



Pond A Closure Plan

J.H. CAMPBELL GENERATING FACILITY

POND A CLOSURE PLAN

West Olive, Michigan



Submitted To: Consumer Energy Company
1945 W. Parnall Road
Jackson, Michigan 49201

Submitted By: Golder Associates Inc.
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January 25, 2019

1667572



**CERTIFICATION****Professional Engineer Certification Statement [40 CFR 257.102(b)(4)]**

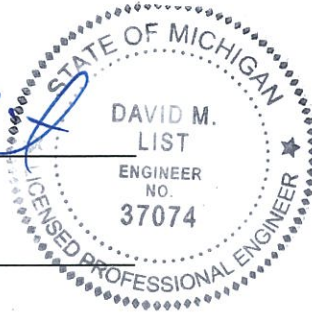
I hereby certify that, having reviewed the attached documentation and being familiar with the provisions of Title 40 of the Code of Federal Regulations Section 257.102 (40 CFR Part 257.102), I attest that this Closure Plan is accurate and has been prepared in accordance with good engineering practices, including the consideration of applicable industry standards, and with the requirements of 40 CFR Part 257.102.

Golder Associates Inc.

Signature

January 25, 2019

Date of Report Certification



David M. List

Name

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Professional Engineer Certification Number



Table of Contents

1.0	INTRODUCTION AND SITE DESCRIPTION	1
2.0	NARRATIVE DESCRIPTION	3
2.1	Pond A CCR Quantity	3
3.0	CLOSURE CONSTRUCTION SEQUENCE	3
3.1	Drainage and Stabilization of Pond A	3
3.2	Filling Sequence	4
4.0	FINAL COVER DESIGN	4
4.1	Final Cover Grades	4
4.2	Design	5
4.2.1	Subgrade Layer	6
4.2.2	HDPE Geomembrane Liner	6
4.2.3	Geotextile Cushion and Drainage	6
4.2.4	30-inch-thick Final Cover Material	7
4.2.5	Seed, Fertilizer, and Mulch	7
4.3	Infiltration	7
4.4	Stability	8
4.5	Final Cover Settlement	8
4.6	Stormwater and Erosion	9
4.6.1	Bench Drain	9
4.6.2	Perimeter Drain	9
4.6.3	Pond A Outlets	10
4.7	Erosion Potential	10
5.0	SCHEDULE	11
5.1	Closure Deadline Extension	11
6.0	POST-CLOSURE	13
7.0	CONCLUSION	14
8.0	GENERAL QUALIFICATIONS	15
9.0	CLOSING	16
10.0	REFERENCES	17



List of Tables

Table 4.2.1	Proposed Seed Mix
Table 5.0.1	Conceptual Final Cover Construction Schedule Milestones

List of Appendices

Appendix A	Engineering Drawings
Appendix B	Construction Quality Assurance Plan
Appendix C	J.H. Campbell Fugitive Dust Control Plan
Appendix D	Geotechnical Calculations
Appendix E	Hydrologic and Hydraulic Calculations
Appendix F	J.H. Campbell Generating Facility Pond A Post-Closure Plan



1.0 INTRODUCTION AND SITE DESCRIPTION

On April 17, 2015, the United States Environmental Protection Agency (EPA) issued the Coal Combustion Residual (CCR) Resource Conservation and Recovery Act (RCRA) Rule (40 CFR 257 Subpart D) (“CCR RCRA Rule”) to regulate the beneficial use and disposal of CCR materials generated at coal-fired electrical power generating complexes. In accordance with the CCR RCRA Rule, any CCR surface impoundment or CCR landfill that was actively receiving CCR on the effective date of the CCR RCRA Rule (October 19, 2015) was deemed to be an “Existing CCR Unit” on that date and subject to self-implementing compliance standards and schedules. Consumers Energy Company (CEC) identified three existing CCR surface impoundments at the J.H. Campbell Generating Facility (JH Campbell):

- Bottom Ash Ponds 1-2 (North and South)
- Bottom Ash Pond 3 (North and South)
- Pond A

This written Closure Plan is being generated pursuant to the following applicable closure performance standards when leaving CCR in place:

- RCRA
 - 40 CFR 257.102(d)
- Michigan Department of Environmental Quality (MDEQ)
 - Part 115 R 299.4304
 - Part 115 R 299.4309
 - Part 115 R 299.4317
 - Part 115 R 299.4446

This plan supports closure of the JH Campbell Pond A CCR surface impoundment in a manner consistent with recognized and generally accepted good engineering practices. Specific requirements for post-closure care, groundwater monitoring, and corrective action are referenced in Section 6.0 Post Closure.

In order to facilitate closure, CEC intends to remove the CCR materials from Bottom Ash Ponds 1-2 and Bottom Ash Pond 3 and consolidate those materials in Pond A. The CCR materials will be placed as either beneficial use material under MDEQ Condition 4 (d) for landfill construction or as a waste in order to meet desired Pond A closure grades. MDEQ approved the work plan for beneficial reuse of CCR materials in a letter dated February 26, 2018. Placement of (or use of) CCR materials from Bottom Ash Pond 3 was previously approved by MDEQ on March 14, 2017 with conditions. The proposed Pond A final cover geometry was developed to accommodate the expected volume of CCR materials from Bottom Ash Ponds 1-2 and Bottom Ash Pond 3 and, therefore, limits the amount of offsite fill required to close. The components and the configuration of the final cover was designed to address the requirements of the State of Michigan Natural Resources and Environmental Protection Act, 1994 P.A. Part 115 R 299.4304(1), R



299.4304(5), R 299.4304(6), and R 299.4309(7) for final covers over Type III landfills and also meet the closure performance requirements set forth in 40 CFR 257.102(d)(3)(i)(A) through (D).

Pond A is located to the southeast of the J.H. Campbell Generating Facility and covers approximately 10 acres. Pond A is bounded on three sides by ash containment dikes separating the CCR surface impoundment from closed ash ponds (Ponds B-K) to the west, north, and east. A perimeter berm bounds Pond A to the south. While in operation, Pond A served as secondary treatment for process waters from power generation units 1, 2, and 3. After treatment, Pond A effluent was directed through an outfall along the southern perimeter of the pond that allowed Pond A to discharge into an open channel ditch that directed flow to the recirculation pond, which ultimately discharges through the National Pollutant Discharge Elimination System (NPDES) permitted outfall into the Pigeon River (Permit MI0001422). The existing site plan is provided as Sheet 2 of Appendix A – Engineering Drawings and contains labels for Ponds B-K (closed), Bottom Ash Ponds 1-2, Bottom Ash Pond 3, Pond A, the recirculation pond, and NPDES Outfall 002A.



2.0 NARRATIVE DESCRIPTION

Pond A at JH Campbell will be closed with CCR in place and capped with a final cover system over the CCR surface impoundment area. Prior to construction of the final cover, Pond A will be dewatered by actively pumping the pond's contents downstream in accordance with all applicable federal, state and local rules and regulations. Once dewatered, active pumping will cease and piping will be permanently abandoned or removed, which will allow Pond A to be reworked and/or backfilled to 30-inches below the final cover grades provided on Sheet 6 of the Engineering Drawings (Appendix A). Final cover design grades will be reached with construction of a 30-inch-thick final cover system designed with a minimum 2.0 percent slope to meet performance standard requirements per 40 CFR 257.102(d)(3)(ii). Details of the closure construction are provided in the following sections.

2.1 Pond A CCR Quantity

Golder characterized CCR in Pond A in May 2016. Through visual observation, the characterization sampling determined that the CCR in Pond A extended to depths that ranged from three to eight feet below the mudline, which correlates to elevations of approximately 600.7 to 602.2 feet (NGVD29). The largest total surface area of Pond A requiring final cover is approximately 10 acres. The maximum inventory of CCR estimated for Pond A in 2016 was approximately 36,000 cubic yards (cy) as reported by Golder Associates Inc. in the J.H. Campbell Generating Facility Pond A Closure Plan dated October 14, 2016.

On March 1, 2017 CEC requested approval from the MDEQ to place CCR materials from Bottom Ash Pond 3 into Pond A. The request was approved by the MDEQ on March 14, 2017 with conditions. In May 2017 Bottom Ash Pond 3N was cleaned out to facilitate construction of concrete bottom ash tanks for future power generation at J.H. Campbell. During the Bottom Ash Pond 3N cleanout, approximately 68,000 cy of CCR was placed in Pond A. In May 2017, it was estimated that approximately 104,000 cy of CCR existed in Pond A. Material from Bottom Ash Ponds 1-2 and Bottom Ash Pond 3S will be hauled and placed in Pond A to meet the closure grades presented herein. Pond A will retain approximately 391,500 cubic yards of CCR once closed in accordance with this plan. MDEQ approved the use of this material as beneficial reuse in a letter dated February 26, 2018.

3.0 CLOSURE CONSTRUCTION SEQUENCE

3.1 Drainage and Stabilization of Pond A

Prior to construction of the final cover, Pond A inflow will be rerouted through existing ditches that are regraded away from Pond A. Inflow will be appropriately treated, as necessary, to meet the site's permitted NPDES requirements. Once inflow is rerouted, Pond A will be decanted via pumping downstream through the permitted NPDES outfall in a manner that maintains permitted effluent limits.



