC K4 and M1, Aquila will provide to MDEQ within 60 days of MDEQ's issuance of the Amendment, an updated EMP and QAPP that addresses information noted in the comment.

Comment #34:
Module 4, References: MDEQ, 2002a and MDEQ 2008 are the same document, but it has been updated.

Response to Comment #34:
Comment noted.

Comment #35:
Module 4, Table 4-1, Aquatic Sampling Station Description: In the previous 632 application review, WRD indicated that AQ1 was not a good location for a "background" condition sampling location. It is upstream of the White Rapids Dam and therefore some parameters [e.g. temperature, TSS, dissolved oxygen, and substrate (habitat)] are likely to be impacted by backwater from the dam. The habitat data in Table 4-2 indicates sediment may have been trapped at AQ1 when compared to AQ2 and AQ3, both of which include some riffle/run habitat. A site should be selected that is downstream of the dam some distance to be out of the direct effects of a dam discharge, but upstream of the proposed mining activities. Provide a revised Table 4-1 with latitude and longitude locations of monitoring locations, including revised location for AQ1, and a revised Figure 4-2 showing aquatic sampling locations. Aquatic sampling should be conducted at the new location pre-operations.

Response to Comment #35:
Aquila agrees to move station AQ1 as directed. In the spring of 2019, Aquila will survey the Menominee River below the dam and identify an appropriate reach of the river for AQ1. This information will be provided to MDEQ as part of a consolidated EMP satisfying MP 01 2016 SPC K4 and M1.

Comment #36:
Module 4, Table 4-2: What quantitative measures will the facility use to describe habitat availability at each station and measure changes in that availability of habitat to biotic communities over time?

Response to Comment #36:
Consistent with MP 01 2016 SPC K4 and M1, Aquila will provide to MDEQ within 60 days of MDEQ's issuance of the Amendment, an updated EMP and QAPP that addresses information noted in the comment.

Comment #37:
Module 4, Table 4-3: Add a foot note that Module 7 covers postclosure monitoring.

Response to Comment #37:
An updated Table 4-3 is provided in Attachment 37.

Consistent with MP 01 2016 SPC K4 and M1, Aquila will provide to MDEQ within 60 days of MDEQ's issuance of the Amendment, an updated EMP and QAPP that addresses information noted in the comment.

Comment #38:
Module 5, Table 5-1: For consistency with the NPDES effluent water quality monitoring, provide a revised Table 2-2 to include the following additional parameters: Barium, Beryllium, Boron, Total Chromium, Hexavalent Chromium, Total Cobalt, Lithium, Molybdenum, Strontium, Thallium, and Vanadium. See item #38 regarding detection levels.

Response to Comment #38:
Table 5-1 lists water quality parameters to be sampled from contact water sources. Aquila agrees that it makes sense to sample these sources of water for the same effluent water quality parameters listed in the NPDES Permit.

Consistent with MP 01 2016 SPC K4 and M1, Aquila will provide to MDEQ within 60 days of MDEQ's issuance of the Amendment, an updated EMP and QAPP that addresses information noted in the comment.

Comment #39:
Module 5, Table 5-2, Wastewater discharge effluent to Menominee River Sampling Parameters: A foot note on the table indicates that target detection levels were "adjusted per laboratory capabilities and requirements of the event." Per the NPDES permit: "Justification for higher quantification levels shall be submitted to the Department within 30 days of such determination. Upon approval from the Department, the permittee may use alternate analytical methods (for parameters with methods specified in 40 CFR 136, the alternate methods are restricted to those listed in 40 CFR 136)." As this would be addressed through the NPDES permit, it is recommended to contact WRD regarding quantification levels.

Response to Comment #39:
Attachment 39 contains an updated version of Table 5-2 without the footnote and corrected quantification levels. Consistent with MP 01 2016 SPC K4 and M1, Aquila will incorporate this change in the forthcoming updated information satisfying these permit conditions.

Comment #40:
Once approved by WRD through compliance with the wetland permit, the wetland monitoring plan shall be submitted to OGMD and the EMP shall be revised to include wetland monitoring during operations and Module 7 shall be updated to include continued wetland monitoring during the postclosure monitoring period.

Response to Comment #40:
Within 60 days of MDEQ's issuance of the Part 632 amendment, Aquila will provide as Module 7 the referenced Wetland Monitoring Plan.

Comment #41:
Module 7, Table 7-3: Is location MSG-9 monitoring the Menominee River, or a tributary?

Response to Comment #41:
See Attachment 27. As noted in the NPDES Fact Sheet, MSG-9 is monitoring an unnamed tributary to the Menominee River.

Comment #42:
Module 7: A written request to terminate the postclosure monitoring shall be provided to the DEQ not less than 18 months before the proposed termination date, including technical data and information demonstrating the basis for termination, as required by R425.407 of Part 632.

Response to Comment #42:
Comment noted.

Comment #43:
Module 8, Quality Assurance Project Plan: What QA/QC protocols will be followed for pre-operations confirmation baseline surface water monitoring required by SPC K5?

Response to Comment #43:
Consistent with MP 01 2016 SPC K4 and M1, Aquila will provide to MDEQ within 60 days of MDEQ's issuance of the Amendment, an updated EMP and QAPP that addresses information noted in the comment.

Comment #44:
Section 5.4 of Module 8: Explain how information from sections 4 and 5 will be documented.

Response to Comment #44:
Documentation information related to Section 5.4.1 through 5.4.5 will be documented in field monitoring reports that will be preserved by Aquila and will be included in annual reports to substantiate the activities.

Environmental Impact Assessment, Volume II:

Comment #45:
Section 2.5 Surface Water: One year of additional baseline data on the surface water stations identified in SPC K3 of the mining permit is required prior to operations. Has Aquila Resources initiated this monitoring?

Response to Comment #45:
Aquila is performing surface water quality monitoring to maintain a record of conditions in surrounding surface water. It is understood by Aquila that the official starting point for one year of additional baseline data is subject to MDEQ approval.

Comment #46:
Section 2.5.1 Potential Impacts to Surface Water Quantity: Part 301 requires a permit to diminish an inland lake or stream. Is mine dewatering induced drawdown of groundwater expected to impact any area streams?

Response to Comment #46:
A groundwater drawdown map (Figure 5-5 - Projected Drawdown, Mine Year 7) was provided in the Groundwater Modeling Report, found in Appendix D-4 of the 2015 EIA (Foth, 2015c). This map shows drawdown is expected to be negligible near area streams. In the case of the Menominee River, this is due to the significant river flow relative to the pit dewatering rate, essentially acting as a constant head boundary. In the case of the smaller streams in the Shakey River watershed, this is due to their distance from the proposed pit and significant watershed size providing baseflow. An environmental water balance was completed to assess this issue and is further described below in response to Comment 47.

Comment #47:
Appendix B, Update to Site-Wide Water Balance: Total streamflow contributions to the Shakey River watershed are predicted to be reduced by 41 m3/hr (6.1% decrease from current conditions) relative to existing conditions during operations. What is the expected impact to streamflows within the Shakey River watershed due to this reduction?

Response to Comment #47:
The 41 m^3/hr reduction in streamflow contributions to the Shakey River watershed represents a 6.1% decrease relative to only the immediate portion of the Shakey River watershed adjacent to the project area. This smaller subsection of the Shakey River watershed, termed the 'affected area', equals 4,379 acres (as shown on Figure 1 – Water Balance Affected Areas, found in the Site-wide Water Balance Memorandum in Appendix D-6 of the 2015 EIA) (Foth, 2015c). By contrast, the full Shakey River/Little Shakey Creek-Shakey River watershed size (also shown on Figure 1) is approximately 34,584 acres.

Therefore, the 6.1% flow contribution reduction, viewed in terms of the overall watershed size, equals 0.77% (6.1% * 4,379 ac /34,584 ac). The change in flow through the Shakey River and its watershed will be *de minimus*, that is, not measureable. Furthermore, there will be no reduction in an inland lake or stream.

Comment #48:
Section 4, Feasible and Prudent Alternatives: Were any other methods evaluated for development of the TMF? Why is the proposed design preferred?

Response to Comment #48:
Yes, several alternative tailings and waste rock management concepts and methods have been evaluated by Aquila since 2008, which have included the following trade-offs:

- Integrated tailings and waste rock facilities vs. separate facilities.
- Thickened tailings vs. conventional slurry vs. filtered tailings.
- Alternative sites, layouts, and configurations.

The specific alternatives that were evaluated are presented in Table 5-1 of the EIAA (Volume II of the MPAA) [Foth, 2018b] and described further in the Wetland Permit Application (Foth, 2017). The alternatives were evaluated in terms of the following criteria:

- Potential aquatic resource impacts.
- Constructability and technical feasibility.
- Economic viability.

The preferred alternative was a thickened (dewatered) tailings stack contained by perimeter thickened tailings berms (TMF) site next to the mine pit, with adjacent and adjoining waste rock stockpiles (SWRF and NWRF) as presented in Appendix C of the MPA (Foth, 2015a). This alternative was selected for the following major reasons:

- Thickened tailings were selected because they allow for a stable and dense tailings mass upon deposition, they retain moisture to reduce acid generating and dusting potential, and they reduce the quantity of water being managed within the TMF. Conventional slurry contrarily require large storage footprints and large water-retaining dam structures, and filtered tailings do not retain moisture which promotes acid and dust generating potential.

- Adjacent and adjoining waste rock stockpiles were selected to isolate potentially acid generating rock to the extent possible so it can be selectively monitored geochemically and backfilled to the mine pit at closure, thereby improving reclamation of the site by minimizing the footprint of mine waste facilities that exist and by restoring the mine pit at closure.

- The TMF was sited next to the mine pit and equipped with an emergency spillway as a contingency for extreme storm events. This feature provides a flow channel to convey contact water from the TMF decant area to the mine pit (which acts as a sump) during the Probable Maximum Precipitation event to maintain TMF stability and to avoid the release of contact water. The emergency spillway, however, is not anticipated to be activated during the mine life because the TMF and decant area are designed to safely contain the 100-year, 24-hour storm.

References

Foth Infrastructure & Environment, LLC, 2018a. *Mining Permit Amendment Application Back Forty Project, Volume I*. November 2018.

Foth Infrastructure & Environment, LLC, 2018b. *Mining Permit Amendment Application Back Forty Project, Volume II, Environmental Impact Assessment Amendment*. November 2018.

Foth Infrastructure & Environment, LLC, 2015a. *Mining Permit Application Back Forty Project*. October 2015.

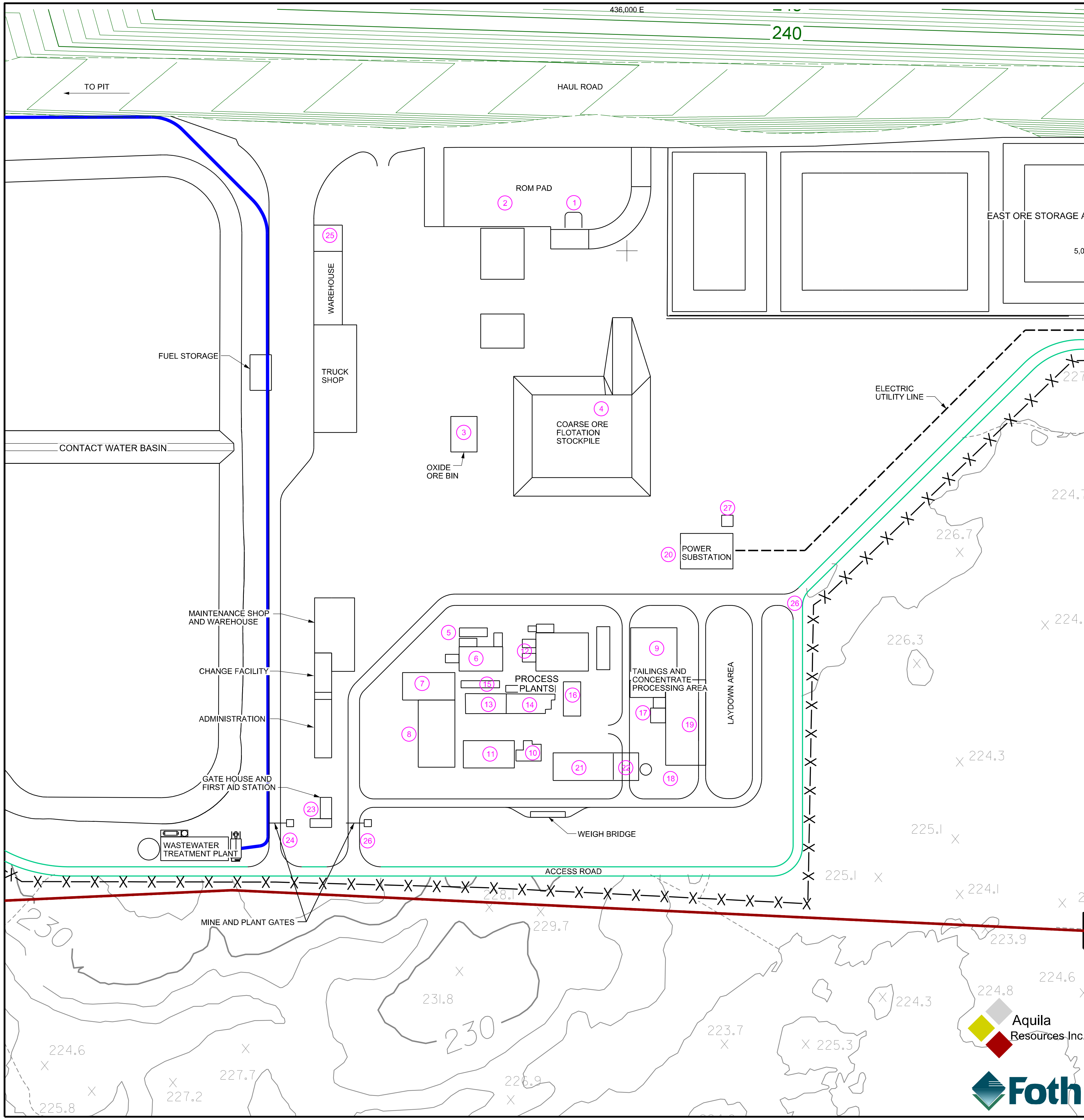
Foth Infrastructure & Environment, LLC, 2015b. *State of Michigan National Pollutant Discharge Elimination System Permit Application for Discharges to Surface Waters Back Forty Project*. October 2015.

Foth Infrastructure & Environment, LLC, 2015c. *Environmental Impact Assessment Back Forty Project*. October 2015.

Foth Infrastructure & Environment, LLC, 2016. *Response to Michigan Department of Environmental Quality Comments dated May 9, 2016 on the Back Forty Project Mine Permit Application*. June 2016.

Foth Infrastructure & Environment, LLC, 2017. *Permit Application – Back Forty Project. MDEQ/USACE Joint Permit Application for Wetland Protection, Inland Lakes and Streams, and Floodplain. MDEQ Submittal No. 2NN-5PE0-MT3W*. October 2017.

Attachment 2



N

LEGEND

1	FLOTATION ORE CRUSHING
2	OXIDE CRUSHING
3	OXIDE ORE BIN
4	FLOTATION ORE STOCKPILE
5	OXIDE MILLING
6	OXIDE PRELEACH THICKENER
7	LEACH
8	CCD CIRCUIT
9	TAILINGS
10	MERRILL CROWE CIRCUIT
11	GOLD ROOM
12	FLOTATION ORE MILLING
13	BULK ROUGHERS/CLEANERS/REGRIND
14	ZINC ROUGHERS/CLEANERS/REGRIND
15	FLOTATION AIR SYSTEM
16	WATER SERVICES
17	FILTRATION SERVICES
18	FILTRATION AREA
19	CONCENTRATE HANDLING
20	HV/MV SWITCHYARD
21	REAGENT MIXING/STORAGE
22	REAGENT UNLOADING SHORT TERM STORAGE
23	GATEHOUSE & FIRST AID STATION
24	MINE/PERSONNEL ACCESS GATE
25	COVERED TRUCK WASH FACILITY
26	PLANT ACCESS GATE
27	CERTIFIED GENERATORS

LEGEND

- PROJECT BOUNDARY
- PROPOSED STRUCTURE
- PROPOSED WATER TREATMENT DISCHARGE PIPELINE
- PROPOSED SITE ACCESS ROAD
- 440 PROPOSED DESIGN CONTOUR

30 0 30 60 90
SCALE 1:3,000 METERS

FACILITY LAYOUTS SUBJECT TO CHANGE

Aquila Resources Inc.

Foth

Foth Infrastructure & Environment, LLC			
REVISED	DATE	BY	DESCRIPTION
1	3/19	AKM	IMPROVED FIGURE

PREPARED BY:	AKM	DATE:	MAR.'19
REVIEWED BY:	MJV2	DATE:	MAR.'19
APPROVED BY:	SVD1	DATE:	MAR.'19

BACK FORTY PROJECT

FIGURE 4-3
ORE PROCESS PLANTS
MINING PERMIT AMENDMENT APPLICATION
STEPHENSON, MICHIGAN

Scale:	AS SHOWN	Date:	MARCH 2019
Drafted By:	JOW	Project No.	17A021

X:\GB\IE\2014\14A021-00\CAD\MPA-Amendment\Figure 4-3 Ore Process Plants.dgn
3/1/2019 jow

Attachment 21

Table 1-1
Identification of Groundwater Monitoring Wells and Piezometers

Well ID	Northing (m)	Easting (m)	Status	Purpose	Action Items
CW-1	5,032,585.00	435,781.00	Proposed	Compliance Well - CWB, process plant and Fuel storage and dispensing area, June 2016 Comment response 35	Install well at appropriate time.[1]
CW-2	5,033,060.00	435,822.00	Proposed	Compliance Well - ore blending	Install well at appropriate time.[1]
CW-3 [3]	5,033,520.00	435,460.00	Proposed	Leachate / Compliance - TMF	Install well at appropriate time.[1]
CW-4	5,033,923.00	436,209.00	Proposed	Leachate / Compliance - TMF	Install well at appropriate time.[1]
CW-5 [3]	5,034,075.00	436,685.00	Proposed	Leachate / Compliance - TMF	Install well at appropriate time.[1]
CW-6 [3]	5,033,580.00	436,905.00	Proposed	Leachate / Compliance - TMF	Install well at appropriate time.[1]
CW-7	5,033,197.00	437,318.00	Proposed	Leachate / Compliance - TMF	Install well at appropriate time.[1]
CW-8	5,032,755.00	436,212.00	Proposed	Compliance Well - Ore Stockpile, process plant	Install well at appropriate time.[1]
CW-9	5,033,100.00	435,495.00	Proposed	Compliance Well - Ore Stockpile / CWB / Haul Road.	Install well at appropriate time.[1]
CW-10	5,032,529.00	434,907.00	Proposed	Compliance Well - Mine Waste Storage Area. June 2016 Comment response 44, south of pit and storage areas, south of mill and west.	Install well at appropriate time.[1]
CW-11	5,033,025.00	434,539.00	Proposed	Compliance Well - South Mine Waste Storage Area, June 2016 Comment Response 44, south of pit and all storage areas	Install well at appropriate time.[1]
CW-12	5,033,380.00	434,734.00	Proposed	Compliance Well - Mine Pit - Cut off wall - Tentative location, confirm upon cut off wall placement	Install well at appropriate time.[1]
CW-13	5,033,624.00	434,879.00	Proposed	Compliance Well - Mine Pit - Cut off wall - Tentative location, confirm upon cut off wall placement	Install well at appropriate time.[1]
CW-14	5,033,745.00	436,010.00	Proposed	Leachate/ Compliance - TMF	Install well at appropriate time.[1]
CW-15	5,033,285.00	435,800.00	Proposed	Leachate/ Compliance - West Ore Stockpile	Install well at appropriate time.[1]
CW-16 [3]	5,032,655.00	435,350.00	Proposed	Compliance Well - CWB	Install well at appropriate time.[1]
CW-17 [3]	5,033,205.00	434,695.00	Proposed	Compliance Well - Pit	Install well at appropriate time.[1]
FMW-1	5,033,146.55	435,834.97	Existing	Obstructed by facility	Abandon at appropriate time.
FMW-2	5,032,879.34	436,198.12	Existing	Obstructed by facility	Abandon at appropriate time.
FMW-3	5,033,276.09	436,328.45	Existing	Obstructed by facility	Abandon at appropriate time.
FMW-4	5,033,662.57	436,134.56	Existing	Obstructed by facility	Abandon at appropriate time.
FMW-5	5,033,865.87	436,547.13	Existing	Obstructed by facility	Abandon at appropriate time.
FMW-6	5,032,979.30	435,249.86	Existing	Compliance Well - CWB / Mine Waste Storage Area	Continue baseline monitoring
FMW-7	5,033,314.70	437,222.03	Existing	Obstructed by facility	Abandon at appropriate time.
FMW-8	5,033,829.36	437,205.32	Existing	Regional Monitoring - within project boundary	Continue baseline monitoring
FMW-10	5,033,470.60	435,816.40	Existing	Obstructed by facility	Abandon at appropriate time.
FMW-11	5,033,469.60	436,122.50	Existing	Obstructed by facility	Abandon at appropriate time.
FMW-12	5,033,197.30	436,028.60	Existing	Obstructed by facility	Abandon at appropriate time.
GMW-1	5,033,376.70	434,794.10	Existing	Obstructed by facility	Abandon at appropriate time.
GMW-2	5,034,350.00	434,804.80	Existing	Obstructed by facility - confirm	Abandon at appropriate time.
GMW-3	5,033,516.80	434,844.80	Existing	Obstructed by facility	Abandon at appropriate time.
GMW-4	5,033,577.30	434,869.90	Existing	Obstructed by facility - confirm	Abandon at appropriate time.
GMW-5	5,033,620.40	434,945.70	Existing	Obstructed by facility	Abandon at appropriate time.
MW-1	5,033,719.09	436,263.18	Existing	Obstructed by facility	Abandon at appropriate time.
MW-2	5,033,396.79	435,575.62	Existing	Obstructed by facility	Abandon at appropriate time.