During decanting, the groundwater elevation in the vicinity of Pond A will drop until it reaches a new equilibrium at approximately 592 feet above mean sea level (amsl), as measured from the National Geodetic Vertical Datum of 1929 (NGVD29) based on the RCRA Vertical Expansion Feasibility Investigation for the J.H. Campbell Solid Waste Disposal Area (Engineering and Environmental Solutions, LLC, 2012). After decanting is complete, Pond A influent and effluent pipes will be removed and/or abandoned in-place to prevent subsequent inflow to the pond. The remaining CCR material within Pond A will be inspected and, if required, stabilized with a 10 oz/sy nonwoven geotextile and a three-foot-thick layer of cohesionless material in accordance with Detail 2 on Sheet 9 (Appendix A). Drainage and stabilization will be achieved, as it is understood that decanting eliminates free liquids; and bridging unsuitable or soft CCR for subsequent filling will stabilize remaining wastes and waste residues to support the final cover system as required by Part 115 R 299.4309(7)(a) and (b).

3.2 Filling Sequence

Once decanted, the CCR that exists within Pond A will be observed and bridged, if necessary, to develop a uniform surface that is capable of bearing the proposed grades presented herein. Once existing CCR in Pond A is sufficient to provide a stable surface to support fill materials, excavated CCR from Bottom Ash Ponds 1-2 and Bottom Ash Pond 3 will be used to fill Pond A to meet the proposed top of liner grading plan provided on Sheet 5 (Pond A Top of Liner Grading Plan) of Appendix A – Engineering Drawings. The CCR fill will be generally void of organic, frozen, or other foreign material and placed in uniform and generally horizontal lifts across the pond. CCR fill will be placed in generally 12-inch-thick lifts and compacted until no excessive rutting or yielding is observed in accordance with the Construction Quality Assurance (CQA) Plan (Appendix B).

The appropriate dust control measures identified in the latest revision of the RCRA J.H. Campbell Fugitive Dust Control Plan for Coal Combustion Residuals that is posted on the publicly accessible website pursuant to 40 CFR 257.107(g)(1) will be followed during earthwork operations. These measures include water trucks applying water to excavations and haul roads, pausing constructing during high winds, and not overfilling haul trucks during material transport. The J.H. Campbell Fugitive Dust Control Plan for Coal Combustion Residuals that was available during development of this Closure Plan is provided in Appendix C – J.H. Campbell Fugitive Dust Control Plan.

4.0 FINAL COVER DESIGN

4.1 Final Cover Grades

The proposed Pond A final cover grades range from approximately 2.0 percent to 25.0 percent in accordance with Part 115 R 299.4304(5). The Pond A outbound perimeter drain is set to a 33.0 percent slope and will be lined to create a drainage swale that conveys stormwater away from Pond A after closure.



The proposed grading plan for Pond A is depicted on Sheet 6 (Pond A Top of Cover Grading Plan) of Appendix A – Engineering Drawings.

The top of liner grade will be overlain with a 30-inch-thick final cover system designed with a minimum 2.0 percent slope to prevent future impoundment of water, sediment, or slurry; prevent/control the release of waste; limit the effects of settlement; and minimize erosion. A final cover settlement assessment was completed to evaluate whether positive drainage on the final cover through the post-closure care period would be achieved. Settlement assessment calculations indicating that positive drainage on the final cover will be maintained are included in Appendix D – Geotechnical Calculations.

The interior bench and perimeter drains have been designed to appropriately convey the surface drainage through the post-closure care period.

4.2 Design

The final cover system, which is depicted on detail 1 in Appendix A, consists of the following components (from bottom to top):

- CCR with sufficient strength to support final cover per Part 115 R 299.309(7)(b)
- 40 mil high-density polyethylene (HDPE) geomembrane liner per Part 115 R 299.4304(6)(a)(ii)
 - 40 mil HDPE textured geomembrane liner per Part 115 R 299.4304(6)(a)(ii) on surfaces where slopes exceed 20.0 percent
- 10 ounce per square yard (oz/sy) non-woven geotextile cushion
- Above-cap drainage collection piping system
- 30-inch-thick final cover material consisting of:
 - 24-inch-thick protective cover per Part 115 R 299.4304(6)(a)(ii) and 40 CFR 257.102(d)(3)(i)(B)
 - 6-inch-thick topsoil per Michigan Department of Transportation (MDOT) 816 – Turf Establishment (erosion layer) per Part 115 R 299.4304(6)(b)
 - Seed, fertilizer, and mulch per Part 115 R 299.4304(6)(b)

The final cover system will be 30-inches-thick and consist of a 40 mil HDPE membrane (infiltration layer) overlain with a 10 oz/sy nonwoven geotextile (cushion). It should be noted that textured geomembrane is required on surfaces where slopes exceed 20.0 percent. The cushion will be overlain with a drainage collection piping system with collection pipes spaced generally 100 feet apart and a 24-inch-thick protective cover. The protective cover will be overlain with a six-inch-thick erosion layer. The erosion layer consists of topsoil, seed, fertilizer, and mulch in accordance with MDOT Standard Specification 816 – Turf Establishment.



The CCR RCRA Rule states in Part 257.102 that the “permeability of the final cover system must be less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1×10^{-5} centimeters per second (cm/sec), whichever is less.” Since Pond A was constructed without an engineered liner system and the natural subsoils present are sandy soils, it has been conservatively assumed that the subgrade soils have a permeability of 1×10^{-3} cm/sec. Therefore, the final cover system was designed to have a permeability of 1×10^{-5} cm/sec or less using a combination of the HDPE geomembrane overlain by 24 inches of protective soil. The published permeability of a typical HDPE geomembrane is 1×10^{-12} cm/sec or less (GSE, 2012).

The final cover system is designed to provide a final cover permeability less than 1×10^{-5} cm/sec; minimize the need for maintenance; control, minimize, or eliminate post-closure infiltration of liquids; minimize releases of CCR and leachate into ground and surface waters or the atmosphere; preclude the probability of future impoundment of water, sediment, or slurry; prevent the sloughing or movement of the liner; and be completed in the shortest amount of time consistent with recognized and generally accepted good engineering practices.

The final cover system will be constructed, inspected, and tested in accordance with the CQA Plan provided in Appendix B and is summarized in the following sections. Calculations to support the infiltration layer requirement are provided in Appendix E – Hydrologic and Hydraulic Calculations.

4.2.1 Subgrade Layer

Once Pond A is filled to the top of liner design grades provided in Appendix A, the top of liner grade will be smooth drum rolled, inspected for stones larger than 0.75 inches, and accepted as the geomembrane subgrade. A puncture resistance calculation is presented in Appendix E and confirms the maximum particle size (0.75 inches) has an acceptable factor of safety for use with the geosynthetic cover system. The subgrade surface will be accepted by the owner’s representative, earthwork contractor, and geosynthetic installer as a surface suitable for geomembrane placement that is generally free of ruts, soft areas, stones larger than 0.75 inches, dust, and/or excessive moisture in accordance with the CQA Plan.

4.2.2 HDPE Geomembrane Liner

A 40 mil HDPE geomembrane liner is proposed for the final cover system. The HDPE membrane will have the properties presented in Appendix B – Construction Quality Assurance Plan or meet current GRI-GM13 Test Methods, Required Properties and Testing Frequencies for HDPE (Geosynthetic Institute, 2016).

4.2.3 Geotextile Cushion and Drainage

A 10 oz/sy nonwoven geotextile cushion will be utilized above the HDPE geomembrane layer. The geotextile cushion will have the properties presented in Appendix B – Construction Quality Assurance Plan or meet current GRI – GT12(a) Test Methods, Required Properties and Testing Frequencies for Cushion



Geotextiles. Calculations to support the 10 oz/sy cushion are provided in Appendix D – Geotechnical Calculations. To assist with drainage on top of the geomembrane liner, the design includes a network of six-inch diameter drain tiles connected to the bench drains and perimeter drains. The drain tiles are designed at approximately 100-foot spacings to prevent accumulation of water on top of the geomembrane liner. Further discussion of the drain tiles is presented in Section 4.3.

4.2.4 30-inch-thick Final Cover Material

The geosynthetic liner system will be covered with a 24-inch-thick protective cover and six inches of topsoil to protect the liner system and to allow for establishment of vegetative cover, respectively. The bottom 24 inches of the final cover system will consist of protective cover soil, which must be classified according to the Unified Soil Classification System (USCS) as either SM, SW, or SP. Since these soils will be placed directly on the geotextile cushion, materials that could be damaging or harm the geosynthetics will be removed. The thickness requirement is consistent with Part 115 R 299.4304(6)(a)(ii) and the CCR RCRA Rule requirement [40 CFR 257.102(d)(3)(i)(B)]. The top six inches of final cover material will consist of available topsoil that meets MDOT Standard Specification 816 for Turf Establishment. Placement of the final cover materials will be performed with low ground pressure construction equipment; and no equipment will be allowed to traverse on the geosynthetics without adequate soil thickness protection, per the CQA Plan.

4.2.5 Seed, Fertilizer, and Mulch

The seed, fertilizer, and mulch have been selected for turf establishment in dry sand to sandy loam soils. Seeding may be performed by hydroseeding, seed drill, or broadcasting. Mulch and fertilizer will be in accordance with MDOT Standard Specifications 816 and 917. The proposed seed mix is as follows:

Table 4.2.1 - Proposed Seed Mix

Seed Variety	Pound/Acre
Kentucky Blue Grass	11
Perennial Rye Grass	55
Hard Fescue	55
Creeping Red Fescue	99
Total:	220

Alternative seed mixes may be selected by CEC for a specific final cover project based on the time of year the seed is placed.

4.3 Infiltration

The final cover is designed with a 2.0 percent grade, which will direct flow toward the bench drain or perimeter drain to reduce water ponding on the final cover system as required by Part 115 R 299.4304(5).



Surface water drained toward the perimeter drainage system is directed to one of two armored downchutes on the southern Pond A perimeter berm. The armored downchutes discharge to a ditch that feeds the recirculation pond and permitted NPDES outfall. Seepage through the topsoil layer in the final cover system will be drained through the sand protective cover layer above the HDPE geomembrane and collected in a network of six-inch diameter drain tiles placed within the protective layer that discharge to the bench drains. The site grading and the drain tile spacing is anticipated to limit mounding to approximately two inches on top of the HDPE membrane. This is considered acceptable given the 24-inch-thick protective cover layer and the demonstration to minimize infiltration with this gradient. Calculations to support the mounding are provided in Appendix E – Hydrologic and Hydraulic Calculations. Hydrologic Evaluation of Landfill Performance (HELP) modeling of the proposed capping system indicates that the lowest permeability layer of the final cover system is the HDPE geomembrane at 2×10^{-12} cm/sec, which meets the minimum permeability requirement of 1×10^{-5} cm/sec. The permeability from the HELP model is a default value used for HDPE flexible membrane liners. The HELP model for Pond A is provided in Appendix E – Hydrologic and Hydraulic Calculations.

4.4 Stability

A stability analysis was performed for the proposed Pond A final grades and final cover system. The Pond A closure geometry was limited to 4H:1V slopes (25.0 percent). As previously stated, the Pond A outbound perimeter drain is set to a 3H:1V slope (33.0 percent) and will be lined to create a drainage swale that conveys stormwater away from Pond A after closure. As a result, the stability assessment utilized 33.0 percent slopes to develop factors of safety.

Two sections were analyzed for global stability using information obtained from subsurface investigations performed during June 2012 and May 2016. One of the sections analyzed was identified as the critical section and is provided in Appendix D – Geotechnical Calculations. Drained and undrained material strength properties were used to evaluate long- and short-term stability for the proposed grades, respectively. A veneer analysis was conducted to assess final cover system stability for various scenarios including equipment forces during construction, seepage forces, and seismic conditions. Details of the stability analysis are provided in Appendix D – Geotechnical Calculations and indicate that the proposed final cover system provides an adequate factor of safety (FoS).

4.5 Final Cover Settlement

Settlement modeling was conducted to confirm that post-settlement cover slopes will maintain long-term positive drainage as required by Part 115 R 299.4304(5). The results indicate that approximately 9.0 inches of long-term settlement can be anticipated in the center of Pond A, and approximately 3.0 inches of long-term settlement can be anticipated along the perimeter of Pond A. These settlement estimates yield a post-



settlement slope which will maintain positive drainage throughout the post-closure care period. The settlement model results are included in Appendix D – Geotechnical Calculations.

4.6 Stormwater and Erosion

Prior to construction of the final cover, Pond A inflow will be rerouted and appropriately treated, if necessary, to meet the site's NPDES permit requirements. Additionally, the perimeter ditch will be graded to manage the precipitation falling directly onto Pond A and promote stormwater drainage away from the final cover system. The stormwater management system will consist of the following components:

- A bench drain on the southern side of Pond A will collect and control stormwater run-off from the Pond A final cover system and discharge to the outlet pipe located in the Southwestern corner of Pond A.
- Perimeter drains established by a perimeter ditch will divert flow to the south side of Pond A and toward the outlet pipe located in the Southeastern corner of Pond A.
- Pond A outlet pipes. Two 30-inch diameter reinforced concrete pipe (RCP) will convey stormwater through the southern perimeter berm to armored down chutes to an existing ditch. The existing ditch discharges to the recirculation pond and ultimately to the permitted NPDES outfall.

The stormwater management system has been designed in accordance with MDEQ Part 115 Solid Waste Management Act to manage run-off from the 25-year, 24-hour Soil Conservation Service (SCS) Type II storm event (4.97 inches). Additionally, the perimeter drain was designed to collect and manage run-off from the SCS Type II, 100-year, 24-hour storm event without overflow. The bench drain, perimeter drain, and Pond A outlets have been designed to manage the calculated run-off for the proposed final closure grades. Modeling and calculations to support the stormwater management system are included in Appendix E – Hydrologic and Hydraulic Calculations.

4.6.1 Bench Drain

A bench drain will convey stormwater collected from the southern half of the Pond A final cover system to the western side of Pond A. Appropriate erosion control (riprap, erosion matting, etc.) will be provided on the sideslopes and at culvert inlets. The armored downchutes provide protection at the culvert outlets. Bench drain details are shown on Sheet 9 of Appendix A – Engineering Drawings. Design calculations to support the proposed minimum size and slope of the bench drains are provided in Appendix E – Hydrologic and Hydraulic Calculations.

4.6.2 Perimeter Drain

Stormwater around the perimeter of Pond A and below the bench drain will be collected in a perimeter drain. The perimeter drain directs water toward the southern culverts and armored downchutes. Appropriate erosion control (riprap, erosion matting, etc.) will be provided on the ditch bottoms, sideslopes, and at culvert inlets. The armored downchutes provide protection at the culvert outlets. Perimeter drain



details are shown on Sheet 8 of Appendix A – Engineering Drawings. Design calculations to support the proposed minimum design slopes are provided in Appendix E – Hydrologic and Hydraulic Calculations.

4.6.3 Pond A Outlets

Two culvert outlets convey stormwater run-off from the Pond A final cover system. Two 30-inch culvert outlets are proposed through the southern perimeter berm and will discharge into two armored down chutes which connect to the existing ditch that directs flow to the recirculation pond. The Pond A outlet culverts will be RCP, and riprap or equivalent erosion protection will be placed at the inlet of the culverts to prevent erosion. The culvert locations and details are shown on Sheets 5, 6, 8, and 9 of Appendix A – Engineering Drawings. Design calculations are provided in Appendix E – Hydrologic and Hydraulic Calculations. Alternative culvert materials and/or configurations may be utilized as long as equal hydraulic performance is achieved.

4.7 Erosion Potential

Calculations using the modified universal soil loss equation were used to estimate the erosion potential for the finished grades of Pond A. Per the analysis, after vegetation is established, the average erosion potential will be less than two tons per acre per year. Design calculations are provided in Appendix E – Hydrologic and Hydraulic Calculations.



5.0 SCHEDULE

CEC initiated closure by providing notification pursuant to 40 CFR 257.102(e) on September 17, 2018. In accordance with 40 CFR 257.102(f)(1)(ii), closure activities are expected to be completed within five years of the notification of intent to initiate closure (by September 17, 2023).

It is anticipated that liner construction will begin on April 1, 2019 and be complete by April 22, 2019. The 24-inch-thick protective cover will be placed over the geosynthetics by May 6, 2019 and topsoil and seed will be placed by May 17, 2019 as recommended by MDOT Specification 816 – Turf Establishment for permanent seeding.

Completion of the final cover construction in 2019 complies with the September 17, 2023 closure deadline. Table 5.0.1 – Conceptual Final Cover Construction Schedule Milestones contains a list of milestone dates that were developed as part of the closure construction schedule to demonstrate that closure will be completed within the self-implementing closure schedule per 40 CFR 257.102(f)(1)(ii).

Table 5.0.1 – Conceptual Final Cover Construction Schedule Milestones

Closure Component	Completion Date
Notification of intent to initiate closure	September 17, 2018
Earthwork (fill to meet liner grade)	April 1, 2019
40 mil geomembrane (infiltration layer)	April 22, 2019
18-inch-thick soil (protective cover)	May 6, 2019
6-inch-thick topsoil (erosion layer)	May 17, 2019
Seed, fertilizer, mulch (erosion layer)	May 17, 2019
Closure activities complete	July 1, 2019
Certified closure report	October 1, 2019
Post-closure care period	January 31, 2049

5.1 Closure Deadline Extension

Closure of existing CCR surface impoundments must be completed within five years of initiating closure in accordance with 40 CFR 257.102(f)(1)(ii). A deadline extension can be obtained as outlined in 40 CFR 257.102(f)(2) if completion of closure is not feasible within five years (e.g., shortened construction season, significant weather delays during construction, time required for dewatering CCR, delays due to state or



local permitting or approval, etc.). An extension must include a narrative description that demonstrates closure is not feasible in the required timeframe in accordance with 40 CFR 257.102(f)(2)(i, iii). The closure deadline for Pond A may be extended up to two years per 40 CFR 257.102(f)(2)(ii)(A).



6.0 POST-CLOSURE

The RCRA Post-Closure Plan that is posted on the publicly accessible website pursuant to 40 CFR 257.107(i)(12) will be followed, including regular inspections. This plan was developed and certified by a qualified professional engineer to assure that the integrity and effectiveness of the final cover is maintained, including erosion control measures, final cover depths, and vegetative cover over the 30-year post-closure care period. Post-closure care will begin once Pond A is certified closed and will be in accordance with the latest revision of the J.H. Campbell Generating Facility Pond A Post-Closure Plan.

The RCRA Post-Closure Plan that was available during development of this Closure Plan is provided in Appendix F – J.H. Campbell Generating Facility Pond A Post-Closure Plan.



7.0 CONCLUSION

This Pond A Closure Plan proposes closure with a final cover system over the CCR surface impoundment area pursuant to State of Michigan Natural Resources and Environmental Protection Act, Public Act 451 of 1994 Parts 115 R 299.4304, R 299.4309, and R 299.4317 and 40 CFR 257.102. This Closure Plan describes the steps necessary to close the JH Campbell Pond A CCR surface impoundment in a manner consistent with recognized and generally accepted good engineering practices.