Table 1-1 ***(Continued)***

Well ID	Northing (m)	Easting (m)	Status	Purpose	Action Items
MW-3	5,032,721.41	435,797.78	Existing	Obstructed by facility	Abandon at appropriate time.
MW-4	5,033,263.96	436,729.27	Existing	Obstructed by facility	Abandon at appropriate time.
MW-5	5,032,658.25	436,928.64	Existing	Regional Monitoring - within project boundary	Continue baseline monitoring
MW-6/6S	5,032,712.76	434,001.97	Existing	Regional Monitoring - within project boundary	Continue baseline monitoring
MW-7	5,032,549.20	434,573.25	Existing	Obstructed by facility	Abandon at appropriate time.
MW-8	5,032,655.65	435,028.44	Existing	Obstructed by facility	Abandon at appropriate time.
MW-9/PC	5,033,795.01	435,093.59	Existing	Regional Monitoring - within project boundary	Continue baseline monitoring
MW-10/PC/SS	5,033,607.06	437,220.83	Existing	Regional Monitoring - within project boundary	Continue baseline monitoring
MW-11PC/S/SS	5,032,467.66	438,206.68	Existing	Regional Monitoring	Continue baseline monitoring
MW-12	5,034,049.62	438,325.38	Existing	Regional Monitoring	Continue baseline monitoring
MW-13D/PC/S/SS	5,035,109.78	437,589.55	Existing	Regional Monitoring	Continue baseline monitoring
MW-14	5,034,548.15	439,394.93	Existing	Regional Monitoring	Continue baseline monitoring
MW-15D/PC/S/SS	5,034,081.98	439,352.12	Existing	Regional Monitoring	Continue baseline monitoring
MW-16	5,033,217.79	439,223.32	Existing	Regional Monitoring	Continue baseline monitoring
MW-17SS	5,032,655.86	438,936.40	Existing	Regional Monitoring	Continue baseline monitoring
MW-18P/PC/S	5,033,355.98	434,735.68	Existing	Obstructed by facility	Abandon at appropriate time.
MW-20	5,034,042.78	434,347.39	Existing	Regional Monitoring (Wisconsin)	Continue baseline monitoring
MW-21	5,034,055.00	435,800.00	Proposed	Regional Monitoring	Install well at appropriate time.[1]
PZ-1/1A	5,033,107.30	434,724.70	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-2/2A	5,032,749.40	435,453.30	Existing	Obstructed by facility	Abandon at appropriate time.
PZ-3	5,033,468.74	435,683.14	Existing	Obstructed by facility	Abandon at appropriate time.
PZ-4	5,033,408.00	439,308.00	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-5/5A	5,032,593.00	436,588.50	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-6/6A	5,034,011.60	437,095.60	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-7	5,035,091.00	437,413.00	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-8	5,034,695.00	438,119.00	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-9/9A	5,034,086.40	439,353.40	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-10/10A	5,033,765.80	435,547.80	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-11/11A	5,032,564.30	435,176.10	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-12/12A	5,032,527.00	434,877.00	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-13/13A	5,033,246.90	435,889.00	Existing	Obstructed by facility	Abandon at appropriate time.
PZ-14/14A	5,033,741.46	435,472.54	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-15/15A	5,032,682.37	435,312.47	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-16/16A	5,032,821.12	436,354.64	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-17/17A	5,032,619.89	436,176.58	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-18/18A	5,032,998.30	436,794.04	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-19/19A	5,032,836.99	436,709.73	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-20/20A	5,033,513.67	436,914.97	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-21/21A	5,033,654.45	436,750.85	Existing	Wetland Monitoring	Continue baseline monitoring
PZ-22/22A	5,034,058.27	436,530.82	Existing	Wetland Monitoring	Monitors WL40, (MP SPC
PZ-23/23A	5,034,097.32	436,639.33	Existing	Wetland Monitoring	Monitors WL40, (MP SPC
PZ-24/24A	5,033,844.00	435,664.40	Existing	Wetland Monitoring	Continue baseline monitoring

Notes:

Prepared by: HLH
Checked by: AKM

[1] Install or abandon monitoirng well prior to or during construction.

[2] Proposed wells will be presented in anticipated 2018 mining permit amendment application. Begin sampling as soon as possible to establish baseline data.

[3] Proposed wells were added or relocated in March 2019 Response to Comments.

abandon

proposed to install

Abbreviations:

MP SPC = Mining Permit 01 2016 Special Condition

CWB = contact water basin;

m = meters

TMF = tailings management facility

Table 1-2
Groundwater Monitoring and Sampling Locations

Well ID	Pre-Construction		Pre-Operations		Operations	
	Groundwater Elevation Frequency	Water Quality Sampling Frequency	Groundwater Elevation Frequency	Water Quality Sampling Frequency	Groundwater Elevation Frequency[3]	Water Quality Sampling Frequency
Monitoring Wells						
CW-1 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-2 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-3 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-4 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-5 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-6 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-7 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-8 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-9 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-10 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-11 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-12 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-13 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-14 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-15 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-16	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
CW-17	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
FMW-1 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
FMW-2 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
FMW-3 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
FMW-4 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
FMW-5 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
FMW-6	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
FMW-7 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
FMW-8	Monthly	None	Monthly	None	Monthly	None
FMW-10 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
FMW-11 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
FMW-12 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
GMW-1 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
GMW-2 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
GMW-3 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
GMW-4 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
GMW-5 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
MW-1 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
MW-2 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
MW-3 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
MW-4 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
MW-5	Monthly	None	Monthly	None	Monthly	None
MW-6/6S	Monthly	None	Monthly	None	Monthly	None
MW-7 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
MW-8 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
MW-9/PC	Monthly	None	Monthly	None	Monthly	None
MW10	Monthly	None	Monthly	None	Monthly	None

Table 1-2 ***(Continued)***

Well ID	Pre-Construction		Pre-Operations		Operations	
	Groundwater Elevation Frequency	Water Quality Sampling Frequency	Groundwater Elevation Frequency	Water Quality Sampling Frequency	Groundwater Elevation Frequency[3]	Water Quality Sampling Frequency
MW-11PC/S/SS	Monthly	None	Monthly	None	Monthly	None
MW-12	Monthly	None	Monthly	None	Monthly	None
MW-13D/PC/S/SS	Monthly	None	Monthly	None	Monthly	None
MW-14	Monthly	None	Monthly	None	Monthly	None
MW-15D/PC/S/SS	Monthly	None	Monthly	None	Monthly	None
MW-16	Monthly	None	Monthly	None	Monthly	None
MW-17SS	Monthly	None	Monthly	None	Monthly	None
MW-18P/PC/S [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
MW-20	Monthly	None	Monthly	None	Monthly	None
MW-21 [1]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
Piezometers						
PZ-1/1A	Monthly	None	Monthly	None	Monthly	None
PZ-2/2A [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
PZ-3 [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
PZ-4	Monthly	None	Monthly	None	Monthly	None
PZ-5/5A	Monthly	None	Monthly	None	Monthly	None
PZ-6/6A	Monthly	None	Monthly	None	Monthly	None
PZ-7	Monthly	None	Monthly	None	Monthly	None
PZ-8	Monthly	None	Monthly	None	Monthly	None
PZ-9/9A	Monthly	None	Monthly	None	Monthly	None
PZ-10/10A	Monthly	None	Monthly	None	Monthly	None
PZ-11/11A	Monthly	None	Monthly	None	Monthly	None
PZ-12/12A	Monthly	None	Monthly	None	Monthly	None
PZ-13/13A [2]	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
PZ-14/14A	Monthly	None	Monthly	None	Monthly	None
PZ-15/15A	Monthly	None	Monthly	None	Monthly	None
PZ-16/16A	Monthly	None	Monthly	None	Monthly	None
PZ-17/17A	Monthly	None	Monthly	None	Monthly	None
PZ-18/18A	Monthly	None	Monthly	None	Monthly	None
PZ-19/19A	Monthly	None	Monthly	None	Monthly	None
PZ-20/20A	Monthly	None	Monthly	None	Monthly	None
PZ-21/21A	Monthly	None	Monthly	None	Monthly	None
PZ-22/22A	Monthly	None	Monthly	None	Monthly	None
PZ-23/23A	Monthly	None	Monthly	None	Monthly	None
PZ-24/24A	Monthly	None	Monthly	None	Monthly	None

Notes:

Prepared by: HLH
Checked by: AKM

[1] These wells will be installed during pre-operations. If they are installed earlier, use the pre-construction monitoring guidance.

[2] These wells will be abandoned during construction. If they are present beyond construction, use the operations monitoring guidance.

[3] In March 2019, CW-3, CW-5, and CW-6 were relocated, CW-16 and CW-17 were added. Groundwater monitoring frequency during operations was changed to monthly.

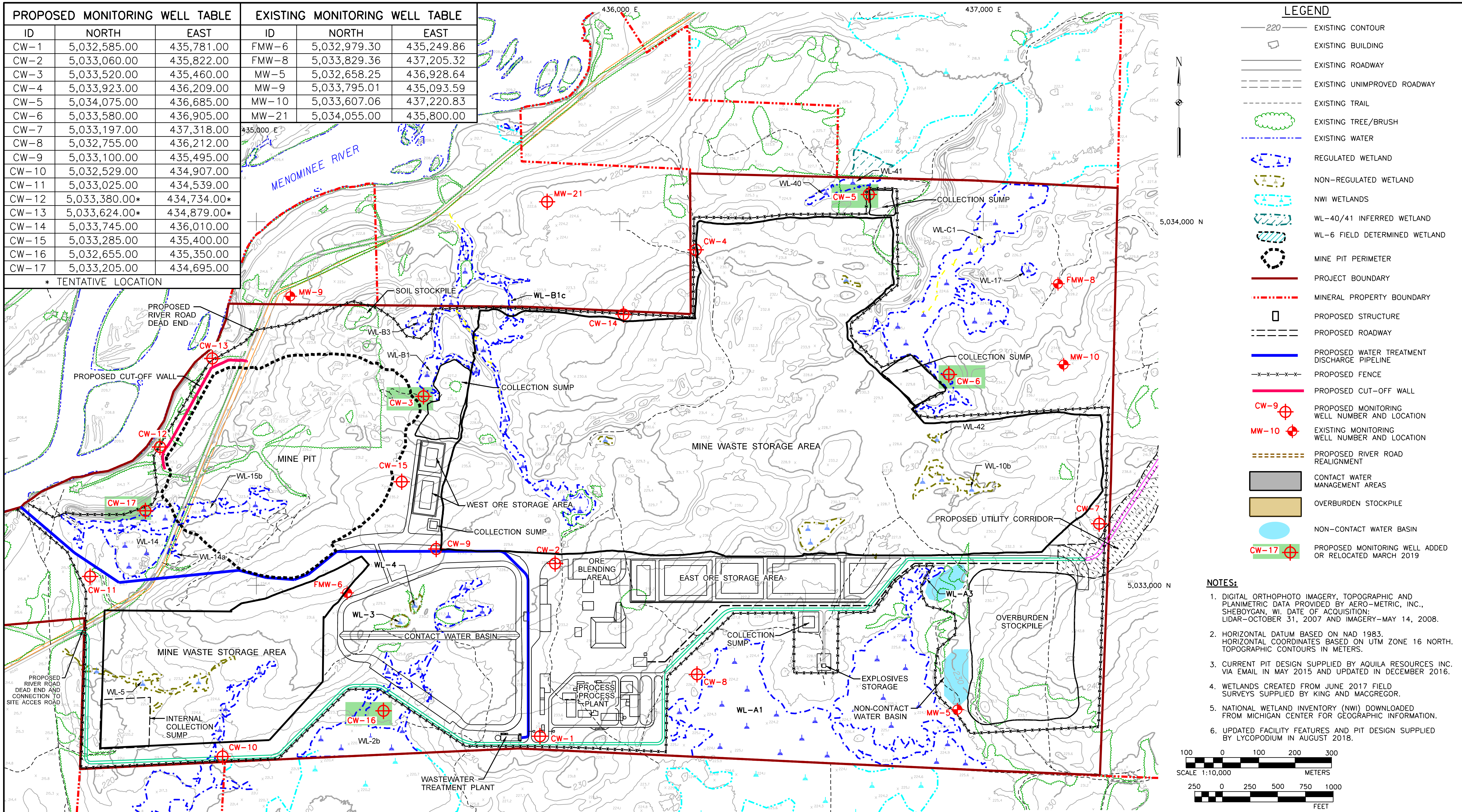
PROPOSED MONITORING WELL TABLE

ID	NORTH	EAST
CW-1	5,032,585.00	435,781.00
CW-2	5,033,060.00	435,822.00
CW-3	5,033,520.00	435,460.00
CW-4	5,033,923.00	436,209.00
CW-5	5,034,075.00	436,685.00
CW-6	5,033,580.00	436,905.00
CW-7	5,033,197.00	437,318.00
CW-8	5,032,755.00	436,212.00
CW-9	5,033,100.00	435,495.00
CW-10	5,032,529.00	434,907.00
CW-11	5,033,025.00	434,539.00
CW-12	5,033,380.00*	434,734.00*
CW-13	5,033,624.00*	434,879.00*
CW-14	5,033,745.00	436,010.00
CW-15	5,033,285.00	435,400.00
CW-16	5,032,655.00	435,350.00
CW-17	5,033,205.00	434,695.00

* TENTATIVE LOCATION

EXISTING MONITORING WELL TABLE

ID	NORTH	EAST
FMW-6	5,032,979.30	435,249.86
FMW-8	5,033,829.36	437,205.32
MW-5	5,032,658.25	436,928.64
MW-9	5,033,795.01	435,093.59
MW-10	5,033,607.06	437,220.83
MW-21	5,034,055.00	435,800.00



NOTES:

1. DIGITAL ORTHOPHOTO IMAGERY, TOPOGRAPHIC AND PLANIMETRIC DATA PROVIDED BY AERO-METRIC, INC., SHEBOYGAN, WI. DATE OF ACQUISITION: LIDAR-OCTOBER 31, 2007 AND IMAGERY-MAY 14, 2008.
2. HORIZONTAL DATUM BASED ON NAD 1983. HORIZONTAL COORDINATES BASED ON UTM ZONE 16 NORTH. TOPOGRAPHIC CONTOURS IN METERS.
3. CURRENT PIT DESIGN SUPPLIED BY AQUILA RESOURCES INC. VIA EMAIL IN MAY 2015 AND UPDATED IN DECEMBER 2016.
4. WETLANDS CREATED FROM JUNE 2017 FIELD SURVEYS SUPPLIED BY KING AND MACGREGOR.
5. NATIONAL WETLAND INVENTORY (NWI) DOWNLOADED FROM MICHIGAN CENTER FOR GEOGRAPHIC INFORMATION.
6. UPDATED FACILITY FEATURES AND PIT DESIGN SUPPLIED BY LYCOPODIUM IN AUGUST 2018.

Aquila Resources Inc.

Foth

Foth Infrastructure & Environment, LLC

REVISED	DATE	BY	DESCRIPTION
1	3/19	AKM	RESPONSE TO COMMENTS

PREPARED BY:	HLH	DATE:	FEB. '19
REVIEWED BY:	AKM	DATE:	FEB. '19
APPROVED BY:	MJV2	DATE:	FEB. '19

BACK FORTY PROJECT

FIGURE 1-2
EXISTING AND PROPOSED GROUNDWATER MONITORING WELL LOCATIONS
ENVIRONMENTAL MONITORING PLAN
STEPHENSON, MICHIGAN

Scale:	AS SHOWN	Date:	FEBRUARY 2019
Drafted By:	JOW	Project No.	17A021

X:\GB\IE\2014\14A021-00\CAD\EMP\MPA Amendment Oct 2018\Figure 1-2 Exist-Proposed Monitoring Well Locations-Feb 2019.dgn
3/1/2019 jow

Attachment 24

Foth Infrastructure & Environment LLC

Standard Operating Procedure - 1

Groundwater Monitoring Well Construction

Introduction

As part of consulting services, Foth Infrastructure & Environment, LLC (Foth) provides oversight of state certified drilling subcontractors for clients during borehole, monitoring well, and piezometer installation activities to ensure construction activities meet state and federal well construction regulations. It is important that proper borehole/well construction procedures are followed in order to eliminate the risk of surface contaminants entering the groundwater at wellheads and to eliminate the potential safety risks associated with inappropriately constructed wells.

Monitoring well construction regulations vary by state. Prior to beginning work it is important to review the state regulations for monitoring well construction in the state that the project site is located in. This Standard Operating Procedure (SOP) should be used in conjunction with all applicable state and federal regulations.

This SOP is applicable to all Foth projects where monitoring wells are constructed.

References

Michigan Administrative Rules. *Well Construction Code Administrative Rules. Report 325.* January 22, 2002. http://www.michigan.gov/deq/0,1607,7-135-3313_3675_3694-9194--,00.html

USEPA. *Region V Guidelines for Class I Well Monitoring Plans.* October 1989. http://www.epa.gov/r5water/uic/r5guid/monitor_well.htm

Personnel Qualifications

Personnel executing this protocol should have existing knowledge of drilling and well installation methods and a minimum of two (2) years field experience in monitoring well construction.

Additional Health and Safety Training Requirements:

- All field personal must have current CPR (Cardiopulmonary Resuscitation) and First Aid training.

- All field personnel must have satisfied Occupational safety and Health Administration (OSHA) training requirements (40 CFR 1910.120) if hazardous materials are expected.

- All field personnel must have satisfied Mine Safety and Health Administration (MSHA) requirements if working on a project site regulated by MSHA.

Equipment and Supplies

- Field forms (Well Construction Documentation Form, Soil Boring Log Field Form)
- Drilling oversight checklist SOP
- Soil borehole logging SOP
- Camera
- Field book
- Distilled water
- 5-gallon pail
- Alconox or equivalent detergent
- Trowel
- Ziploc® bags
- Tape measure
- Water interface probe
- Munsell soil color chart
- Pocket penetrometer
- Nitrile gloves
- Personal protective equipment
- Drill rig
- Contaminant free pens/permanent markers
- Well construction material (i.e. riser pipe, bentonite chips, filter pack, screen, etc.)
- Appropriate state administrative code and rules

Procedures

The following procedure should be used as a guideline by Foth employees in conjunction with all applicable state and federal well construction regulations found in the reference section of this SOP to ensure proper documentation and oversight of well installation:

1. Mobilization to proposed monitoring well location as specified in the project work plan.

2. Complete the drilling section of the Drilling Oversight Checklist SOP.

3. Log all drill core obtained in accordance with the Soil Logging Procedure for Unconsolidated Sediment Borehole Logging.

4. Verify well construction plans based on field observations with the technology coordinator or project manager as appropriate.

5. Once the target depth is met and the borehole is reamed, verify the depth by tagging the bottom of the borehole. Record this in the field log book.

6. Watch as the monitoring well is constructed in the borehole. Record all observations in the Field Log Book and well construction field form.

    a. Count each segment of the well screen, and determine the well screen footage. Verify the screen slot size and length is correct.
    b. Count each segment of the well casing, and determine the well casing footage. Verify the well casing diameter, thickness, and length is correct.
    c. Sum the length of the installed well screen and well casing. Verify the total well length is correct.

7. Watch as the annular space is filled. Record all observations in the Field Log Book and well construction field form.

    a. Record the type of filter pack material being used. Verify that the filter pack being used is in compliance with the work plan and any applicable regulations.
    b. Verify that the filter pack is being placed using a tremie method.
    c. Have the driller tag the top of the filter pack, verify that the top of the filter pack is placed as required by the work plan or applicable regulations at the appropriate height above the well screen. Verify that the driller has surged the well screen, and that the filter pack is at the appropriate height.
    d. If transition sand is being used, complete the last three steps with the transition sand layer.
    e. Record the type of bentonite chip/pellet seal being placed between the filter pack (or transition sand) and the annular seal.
    f. Verify that the seal is being placed using a tremie method.
    g. Have the driller tag the top of the bentonite chip/pellet seal, and verify that the top of the seal is placed as required by the work plan or applicable regulations at the appropriate height above the well screen. Verify that the driller hydrates this layer prior to placing the bentonite seal.
    h. Record the type of annular seal material being used.
    i. Record the ratio of bentonite/cement/water mixture being used.
    j. Count the number of bags of mix and gallons of seal placed down the hole. Compare the volume to the table below to ensure enough material was placed in the borehole.