8.0 GENERAL QUALIFICATIONS

This Closure Plan has been prepared in general accordance with normally accepted civil engineering practices. Golder has prepared this plan for the purpose intended by CEC. No other warranty, either expressed or implied, is made. The scope is limited to the specific project and location described herein, and our description of the project represents our understanding of the significant aspects relevant to the site. In the event that any changes in the design or location of the facilities as outlined in this Closure Plan are planned, Golder should be informed so that the changes can be reviewed and the conclusions of this plan modified, as necessary, in writing by the engineer.



9.0 CLOSING

This Closure Plan is respectfully submitted to CEC. If you have questions or require additional information, please contact Jeff Piaskowski at (920) 309-1548.

Sincerely,

GOLDER ASSOCIATES INC.

Bryan Weldon, P.E.
Project Engineer

Jeff Piaskowski, P.E.
Senior Project Engineer

Dave List, P.E.
Senior Consultant



10.0 REFERENCES

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APPENDIX A
ENGINEERING DRAWINGS

CONSUMERS ENERGY COMPANY
J.H. CAMPBELL GENERATING FACILITY
POND A CLOSURE PLAN

PREPARED FOR:



CONSUMERS ENERGY COMPANY
J.H. CAMPBELL GENERATING PLANT
17000 CROSWELL STREET
WEST OLIVE, MI 49460

PREPARED BY:

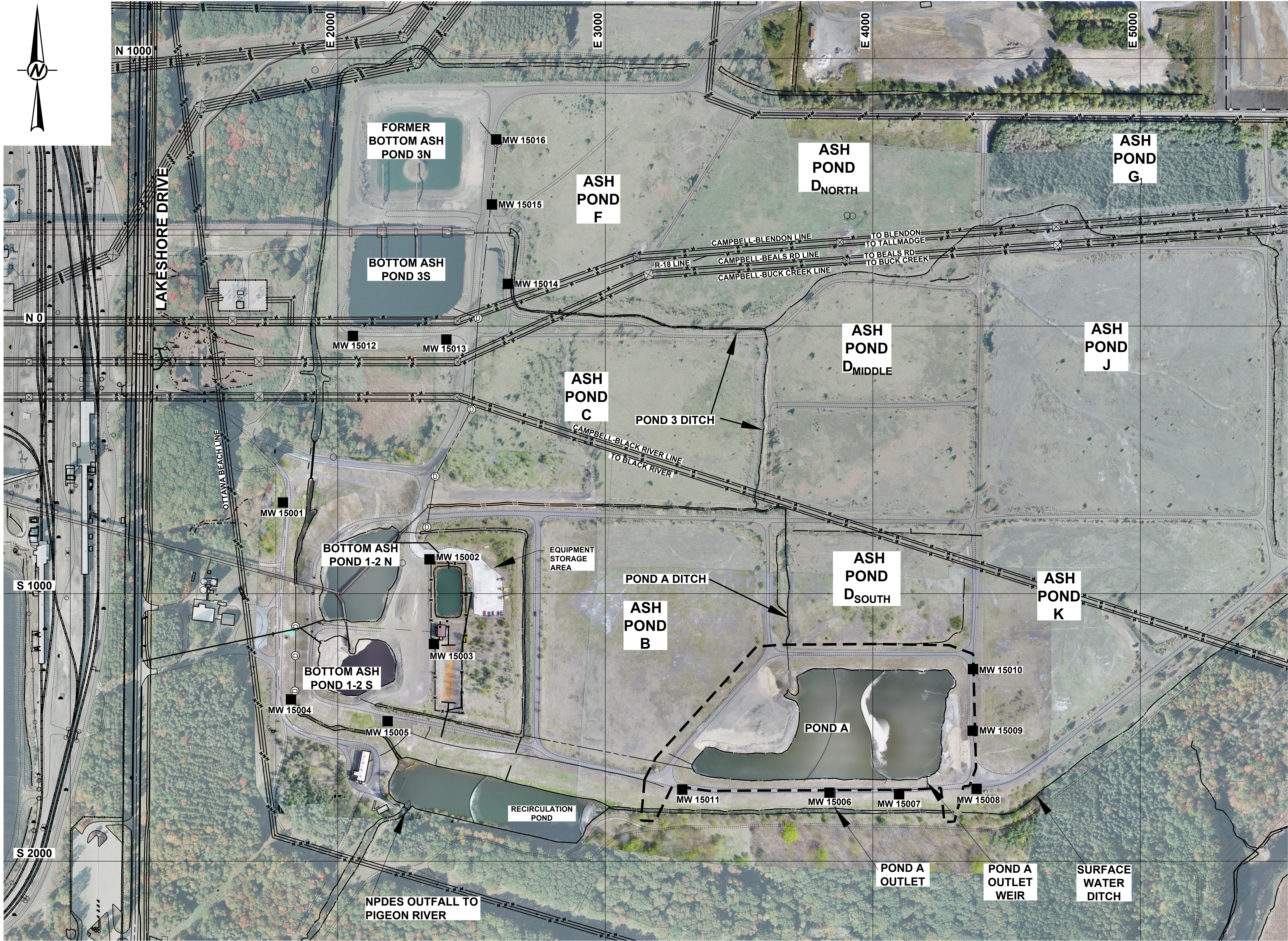


GOLDER
GOLDER ASSOCIATES INC.
15851 SOUTH US 27
SUITE 50
LANSING, MI 48906

DRAWING LIST		
SHEET NUMBER	DRAWING TITLE	DRAWING REV.
1	COVER SHEET	A
2	EXISTING SITE PLAN & WORK AREA	A
3	POND A EXISTING CONDITIONS	A
4	POND A DEMOLITION PLAN	A
5	POND A TOP OF LINER GRADING PLAN	A
6	POND A TOP OF COVER GRADING PLAN	A
7	POND A CROSS SECTIONS	A
8	DETAILS	A
9	DETAILS	A



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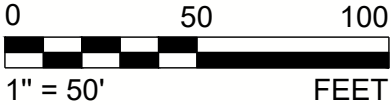
LEGEND


- EXISTING STORM LINE
- EXISTING DITCH
- EXISTING OVERHEAD POWER LINE
- EXISTING ROAD
- EXISTING MONITORING WELL
- PROPOSED LIMITS OF WORK

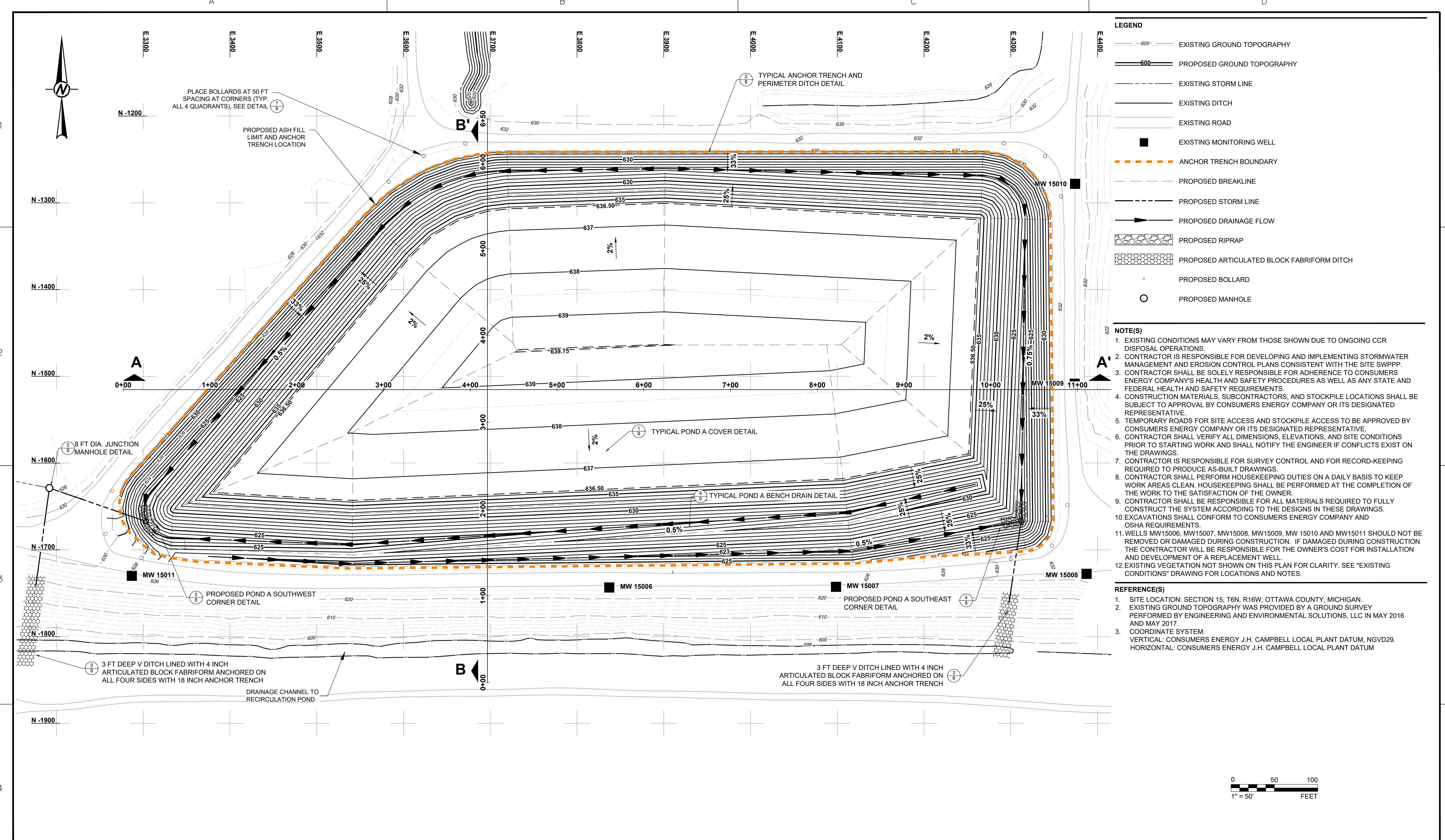
- NOTE(S)**
- EXISTING CONDITIONS MAY VARY FROM THOSE SHOWN DUE TO ONGOING CCR DISPOSAL OPERATIONS.
 - CONTRACTOR IS RESPONSIBLE FOR DEVELOPING AND IMPLEMENTING STORMWATER MANAGEMENT AND EROSION CONTROL PLANS CONSISTENT WITH THE SITE SWPPP.
 - CONTRACTOR SHALL BE SOLELY RESPONSIBLE FOR ADHERENCE TO CONSUMERS ENERGY COMPANY'S HEALTH AND SAFETY PROCEDURES AS WELL AS ANY STATE AND FEDERAL HEALTH AND SAFETY REQUIREMENTS.
 - CONSTRUCTION MATERIALS, SUBCONTRACTORS, AND STOCKPILE LOCATIONS SHALL BE SUBJECT TO APPROVAL BY CONSUMERS ENERGY COMPANY OR ITS DESIGNATED REPRESENTATIVE.
 - TEMPORARY ROADS FOR SITE ACCESS AND STOCKPILE ACCESS TO BE APPROVED BY CONSUMERS ENERGY COMPANY OR ITS DESIGNATED REPRESENTATIVE.
 - CONTRACTOR SHALL VERIFY ALL DIMENSIONS, ELEVATIONS, AND SITE CONDITIONS PRIOR TO STARTING WORK AND SHALL NOTIFY THE ENGINEER IF CONFLICTS EXIST ON THE DRAWINGS.
 - CONTRACTOR IS RESPONSIBLE FOR SURVEY CONTROL AND FOR RECORD-KEEPING REQUIRED TO PRODUCE AS-BUILT DRAWINGS.
 - CONTRACTOR SHALL PERFORM HOUSEKEEPING DUTIES ON A DAILY BASIS TO KEEP WORK AREAS CLEAN. HOUSEKEEPING SHALL BE PERFORMED AT THE COMPLETION OF THE WORK TO THE SATISFACTION OF THE OWNER.
 - CONTRACTOR SHALL BE RESPONSIBLE FOR ALL MATERIALS REQUIRED TO FULLY CONSTRUCT THE SYSTEM ACCORDING TO THE DESIGNS IN THESE DRAWINGS.
 - EXCAVATIONS SHALL CONFORM TO CONSUMERS ENERGY COMPANY AND OSHA REQUIREMENTS.
 - EXISTING VEGETATION SHOWN FROM 2012 AERIAL SURVEY. SOME TREES MAY HAVE BEEN CUT DOWN OR REMOVED. CONTRACTOR TO FIELD VERIFY.


- REFERENCE(S)**
- SITE LOCATION: SECTION 15, T6N, R16W, OTTAWA COUNTY, MICHIGAN.
 - EXISTING GROUND TOPOGRAPHY WAS PROVIDED BY AN AERIAL SURVEY PERFORMED BY ROWE PROFESSIONAL SERVICES COMPANY IN APRIL 2012.
 - EXISTING AERIAL PHOTO WAS PROVIDED BY AN AERIAL SURVEY PERFORMED BY ROWE PROFESSIONAL SERVICES COMPANY IN OCTOBER 2012 AND A DRONE SURVEY FOR PONDS 1-2 AND POND A PERFORMED BY ENGINEERING AND ENVIRONMENTAL SOLUTIONS, LLC IN MAY 2017.
 - COORDINATE SYSTEM:
VERTICAL: CONSUMERS ENERGY J.H. CAMPBELL LOCAL PLANT DATUM, NGVD29.
HORIZONTAL: CONSUMERS ENERGY J.H. CAMPBELL LOCAL PLANT DATUM.

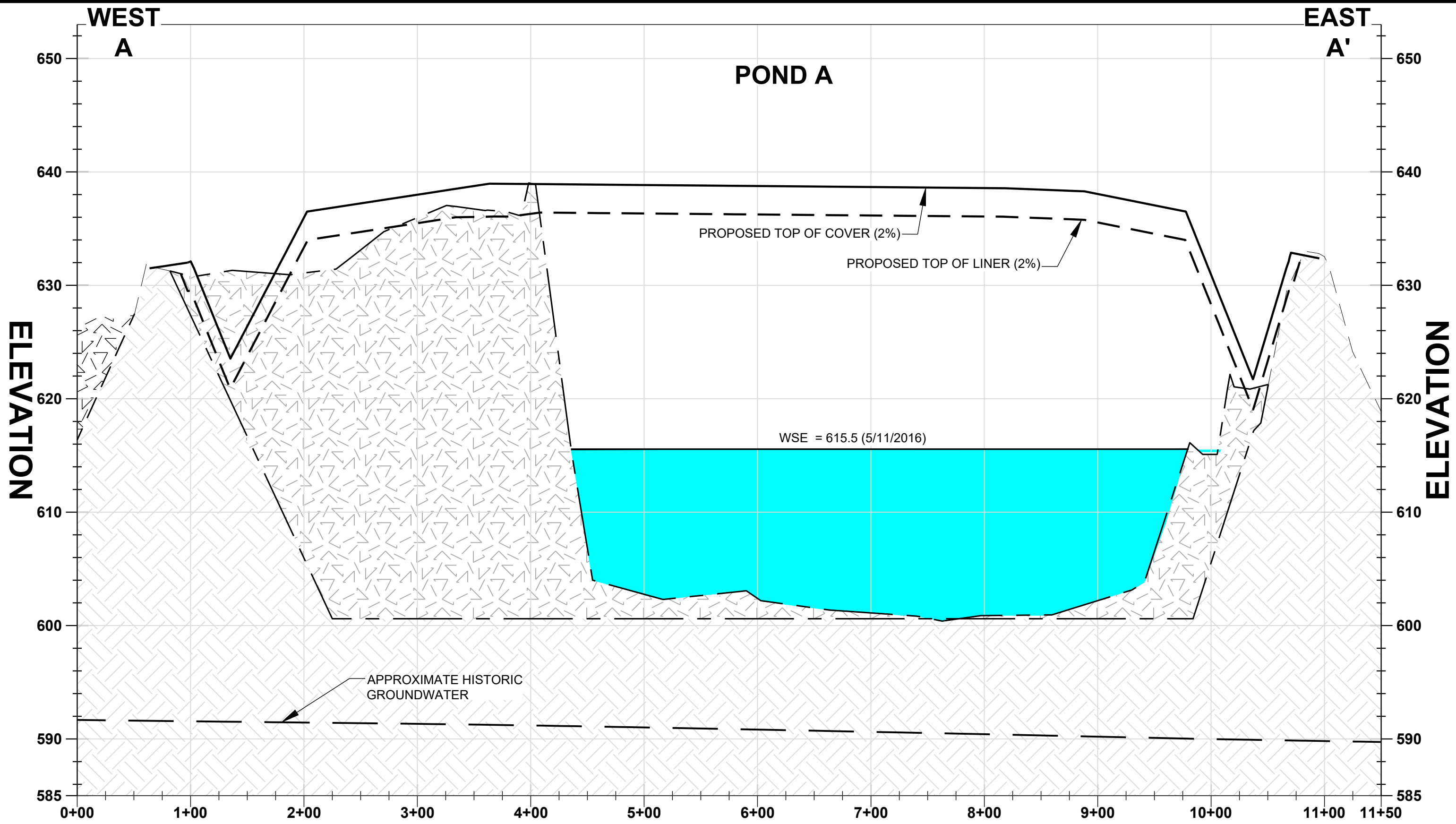
										SIGNATURE <i>[Signature]</i> NAME DAVID M. LIST MICHIGAN P.E. No. 6201037074								EXISTING SITE PLAN & WORK AREA			
															J.H. CAMPBELL PLANT WEST OLIVE, MI			SCALE: 1"=200'			
REFERENCE DRAWINGS										A 01-22-19 ISSUED FOR MDEQ SUBMITTAL					DS BW DL JP			DRAWING NO.			
REV DATE DESCRIPTION DR BY CHK APP CO										REV DATE DESCRIPTION DR BY CK APP CO								SHEET 2			
																		REV. A			



																		 J.H. CAMPBELL PLANT WEST OLIVE, MI	POND A TOP OF LINER GRADING PLAN			
					</																	



										SIGNATURE <i>David M. List</i> NAME DAVID M. LIST MICHIGAN P.E. No. 6201037074					 J.H. CAMPBELL PLANT WEST OLIVE, MI		POND A TOP OF COVER GRADING PLAN			
																	SCALE: 1"=50' JOB: PT-02043			
																	DRAWING NO.			
																	SHEET 6			
																	REV. A			
REFERENCE DRAWINGS										A 01-22-19 ISSUED FOR MDEQ SUBMITTAL					DS BW DL JP					
REV DATE DESCRIPTION DR BY CHK APP CO										REV DATE DESCRIPTION					DR BY CK APP CO					



LEGEND

EXISTING GROUND

APPROXIMATE HISTORIC GROUNDWATER

APPROXIMATE LIMIT OF EXISTING CCR

PROPOSED TOP OF LINER

PROPOSED TOP OF COVER

EXISTING CCR

EXISTING NATIVE SOIL

EXISTING WATER

NOTE(S)

1. EXISTING CONDITIONS MAY VARY FROM THOSE SHOWN DUE TO ONGOING CCR DISPOSAL OPERATIONS.

2. CONTRACTOR IS RESPONSIBLE FOR DEVELOPING AND IMPLEMENTING STORMWATER MANAGEMENT AND EROSION CONTROL PLANS CONSISTENT WITH THE SITE SWPPP.