Volume of Open Boreholes and Annulus Between Casing and Hole							
Hole Diameter	Volume/ Lineal Ft. of Hole		Nominal Casing Diameter	Volume Gal/Linear Ft. of Annulus		Lbs Sand/ Lineal Ft. of Annulus	Lbs 1/2 " Pellets Per Lineal Ft. of Annulus
	Gal.	Cu Ft.		Gal.	Cu Ft.		
7 1/4"	2.14	.29	1 1/4"	2.03	0.27	27	21
7 1/4"	2.14	.29	2"	1.91	0.26	26	20
7 3/4"	2.45	.33	2"	2.22	0.30	30	23
8 1/4"	2.78	.37	2"	2.55	0.34	34	26
10 1/4" 1/4"	4.29	.57	2"	4.06	0.54	54	41
8 1/4"	2.78	.37	3"	2.28	0.30	30	23
10 1/4" 1/4"	4.29	.57	3"	3.79	0.51	51	38
12 1/4" 1/4"	6.13	.82	3"	5.62	0.75	75	57
8 1/4"	2.78	.37	4"	1.95	0.26	26	20
10 1/4" 1/4"	4.29	.57	4"	3.46	0.46	46	35
12 1/4" 1/4"	6.13	.82	4"	5.30	0.71	71	54
12 1/4"	6.13	.82	6"	4.33	0.58	58	44

8. Watch as the monitoring well is completed. Record all observations in the Field Log Book and well construction field form.

9. Verify that the monitoring well casing is cut level at the appropriate height above ground surface.

10. Using the water probe, record the water level and total well length in the well construction field log.

11. Verify that the well has been installed straight by physically looking straight down the hole with a light.

12. Verify that an approved protective well completion and well cap was installed in accordance with the work plan and applicable regulations.

13. Upon completion of the monitoring well and protective casing completion:

    a. Mark north on the top of the well casing and label the casing and well cap with the well identification number using a permanent, contaminant free marker.
    b. Install an approved lock on the protective well casing.

Foth Infrastructure & Environment LLC

Standard Operating Procedure - 2

Groundwater Monitoring Well Development

Introduction

As part of consulting services, Foth Infrastructure & Environment, LLC (Foth) provides oversight of state certified drilling subcontractors or performs well development for clients after monitoring well and piezometer construction activities. It is important that proper monitoring well/piezometer development procedures are followed in order to insure representative samples will be collected from the monitoring well or piezometer.

This Standard Operating Procedure (SOP) is applicable to all Foth projects where groundwater wells are developed.

References

Michigan Administrative Rules. Well Construction Code Administrative Rules. Report 325. January 22, 2002. http://www.michigan.gov/deq/0,1607,7-135-3313_3675_3694-9194--,00.html

USEPA. Region V Guidelines for Class I Well Monitoring Plans. October 1989. http://www.epa.gov/r5water/uic/r5guid/monitor_well.htm

Personnel Qualifications

Personnel executing this protocol should have existing knowledge of well development methods and a minimum of two (2) years field experience in well development procedures. Personnel operating a well development rig should have a minimum of one (1) year experience working on a well development rig.

Additional Health and Safety Training Requirements:

- All field personnel must have current CPR (Cardiopulmonary Resuscitation) and First Aid training.
- All field personnel must have satisfied Occupational safety and Health Administration (OSHA) training requirements (40 CFR 1910.120) if hazardous materials are expected.
- All field personnel must have satisfied Mine Safety and Health Administration (MSHA) requirements if working on a project site regulated by MSHA.

Equipment and Supplies

- Well Development Documentation Forms (Attachment A or applicable state form)
- Field Book
- Pens/Permanent Markers
- Water Level Indicator
- Bailer or Pump
- Power source for pump
- Bailer or Surge Block
- Rope
- pH and Conductivity meter, if needed
- Appropriate State administrative code and rules

Procedures

It is the policy of Foth to follow the procedures used for the installation and development of groundwater monitoring wells which are outlined in the administrative codes and rules given in the reference section of this SOP. The appropriate administrative codes and/or rules will be determined based on which state the groundwater wells are in.

The following presents a general procedure for personnel to follow to ensure the proper development of monitoring wells:

All monitoring wells will be developed by the driller after the grout has set for at least

24 hours by surging and bailing or by over-pumping. By alternating pumping and well recovery, over-pumping will agitate the filter pack sufficiently to remove fines. Alternatively, surging with a surge block or bailer will agitate the filter pack to remove fines. The discharge from the well will be monitored continuously.
Before they are developed, water levels will be measured with an electronic water level probe. The bottom of the well will be tagged with a decontaminated measuring tape to determine the amount of sediment that accumulated in the monitoring well during construction.

The well will be developed until a particulate-free discharge is observed and the field parameters (pH, specific conductance, turbidity, and temperature) have stabilized. Field parameters will be recorded on the well development record after removing each well volume.

The field staff will record the following during well development:

- Field parameters
- Time spent on each operation: surging, bailing, and pumping
- Well volumes and gallons removed
- Estimated pumping rate

Development will continue until field parameters have stabilized within 10 percent of the previous reading. The field staff will discuss the field parameter data and development with the Field Manager. The Field Manager and Project Manager will decide when development is complete. All development equipment will be decontaminated after developing each well.

Foth Infrastructure & Environment, LLC

Standard Operating Procedure - 3

Staff Gauge Installation and Elevation Recording

Introduction

The purpose of this Standard Operating Procedure is to establish a field procedures for installing the staff gauge and recording the stream elevation. Staff gauge measurements are measured at established locations, including drainage ditch or streams that feature water that generally moves uni-directionally. The staff gauges will allow for stream elevations to be measured when surface water sampling events are initiated during high rain events.

Personnel Qualifications

A minimum of one person is required to complete the installation and elevation measurements and should be trained in this measurement technique.

Equipment and Supplies

- Portable Staff Gauge
- Level
- Waterproof boots
- Sharpie or waterproof marker
- Field Log Book (refer to the *Field Log Book* SOP)

Staff Gauge Installation Procedures

Upon arrival at each staff gauge location, the initial set up will ideally follow the criteria listed below to obtain the highest quality and consistency of the staff gauge elevation measurement. The selected staff gauge locations are readily and safely accessible for ease of installation and safety during recording of the stream elevation.

Staff Gauge Installation Criteria

1. Check the staff gauge location to ensure no debris is present or rock interference. Note any issues in the field log book (For additional information on field logging, please review the appropriate *Field Log Book* SOP).
2. Examine the staff gauge brackets for damage. Note any issues in the field log book.

3. Set the staff gauge in the proper location on the bracket and confirm the bolt hole points line up. The staff gauge goes on the flat edge of the bracket and on the inside of the end plate.
4. Secure the staff gauge to the staff gauge bracket with the bolt and wing nuts with the rubber spacer located between the staff gauge and bracket.
5. At the staff gauge location, use a level to confirm the staff gauge is vertically true.
6. Tighten the wing nuts once true vertical is confirmed and proceed to record the surface water elevation.

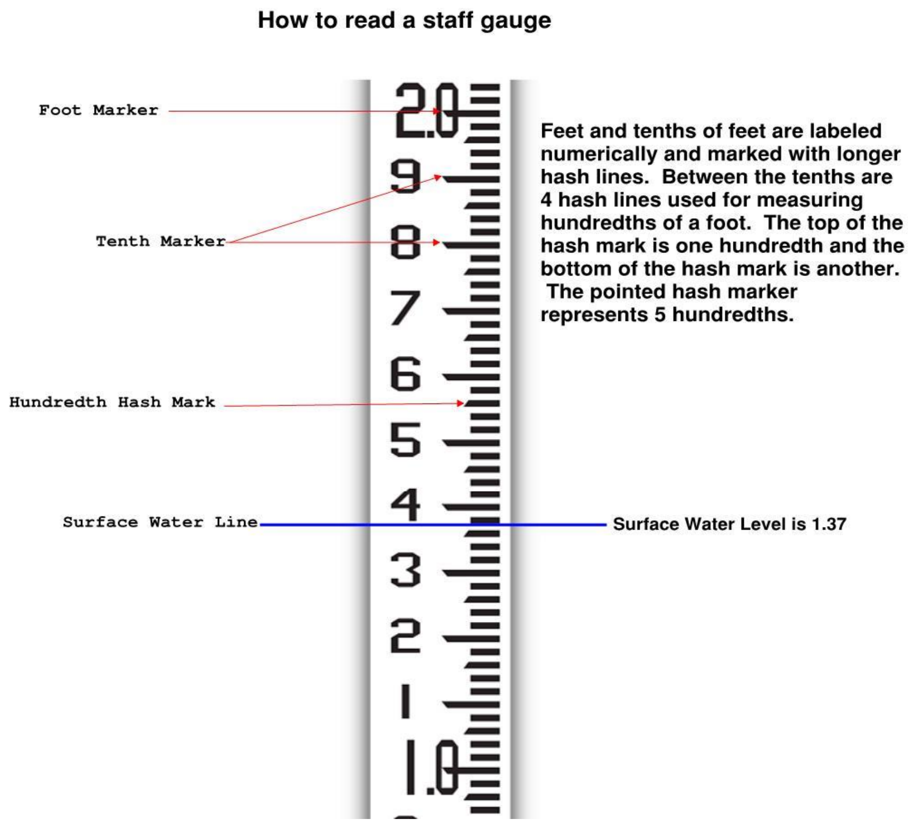
Staff Gauge Elevation Reading Procedures

Once the staff gauge is securely in place, the surface water elevation can be recorded. Use the following procedures to record the surface water elevation. Staff Gauges are similar to reading a ruler. Feet and Tenths of feet are labeled numerically and marked with longer downward hash line. Between the tenths are 4 hash lines used for measuring hundredths of a foot. The top of the hash mark is one hundredth and the bottom of the hash mark is another. The pointed hash mark represents 5 hundredths.

Surface Water Elevation Recording Procedures

1. Note the foot label above the water line and subtract 1 foot.
2. Note the tenth label above the surface water line and subtract 1 tenth.
3. Count the hundredth hashes down to the water surface. Subtract the number by 9 and record that number.
4. Record the surface water value in the field log book.

Image below illustrates how to read a staff gauge.



Foth

Foth Infrastructure & Environment, LLC

Standard Operating Procedure - 4

Groundwater Level Measurements

Introduction

The purpose of this Standard Operating Procedures (SOP) is to establish a standard procedure for collecting groundwater level measurements inside of a groundwater well.

The in-well measurements of groundwater level are the basis for understanding groundwater movement. Groundwater level measurements need to be accurate and reproducible for use as absolute measurements of groundwater elevation.

This SOP concerns measurements made in one well only and does not address issues concerning measuring these parameters in multiple wells. A complete groundwater sampling plan should be outlined using site-specific information on a per-site basis. Factors that should be taken into account when developing a site-specific procedure include number of wells to be measured, accessibility of the wells, proximity to non-groundwater water sources (i.e., oceans, lakes, rivers, storm drains, outfalls, lawn sprinklers, septic systems, etc.), time of day, time of year, traffic patterns (e.g., trains, cars, etc.), and anything else that could influence groundwater levels.

This SOP only covers groundwater measurements using an electronic water detecting probe.

References

The following SOPs are referenced in this document and will be necessary to complete this work.

Foth Infrastructure & Environment, LLC, 2012. *Environmental Checklists*.

Personnel Qualifications

None

Equipment and Supplies

Use the *Environmental Checklists* to ensure that necessary equipment, materials, and supplies are procured. Choose items from the following checklists:

- Travel

- Project Information
- Health and Safety
- General Sampling
- Groundwater Sampling
- Decontamination
- Waste Management

Special considerations for choosing the appropriate electronic probe for groundwater level measurements:

1. The diameter of the probe must be less than the open diameter of the wells at the site. Keep in mind that some wellhead locking mechanisms will decrease the opening of the well to less than the casing diameter.

2. The electronic probe must have sufficient measuring tape (cable) length to reach the bottom of all wells at the site.

The measuring tape (cable) must have length gradations of sufficient precision (0.01 feet) for the level required for that site. Most tapes can be read to one hundredth of a foot. However, some tapes are only graded to the nearest tenth of a foot.

Procedures

1. Review the Health and Safety Plan (HASP), Work Plan, and manufacturers' instructions for operating instruments.

2. Assemble inventory of materials, supplies and equipment.

3. Clean the probe and cable end by spraying with Alconox® solution, degreasing agent (i.e., 409® brand spray), or other appropriate cleanser. Wipe with cloth or paper towel and apply clean water. CAUTION: Do not use a cleaning agent that contains a constituent of concern or a constituent for which you will be analyzing.

4. Check the batteries by turning on the well probe and pressing the check button. Replace the batteries and repeat the battery check procedure if response does not occur.

5. Sometimes the cable has been damaged in the past and the end of the cable has been cut off such that the distances noted on the cable are no longer valid. Inspect the fluid measuring device from the tip of the probe to at least the first foot designation. Verify that this length is a foot. Note in a Field Log Book, or other field form, if there is a discrepancy and what the discrepancy is between what the cable reads and the actual length.

6. Examine the well and protective casing for signs of damage or tampering. If such indications are evident, contact the project manager for instructions prior to proceeding.

7. Examine the area around the well head and note in a Field Log Book, or appropriate field form, any conditions that could impact the fluid level reading. These conditions include standing water, nearby water discharge pipes, downspouts, landscape sprinklers, moving trains, leach fields, septic systems, etc.

8. Remove objects from shirt pockets that might fall into the well.

9. Unlock and open the well.

10. Perform any monitoring activities required by the HASP.

11. Note if any pressure change occurs when opening the well (i.e., the cap is hard to get off because of suction, there is a hissing sound as the cap is removed, etc.). If there is evidence of pressure change, allow the well to remain open for several minutes before taking any measurements. This will let the fluid levels equilibrate to atmospheric pressure.

12. Find the measuring point on the top of the well casing. This is usually marked with black ink and can be found on the outside, top, or inside of the well casing. If there is no mark, use a black permanent marker to mark the measuring point. If the top of the well casing is generally level, place this mark on the north side of the well casing. If the top of the well casing is very uneven, place this mark on the highest point on the casing.

13. Lower the probe into the well by pulling the cable from the reel. This can be done rather quickly if the depth to fluid is large. However, once near the anticipated fluid level, the probe should be lowered slowly so as not to overly disrupt the fluid surface one the probe makes contact with the fluid.

14. Once the probe reaches the water, either an indicator light will illuminate on the reel, an audible signal will sound, or both will occur.

15. Measure the depth to water by slowly moving the cable up and down while listening for, or watching for, the indicator. At the point where the indicator just starts (i.e., moving the cable up one hundredth of a foot causes the indicator to stop), note the cable reading that corresponds to the marked reference point at the top of the well casing. Record the cable reading to the nearest one hundredth of a foot (or the smallest increment on the cable), the well number, and the time and date of the measurement in the field book or other appropriate field form.

16. Measure the total depth of the well by continuing to lower the cable until the probe reaches the bottom of the well.

17. Reel cable back onto the spool. It is suggested that as the cable is being extracted from the well, a rag be used to clean the cable before it reaches the spool.

18. Dry and decontaminate any wet parts of the cable before fully retracting onto the spool. Clean the cable and probe from all products thoroughly with Alconox®, or similar solution, before fully retracting cable onto spool.

19. If no more activity is to occur at this well, replace well cap and any other wellhead covers/locks.

Foth Infrastructure & Environment, LLC

Standard Operating Procedure - 5

Low Flow - Stabilization Purging and Sampling Procedure

Introduction

Foth Infrastructure & Environment, LLC (Foth) gathers data for analytical evaluation of groundwater quality. Before groundwater quality samples or measurements are gathered, stagnate water must be removed from the source being monitored. Stabilization purging is one option for groundwater monitoring points (wells, piezometer, etc.) that do not go dry. Other purging methods may require a specific well volume removed. All well sampling events should specify the purging method used prior to sampling.

Representative sampling of groundwater data means that the sample represents in-situ, unaltered groundwater conditions having the same physical and chemical composition of the aquifer in the surrounding geologic formation being monitored. Purging by stabilization procedures provides a consistent method and process for collecting representative groundwater samples. Successful stabilization purging increases confidence of sample data collected in the field.

Low flow purging and sampling low-flow refers to the velocity that water enters the pump intake and is imparted to the formation pore water in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface that can be affected by flow regulators or restrictions. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation. The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practical, taking into account established site sampling objectives. Typically, flow rates on the order of 0.1 - 0.5 liters per minute (L/min) are used; however this depends on site-specific hydrogeology.

Stabilization refers to the measurements of water quality indicator parameters taken during the purging process. It is recommended that water quality indicator parameters be used to determine purging needs prior to sample collection in each well. Stabilization of parameters such as pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature and turbidity should be used to determine when formation water is accessed during purging. In general, the order of stabilization is pH, temperature, and specific conductance, followed by oxidation-reduction potential, dissolved oxygen, and turbidity.

Low flow-stabilization purging does not address all potential technical issues related to the sampling of groundwater monitoring wells containing light or dense non-aqueous phase liquids (LNAPL or DNAPL). The primary objective of purging a well, using the stabilization purging method, is to remove any stagnant water residing in the well screen, filter pack, and casing interval before sample collection. Low flow-stabilization purging procedures accomplish the removal of stagnant water. Always purge a well before sampling because standing water does not likely represent true groundwater chemistry.

Low flow-stabilization purging procedures is one purging option for monitoring points (wells, piezometers, etc.) that tend to yield the high level of data quality for wells. However, the method is not acceptable for points that may go dry during purging. In any purging process, one should consider minimizing agitation of sediments, aeration of water, and stress on the surrounding geologic formation.

Advantages of low flow-stabilization purging include:

- Samples are representative of the contaminant or constituent being monitored
- Minimal disturbance of sampling point minimizing sampling artifacts
- Less operator variability, greater operator control
- Reduces stress on the geological formation (minimal drawdown)
- Less mixing of stagnant casing water with formation water
- Reduce need for filtration
- Smaller purging volumes
- Better sample consistency

Some disadvantages of low flow-stabilization purging include:

- Higher initial capital costs
- Greater set-up time in the field
- Additional equipment needs to be transported to and from the site
- Increased training needs
- Resistance to change on the part of sampling practitioners
- Concern that new data will indicate a change in conditions and trigger an action

References

USEPA, 1998, "Low Stress (Low Flow) Purging and Sampling," US EPA Region II Groundwater Sampling Procedure, March 16, 1998.

Puls, Robert W. and Michal J. Barcelona, 1996, "Low Flow (Minimal Drawdown) Groundwater Sampling Procedures," *USEPA Ground Water Issue*, EPA/540/S-95/504, April 1996.

Wisconsin Department of Natural Resources, 1996, *Groundwater Sampling Desk Reference*, PUBL-DG-037 96, Wisconsin Department of Natural Resources Bureau of Drinking Water and Groundwater, September 1996, pp. 66-69.

ASTM Designation: D 6771 – 02, "Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations."

Personnel Qualifications

Qualifications of personnel are as directed in the Project Planning Document (PPD), Health and Safety Plan, and appointed by the Project Manager (PM). A minimum of one person is required to complete sampling and should be trained in this sampling technique. Additional persons may be required to complete sampling protocols and should be trained in this sampling technique.

Additional Health and Safety Training Requirements:

- All field personnel must have current CPR (Cardiopulmonary Resuscitation) and First Aid training.

- All field personnel must have satisfied Occupational Safety and Health Administration (OSHA) training requirements (40 CFR 1910.120) if hazardous materials are expected.

- All field personnel must have satisfied Mine Safety and Health Administration (MSHA) requirements if working on a project site regulated by MSHA.

Equipment and Supplies

- Purging system options
  - Bailers are an option but not recommended
  - Dedicated pumps are the best choice
  - Portable pumps
    - Appropriate decontamination supplies
    - QED Micro Purge System – Sample Pro Kit

- Multi parameter probe
  - Hydrolab or similar meter
  - Closed flow through cell

- Water level indicator
- Five-gallon pail or other bulk size container to measure discharge volume
- Appropriate field recording data sheets or electronic data recording methods

Procedures

Stabilization Purging Procedure
To obtain the highest quality, most representative, and consistent groundwater quality measurements, the purge volume rate should be less than or equal to the natural flow conditions existing in the aquifer influenced by the well. When natural flow rates are not known, typical flow rates are on the order of 0.1-0.5 L/min. This can only be accomplished with a pump and by setting the intake velocity of the sampling/purging pump to a flow rate that limits drawdown inside the well casing. Drawdown during purging should be minimal and the water level in the well should stabilize before commencing sampling. This procedure may be enhanced by using a dedicated pumping system.

Stabilization Purging Setup

1. Bailers can be used but are not recommended devices for stabilization purging.
2. Reference owner's operational manual for dedicated or portable pump purging and sampling equipment. Care should be taken not to pump into the well.

3. The pump level should not be placed at the bottom of the well casing but be placed in the middle of the screen interval whenever possible to minimize disturbance and mixing of stagnant water above the screened interval.

4. Pump flow rates should be adjusted so that the surrounding aquifer is not depressed.

5. While purging, the sampling team should monitor the indicator parameters from the discharge liquid:

   a. Preferably in a closed flow-thru cell until the readings are stabilized.
   b. Other methods of monitoring indicator parameters:
      1. down hole or in-situ
      2. purge water container
   c. Liquid levels should be taken down hole during purging phase.

6. Prior to sampling, all sampling devices and monitoring requirements should be calibrated according to manufacturer's recommendations and the site Quality Assurance Project Plan (QAPP), Field Sampling Plan (FSP), and Plan for Analysis (PFA).