3. CONTRACTOR SHALL BE SOLELY RESPONSIBLE FOR ADHERENCE TO CONSUMERS ENERGY COMPANY'S HEALTH AND SAFETY PROCEDURES AS WELL AS ANY STATE AND FEDERAL HEALTH AND SAFETY REQUIREMENTS.

4. CONSTRUCTION MATERIALS, SUBCONTRACTORS, AND STOCKPILE LOCATIONS SHALL BE SUBJECT TO APPROVAL BY CONSUMERS ENERGY COMPANY OR ITS DESIGNATED REPRESENTATIVE.

5. TEMPORARY ROADS FOR SITE ACCESS AND STOCKPILE ACCESS TO BE APPROVED BY CONSUMERS ENERGY COMPANY OR ITS DESIGNATED REPRESENTATIVE.

6. CONTRACTOR SHALL VERIFY ALL DIMENSIONS, ELEVATIONS, AND SITE CONDITIONS PRIOR TO STARTING WORK AND SHALL NOTIFY THE ENGINEER IF CONFLICTS EXIST ON THE DRAWINGS.

7. CONTRACTOR IS RESPONSIBLE FOR SURVEY CONTROL AND FOR RECORD-KEEPING REQUIRED TO PRODUCE AS-BUILT DRAWINGS.

8. CONTRACTOR SHALL PERFORM HOUSEKEEPING DUTIES ON A DAILY BASIS TO KEEP WORK AREAS CLEAN. HOUSEKEEPING SHALL BE PERFORMED AT THE COMPLETION OF THE WORK TO THE SATISFACTION OF THE OWNER.

9. CONTRACTOR SHALL BE RESPONSIBLE FOR ALL MATERIALS REQUIRED TO FULLY CONSTRUCT THE SYSTEM ACCORDING TO THE DESIGNS IN THESE DRAWINGS.

10. EXCAVATIONS SHALL CONFORM TO CONSUMERS ENERGY COMPANY AND OSHA REQUIREMENTS.

11. APPROXIMATE HISTORIC GROUNDWATER PROFILE IS FROM STS CONSULTANTS LTD. PLAN DATED MARCH 6, 1996 AND ESTIMATED FOR THE ASH POND LOCATIONS DEPICTING LEVELS AFTER THE POND 1-2 NORTH AND SOUTH AND POND 3 NORTH AND SOUTH ARE NO LONGER IN USE.

REFERENCE(S)

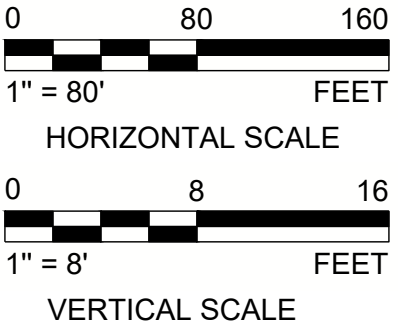
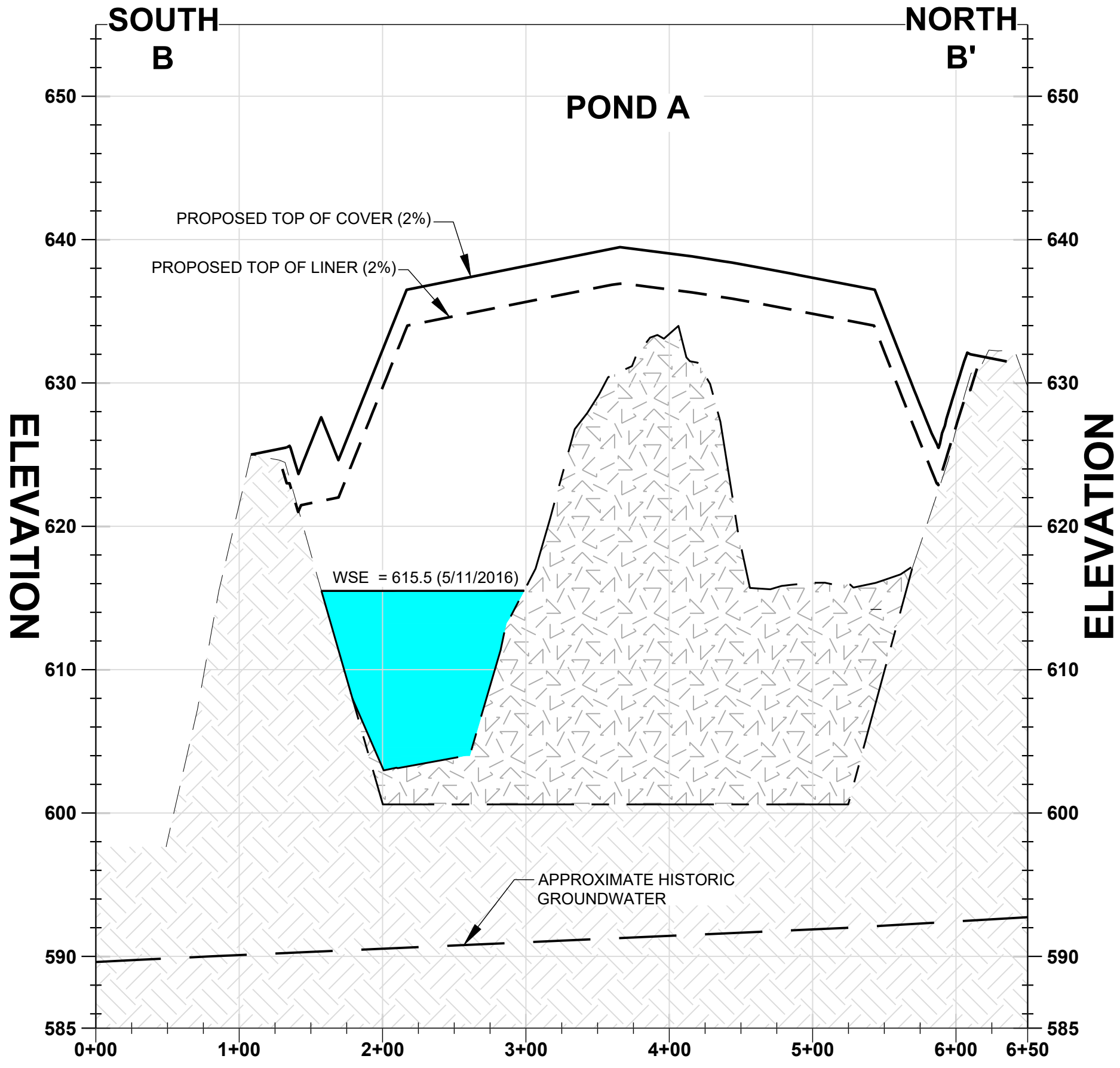
1. SITE LOCATION: SECTION 15, T6N, R16W, OTTAWA COUNTY, MICHIGAN.

2. EXISTING GROUND TOPOGRAPHY AND WATER LEVELS WERE PROVIDED BY A GROUND SURVEY PERFORMED BY ENGINEERING AND ENVIRONMENTAL SOLUTIONS, LLC IN MAY 2016 AND MAY 2017.

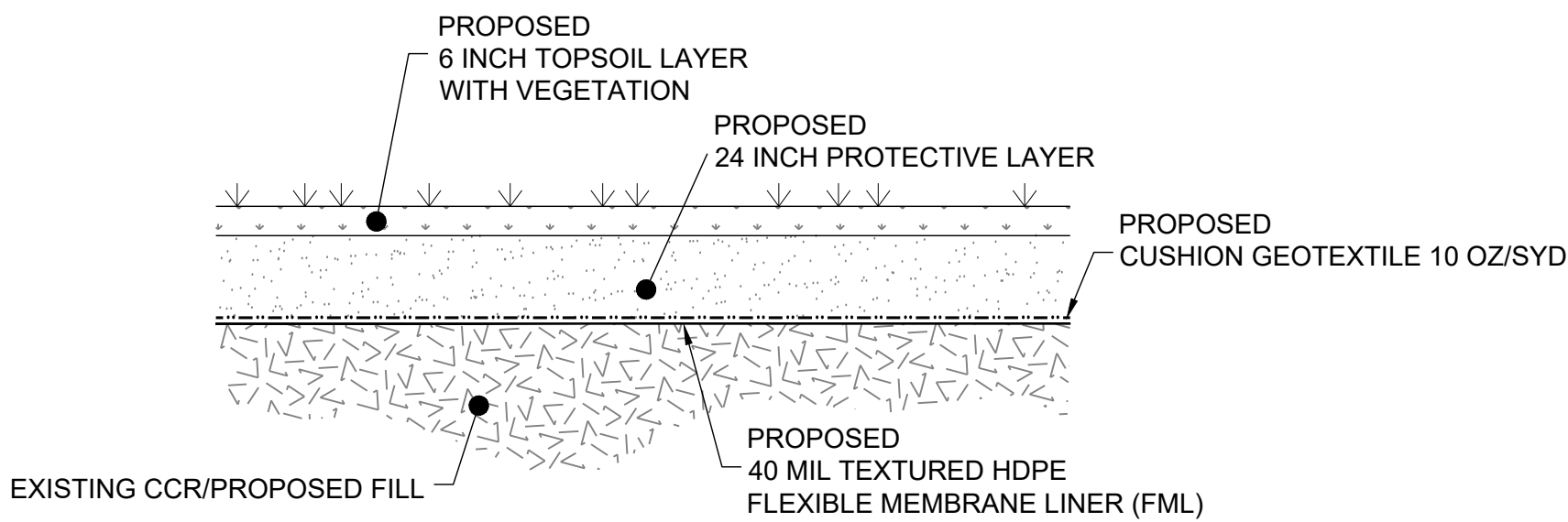
3. COORDINATE SYSTEM:

VERTICAL: CONSUMERS ENERGY J.H. CAMPBELL LOCAL PLANT DATUM, NGVD29.

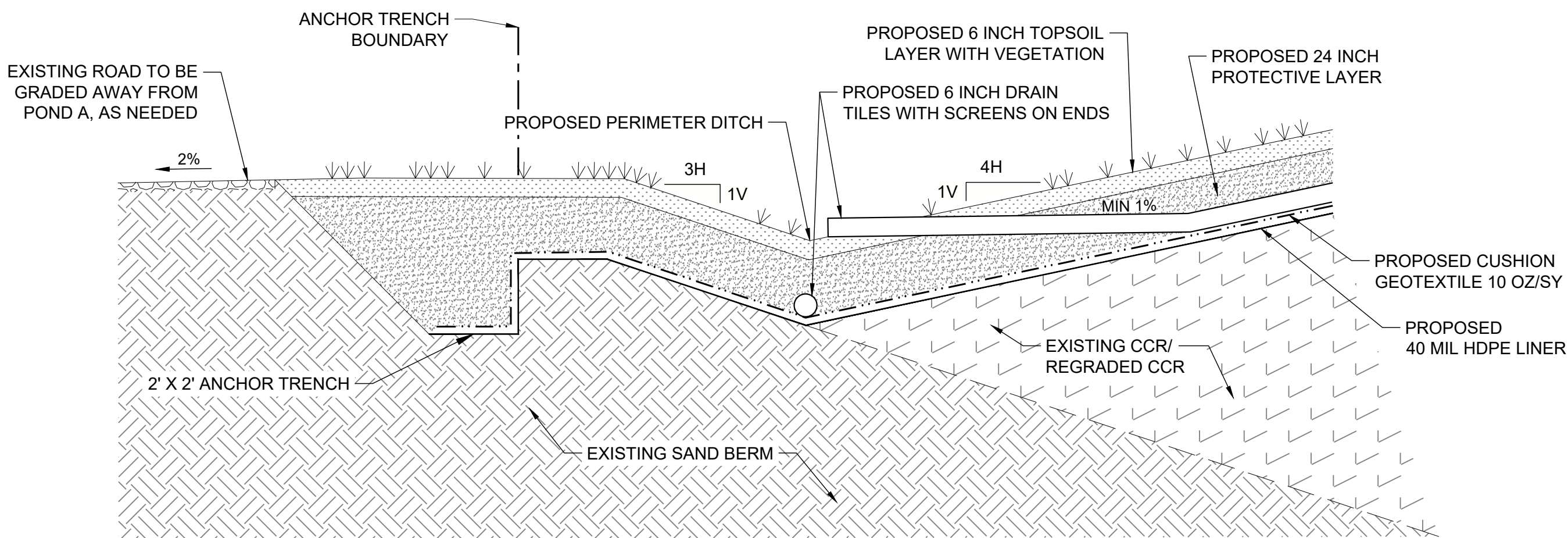
HORIZONTAL: CONSUMERS ENERGY J.H. CAMPBELL LOCAL PLANT DATUM



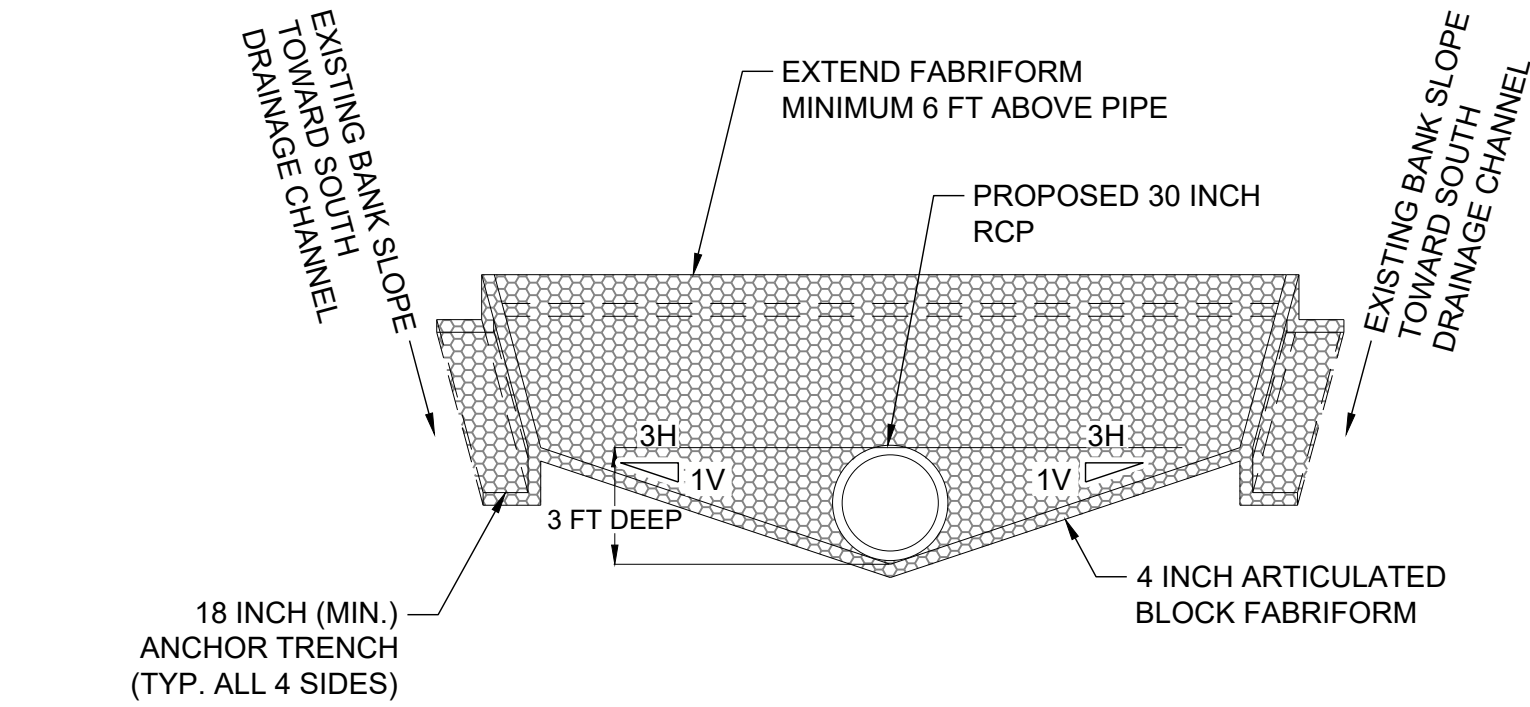
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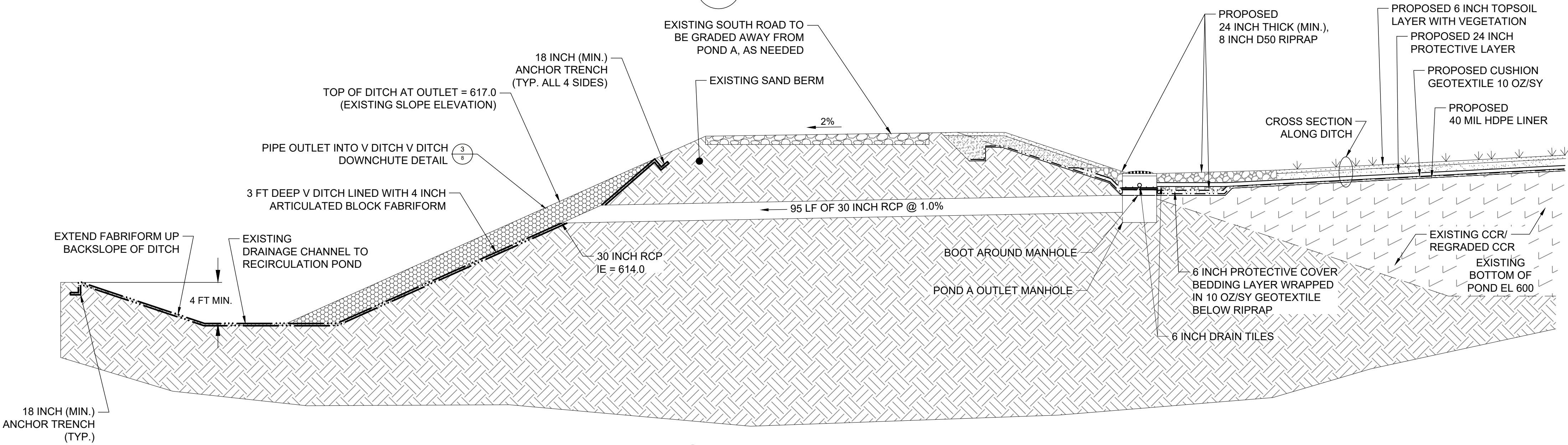
NOT TO SCALE 1 8 TYPICAL POND A COVER DETAIL