7. Consider Total Suspended Solids (TSS) as an additional parameter if purge water remains turbid during purging phase.

8. Recommended parameters monitored for well stability during purging are dissolved oxygen, turbidity, Eh/Redox/ORP, Specific Conductance, pH,

temperature, amount purged, time intervals between readings, and water levels. Foth has a prepared form EES004 (rev 6/00), Monitoring Well Stabilization Test (Attachment 1). It can also be found at: I:\Corel2000\Custom WP Temp\IE SBU\IE - Monitoring\Monitoring Well Stabilization Test.wpt. These readings can also be tracked through the Environmental Data Management System or by data logging capabilities.

The well should be purged until three consecutive readings, spaced at least two minutes or 0.5 well volumes or more apart, are within the following indicator parameter ranges or limits:

Parameter	Range	Limits
Dissolved Oxygen	+/- 0.2 mg/l (milligrams/liter)	+/- 10%
Specific Conductance	+/- 5.0 umhos/cm for values <1000 umhos/cm (micromhos/centimeter)	+/- 3%
	+/- 10.0 umhos/cm for values > 1000 umhos/cm	+/- 3%
pH	+/- 0.1 pH standard units	+/- 0.1 pH standard nits
Temperature	+/- 0.1 ºC (Celsius)	+/- 3%
Turbidity	< 5 NTUs (Required if metals samples will not be filtered. Recommended if sorptive compounds or elements are collected. Optional, but recommended if other compounds or elements are collected.	+/- 10% (for values greater than 1 NTU) [Nephelometric Turbidity Unit])
Eh	+/- 10mv (millivolts)	--
Water Level	No change in water level	--

Alternatively, purging of the well should continue until the readings for each parameter listed above varies within +/- 10 percent, over three consecutive readings spaced approximately two minutes, or approximately 0.5 well volumes or more apart.

Stabilization outcomes should be recorded to verify that samples were taken after stabilization purging was successfully completed.

To avoid cross-contamination between monitoring wells, or from site to site, the tubing, pumps, and sampling equipment should be rinsed and cleaned between sampling locations. Follow the sampling plan for proper management of rinse water.

9. Fill sample bottles in accordance with the project sampling and analysis plan.

Attachment 1

Monitoring Well Stabilization Test (Form EES004, rev 6/00)

Client: ______________________ Project I.D.:______________
Project: ______________________ Page :________________
Prepared by: __________________ Date: ________________
Checked by:____________________ Date: ________________

Monitoring Well Stabilization Test

Project Name: ______________________ **Date:** ______________
Weather: ______________________ **Sampler(s):** ______________
Location: ______________________ **Sampling Time:** ______________
Sample ID: ______________________
ID: ______________________

Odor: ______________ Static Water Level ______________
Appearance: ______________ Total Depth ______________
Color: ______________ Water Column thickness ______________
Calculated Well Volume ______________
Purge Method ______________
Purge Rate ______________

Sampling Method: ______________________________

Tag	#Collected	Bottle	Preservative	Parameter

Photographs: ______________________________
Remarks: ______________________________

Stabilization Test:	Start Time:	Stop Time:

Time	Water level (ft or meters)	Ph (SU)	Spec Cond (µmhos/cm @ 25°C)	Temp (°C)	D.O. (mg/l)	Turbidity (NTU or comment)	Redox (mV)

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Standard Operating Procedure - 6

Measuring Static Water Level SOP

Introduction

The purpose of this Standard Operating Procedures (SOP) is to establish a standard procedure for measuring Static Water Levels. These step-by-step instructions describe the equipment and methods needed to measure the water level in a well using flat-tape electric water level meters. Measuring a water level in a well can sometimes be difficult. These instructions do not guarantee that you will be able to measure the water level in a well due to unique site conditions. Proceed cautiously if you choose to take a water level measurement in your well. There is always a potential that you could damage the well equipment or the water level meter.

Definitions of Terms

Flat-Tape Water Level Meter: A water level meter used to measure the water level in a well through a flat tape (marked in engineering, standard, or metric scale) that emits a sound when water is detected.

Recovering Water Level: A water level in a well that is recovering (rising) after the pump in the well has been turned off, but before the water level has stabilized.

Static Water Level: A stable water level in a well not affected by withdrawal (pumping) of ground water. This water level is most representative of surrounding aquifer conditions.

Water Table: The top of the water surface in the saturated part of an aquifer.

Well Cap or Sanitary Seal: A tight fitting, vermin-proof seal designed to prevent contaminants from flowing down inside the well casing.

Well Casing: A tubular structure made of metal or plastic and placed in a well borehole to maintain the well opening. The casing also helps to confine ground water to a specific ground water zone and helps to prevent contaminants from mixing with the water.

Well Liner: Often used in conjunction with a well casing, this metal or plastic insert is placed inside the well borehole to prevent a collapse.

Well Seal: This is a cement-like fluid injected into the well borehole to help protect the well casing.

References

Wisconsin Department of Natural Resources Groundwater Sampling Field Manual; PUBL-DG-038 96, September 1996.

Wisconsin Department of Natural Resources Groundwater Sampling Desk Reference; PUBL-DG-037 96, September 1996.

Personnel Qualifications

None.

Equipment and Supplies

Equipment and procedures used for taking water level measurements vary substantially. Choose water level measuring devices based on their accuracy, precision, ease of use, reliability, durability, ease of decontamination, and cost. Under most circumstances, requires that water level measurements be read to the nearest 0.01 foot (0.25 centimeter [cm]).

Water level measuring devices typically are either manual, non-recording devices or continuous measuring devices that provide a paper or electronic record of changing water levels over time. The Foth-preferred device is a **flat-tape styled water level indicator.**

A flat-tape water level meter uses a flat "measuring tape" to transmit a signal to a buzzer when water is encountered. These tapes are usually 3/4-inch wide. The flat-tape water level meter is easier to read than a coaxial water level meter because the depth-to water measurements are read directly off of the measuring tape.

Procedures

Important technical considerations for collecting accurate water level measurements include:

1. Measure the static water level for a well before purging, sampling, or inserting any instrument or device into a well. If a well is purged, sampled, or a device is inserted into a well before measuring the static water level in the well, the measurement will not represent the static "undisturbed" water level or hydraulic head existing in the well.

2. Collect measurements from all wells on the site as quickly as possible. The best method is to collect measurements from all of the site's wells before doing any other tasks on the wells. This may be impractical and too time consuming for

some sites. Typically, you take a water level measurement, sample the well, measure the next well's water level, sample that well, and so on. This method is acceptable if you collect all water level measurements at a site on the same day and the barometric pressure for that day does not change significantly (e.g., changing high or low pressure, advancing storm, etc.). If the barometric pressure does change significantly during collection, a second round of measurements may be appropriate.

3. Collect measurements in the order of least-to-most contaminated wells. Furthermore, decontaminate the measuring device between each well to prevent cross-contamination. Do not let any part of the instrument or tape touch the ground or any contaminated surface.

4. Read measurements from the top of the casing or a reference elevation on the well. This is usually a permanently and clearly-marked or notched spot located at the highest point on the top of the well casing. All top-of-casing or reference elevations must be surveyed to a common point of known elevation so that the water level measurements can be converted to groundwater level elevations, usually expressed as feet above mean sea level (MSL) or as U.S. Geological Survey (USGS) datum. Water level measurements must be accurate and precise to ±0.01 foot (± 0.25 cm.).

5. Whenever possible, use one measuring device and one person operating it for all wells at a site during each sampling event. Better yet, use the same measuring device and same person for all wells at a site over the life of a project. This will help ensure that water level data are accurate and comparable. If more than one measuring device is used, check both instruments against a calibrated standard, the same well, and against each other to ensure that they provide the same water level measurements. If necessary, use a correction factor to equalize the readings. Do this after checking each device to determine which tape length is correct.

6. Review information about the well.

    - Well Construction Log
      The well report (well log) contains important information such as the static water level when the well was constructed. A static water level is a stable water level when the well is not being pumped and the well has had sufficient time to recover and total depth of well casing.

    - Well Identification (ID) Number
      The Well ID Number is a unique identification number attached to the well casing.

    - Potential for measuring IMMISCIBLE LAYERS

An immiscible layer may exist in a monitoring well either as a light non-aqueous phase liquid (LNAPL) or as a dense non-aqueous phase liquid (DNAPL). LNAPLs, also known as "floaters" or "floating free product," are relatively water-insoluble organic liquids (e.g., gasoline and diesel fuel), are less dense than water (i.e., they have a specific gravity <1.0) and they typically spread on top of the capillary fringe and water table. DNAPLs, also known as "sinkers" or "sinking free product," are also relatively water- insoluble organic liquids (e.g., trichloroethylene), are more dense than water (i.e., the have a specific gravity >1.0) and typically migrate downward in an aquifer.

7. Turn off any well pump and record the time.

8. Remove well access cover – Well caps, Slip cap, Friction cap, Sanitary Seal, or Turtle Back Plug. Document if well cap popped or well is under vacuum or positive pressure conditions in the well casing. Document these conditions and condition of well cap.

9. Determine measuring point. The measuring point is a reference point on the well casing or cap from which all measurements are made. It may be helpful to draw a sketch or description of this measuring point on your water level data sheet and mark the measuring point with permanent marker. Future water level measurements should always be taken from the same spot. Due to equipment limitations, surveyors always survey top of casing from the highest point on the casing if the well casing top is not level.

10. Before you lower the water level meter into the well to complete the measurement process, there are four problems that could occur during the measurement.

    - Liners - If a liner is present in your well the water level meter must be inserted inside the liner to get a reliable water level measurement. CAUTION: False readings are common if the probe is inserted outside of the liner. If the water level meter is inserted outside of the liner, you may get a false reading with a shallower than expected water level depth. If you are outside the liner, the line and probe may be covered in grit or grime when you reel it up. IMPORTANT: Liners are not always centered in the well or near the top of the casing. Check the well report or look inside the well to see if a liner is present.

    - Hang-Ups - These may happen while lowering or raising the water level meter. Liners, pumps and wires, joints in the discharge pipe, ice blocks, well damage and rough edges on the inside of the well may cause hang-ups. These conditions need to be documented.

- Cascading - Water or condensate on the side of well casing. Water may enter the well above the static water level and drip or cascade down the borehole. This may be due to poor well casing seal, damaged well casing or temperature difference in a saturated atmosphere of the well casing. The water falling down the borehole may cause the water level meter to give a false reading. Sometimes you may be able to hear if cascading water is present.

- DNAPL and LNAPL layers present - Although measuring LNAPL and DNAPL is not the purpose of this SOP. Their presence may interfere with water level measurement accuracy.

Now you may begin to measure the water level. Follow owner's manual for specific water level meter operation.

1. Turn the lower switch to the test position and make sure the battery is good. (The buzzer will sound and the light will turn on.)

2. Turn the lower switch to either the BUZZ position or the LED position. The BUZZ position is recommended because you can hear the buzzer easier than you can see the light from the LED position.

3. Turn the sensitivity switch all the way to the right.

4. Slowly release some line down the well casing, allowing the line to slide over your outstretched hand and down the well. CAUTION: Do not let the line free fall because the line can give you a "burn" similar to a rope burn if it slides through your hand too fast or the line may get stuck in the well.

5. Check the "feel" of the line and probe. The "feel" of the weight on the line is similar to when you are fishing. You "feel" the line for the tug of a fish nibbling the bait. As the probe goes deeper, the weight should increase. If it does not, STOP lowering the line — go to Step 7.

6. Repeat Steps 4 and 5 until the water level meter indicates the probe is in water or if the probe becomes stuck or hung-up. Remember to check the "feel" of the line and probe about every 20 feet.

7. If you can no longer feel the weight, raise the probe slowly. Continue checking the line to determine whether or not you have regained the weight of the probe. Once you can feel the weight again, begin lowering the probe very slowly. At the point when you cannot feel the weight, stop lowering the probe. Gently bounce the probe by raising and lowering the line about two feet. This method may allow

the probe to slide past the hang up. *Ice at ground surface* should be reported as ice but does not represent top of water at the time of measurement.

8. When the water level meter indicates water, check and make sure that you do not have cascading water. Determining if you have cascading water depends on the position of the lower switch. If the switch is set for BUZZ, the buzzer will chatter rather than sound a steady buzzing noise. If the switch is set for LED, the light will flicker off and on. Turn the sensitivity switch down to minimize the background noise.

9. Once you have determined that the probe is in the water, use the reference point mark that has been identified and previously surveyed to measure from.

10. Raise the line until the light or buzzer goes off. Lower the line until the light or buzzer comes back on. Raise the line until the light or buzzer goes off, and hold the flat tape scale in this position at reference point to determine if the water is rising. At this time, you will know if your water level is rising, falling, or static. <u>IMPORTANT</u>: It is best to record a static water level. If the water level is still recovering (rising) from recent pumping or pressure from inside of well water, you have three options:

    - Wait another 5 to 10 minutes to take another measurement or continue measuring periodically until the water level is stable.

    - Come back another time to take a water level measurement.

    - Record the existing water level measurement on your datasheet and clearly indicate that the water level is rising.

11. After determining that you have a static water level measurement, use your other hand to pinch the line at the measuring point near the top of the well (which varies depending on the well cap).

12. Now you will need to determine the water level measurement at the measuring point by reading the tape at the pinch point or if able directly read measurement on the tape. Record measurement, date, and time of measurement.

13. Final step is to interpret your water level measurements for accuracy of measurement by:

    - Comparing to historical data
    - Check for data entry errors such as placement of decimal.

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Standard Operating Procedure - 7

Stream Flow Measurements

Introduction

As part of engineering services, data is gathered from flowing water sites to assess stream flow conditions. These stream flow measurements can be measured from several types of flowing water sites such as rivers, streams, creeks, springs, drainage ditches, irrigation channels, sewage plant flumes, or any other surface feature that water generally moves uni-directionally. Please refer to the appropriate SOPs for monitoring of small diameter or submerged culverts and weirs, which require measurements of stage, head losses, and to obtain the hydraulics of the structure. The following information provides field procedures for collecting stream flow measurements.

References

U.S. Geological Survey (USGS, 1982). "Measurement and Computation of Stream Flow: Volume 1 Measurement of Stage and Discharge", Chapter 5 Measurement of Discharge by Conventional Current-Meter Method, Water Supply Paper 2175.

Personnel Qualifications

Qualifications of personnel are, as directed in the Project Planning Document (PPD), Health and Safety Plan (HASP), and appointed by the Project Manager (PM). A minimum of one person is required to complete measurements and should be trained in this measurement technique. Additional persons may be required to complete measurement protocols and should be trained in this measurement technique.

Additional Health and Safety Training Requirements:

- All field personnel must have current CPR (Cardiopulmonary Resuscitation) and First Aid training.
- All field personnel must have satisfied Occupational safety and Health Administration (OSHA) training requirements (40 CFR 1910.120) if hazardous materials are expected.
- All field personnel must have satisfied Mine Safety and Health Administration (MSHA) requirements if working on a project site regulated by MSHA.

Equipment and Supplies

- Flat tape measure
- Marsh-McBirney Flow Mate Flow Meter
- Metered rod for sensor and measuring vertical distance
- Sharpie or waterproof marker
- Field Book
- Stop Watch
- Bucket

Procedures

Selection of stream flow sites will ideally meet the criteria listed below. Rarely, will a site meet all of these criteria, so professional judgment must be exercised in site selection. The criteria are listed from high priority criteria (1) to low priority criteria (12). Sites are often pre-selected from aerial photographs and topographic maps. If field observations of the pre-selected stream flow sites violate priority criteria, please inform the project manager and note the site location ID and violated priority criteria in the field book. At the discretion of the PM, this information will be used to optimize (i.e., relocate, remove, etc.) the stream flow sites during or after baseline studies.

Stream Flow Site Selection Priority Criteria

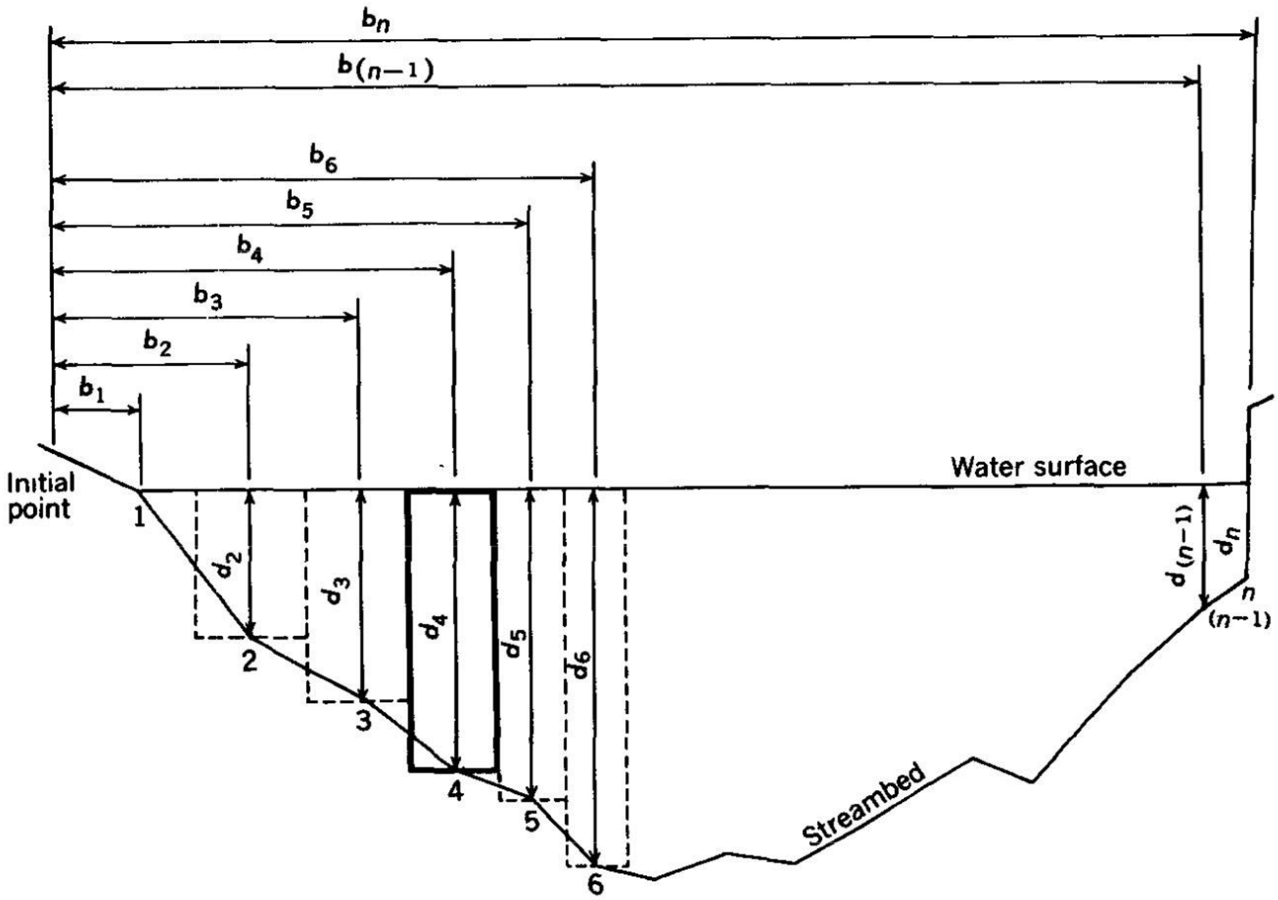
1. The stream flow site is readily and safely accessible for ease of installation and operation of the flow meter during any season (i.e., high flow or low flow).
2. The stream flow site provides measurable flow during most months of the year (i.e., spring, summer, fall).
3. The stream channel and stream bed, in the vicinity of the stream flow site, are stable (i.e., not subject to scour, fill, vegetative cover or aquatic growth) during most months of the year (i.e., spring, summer, fall).
4. The stream channel, in the vicinity of the stream flow site, is either a gaining stream, a losing stream, or a neutral stream during most months of the year (i.e., spring, summer, fall).
5. The general course of the stream channel, upstream and downstream of the stream flow site, is straight for 100 feet or as long as possible.
6. The stream flow site contains relatively uniform flow, free of eddies, slack water, and excessive turbulence.
7. The stream flow site is at least 20 feet downstream of where analytical samples are to be collected.

8. The stream flow site is at least 5 diameters upstream and/or 10 diameters downstream of any culvert. If multiple culverts are present, use the diameter of the largest culvert to determine the upstream and/or downstream stream flow site location. Note: If a culvert is the target for flow measurement, please refer to an approved culvert flow SOP for instruction.
9. The stream flow site is at least 100 feet upstream and/or downstream of a narrowing of the stream channel, due to natural conditions (i.e., tree fall, meandering stream) or unnatural conditions (i.e., bridge).
10. The stream flow site is at least 100 feet upstream and/or downstream of widening of the stream channel (i.e., confluences with other streams).
11. The stream flow site is located where other data is collected.
12. Site is at or near a gauging station to obtain concurrent surface-water discharge data required for computing constituent-transport loads and to determine relationships between discharge and constituent concentrations.

Monitoring with clear evidence of bank erosion, a rocky stream bed, and construction may be hard to avoid, but these conditions should be noted when they occur.

Stream Flow Measurement

The following diagram shows the measurements required for stream flow, or discharge measurement, using a current flow meter (e.g., Marsh McBirney Flowmate). All measurements shall be recorded on the attached field form. Position, weather, wind direction and speed, general stream condition (e.g., turbid, clear, low level, floating debris, water temperature, type of streambed material, etc.), relative observations, instrument problems, or public interaction will be recorded in the field book. For additional information on field logging, please review the appropriate Field Book SOP.



EXPLANATION

1, 2, 3 .... n	Observation verticals
$b_1, b_2, b_3, \ldots b_n$	Distance, in feet or meters, from the initial point to the observation vertical
$d_1, d_2, d_3, \ldots d_n$	Depth of water, in feet or meters, at the observation vertical
Dashed lines	Boundaries of subsections; one heavily outlined is discussed in text

As additional explanation, the "Observation Verticals" are represented by the "Station Number" in the field form. The "Initial Point" is indicated as "Station 0" in the field form. The "b" variable is recorded as the "Station Distance" in the field form. The "d" variable is recorded as the "Station Depth" in the field form. The dashed lines represent the width calculations conducted in Excel.

Stream Flow Measurement Procedures

1. From the stream bank, determine the direction of flow and record it as a cardinal direction (i.e., N, NE, S, SW, etc.) in the field book. Use the handheld GPS as necessary to assist with determining direction.

2. From the stream bank, determine (relative to the stream flow direction) which bank Station 0 is located and record the cardinal direction in the field book. For example, if the stream flow direction is SE, then Station 0 would either be located at the southwest bank or northeast bank.

3. From the stream bank, identify a transect line through the stream that is approximately perpendicular to the direction of flow. Using a stake or equivalent, fix the starting end of the flat tape to the stream bank. This will represent Station 0. Record the flat tape value at Station 0. Spool out the flat tape across the stream, perpendicular to the stream flow direction, and fix the flat tape to the opposite stream bank. This will be Station #N.

4. Based on the total width of the stream identified from the flat tape in step 3, determine a regular interval to divide the stream into equal width subsections. As a general rule, enough subsections should be established to prevent more than 10% of the total discharge from passing through any one subsection. For example, for a 60-foot channel, use no less than 6-foot wide subsections (60 *0.10 = 6). The following can also be used as a guide to determine the subsection widths:

   a. Small stream channel (12 feet wide or less) – use 1-foot wide subsections.
   b. Medium stream channel (16-30 feet wide) – use 2-foot wide subsections.
   c. Large stream channel (30 feet or large) – use 3-foot wide subsections.

5. Once the interval width of each subsection has been identified, the number of stations will be known. For example, in a 16-foot wide channel, Stations 1-8 will be used to collect depth and velocity measurements. Note, at Station 0, where the flat tape is fixed, only record the tape measure value in the "Station Distance" field. Depth and velocity measurements do not apply at this station.

6. For each "Station Number" in the field form, record the "Station Distance" from the flat tape and "Station Depth" from the meter rod. Depending on the depth, apply the appropriate velocity measurement method. The one-point method (0.6 depth method) specifies a velocity measurement at a depth below the surface that is equal to 0.6 * Station Depth. The two-point method (0.2 and 0.8 depth method) specifies velocity measurements at two depths below the surface that are equal to 0.2 * Station Depth (shallower) and 0.8 * Station Depth (deeper).

    a. If the depth is less than 2.5 feet, use the one-point method for measuring velocity at that specific station. Special consideration should be given for depths less than 0.75 feet because the flow may be underestimated due to stream bed interferences with meter. If any of these conditions are encountered, please record in the field book.

    b. If the depth is greater than 2.5 feet, use the two-point method for measuring velocity at that specific station. To field test whether two-point velocity measurements are representative, compare the 0.2 velocity measurement to the 0.8 velocity measurement. The 0.2 velocity should be greater than the 0.8 velocity but less than twice the 0.8 velocity. If this is violated, use the one point method. Special consideration should be given if depths are too great for the meter rod (creating an unsafe situation to collect the 0.8 measurement); or in the presence of surface debris or ice (resulting in non-representative flows at the 0.2 measurement); or when the stream is moving too swiftly or stage is changing too quickly (creating an unsafe situation and/or non-representative flow in the time required to collect 2 measurements). The one-point method is acceptable in those special situations. If any of these conditions are encountered, please record in the field book.

7. If the stage (i.e., depth) or velocity is rapidly changing during measurement, note this on the field form. When applicable or appropriate, velocity readings should be allowed to stabilize to within 10% of the previous reading. For example, record the reading "15 cts" if subsequent reading is between "13.5 and 16.5 cfs;" otherwise, continue collecting readings.

8. Once the Station Distance, Station Depth, and velocity(s) are recorded next to the appropriate Station Number, move to the next station and repeat this procedure. Note, Station 1 is located at the very edge of the stream channel where the water depth is negligible (i.e., several inches or less) and water velocity is negligible (i.e., immeasurable). The depth and velocity at Station 1 are assumed to be zero and recorded as such in the field form. At Station 1, record the "Station Distance" from the flat tape. Special consideration: if the edge(s) of the stream is a vertical abutment (e.g., bridge, pier, etc.), the "Station Distance" should be measured to the abutment, but the velocity should be measured next to or as close to the abutment as possible. If any of these conditions are encountered, record the observation in the field book.

Some additional notes should be kept in mind when taking stream discharge measurements:

- Stand behind and well to the side of the meter as readings are taken.
- Avoid disturbing or standing along the streambed beneath the cross-sectional measuring points.
- Where possible, try to use the same transect for each monitoring location throughout the study period. Good field notes and use of a camera will help to re-occupy the same location.

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Standard Operating Procedure - 8

Open Channel and Streamflow Measurements – Velocity Area Method

Introduction

The purpose of this Standard Operating Procedure (SOP) is to provide guidance for gathering data from flowing streams and constructed channels to use in calculating flowrates. Streamflow measurements can be made in a variety of conveyances, including: rivers, streams, creeks, springs, drainage ditches, irrigation channels, sewage plant flumes, or any other surface feature characterized by predominantly one-dimensional flow and open channel conditions (as opposed to a closed or full conduit).

This SOP defines the method for calculation of volumetric flowrates for water in open channels using measurements of velocity, flow depth, and cross-sectional area. This procedure is based on the use of current meters to measure flow velocity. It also provides a basic description of methods for measurement of flow depth. This procedure is applicable to streamflow measurements made via wading, bridges, cableways, and boats. Methods for measurement of flow and water depth under ice are also provided.

Definitions

ASTM – American Society for Testing and Materials
HASP – Health and Safety Plan
PPD – Project Planning Document
USGS – U.S. Geological Survey

References

ASTM Standard D3858-95, 2014. "Standard Test Method for Open-Channel Flow Measurement of Water by Velocity-Area Method," ASTM International, West Conshohocken, PA, 2014, DOI: 10.1520/D3858-95R14, www.astm.org.

ASTM Standard D5089-95, 2014. "Standard Test Method for Velocity Measurements of Water in Open Channels with Electromagnetic Current Meters," ASTM International, West Conshohocken, PA, 2014, DOI: 10.1520/D5089-95R14, www.astm.org.

ASTM Standard D4409-95, 2014. "Standard Test Method for Velocity Measurements of Water in Open Channels with Rotating Element Current Meters," ASTM International, West Conshohocken, PA, 2014, DOI: 10.1520/D4409-95R14, www.astm.org.

U.S. Geological Survey, 2010. "Discharge Measurements at Gaging Stations," Chapter 8 of Book 3, Section A, Techniques and Methods 3-A8, U.S. Geological Survey, Reston, VA, http://pubs.usgs.gov/tm/tm3-a8/pdf/tm3-a8.pdf.

U.S. Geological Survey, 1982. "Measurement and Computation of Stream Flow: Volume 1 Measurement of Stage and Discharge," Chapter 5 Measurement of Discharge by Conventional Current-Meter Method, Water Supply Paper 2175.

Personnel Qualifications

A qualified person shall be someone who is formally trained in hydrology via an Accreditation Board for Engineering and Technology (ABET)-accredited engineering college or university and experienced in making open channel flow measurements. Additionally, a qualified person may also be a technician lacking formal college training in hydrology but whom has been formally trained in open channel flow measurements using the procedures described in this SOP.

Personnel performing open-channel flow measurements shall have access to the project Health and Safety Plan (HASP) and the project Quality Control and Quality Assurance Plan (QCQAP).

Additional Health and Safety Training Recommendations:

- Field personnel shall have current CPR (Cardiopulmonary Resuscitation) and First Aid training.
- Field personnel shall have satisfied Occupational Safety and Health Administration (OSHA) training requirements (40 CFR 1910.120) if hazardous materials are known to be or may be present at the site.

Field personnel shall have satisfied Mine Safety and Health Administration (MSHA) safety training requirements prior to making open channel flow measurements at mine sites.

Equipment and Supplies

Required equipment will vary according to the measurement method and may include the following:

- Flat tape measure
- Current meter (rotating element, electromagnetic, and acoustic current meters can be used in conjunction with this procedure)
- Graduated wading rod (USGS-style top-setting wading rod or conventional graduated wading rod can be used; example of top-setting style is Rickly 12-foot Breakdown Top Set Rod. Wading rods are available from Rickly Hydrological, Hydrological Services America, Ben Meadows, and others)
- Weighted and graduated sounding reel or sounding line
- Waterproof marker or pen
- Field Log Book
- Hip or chest waders
- USGS-approved personal flotation device
- Rain gear, if applicable
- Ice fishing auger, if ice cover is expected
- Chalk

Procedures

1. Preparation prior to sampling

    a. Review the HASP and QCQAP with field personnel.

    b. Check current weather conditions. Stream gauging may be hazardous during extreme weather and icy conditions may require additional equipment.

    c. Check the current meter for signs of wear or damage and ensure that the battery is fully charged, if applicable. Inspect other equipment to ensure all essential components are in proper working order. Replace equipment that is damaged, worn, or of questionable integrity.

2. The procedure for making velocity measurements in streams and open channels using an electromagnetic current meter is provided in ASTM D5089-95. ASTM D5089-95 is incorporated by reference to this procedure. Methods detailed in ASTM D5089-95 shall be followed when using electromagnetic current meters for velocity measurements in open channels and streams.

3. The procedure for making velocity measurements in streams and open channels using a rotating element current meter is provided in ASTM D4409-95. ASTM D4409-95 is incorporated by reference to this procedure. Methods detailed in ASTM D4409-95 shall be followed when using rotating element current meters for velocity measurements in open channels and streams.

4. The procedures for collection of field measurements and calculation of flows in open channels characterized by flow that is predominantly one-dimensional using a current meter is provided in ASTM D3858-95. ASTM D3858-95 is incorporated by reference to this procedure. Methods detailed in ASTM D3858-95 shall be used when collecting open-channel velocity measurement and using such measurements to estimate open channel or stream discharge. Use the two-point method described in Section 10.9.2 of ASTM D3858-95 for velocity measurements unless site-specific conditions require use of an alternate method. Note in the field logbook why an alternative method is required in such instances and note the alternate method(s) used. Alternate methods shall be chosen from those described in ASTM D3858-95. When the direction of flow is known or believed to vary substantially as a function of depth, rotating element and electromagnetic current meters shall not be used for the measurement of velocity. Rather, velocities shall be measured using acoustic Doppler current profiling (ACDP) devices and methods.

5. If negative flow velocities are measured in any portions of the stream, the following procedure should be used to supplement the calculation procedure detailed in ASTM D3858-95:

    a. When negative flow velocities are encountered during the velocity measurement process, additional flow and depth measurements should be collected at regular intervals within that subsection as shown on Figure 1.

    b. Divide the subsection into three equal-width subsections.

    c. Make and record stream depth soundings, d_n, d_{n+1}, and d_{n+2} (using a top-setting wading rod, standard wading rod, or sounding cable), at the center of each subsection.

    d. Make and record velocity measurements at depths appropriate for the chosen method (generally 0.2d and 0.8 d below the water surface) at the centers of each newly-defined subsection, as shown in Figure 1.

    e. Compute the discharge for each subsection as $[(V_{i,0.2} + V_{i,0.8})/2]*d_i*w_i$.

6. Whenever possible, subsection width, depth, and velocity measurements shall be made along a section line (or bridge) that is oriented orthogonal to the velocity vector for the majority of the streamflow. When the predominant velocity vector is not normal to the measuring section, a correction shall be applied to the velocity measurement as described on page 24 of USGS (2010). Velocity values used to calculate flux for a subsection shall be calculated as $V_O = V_M*\cos(\alpha)$, where V_O is the velocity orthogonal to the measuring section (used to estimate discharge), V_M is the maximum velocity in the channel or stream (measured using current meter), and α is the angle between the maximum velocity vector and the orthogonal to the measuring section.

7. When stream depths and flow velocities are modest, depth and velocity measurements shall be made via wading. In this instance, a pre-marked tag line shall be set across the stream and used to subdivide the stream into measurement subsections as described in ASTM D3858-95. Depth measurements shall be made using a graduated wading rod. A top-setting wading rod shall be used in all instances because a top-setting rod simplifies the measurement of depths and the positioning of the current meter at proper depths for velocity measurements. Refer to the instructions provided for the specific model of top-setting rod used for the proper method of measuring stream depth and setting of current meter depth. Stream depths shall be recorded for each sub-section. Velocity measurement depth shall be calculated based on the stream depth and the total depth fraction specified by the chosen method. Generally, the two-point velocity measurement method shall be used. For the two-point method, velocity is measured at two vertical positions within the stream. Measurements are always made at the horizontal midpoint of each subsection as shown on Figure 1. Velocity measurement depths for each sub-section shall be recorded on the field log form. Velocities recorded at each depth shall be recorded adjacent to the recorded depth value.

8. When stream depth or velocity exceeds limits for safe wading, measurements of depth and velocity may be made using alternative methods. Measurements may be made from a bridge, from a boat, from a suspended cable-way, or via use of an un-manned boat and ACDP unit. Procedures for use of cable-ways and ACDP units are outside the scope of this procedure. In selecting an alternate method for stream and measurement access, consider the following aspects of boat versus bridge access and follow the procedures described:

    a. Measurements from a boat are compatible with wading rod use for depth sounding and meter positioning, unless stream depths exceed 8 to 10 feet. Use of a wading rod is easier, quicker, and more accurate than use of a sounding cable/reel and weight.

b. Measurements from a bridge can be made using a wading rod if the bridge deck is close to the stream and the stream is not deep.

c. Measurements from a boat allow the technician to set a tag line for lateral positioning and sub-section width measurement. Setting of the tag line precludes complications arising from a measurement section that is oblique to the bulk streamflow velocity vector.

d. If measurements are to be made from a bridge, a bridge should be selected that is orthogonal to the bulk streamflow velocity vector. If the bridge is not orthogonal to the velocity vector, the technician shall correct measured velocities using the method described in Section 5.e of this procedure.

e. Measurements made from a bridge may require use of a sounding cable and weight if the distance to the water surface and/or channel bottom exceed the reach of a wading rod (standard wading rods, often longer in length than top-setting wading rods, may be used to make depth measurements and to position velocity meters when making depth and velocity measurements from a bridge). Depth measurements and positioning of velocity meters using sounding cables and reels in the presence of swift water is complicated by the deflection of the sounding weight and cable. This practice is outside the scope of this procedure. Use of sounding cables for depth measurements and meter positioning from bridges is permitted only when velocities are modest such that deflection of the cable is minimal.

f. When making measurements from a bridge with the use of a sounding cable and real, the sounding cable shall be used to make and record depth soundings for all sub-sections prior to making velocity measurements. Depth soundings shall be made by measuring and recording the distance to the water surface and then the distance to the bottom of the channel. When these measurements are made for a particular sub-section, the technician shall establish a fixed reference point for each of the two measurements in a subsection. The reference point from one subsection to another need not be at the same absolute elevation. The reference point *must* be the same for both measurements (distance to water surface and distance to channel bottom) for each individual subsection. Measure and record each depth using the specific operating procedure provided by the unit manufacturer. Subtract the distance to the water surface from the distance to the channel bottom to obtain the stream or channel depth. Use of a sounding-reel bridge dolly simplifies depth sounding and meter positioning from bridges. Use of a sounding-reel bridge dolly also improves accuracy of depth soundings and meter positioning for bridge-access streamflow measurements.

g. Measurements made from a boat require two technicians. One technician shall operate the boat and be responsible for occupant safety and positioning the boat at the required subsection centers across the measuring section. The second technician shall make and record depth and velocity measurements.

h. A boat may be controlled by manual use of anchor lines, a motor, or oars. For use of anchor lines, one anchor line is attached to an anchor point on each side of the stream. The anchor points must be considerably upstream of the section line across which measurements of depth and velocity are to be made. The boat operator shall hold both anchor lines, pulling in on one line and paying out of the other so as to position the boat at the needed locations along the measurement section. The anchor lines shall never be fixed to the boat, to any boat occupant, or to any control device on the boat. The boat operator shall be seated in the front of the boat during use of anchor lines. The excess anchor line shall not be stored in the boat. In the event of upstream flotsam approaching the boat, the operator shall manipulate the anchor lines to avoid the flotsam or the operator shall drop the anchor lines, freeing the boat to move downstream with the current. Under all conditions, the boat shall be equipped with oars to maneuver the boat. Technicians shall wear personal flotation devices with affixed USCG-approval labels at all times.

i. When making depth sounding measurements from a boat using a wading rod, the boat will move in the vertical plane due to water movement and movements within the boat. The technician making the measurements shall strive to keep the wading rod fixed firmly against the channel bottom. This will eliminate the need to interpret depth variations caused by movement of the boat. For deep settings wherein a wading rod is too short, use of sounding cable and reel is required. The operator shall avoid fixing the sounding cable and/or reel against the boat. The sounding cable and attached weight shall be deployed into the stream with the technician holding the sounding cable such that fluctuations in the boat elevation do not raise the weight away from the channel bottom. Using this approach, read the channel depth from the sounding cable at the water surface. Record the measured depth.

j. Calculate the distance between the sounding weight and the velocity meter using the measured depth and the appropriate fraction for the method being used (0.2d and 0.8d for the standard, two-point method). Fix the meter the appropriate distance from the weight. Lower the sounding cable and weight into the water until the weight contacts the stream bottom. Maintain this position until the velocity measurement is completed. Adjust the distance between meter and weight and repeat for remaining required velocity measurement depths. Record each velocity measurement. Additional guidance on making stream depth and velocity measurements from boats is provided on pages 32-35 of USGS (2010).

9. Streamflow measurements can also be made in frozen streams when ice is of sufficient thickness to permit foot access. Note, however, that ice thickness is extremely variable when the water beneath the ice is flowing, as is the case for all streams. Accordingly, measurements of stream discharge under frozen, iced-over conditions are considered very dangerous and generally not recommended. For instances where this practice will be used, the technician shall be accompanied by a partner. Both persons shall be trained in ice safety and ice/water rescue. Procedures for making the measurements themselves do not differ from those described above. An ice auger is required to gain access to the stream through the ice. Subsection width should be kept relatively large. If not, the closely spaced access holes augered through the ide will weaken the ice mass along the shelf, increasing the risk of the technician falling through the ice. Additional details regarding the measurement of stream discharge in ice-covered streams and open channels is provided on pages 29-31 of USGS (2010).

Foth Infrastructure & Environment, LLC

Standard Operating Procedure - 9

Stream Flow Measurement Using FlowTracker2 ADV

Introduction

This Standard Operating Procedure (SOP) defines the methodology to be used for measuring stream flow in a wadeable stream using the SonTek FlowTracker2, an Acoustic Doppler Velocimeter (ADV).

References

The following references and SOPs are cited in this procedure. These documents shall be referred to during the execution of the work described herein.

Foth, 2014, Foth Site-Specific Standard Operating Procedure, *Aquila Stream Flow for Wadeable Streams Measurement.*

Foth, 2009, Foth Standard Operating Procedure #3200, *Environmental Checklists.*

SonTek, 2016, *FlowTracker2 User's Manual 1.1, Software Version 1.1, Firmware Version 1.17.* SonTek, San Diego, California. http://www.geotechenv.com/Manuals/SonTek_Manuals/sontek_flowtracker2_manual.pdf

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. (Also available at *http://pubs.usgs.gov/tm/tm3-a8/*.)

Personnel Qualifications

A minimum of one person is required to complete measurements and should be trained in this measurement technique. One or more additional person may be required to safely complete measurement protocols. Additional support personnel should be trained in the activities associated with this procedure prior to execution of field work.

Additional Health and Safety Training Requirements:

- All field personnel must have satisfied Mine Safety and Health Administration (MSHA) requirements if working on a project site regulated by MSHA.

Equipment and Supplies

FlowTracker2 handheld unit and probe
Top setting wading rod with attachment for FlowTracker2
Measuring tape or graduated tag line
Stakes
Rake
Field Form
Pen
8 extra AA batteries

Stream Flow Site Selection Priority Criteria

Selection of stream flow sites will ideally meet the criteria listed below. Rarely will a site meet all of these criteria, so professional judgment must be exercised in site selection. The criteria are listed from high priority criteria (1) to low priority criteria (15). Sites are often pre-selected from aerial photographs and topographic maps. If field observations of the pre-selected stream flow sites violate priority criteria, please inform the project manager and note the site location ID and violated priority criteria in the field book. At the discretion of the project manager, this information will be used to optimize (i.e., relocate, remove, etc.) the stream flow sites during or after baseline studies.

1. The stream must be safely wadeable. If the stream is not wadeable based on depth or velocity, the field team will need to use a different method (summarized below) or different location to collect flow data.

2. The stream flow site is readily and safely accessible for ease of installation and operation of the flow meter during any season (i.e., high flow or low flow).

3. The stream flow site provides measurable flow during most months of the year (i.e., spring, summer, fall).

4. The stream channel and stream bed, in the vicinity of the stream flow site, are stable (i.e., not subject to scour, fill, vegetative cover or aquatic growth) during most months of the year (i.e., spring, summer, fall).

5. The stream flow, in the vicinity of the stream flow site, is sufficient enough (i.e., high enough) for year round measurement, considering the precision of the intended flow metering instruments.

6. The general course of the stream channel, upstream and downstream of the stream flow site, is straight for 100 feet or as long as possible.

7. The stream flow site contains relatively uniform flow, free of eddies, slack water, excessive turbulence, and obstructions such as protruding rocks.

8. The stream flow site avoids locations where the stream channel has an abrupt narrowing or widening. An abrupt reduction, or enlargement, is a 30-50% decrease, or increase, from the average channel width over a channel length of 100 feet or less. The average channel width should be estimated from a channel length of 100 feet or more. Such abrupt changes in the channel width require additional considerations including hydraulic grade line, friction effects and turbulent flow, which are beyond the scope of this SOP.

9. The stream flow site is at least 5 diameters upstream and/or 10 diameters downstream of any culvert. If multiple culverts are present, use the diameter of the largest culvert to determine the upstream and/or downstream stream flow site location. Note: if a culvert is the target for flow measurement, please refer to an approved culvert-flow SOP for appropriate procedures.

10. The stream flow site is at least 100 feet upstream and/or downstream of widening of confluences with other streams.

11. The stream flow site is located where other data is collected.

Field Procedures

1. Review the Health and Safety Plan (HASP), Work Plan, and manufacturer's instructions for operating the FlowTracker2.

2. Assemble inventory of materials, supplies, and equipment.

3. Prior to departing to the field site, perform the Office Diagnostic Procedure on the FlowTracker2 as described in Section 7.1.3 of the FlowTracker2 User's Manual. From the Utilities menu, manually check the battery life, clock, and GPS location. To verify Raw Data and Beam Check functions, place the FlowTracker2 probe in a bucket of water. Check the velocity, SNR, temperature, and tilt plots to ensure they conform to expected values as defined in the User's Manual. Execute the Automated Beam Check. The Automated Beam Check should complete successfully without error messages. It may be necessary to add a small amount of sediment to the water for the beam check to work properly. If the Beam Check generates errors, contact the manufacturer for resolution or servicing of the instrument.

4. The FlowTracker2 default setting is metric units. If U.S. Customary Units (USCS) are required, change the unit setting: from the main menu, select Device Configuration, then Application Settings. Set units to "English."

5. At the selected discharge measurement location, fix a measurement tape or tag line across the water at a height visible while wading in stream. The line must be graduated in units of length using a system of units consistent with those that will be recorded via the FlowTracker2. Secure the tape to stakes, competent trees, or another method that will provide a secure fixture for the tape. Do not fix lines across a stream if there is a risk of entanglement with water-craft users.

6. Assemble the FlowTracker2 and a top-setting wading rod and position the FlowTracker2 in the stream such that the blue arm that attaches the FlowTracker2 probe to the wading rod is pointing upstream and the wading rod is vertical (no tilt). Face upstream and position the FlowTracker2 upstream of the operator. Measurements can be initiated from either the right bank or left bank. Maintain an upstream-facing position with the FlowTracker2 deployed upstream of the operator during all measurements.

7. Activate the FlowTracker2 to begin recording velocities/discharge. In the main FlowTracker2 menu, select "Measurement." On the next screen, "New File Type," select "Discharge." On the next screen, "New File Template," then select "Default". On the next screen, "New Data File," populate the site information. Press OK to continue.

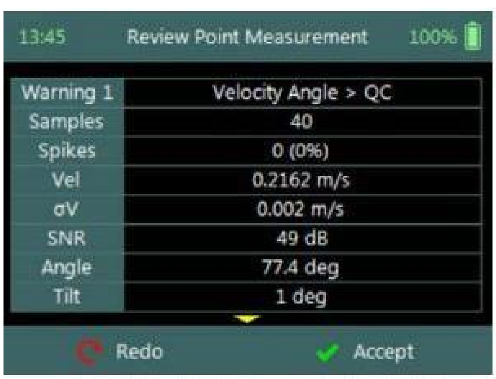
8. The FlowTracker2 menu will then prompt you to make an automated Beam Check. With the FlowTracker2 probe submerged in moving water and well away from underwater obstacles, press "Start." Allow the beam calibration cycle to complete. If the Beam Check completes without errors, press "Done" and continue step 9. If the Beam Check does not complete without errors, repeat the Beam Check. Failure to submerge the probe in moving water may result in Beam Check errors. If repeated, Beam Check calibrations fail to complete free of errors, terminate the measurement effort and contact the manufacturer for service.

9. Make the first measurement at the bank. In the "Data Collection" screen, press "Add Station." Input distance reading from the tag line corresponding to the position of the wading/suspension rod ("Location") and water depth as indicated on the wading. Water depth should be entered to the maximum precision provided by the wading rod. A properly graduated wading rod must be used to obtain required accuracy. Using the drop down menu, define whether the first measurement is at the left or right bank (left or right bank definition is made by the user based upon a reference frame oriented downstream). Leave the "Correction Factor" on the default setting of 1. Select the "Velocity Method." The preferred option for the velocity method is 0.2/0.8 in which measurements are made at depths below the water surface of 0.2 x full depth and 0.8 x full depth (0.2/0.8d). If the stream is less than 2.5 feet deep, select the 0.6-depth method to collect velocity measurements at only one depth (0.6 x full depth below the water surface) per station. Select "Measure." If using the 0.2/0.8d velocity method, the "Measurements" screen will

appear and the user will be prompted to select the 0.2d measurement or the 0.8d measurement. Select the desired depth for the first measurement.

10. The display on the handheld unit will update and prompt the user to position the suspension rod such that the Vernier scale on the wading rod corresponds to the depth selected in the previous step. Adjust (raise or lower) the suspension rod according to the graphic display to position the probe to the appropriate depth. Press “Start” and hold the rod upright until the measurement is completed; the measurement-progress graphic display indicates the progress of the measurement and when it has been completed. If the green bubble indicator on the screen turns red, it is an indication of excessive tilt of the wading/suspension rod. If excessive tilt is indicated, reposition the rod to eliminate the warning and repeat the measurement.

11. Following completion of the measurement described in the previous step, the handheld unit will index to the next screen, “Review Point Measurement” (shown below). On this screen, review the measurement just completed. See pages 124-126 of the FlowTracker2 User’s Manual for definitions of variables. Verify that the measured flow velocity is within the expected range based on historic measurements and observed conditions. If the measurement is acceptable, record the measurement data on the field form and select “Accept” using the FlowTracker2 user interface.



If the measurement is not acceptable, repeat the measurement (Step 10). Encountering a negative velocity is indicative of instrument error or a flow reversal. Observe the current in the stream. If a flow reversal is apparent or likely, consider selecting a different location free from eddies and flow reversals. If actual reversed flow is likely and an alternate section is not an option, turn the instrument to direct it downstream with the operator standing upstream and slightly to the side. Observe the indicated velocity. If the velocity observed in this reversed orientation is similar to the absolute value of the negative velocity observed during normal (upstream) orientation, turn around to face in the upstream direction and reposition the probe and wading rod in the same location as that occupied when the original negative velocity was observed. Complete the measurement as normal and “Accept” and record the negative velocity. Reduce the width of station sections until positive velocities are observed and continue making measurements. When calculating total discharge, check calculations to ensure that the negative velocity stations are treated as negative flow. If using a multi-point method per station, such as the 0.2/0.8d method, the user will be prompted via the "Measurements" screen to setup for the next measurement at the current station. Select the desired measurement. Repeat steps 10 and 11 for the remaining measurements at the current station.

12. Move the probe to the next station. The distance between stations should generally be approximately 1/20th of the stream width with approximately 5% of the total discharge passing through each station section. In those portions of the stream section characterized by higher velocity, station section width should be reduced by using smaller horizontal offsets between each measurement. Repeat steps 9-11. On the "Add Station" screen, select "Station Type Open Water."

13. When velocity/discharge measurements have been completed at each station across the stream section, including the Left Bank and Right Bank measurements, view the discharge summary from the "Data Collection" menu and record the total discharge on the Field Form.

Review individual station data and the total discharge result and compare to historic results and observed site conditions. Determine if any results depart widely from past results or observed conditions.

If an erroneous measurement is suspected, delete the station and collect a new measurement at or near the previous measurement location. Also, if one or more stations recorded more than 5% of the total discharge, further subdivide the stream section at that station by making additional station measurements (using the same vertical discretization as used in the suspect stations) to either side of the original measurement location.

14. When measurement is complete, select "Complete Measurement" from the "Data Collection" menu. Select "OK," then "Complete." This will close the measurement file and the user will not be able to add additional stations or make

any changes to the data. From the Summary page, copy the final discharge onto the field form.

15. Download FlowTracker2 software to a laptop or desktop computer from the flash drive provided with the FlowTracker2. See pages 206-207 of the FlowTracker2 User's Manual for directions to install and navigate the software.

16. Open the FlowTracker2 program on the computer. Connect the FlowTracker2 handheld unit to the computer using the USB to micro USB cord included with the FlowTracker2. The measurement probe does not have to be connected to the handheld unit during this process. Turn on the FlowTracker2. From the main menu, select "Communication." On the computer, select the "Device" icon in the upper left corner of the FlowTracker2 user interface, then select "USB." Files stored in the FlowTracker2 handheld unit will display in a list. Highlight the desired files and select "Export" in the upper left corner of the screen. Select a location to save on the computer hard drive. Locate the files on the computer and email them to the Foth Project Hydrologist.

Stream Discharge using the Float Method - 10

Harrelson, et al., 1994. "USPS Guidance on Stream Channel Field Techniques."

The amount of water passing a point on the stream channel during a given time is a function of velocity and cross-sectional area of the flowing water.

$$Q = AV$$

where Q is stream discharge (volume/time), A is cross-sectional area, and V is flow velocity

You need:

- tape measure
- stop-watch
- rod, yard or meter stick to measure depth
- at least three highly visible buoyant objects such as a drifting branches or logs, pine cone, coffee stir sticks, half filled bottles, or oranges (objects buoyant enough not to be effected by the wind)
- stakes for anchoring tape measure to stream banks
- Waders

1. **Float method** – inexpensive and simple. This method measures surface velocity. Mean velocity is obtained using a correction factor. The basic idea is to measure the time that it takes the object to float a specified distance downstream.

$V_{surface}$ = travel distance/ travel time = L/t

Because surface velocities are typically higher than mean or average velocities
$V_{mean} = k\ V_{surface}$ where k is a coefficient that generally ranges from 0.8 for rough beds to 0.9 for smooth beds (0.85 is a commonly used value)

Step 1. Choose a suitable straight reach with minimum turbulence (ideally at least 3 channel widths long).

Step 2. Mark the start and end point of your reach.

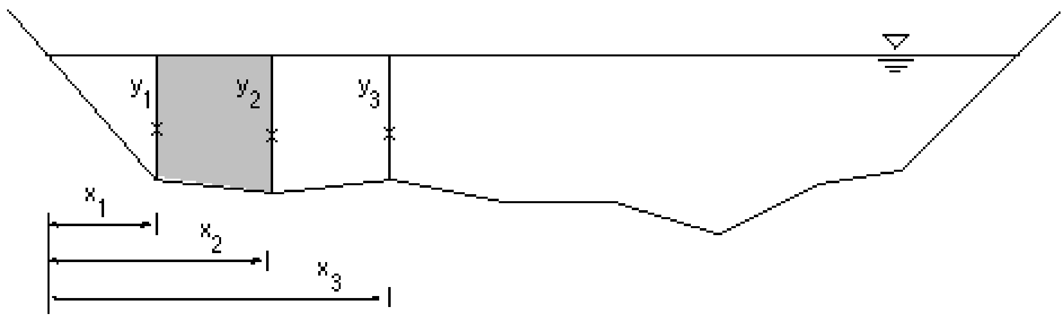
Step 3. If possible, travel time should exceed 20 seconds.

Step 4. Drop your object into the stream upstream of your upstream marker.

Step 5. Start the watch when the object crosses the upstream marker and stop the watch when it crosses the downstream marker.

Step 6. You should repeat the measurement at least 3 times and use the average in further calculations.

Step 7. Measure stream's width and depth across at least one cross section where it is safe to wade. If possible, measure depth across the stream's width at the start and stop markers and average the two but if measuring one cross section choose the downstream side. Use a marked rod, a yard or meter stick to measure the depth at regular intervals across the stream. Ten depth measurements is the minimum required but more is better, especially in larger streams. Or another method, walk heal to toe, and measure stream depth every left big toe, along the downstream cross section. Average your cross-sectional areas (A): Using the average area and corrected velocity, you can now compute discharge, Q.



Q = Cross section area (A) * mean velocity (V)
Essentially the cross section technique estimates each of the terms on the right hand side of the equation(s) and multiplies them together. The cross section area of the channel is estimated at a transect, across which water depth and average water column velocities are measured at a series of points (verticals).

Optional steps:

If increased accuracy is desired and the stream is wide enough, you can divide the stream into 3 or more sections or float lanes, and measure surface velocities in each lane.

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Standard Operating Procedure - 11

Instrumentation Calibration

Introduction

The purpose of this Standard Operating Procedure (SOP) is to eliminate or minimize factors that cause inaccurate measurements which is a fundamental aspect of instrumentation design.

Instrument calibration is one of the primary processes used to maintain instrument accuracy. Calibration is the process of configuring an instrument to provide a result for a sample within an acceptable range.

Although the exact procedure may vary from instrument to instrument, the calibration process generally involves using the instrument to test samples of one or more known values called “calibrators.” The results are used to establish a relationship between the measurement technique used by the instrument and the known values. The process in essence “teaches” the instrument to produce results that are more accurate than those that would occur otherwise. The instrument can then provide more accurate results when samples of unknown values are tested in the normal usage of the product.

Calibrations are performed using only a few calibrators to establish the correlation at specific points within the instrument’s operating range. While it might be desirable to use a large number of calibrators to establish the calibration relationship, or “curve”, the time and labor associated with preparing and testing a large number of calibrators might outweigh the resulting level of performance. From a practical standpoint, a tradeoff must be made between the desired level of product performance and the effort associated with accomplishing the calibration. The instrument will provide the best performance when the intermediate points provided in the manufacturer’s performance specifications are used for calibration; the specified process essentially eliminates, or “zeroes out”, the inherent instrument error at these points.

References

American Society of Testing and Materials, 2014. *Standard Guide for the Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells*, D6634-14, West Conshohocken, PA.

Brown, Philip J., 1993. Measurement, Regression, and Calibration. Oxford Statistical Science Series, 12. Oxford [England]: Clarendon Press.

Skoog, D.A., F.J. Holler, S.R. Crouch, 2007. Principles of Instrumental Analysis, 6th Ed.

U.S. Army Corps of Engineers, 2001. *Requirements for the Preparation of Sampling and Analysis Plans*, Appendix C, EM-200-1-3, Washington, D.C.

Definitions

Calibration refers to the act of evaluating and adjusting the precision and accuracy of measurement equipment. Instrument calibration is intended to eliminate or reduce bias in an instrument's readings over a range for all continuous values.

Precision is the degree to which repeated measurements under unchanged conditions show the same result.

Accuracy is the degree of closeness of measurements of a quantity to its actual true value.

Purpose

For this purpose, reference standards with known values for selected points covering the range of interest are measured with the instrument in question. Then a functional relationship is established between the values of the standards and the corresponding measurements.

There are two basic situations.

1. Instruments which require correction for bias:

   The instrument reads in the same units as the reference standards. The purpose of the calibration is to identify and eliminate any bias in the instrument relative to the defined unit of measurement. For example, optical imaging systems that measure the width of lines on semiconductors read in micrometers, the unit of interest. Nonetheless, these instruments must be calibrated to values of reference standards if line width measurements across the industry are to agree with each other.

2. Instruments whose measurements act as surrogates for other measurements:

   The instrument reads in different units than the reference standards. The purpose of the calibration is to convert the instrument readings to the units of interest. An example is densitometer measurements that act as surrogates for measurements of radiation dosage. For this purpose, reference standards are irradiated at several dosage levels and then measured by radiometry. The same reference standards are measured by densitometer. The calibrated results of future densitometer readings on medical devices are the basis for deciding if the devices have been sterilized at the proper radiation level.

Basic steps for correcting the instrument for bias
The calibration method is the same for both situations stated above and requires the following basic steps:

1. Selection of reference standards with known values to cover the range of interest.

2. Measurements on the reference standards with the instrument to be calibrated.

3. Functional relationship between the measured and known values of the reference standards (usually a least-squares fit to the data) called a Calibration Curve.

4. Correction of all measurements by the inverse of the calibration curve.

How to reveal and avoid errors in the instruments
Some people mix up field check and calibration. Field check is when two instruments have the same reading; this does not mean they are calibrated; it may be that both instruments are wrong. The easiest way to determine if it is accurate and fix it is to send the instrument to a calibration laboratory. Another way to reveal constant errors is to have one or more similar thermometers. One instrument is used and then replaced by another instrument. If readings are divided among two or more instrument, inconsistencies among the instrument will ultimately be revealed.

It is important to save all documentation for calibrations or certifications from a manufacturer, rental companies, and/or suppliers.

Responsibilities

Foth employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure and the specific calibration procedures of the specific instrument that is being calibrated or required in the Sampling and Analysis Plan. Foth employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e., checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

Equipment

The following equipment is recommended for performing calibrations measurements:

- Water quality meter(s)
- Gas quality meters
- Survey equipment
- Colorimetric meters
- Nuclear density meters
- Stream velocity meters
- Sound meters

The above list is not intended to be a complete list of items that need to be calibrated.

Procedures

To ensure approximate instrument calibration, follow the general instructions below or the manufacturer's recommendations.

When do instruments need to be calibrated?

- At a minimum of once per day

- Before major critical measurements
  - Before any measurements that requires highly accurate data, send the instruments out for calibration and remain unused before the test.

- After major critical measurements
  - Send the instrument for calibration after the test helps user decide whether the data obtained were reliable or not. Also, when using an instrument for a long time, the instrument's conditions will change.

- After an event
  - The event here refers to any event that happens to the instrument. For example, when something hits the instrument or any kinds of accidents that might impact the instrument's accuracy. A safety check is also recommended.

- When observations appear questionable
  - When you suspect the data's accuracy that is due to instrumental errors, send the instrument to calibrate.

- Per sampling plan requirements
  - Some experiments require calibration certificates. Check the requirements first before starting the experiment.

- Indicated by manufacturer
  - Every instrument will need to be calibrated periodically to make sure it can function properly and safely. Manufacturers will indicate how often the instrument will need to be calibrated.
  - Certifications are to be completed as per manufactures suggestions or when meter is perceived to be working improperly or required by a regulatory permit.

Why is calibration of an instrument so important?
Instrument calibration will increases the reliability, repeatability, credibility, and confidence of the data collected with the calibrated instrument verses the uncalibrated instrument.

Calibration
Calibration ***must*** *be performed* ***at least once per day*** *during operation. Calibrate the meter according to the instrument's operating manual. If sampling and monitoring is being performed for long periods of time, periodically check the instrument calibration using the operating manual's recommended frequency.*

In order to avoid limiting the field personnel to one particular model, only general calibration instructions are presented in this procedure:

- When choosing the appropriate instrument, ensure that the measuring range of the instrument encompasses the expected sample concentration or units.

- Before going to the field, locate all necessary field supplies such as deionized water, calibration solutions, decontamination supplies, spare parts, batteries, Sampling and Analysis Plan, and bench mark coordinates.

- Save all calibration forms supplied by the rental company or received from manufacturer or certifying agency.

- Follow the manufacturer's operational manual for all calibration procedures. Reference these procedures in all documentation. Consult the instrument's operation manual as well as the project-specific Sampling and Analysis Plan to verify that you have prepared the proper equipment and supplies to successfully complete the work.

- Locate a clean, protected area in which to set up and calibrate the instrument. Ensure that sufficient supplies of de-ionized water, clean paper towels, buffer solutions, and standard solutions are available.

- Inspect the meter and probes for damage. Some of the probes are very delicate or have a thin membrane installed over the probe. Be careful when handling the meter/probes so as not to damage them. If damaged, replace probes in accordance with the instrument's operating manual or obtain a different meter.

- Turn on the meter and allow it to "warm-up" for the manufacturer-specified time (usually 15 to 30 minutes). Check the battery power to determine if the meter has sufficient power to operate for the monitoring period. Replace the batteries, if necessary.

- Document all calibration methods and solutions (manufacturer, lot no., date open, and date expired). In addition, document units calibrated.

- Calibrate the meter according to the instrument's operating manual. In general, calibration is performed by immersing the probe(s) in aliquots of calibration standard solution(s) and following certain meter keystrokes to set the calibration for each parameter. Do not immerse the probe into the stock container of the solution. Always transfer a small amount of the solution into a separate container to calibrate the probe(s). If calibrating for multiple parameters using more than one solution, be sure to wipe off and rinse the probe with deionized water between solutions.

- Recheck each parameter after calibration by immersing the probe into the calibration solution and reading it like a sample reading. If the agreement is not within 25% of the solution's known concentration, repeat the calibration process with a new solution aliquot.

- Discard the used calibration solution aliquots when finished into an appropriate waste container.

- Survey equipment should record two control points or benchmarks at the beginning of survey day and one at the end of the survey day.

- Record the calibration data in the Field Log Book or calibration log sheet.

- Save all electronic calibration forms, curves, or information in appropriate file locations.

Standard Operating Procedure - 12

Water Quality Meter Use

Introduction

This Standard Operating Procedure (SOP) is intended to provide general guidance and methods for using a field meter to measure water quality parameters from groundwater or surface water that is being purged, sampled, or monitored.

This procedure is applicable to all Foth projects where water quality monitoring is required using a water quality meter. The water quality meter may be a stand-alone meter or it may be a combined multi-probe unit used to measure temperature, pH, specific conductance, and/or other water quality parameters. The most common methods used for measuring water quality are instruments that measure in-situ parameters in one of the following two ways:

Water is extracted from its source using a pump and measured in a flow-through cell or in some instances captured and then measured in individual aliquots. This method is preferred when monitoring wells are sampled for laboratory analysis of chemical parameters, and groundwater purging is required.

The meter is submerged directly into the sample source, such as a monitoring well or surface water body, to collect in-situ monitoring parameters.

References

American Society of Testing and Materials, *Standard Guide for Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells*, D6634-01, West Conshohocken, PA.

American Society of Testing and Materials, *Standard Guide for Sampling Ground-Water Monitoring Wells*, D4448-01, West Conshohocken, PA.

U.S. Army Corps of Engineers, 2001. *Requirements for the Preparation of Sampling and Analysis Plans*, Appendix C, EM-200-1-3, Washington, D.C.

Definitions

- Water Quality Meter – A device used to measure specific field parameters indicative of water quality, such as temperature, pH, specific conductance, and/or other parameters. The meter may be stand-alone or it may be a combined multi-probe unit.

- Pump – An electric, compressed air, or inert gas-driven device that raises liquids by means of pressure or suction. The types of pumps that should be used for water quality monitoring should be chosen based on the well size and depth, the type of contaminants, and the specific factors affecting the overall performance of the sampling or monitoring effort. The types of pumps that may be used include centrifugal, peristaltic, centrifugal submersible, gas displacement, and bladder pumps.

- pH – The negative log of the hydrogen ion concentration (-log10 [H+]); a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. The scale is 0 to 14.

- Turbidity – A measure of overall water clarity determined by measurement of the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles. Turbidity is commonly measured in Nephelometric Turbidity Units (NTU) but may also be measured in Jackson Turbidity Units (JTU).

- Specific Conductance (SC) – A measure of how well water can conduct an electrical current. Conductivity increases with increasing amount and mobility of ions such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution. The unit of conductance is expressed as microsiemens (1/1,000,000 siemen) per centimeter, or µS/cm.

- Oxidation-Reduction (Redox) Potential (ORP) – A measure in volts of the affinity of a substance for electrons compared with hydrogen. Liquids that are more strongly electronegative than hydrogen (i.e., capable of oxidizing) have positive redox potentials. Liquids less electronegative than hydrogen (i.e., capable of reducing) have negative redox potentials. Although the standard hydrogen electrode (SHE) is the ultimate reference for all ORP measurements, in practice an ORP field measurement may be made with other electrodes, such as silver chloride. These values may be converted to SHE values.

- Dissolved Oxygen (DO) – Refers to the amount of oxygen expressed as milligrams per liter (mg/L) that is contained in particular water. The amount of oxygen that can be held by the water depends on the water temperature, salinity, purity, and pressure.

- Salinity – The amount of dissolved salts in water, generally expressed in parts per thousand (PPt).

Responsibilities

Foth employees performing this task, or any portion thereof, are responsible for meeting the requirements of this procedure. Foth employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e., checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

Equipment

The following equipment is recommended for use in performing water quality measurements:

- Water quality meter(s)
- Spare parts such as alkaline batteries (if used) and sensor probes
- Pump and discharge hose/line for use with a flow-through cell
- Paper towels or lint-free wipes
- Deionized water
- Sample gloves
- Calibration solutions for all parameters being measured; within expiration dates
- Plastic sheeting
- Field Log Book or log sheets

Procedures

General Instructions

- Ensure that the measuring range of the instrument encompasses the expected sample concentration or units.

- Before going to the field, locate all necessary field supplies such as deionized water, calibration solutions, decontamination supplies, and spare parts.

- Consult the instrument's operation manual as well as the project-specific sampling plan to verify that you have prepared the proper equipment and supplies to successfully complete the work.

Calibration

Calibration ***must*** *be performed* ***at least once per day*** *during operation. Calibrate the meter according to the instrument's operating manual. If sampling and monitoring is being performed for long periods of time, periodically check the instrument calibration using the operating manual's recommended frequency.*

In order to avoid limiting the field personnel to one particular model, only general calibration instructions are presented in this procedure.

- Locate a clean, protected area in which to set up and calibrate the instrument. Ensure that sufficient supplies of de-ionized water, clean paper towels, buffer solutions, and standard solutions are available.

- Inspect the meter and probes for damage. Some of the probes are very delicate or have a thin membrane installed over the probe. Be careful when handling the meter/probes so as not to damage them. If damaged, replace probes in accordance with the instrument's operating manual or obtain a different meter.

- Turn on the meter and allow it to "warm-up" for the manufacturer-specified time (usually 15 to 30 minutes). Check the battery power to determine if the meter has sufficient power to operate for the monitoring period. Replace the batteries, if necessary.

- Calibrate the meter according to the instrument's operating manual. In general, calibration is performed by immersing the probe(s) in aliquots of calibration standard solution(s) and following certain meter keystrokes to set the calibration for each parameter. Do not immerse the probe into the stock container of the solution. Always transfer a small amount of the solution into a separate container to calibrate the probe(s). If calibrating for multiple parameters using more than one solution, be sure to wipe off and rinse the probe with deionized water between solutions.

- Recheck each parameter after calibration by immersing the probe into the calibration solution and reading it like a sample reading. If the agreement is not within 25% of the solution's known concentration, repeat the calibration process with a new solution aliquot.

- Discard the used calibration solution aliquots when finished into an appropriate waste container.

- Record the calibration data in the Field Log Book or log sheet.

Operation of the Instrument

- If using a flow-through cell system, attach the extraction pump and lines in accordance with the pump and meter manufacturer's instructions. Allow the lines to fill and the probes to become immersed before switching the instrument to its measurement mode.

- If using a down-hole system, allow a few minutes for the probe to stabilize before taking a reading.
- Operate the meter in accordance with the instrument's operating manual.
- Collect the field parameter reading(s) per the project requirements, and record them in a Field Log Book or on log sheets.
- Decontaminate the meter before collecting data from the next sample source. For a flow-through system, flush the lines with three line volumes of deionized water or replace with new ones between samples.

Foth Infrastructure & Environment, LLC

Standard Operating Procedure - 13

Low Level Mercury Surface Water Sampling

Introduction

The general procedures to be utilized in obtaining low level mercury samples in surface waters are outlined below. Grab samples will be obtained by submerging the sample bottle under the water surface interface prior to opening. Samples will be collected in a well-mixed area of flow, representative of the surface water being sampled.

Low level mercury analysis uses an extremely sensitive test method that can be affected by even slight contamination not related to the mercury level in the surface water. Contamination of samples or sample containers may originate from air, sampling personnel or contacted surfaces. To avoid contamination and to properly collect representative samples for low level mercury analysis, the persons obtaining the samples should have a team of at least two people with a good understanding of potential sources of contamination. The team shall follow the "clean hands/dirty hands" procedure for sample collection. Each day a sample is collected for low level mercury analysis, a field blank must be generated and analyzed, because even slight contamination can adversely affect surface water or background sample results. A field blank is a portion of mercury-free water that is processed through the full sequence of sampling steps.

References

U.S. Environmental Protection Agency, Method 1669, “Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels,” July 1996 (William A. Telliard, et al.).

U.S. Geologic Survey Water Resource Division, “Low Level Collection Techniques and Species- Specific Analytical Methods for Mercury in Water, Sediment, and Biota,” by Mark Olson and John F. De Wild reported in the USGS Water-Resource Investigations Report 99-4018B, 1999.

“Water Quality Criteria Levels,” July 1996 (William A. Telliard, et al.).

Personnel Qualifications

Qualifications of sampling personnel are as directed in the Project Planning Document (PPD), Health & Safety Plan, and appointed by the Project Manager:

- One person must be trained in this sampling technique.

- A minimum of two people are required to conduct sampling, but a third person is ideal for assistance depending on sample location or boat navigation.
  - "Clean hands" person
  - "Dirty hands" person
  - If sampling is conducted from a water craft, the person operating the water craft must have boating safety.

- Additional Health and Safety Training Requirements:
  - All field personnel must have current CPR (Cardiopulmonary Resuscitation) and First Aid training.
  - All field personnel must have satisfied Occupational safety and Health Administration (OSHA) training requirements (40 CFR 1910.120) if hazardous materials are expected.
  - All field personnel must have satisfied Mine Safety and Health Administration (MSHA) requirements if working on a project site regulated by MSHA.

Equipment and Supplies

- Shipping container(s) for the sampling event to identify and protect bottles from possible sources of cross-contamination and breakage during storage and transportation.

- The correct quantity of properly cleaned and prepared glass or fluoropolymer (Teflon®) bottles (polyethylene bottles should not be used), stored in double self-seal plastic bags (remember blank(s) and extra bottles, if glass, to account for breakage. Note: Sample bottles will be pre-preserved in the laboratory.

- Mercury free lab water, for blanks, in containers and sealed in plastic bags.

- Provision for labeling samples (pre-labeled outer bags or other method).

- A sampling table and clean plastic sheeting to cover the table top and plastic clamps or other provision for retaining the plastic sheet on the table (the table may not be necessary if you don't have to set down bottles or you may set them down on another plastic-covered surface such as a cooler).

- Data log book, lab sheets, and chain of custody forms.

- Personal protective equipment that normally used when collecting samples at the sample collection site.

- Waders may be needed if entering a stream to collect samples.

- Tyvek® (or equivalent) coveralls for sampling personnel (unnecessary if you are able to collect uncontaminated samples without them. Note: Blue Tyvek® is NOT acceptable. No metal zippers, clasps, buttons, jewelry, etc. shall be exposed. Face masks or full face shields must be worn if any member of the sampling team uses tobacco products (smokes, chewing tobacco, etc.) or has mercury dental fillings or metal braces. Hoods (or equivalent) shall be worn to cover earrings.

Procedures

This is the basic procedure for collecting one sample. The procedure should give sampling personnel an idea which surfaces each person on the team may touch. To incorporate collection of field blanks into the procedure you may add a third person (second “clean hands”) to the team or you may try a procedure where "clean hands" sets sample bottles down on previously spread plastic sheeting.

Descriptions of possible field blank procedures follow the basic procedures for collecting samples.

1. All team members carry the equipment near the sampling site. If using a water craft, place equipment on plastic in water craft.

2. All members remove Tyvek® suits from protective bag and put them on (if used). “Dirty hands” may need to put on waders if accessing stream by wading. Face masks and hoods are to be donned, if applicable.

3. Prepare the sampling area for low-level technique to minimize contamination. Lay plastic sheeting down if needed for clean work area. Check wind and weather conditions. In field book, note operations of heavy equipment or other gas power equipment operating in area, exhaust from buildings, and any other potential sources of contamination. If any of the above conditions affect sample collection, the sampling event shall cease until conditions permit accurate sample collection. Plan to enter the surface water, downstream from sample location. Sample location should be upstream of any culvert or bridge.

4. Designate one member of the team as "clean hands" and the other as "dirty hands.” “Clean hands” may only touch the inner bag and sample bottle and performs the sampling. “Dirty hands” may NOT touch the inner bag or sample bottle but may touch anything else and performs tasks to assist “clean hands.”

5. "Dirty hands" opens a bag containing non-talc gloves.

6. "Clean hands" removes a pair of clean gloves and puts them on.

7. "Dirty hands" removes a pair of clean gloves and puts them on.

8. "Dirty hands" removes a second pair of clean gloves and puts them on “clean hands” for double-gloving. "Clean hands" touches only the inner bag and sample bottle from this point forward. Prior to collecting the sample, the “clean hands” member should have fingers interlocked and in front of his/her face until sampling is performed.

9. "Dirty hands" removes an empty bagged sample bottle from the shipping container, closes the container, and opens the outer bag.

10. "Clean hands" opens the inner bag, removes the bottle, and folds the inner bag down into the outer bag.

11. "Dirty hands" seals the outer bag and puts it back in the shipping container.

12. "Clean hands" enters the surface water and submerges the bottle at sample location. Sample bottle should be upright and pointed upstream into the flow.

13. "Clean hands" removes the bottle cap slightly from the bottle and bleeds surface water into the sample bottle at a slow rate. Air bubbles will indicate the bottle is filling. The sample bottle is partially filled and bottle cap tightened before bottle is removed from the water. Triple rinse is performed by shaking water in bottle and dumping back into the surface water, if the bottle is not pre-preserved. If sample bottle is pre-preserved, do not triple rinse bottle

14. After triple rinsing, the same procedure in Step 13 is used to collect sample; air bubbles will indicate the bottle is filling. When bubbles cease, the bottle is full--leaving a slight headspace.

15. "Clean hands" tightly screws the cap back onto the bottle under water. "Clean hands" returns to a position which maintains contaminant-free sampling while holding the sample bottle, awaiting next step.

16. "Dirty hands" retrieves the bags and opens the outer bag.

17. "Clean hands" reaches inside to re-open the inner bag, puts the sample bottle inside, and seals the inner bag.

18. "Dirty hands" seals the outer bag and places the bagged sample into the shipping container.

19. “Dirty hands” or third member of the team then records the sample bottle number with description and other relevant data.

20. “Clean hands” returns to a position which maintains contaminant-free sampling and prepares for filling the field blank.

21. Repeat Steps 9-20 for filling additional bottles, split samples, duplicates, or the field blank.

At the end of the sampling event, document the above sampling procedure in the project field notebook, including sampling team names. Note: Any possible sources of cross contamination that could affect the results during the sampling procedure.

Field Blank Collection Procedures

It may be useful to include a third person (second "clean hands") for field blank collection. Alternatively, the "clean hands" person may set sample bottles or field blank bottles down on previously spread, clean plastic sheeting. The field blank is for checking field contamination. Enough mercury-free water is needed to complete a triple rinse and fill sample bottle for sample collection. Document field conditions each time you prepare a field blank. If sources of contamination cannot be determined in the field, ask the lab to prepare a trip blank for low-level mercury to accompany the samples.

Note: A field blank is a volume of mercury-free water (usually shipped from the lab) that is processed through the full sequence of sampling steps and certified. Contrast this to a trip blank that is a bottle of mercury-free water (provided by the lab) that "goes along for the ride" but remains unopened at the sampling site.

Preservation and Storage for Low Level Mercury

Ship collected samples to the lab following the procedures you and your lab agreed to.

1. Low level mercury samples shall be shipped/delivered on ice to the laboratory. In very cold weather, prevent the samples from freezing such as by shipping overnight.

2. Follow the instructions of your laboratory for chemical preservation, if any. Preservation of low level samples in the field is optional. Regulatory agencies recommend omitting field preservation, thereby eliminating that step as a potential source of contamination.

Note: Sample bottles that contain acid preservative may need to be shipped in accordance with the federal hazardous materials rules (49 CFR, Part 172).

Attachment 27

Permit No. MI0059945

FACT SHEET

PERMITTEE/FACILITY NAME: Aquila Resources Inc. / Back Forty Project

COUNTY: Menominee

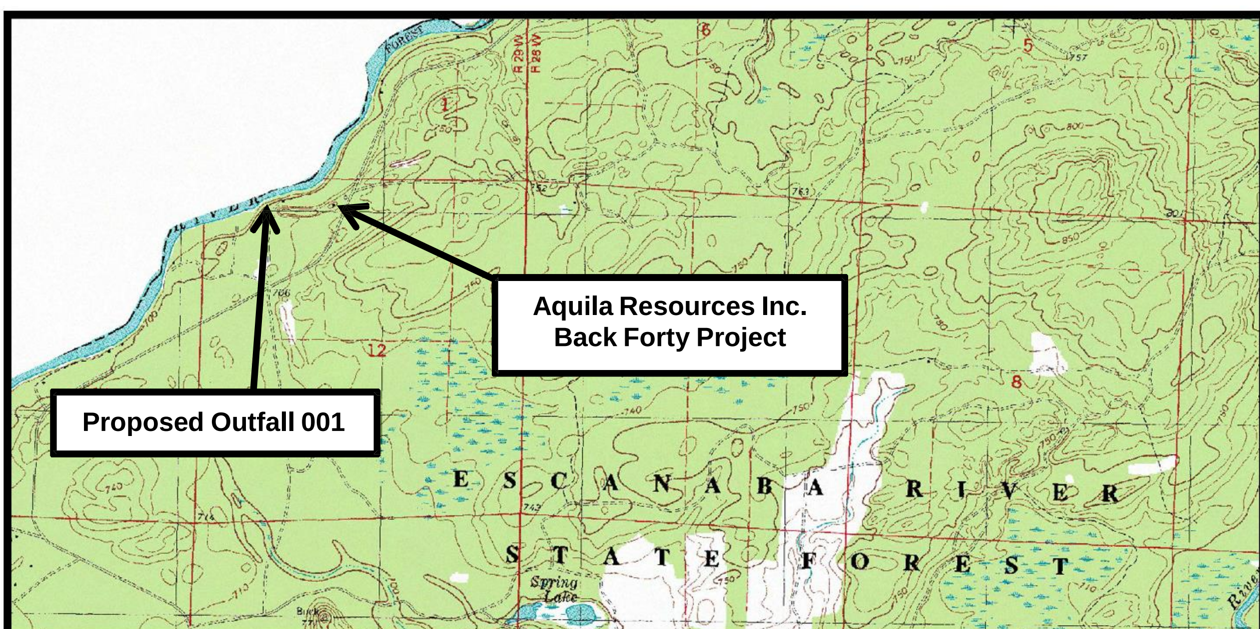
DESCRIPTION OF PROPOSED WASTEWATER TREATMENT FACILITIES

All water generated including storm water runoff will be collected in two lined contact water basins. Some quantities of water will be withdrawn, used, and returned to the contact water basins. Excess amounts of water from the contact water basins will be treated and discharged through outfall 001 to the Menominee River. Water will be pumped from the contact water basins to the treatment plant and treated in two mixed reactor tanks in series where sodium hydroxide or lime, coagulants, metal chelating polymers, flocculants, and sodium hypochlorite will be added. The water from the reactor tanks will flow to a clarifier and will then be followed by a filtration process with a membrane system. The pH of the effluent will be adjusted by adding sulfuric acid or sodium hydroxide prior to discharge. The solids generated by treatment will be thickened with a gravity thickener and the decant will be returned to the mixed tank reactors. The thickened solids will be processed by a plate and flame filter press and the resulting solids will be transported and disposed offsite.

Prior to returning to the contact water basins, pretreatment for the leachate from the oxide tailings and waste rock management facility may be added. Treatment steps similar to the treatment plant are proposed for the pretreatment.

MAP OF DISCHARGE LOCATION

Facility Coordinates
Latitude 45.45068475, Longitude -87.8335155



RECEIVING WATER

The Menominee River is protected for agricultural uses, navigation, industrial water supply, public water supply in areas with designated public water supply intakes, warm-water fish, other indigenous aquatic life and wildlife, partial body contact recreation, total body contact recreation (May through October), and fish consumption.

The receiving stream flow used to develop effluent limitations is the 7-day Q10 flow of 940 cfs. This flow is used in accordance with previous agreements with the State of Wisconsin concerning design river flows for facilities that discharge to Michigan/Wisconsin border waters. The Wisconsin Department of Natural Resources reviewed the proposed effluent limits and concurred that they were protective of Wisconsin water quality standards. The 7-day Q10 flow is also equal to the lowest 95 percent exceedance flow of 940 cfs.

MIXING ZONE

For toxic pollutants, the volume of the Menominee River used to ensure that effluent limitations are sufficiently stringent to meet Water Quality Standards is 25 percent of the applicable design flow of the receiving stream.

For other pollutants, the volume of the Menominee River used to ensure that effluent limitations are sufficiently stringent to meet Water Quality Standards is the applicable design flow of the receiving stream.

PROPOSED EFFLUENT QUALITY: (from completed application dated December 8, 2015)

Parameter	Minimum Daily	Maximum Monthly	Maximum 7-Day	Maximum Daily	Units
Antimony	---	---	---	≤ 2,300	ug/l
Arsenic	---	---	---	≤ 680	ug/l
Barium	---	---	---	≤ 2,845	ug/l
Beryllium	---	---	---	≤ 59	ug/l
Boron	---	---	---	≤ 55,000	ug/l
Cadmium	---	---	---	≤ 9.7	ug/l
Chromium	---	---	---	≤ 1,259	ug/l
Cobalt	---	---	---	≤ 740	ug/l
Copper	---	---	---	≤ 30	ug/l
Cyanide	---	---	---	≤ 44	ug/l
Fluoride	---	---	---	≤ 3,100	ug/l
Lead	---	---	---	≤ 440	ug/l
Lithium	---	---	---	≤ 1,800	ug/l
Manganese	---	---	---	≤ 9,270	ug/l
Mercury	---	---	---	≤ 0.0013	ug/l
Molybdenum	---	---	---	≤ 58,000	ug/l
Nickel	---	---	---	≤ 1,038	ug/l
Phosphorus	---	---	---	≤ 1,000	ug/l
Selenium	---	---	---	≤ 120	ug/l
Silver	---	---	---	≤ 0.06	ug/l
Zinc	---	---	---	273	ug/l

PROPOSED EFFLUENT LIMITATIONS: (see draft permit)

BASIS FOR PROPOSED EFFLUENT LIMITATIONS: (see Basis for Decision Memo)

ADDITIONAL INFORMATION

The Department proposes that the applicant's Antidegradation Demonstration, based on information required by Subrule (4) of R323.1098, shows that lowering of water quality is necessary to support the identified important social and economic development in the area. This is solely for purposes of satisfying state water quality regulations and is not intended to supplant local requirements, including land use or zoning laws. It is not, and should not be construed as, a finding by the Department that the proposed development meets local requirements or ordinances.

PUBLIC COMMENT

The draft NPDES permit was on public notice between August 3, 2016 and September 2, 2016. A responsiveness summary and copies of the individual response letters to comments received in writing during the NPDES public notice period are available to the public in MiWaters.

In addition, a 64 day consolidated public comment period was held from September 1, 2016 through November 3, 2016. A consolidated public hearing was held on October 6, 2016 on the Aquila Resources Inc-Back Forty Mine Project regarding the permit applications and draft permits for air, mining, and water. Response to comments received during the consolidated public hearing can be found in the document titled "*Compiled Responses to Public Comments Regarding the Permit Applications and Related Regulatory and Administrative Concerns about the Proposed Back Forty Mine Project*" at the following link: http://www.michigan.gov/documents/deq/deq-oogm-Mining-AquilaBack40-responsecomments_547561_7.pdf.

ACTIONS TAKEN TO ADDRESS COMMENTS RECEIVED

1. Based on comments received, a reopener clause was added to Part I, Section A.1.j. of the permit. The reopener clause references the required ambient surface water monitoring in the Part 632 Mining permit, and incorporates the requirement to submit the ambient surface water data, into the NPDES permit.

   The ambient surface water monitoring must be collected quarterly, at each location for the parameters listed in Table 2.1 of the Environmental Monitoring Plan submitted with the Part 632 Mining permit application. Table 1 below lists the specific locations where ambient surface water sampling must be conducted consistent with the Environmental Monitoring Plan. Table 2 lists the parameters required to be sampled, the analytical method, and detection level for each parameter.

   Figure 1 shows the location of the ambient surface water monitoring coordinates listed in Table 1.

2. Based on comments received, Whole Effluent Toxicity (WET) testing requirements using a freshwater mussel species (*Ambleca plicata*), native to the Menominee River, have been added to Part I, Section A.1.i. of the permit due to the sensitivity of these organisms to a variety of contaminants.

3. Based on comments received, the quantification level for arsenic was reduced from 1.0 ug/l to 0.5 ug/l.

Table 1: Ambient Surface Water Monitoring Station Locations and Descriptions[1]

Site Name	Waterbody	Latitude	Longitude
MSG-1	Shakey Lake System - Long Lake	45.42067521	-87.84253047
MSG-2	Shakey Lake System – Bass Lake	45.41550164	-87.82074879
MSG-3	Shakey Creek	45.42050841	-87.78635801
MSG-4	Shakey River	45.44943693	-87.76443477
MSG-5	Little Shakey River	45.44867032	-87.75038542
MSG-6	Shakey River	45.46419466	-87.76761881
MSG-7	Shakey River	45.47178551	-87.76283686
MSG-8	Menominee River Tributary – Boerner Lower	45.46409072	-87.81193755
MSG-9	Menominee River Tributary – Unnamed (Schoneks)	45.47250087	-87.80469452
MSG-10	Menominee River	45.45090613	-87.83507940
MSG-11	Menominee River	45.38415846	-87.86635280
MSG-12	Shakey River	45.45585030	-87.77272923
MSG-13	Menominee River	45.45705168	-87.82986579
MSG-14	Menominee River	45.44360004	-87.84754471
MSG-15	Shakey Lakes System – Spring Lake	45.43130476	-87.82276211
MSG-16	Menominee River Tributary – Unnamed (WE Creek)	45.48036555	-87.80170459
MSG-17	Spring Creek	45.43855000	-87.82766000
MSG-18	Menominee River Tributary – Boerner Upper	45.46220000	-87.81110000
MSG-19	Menominee River Tributary – Boerner Lower	45.46421000	-87.81224000
MSG-20	Unnamed Tributary to Boerner Upper	45.45568600	-87.80680500

[1] Environmental Monitoring Plan, Appendix G, Part 632 Mining Permit Application, October 2015; the Part 632 Mining Permit MP 01 2016, and the Memorandum, Back Forty Project – Surface Water Monitoring Location Clarification, Foth Infrastructure & Environment, LLC, March 21, 2017.

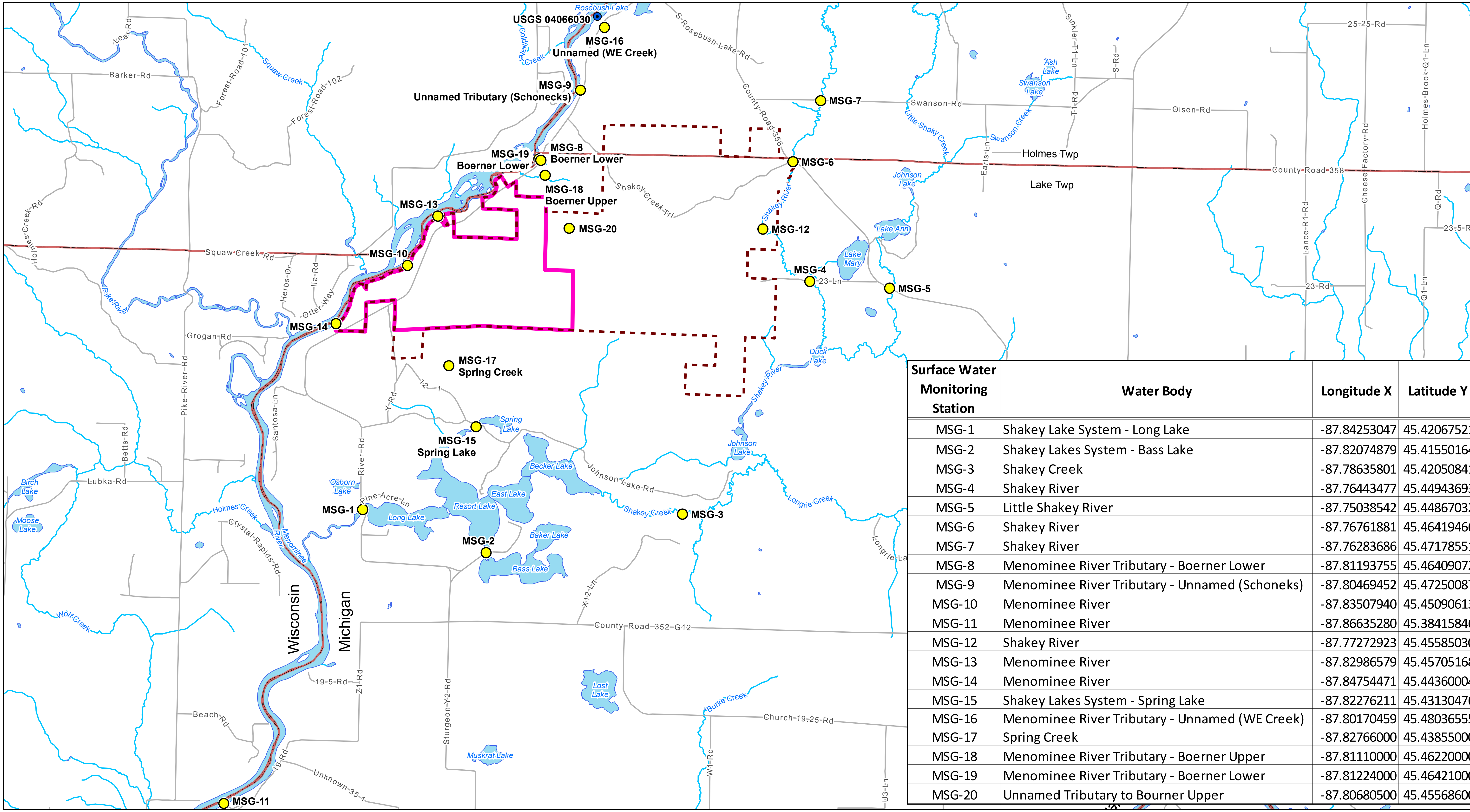
Table 2: Ambient Surface Water Sampling Parameter List[2]

Parameter	Units	Analytical Method	Detection Level
Field			
Oxidation Reduction Potential	mV	Field Measured	NA
Field pH	S.U.	Field Measured	NA
Specific Conductance	umhos/cm	Field Measured	NA
Temperature	°F	Field Measured	NA
Dissolved Oxygen	mg/l	Field Measured	NA
Color	PCU	Field Measured	NA
Turbidity	NTU	Field Measured	NA
Lab			
Acrylamide	µg/l	8032A/8316/8270C	0.5
Alkalinity, Bicarbonate	mg/l	EPA 310.1/SM 2320 B	10.0
Alkalinity, Carbonate	mg/l	EPA 310.1/SM 2320 B	10.0
Ammonia	mg/l	EPA 350.1	0.02
Antimony	µg/l	EPA 200.8/6020	2.0
Arsenic	µg/l	EPA 200.8/6020	5.0
Cadmium	µg/l	EPA 200.8/6020	1.0
Calcium	mg/l	EPA 200.7/6010 B	0.50
Chloride	mg/l	EPA 325.2/4500 CL E	1.0
Copper	µg/l	EPA 200.8/6020	4.0
Cyanide	µg/l	EPA 335.4	0.005
Fluoride	mg/l	9056A	0.1
Hardness	mg/l	SM 2340C	1.0
Iron	mg/	EPA 200.7/6010 B	200
Lead	µg/l	EPA 200.8/6020	3.0
Magnesium	µg/l	EPA 200.7/6010 B	1.0
Manganese	µg/l	EPA 200.8/6020	50
Mercury	ng/l	EPA 1631 E	0.5
Nickel	µg/l	EPA 200.8/6020	1.0
Nitrate-N	mg/l	EPA 353.2/4500 NO3F	0.02
Nitrite	mg/l	EPA 353.2 or 353.1/4500 NO2B	0.02
Potassium	mg/l	EPA 200.7/6010 B	0.50
Radium	pCi/l	EPA 930.1/904	1.0
Selenium	µg/l	EPA 200.8/6020	5.0
Silver	µg/l	EPA 200.8/6020	0.2
Sodium	mg/l	EPA 200.7/6010 B	1.0
Sulfate	mg/l	EPA 375.4/9038	2.0
Sulfide	mg/l	EPA 376.1/4500 S2 F	1.0
Total Dissolved Solids	mg/l	EPA 160.1	5.0
Total Suspended Solids	mg/l	EPA 160.2	5.0
Uranium	µg/l	ASTM D5174	0.25
Volatile Organic Compounds	µg/l	8260B	various
Zinc	µg/l	EPA 200.8/6020	500

[2] Derived from Table 2-1 in the Environmental Monitoring Plan, Appendix G, Part 632 Mining Permit Application, October 2015; the Part 632 Mining Permit MP 01 2016, and the Memorandum, Back Forty Project – Surface Water Monitoring Location Clarification, Foth Infrastructure & Environment, LLC, March 21, 2017.

Table Abbreviations:

ASTM = American Society for Testing and Materials
EPA = Environmental Protection Agency
°F = degrees Fahrenheit
H_2SO_4 = Sulfuric acid
HNO_3 = Nitric acid
mg/l = milligrams per liter
mL = milliliters
mV = millivolts
NA = not applicable
NaOH = Sodium hydroxide
ng/l = nanograms per liter
NTU = Nephelometric Turbidity Units
PCU = Platinum Cobalt Units
pCi/l = picocuries per liter
S.U. = standard unit
µg/l = micrograms per liter
µmhos/cm = micromhos per centimeter



Surface Water Monitoring Station	Water Body	Longitude X	Latitude Y
MSG-1	Shakey Lake System - Long Lake	-87.84253047	45.42067521
MSG-2	Shakey Lakes System - Bass Lake	-87.82074879	45.41550164
MSG-3	Shakey Creek	-87.78635801	45.42050841
MSG-4	Shakey River	-87.76443477	45.44943693
MSG-5	Little Shakey River	-87.75038542	45.44867032
MSG-6	Shakey River	-87.76761881	45.46419466
MSG-7	Shakey River	-87.76283686	45.47178551
MSG-8	Menominee River Tributary - Boerner Lower	-87.81193755	45.46409072
MSG-9	Menominee River Tributary - Unnamed (Schoneks)	-87.80469452	45.47250087
MSG-10	Menominee River	-87.83507940	45.45090613
MSG-11	Menominee River	-87.86635280	45.38415846
MSG-12	Shakey River	-87.77272923	45.45585030
MSG-13	Menominee River	-87.82986579	45.45705168
MSG-14	Menominee River	-87.84754471	45.44360004
MSG-15	Shakey Lakes System - Spring Lake	-87.82276211	45.43130476
MSG-16	Menominee River Tributary - Unnamed (WE Creek)	-87.80170459	45.48036555
MSG-17	Spring Creek	-87.82766000	45.43855000
MSG-18	Menominee River Tributary - Boerner Upper	-87.81110000	45.46220000
MSG-19	Menominee River Tributary - Boerner Lower	-87.81224000	45.46421000
MSG-20	Unnamed Tributary to Bourner Upper	-87.80680500	45.45568600

NOTES:

1. Road and boundary information downloaded from Michigan Center of Geographic Information (http://www.mcgi.state.mi.us/mgdl/).
2. Hydrographic features generated from Michigan Geographic Framework and the Wisconsin DNR 24K Hydro datasets.
3. Gage and station data supplied by ERM in June 2012.
4. Horizontal datum based on NAD 83. Horizontal coordinates based on UTM Zone 16N.

LEGEND

- Existing USGS Staff Gage
- Surface Water Monitoring Location
- Mineral Property Boundary
- Project Boundary
- Minor Civil Division Boundary
- Major Road
- Minor Road
- Streams
- Lakes/Rivers

Aquila Resources Inc.

Foth

Foth Infrastructure & Environment, LLC

REVISED	DATE	BY	DESCRIPTION

PREPARED BY: AKM DATE: MAR. '17
REVIEWED BY: KKB DATE: MAR. '17
APPROVED BY: SVD1 DATE: MAR. '17

BACK FORTY PROJECT

FIGURE 1

SURFACE WATER MONITORING LOCATIONS
STEPHENSON, MICHIGAN

Scale: 0 500 1,000 Meters 1:50,000
Date: MARCH 2017
Drafted by: DAT
Project No: 14A021

Path: X:\GB\IE\2014\14A021-00\GIS\mxd\SWML\Figure 1 - Surface Water Monitoring Locations.mxd Date: 3/21/2017

Attachment 37

Updated Table 4-3
Scope of Aquatic Evaluations

Evaluation[5]	Aquatic Sampling Stations									
	AQ1[1,4]	AQ2[1]	AQ3[1]	AQ4[2]	AQ5[3]	AQ6[3]	AQ7[3,4]	AQ8[2]	AQ9[2,4]	AQ10[2]
3	x	x	x	x	x	x	x	x	x	x
Sediment Quality - Preconstruction	x	x	x	x	x	x	x	x	x	x
Water Quality - Operations	x	x	x	x	x	x	x	x	x	x
Sediment Quality - Operations	x	x	x	x	x	x	x	x	x	x
Macroinvertebrate Community Assessment - Operations	x	x	x	x	x	x	x	x	x	x
Macroinvertebrate Community Assessment - Preconstruction	x	x	x	x	x	x	x	x	x	x
Habitat Assessment	x	x	x	x	x	x	x	x	x	x
Periphyton Community Assessment	x	x	x	x				x	x	x
Pytoplankton and Zooplankton Community Assessment					x	x	x			
Mussel Assessment	x	x	x	x	x	x	x	x	x	x
Fish Community Assessment	x	x	x	x	x	x	x	x	x	x

Notes:

[1] Menominee River Stations: AQ1, AQ2, AQ3.

[2] Shakey River Stations: AQ4, AQ8, AQ9, AQ10.

[3] Shakey Lakes Stations: AQ5, AQ6, AQ7.

[4] Reference Stations: AQ-1, AQ-7, AQ-9.

[5] Postclosure monitoring is covered in Module 7 of the Environmental Monitoring Plan

Prepared by: AKM
Checked by: HLH

Attachment 39

Table 5-2

Wastewater Discharge Effluent to Menominee River Sampling Parameters

Parameter	Units	Analytical Method	Target Detection Level	Monitoring Frequency	Sample Type
pH	S.U.	Field	NA	Daily	Grab
Temperature	ºC	Field	NA	Continuous	Measure
Dissolved Oxygen	mg/L	Field	NA	Daily	Grab
Total Suspended Solids	mg/L	EPA-160.2	5	Weekly	Grab
Total Dissolved Solids	mg/L	EPA-160.1	5	Weekly	Grab
Ammonia Nitrogen (as N)	mg/L	EPA 350.1	0.02	Weekly	Grab
Total Phosphorus (as P)	mg/L	EPA 365.4	0.05	Weekly	24-Hr Composite
Total Residual Chlorine	ug/L	Field	TBD	Daily	Grab
Total Arsenic	ug/L	EPA-200.8/6020	5	Weekly	24-Hr Composite
Total Cadmium	ug/L	EPA-200.8/6020	1	Weekly	24-Hr Composite
Total Copper	ug/L	EPA-200.8/6020	4	Weekly	24-Hr Composite
Total Fluoride	mg/L	9056A	0.1	Weekly	24-Hr Composite
Total Lead	ug/L	EPA-200.7/6010B	3	Weekly	24-Hr Composite
Total Manganese	ug/L	EPA-200.8/6020	50	Weekly	24-Hr Composite
Total Nickel	ug/L	EPA-200.8/6020	1	Weekly	24-Hr Composite
Total Selenium	ug/L	EPA-200.8/6020	5	Weekly	24-Hr Composite
Total Zinc	ug/L	EPA-200.8/6020	500	Weekly	24-Hr Composite
Total Antimony	ug/L	EPA-200.8/6020	2	Weekly	24-Hr Composite
Total Barium	ug/L	EPA 6020	5	Weekly	24-Hr Composite
Total Beryllium	ug/L	EPA 6020	1	Weekly	24-Hr Composite
Total Boron	ug/L	EPA 6020	20	Weekly	24-Hr Composite
Total Chromium	ug/L	EPA 6020	10	Weekly	24-Hr Composite
Hexavalent Chromium	ug/L	SM 3500	5	Weekly	Grab
Total Cobalt	ug/L	EPA 6020	15	Weekly	24-Hr Composite
Available Cyanide	µg/L	EPA 335.4	0.005	Weekly	Grab
Total Lithium	ug/L	EPA 6020	10	Weekly	24-Hr Composite
Total Molybdenum	ug/L	EPA 6020	5	Weekly	24-Hr Composite
Total Silver	ug/L	EPA-200.8/6020	0.2	Weekly	24-Hr Composite
Total Strontium	mg/L	EPA 6020	1	Weekly	24-Hr Composite
Total Thallium	ug/L	EPA 6020	1	Weekly	24-Hr Composite
Total Vanadium	ug/L	EPA 6020	2	Weekly	24-Hr Composite
Total Uranium	ug/L	ASTM D5174	0.25	Weekly	24-Hr Composite
Total Chloride	mg/L	325.2/4500-CL E	1	Weekly	Grab
Total Sulfate	mg/L	EPA-375.4/9038	2	Weekly	Grab
Total Hardness	mg/L				
- Discharge	mg/L	SM 2340C	1	Monthly	Grab
- Receiving Water Upstream of Discharge	mg/L	SM 2340C	1	Monthly	Grab
Total Mercury	ng/L				
-- Corrected	ng/L	---	---	Weekly	Calculation
-- Uncorrected	ng/L	EPA-1631E	0.5	Weekly	Grab
-- Field Duplicate	ng/L	EPA-1631E	0.5	Weekly	Grab
-- Field Blank	ng/L	EPA-1631E	0.5	Weekly	Preparation
-- Laboratory Method Blank	ng/L	EPA-1631E	0.5	Weekly	Preparation
Outfall Observation	---			Daily	Visual
Acute Toxicity (fathead minnow and *Ceriodaphnia dubia*)	^{TU}A	TBD	TBD	Monthly	24-Hr Composite
Acute Toxicity (*Amblema plicata*)	^{TU}A	TBD	TBD	Annually	24-Hr Composite

Abbreviations:
°C = degrees Celsius
ASTM = American Society for Testing and Materials
EPA = United States Environmental Protection Agency
mg/L = milligrams per liter
NA = not applicable
ng/L = nanograms per liter
NTU = Nephelometric Turbidity Units
S.U. = standard unit
TBD = to be determined
µg/L = micrograms per liter

Prepared by: AKM
Checked by: HLH