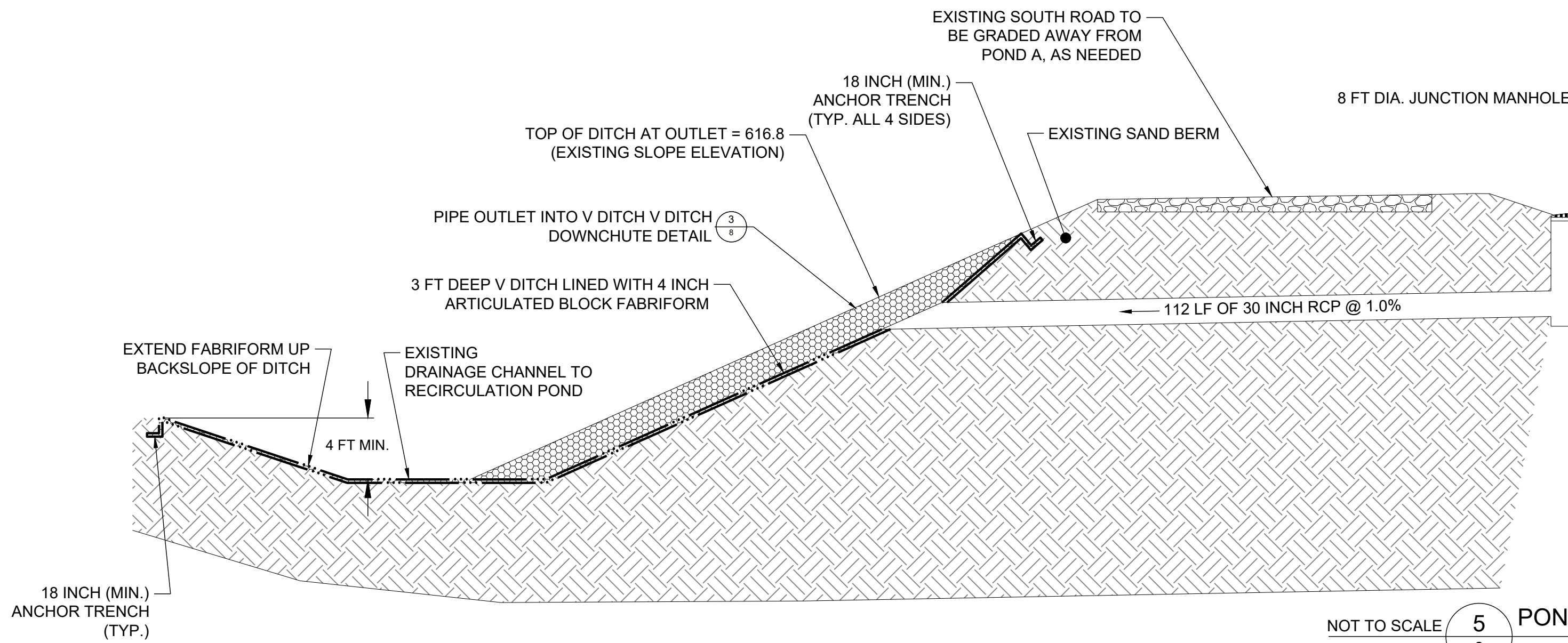
NOT TO SCALE 2 8 TYPICAL ANCHOR TRENCH AND PERIMETER DITCH DETAIL



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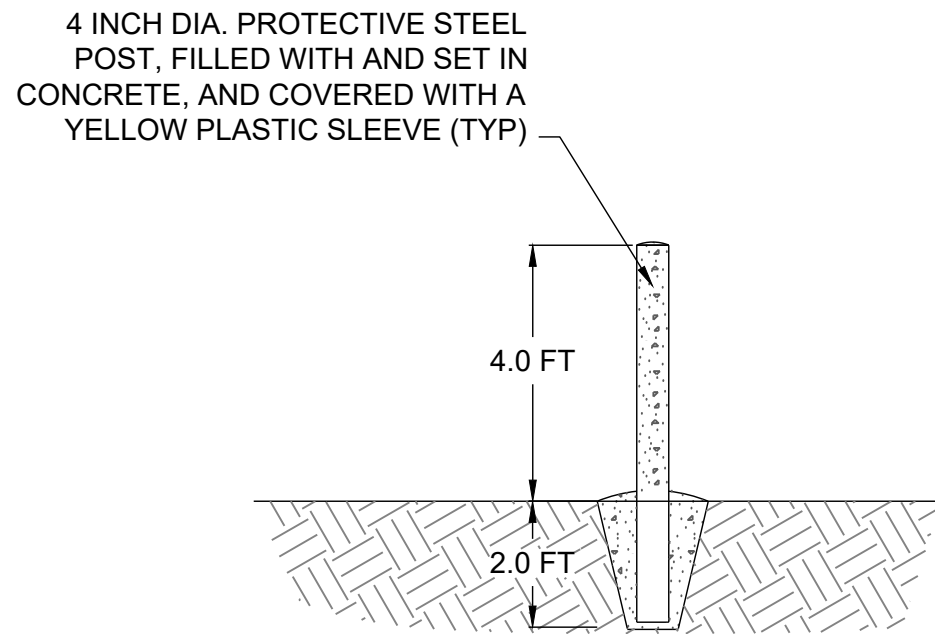


NOT TO SCALE 5 8 POND A SOUTHWEST CORNER OUTLET PIPE DETAIL

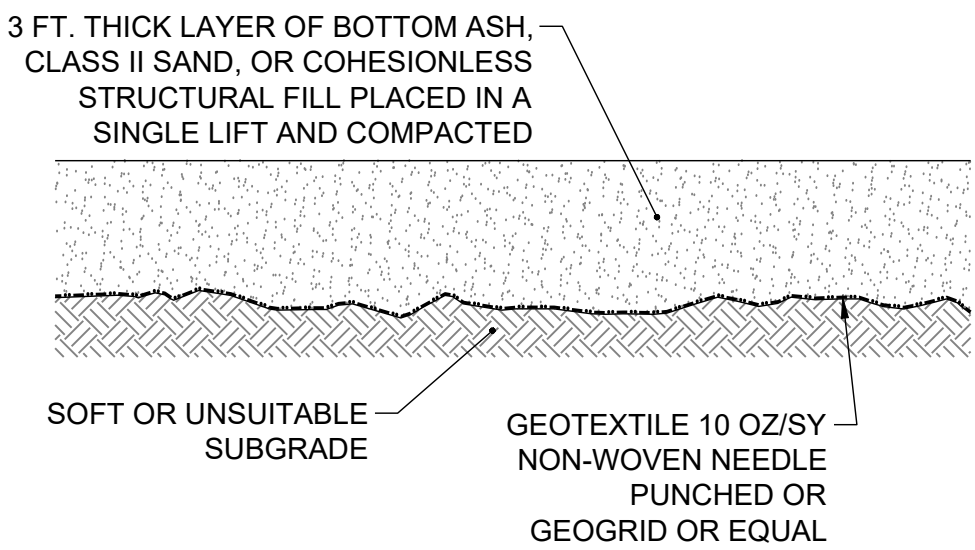
NOTE(S)
1. ALL DIMENSIONS SHOWN ARE NOMINAL OR APPROXIMATE UNLESS SPECIFIED OTHERWISE.

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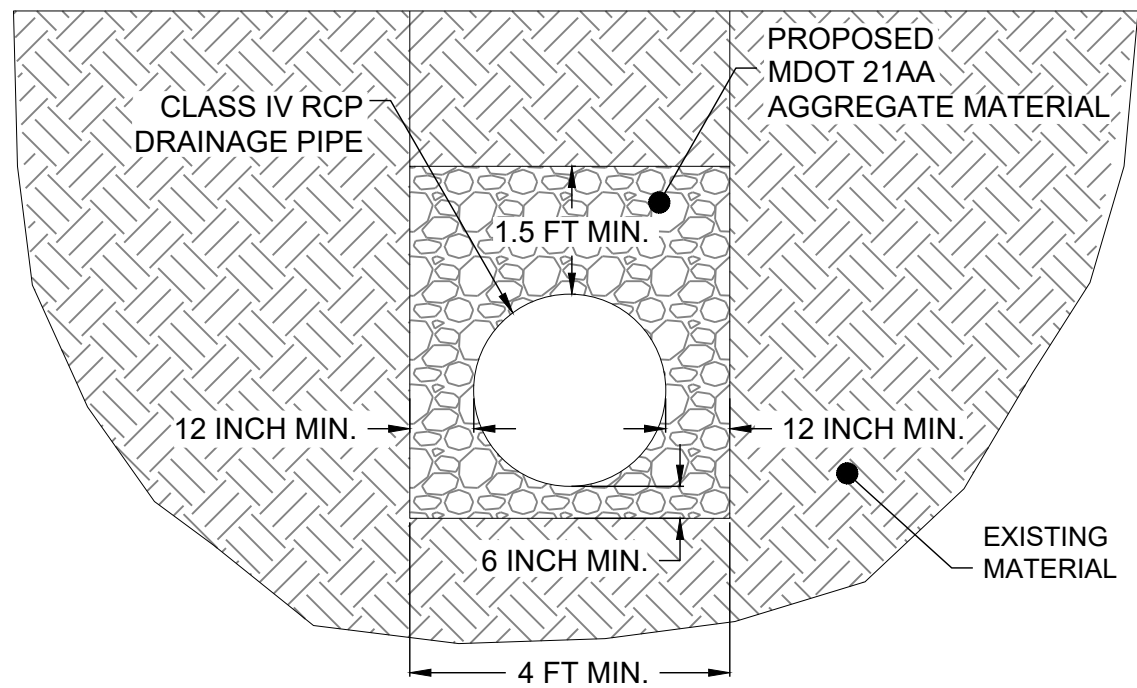
1



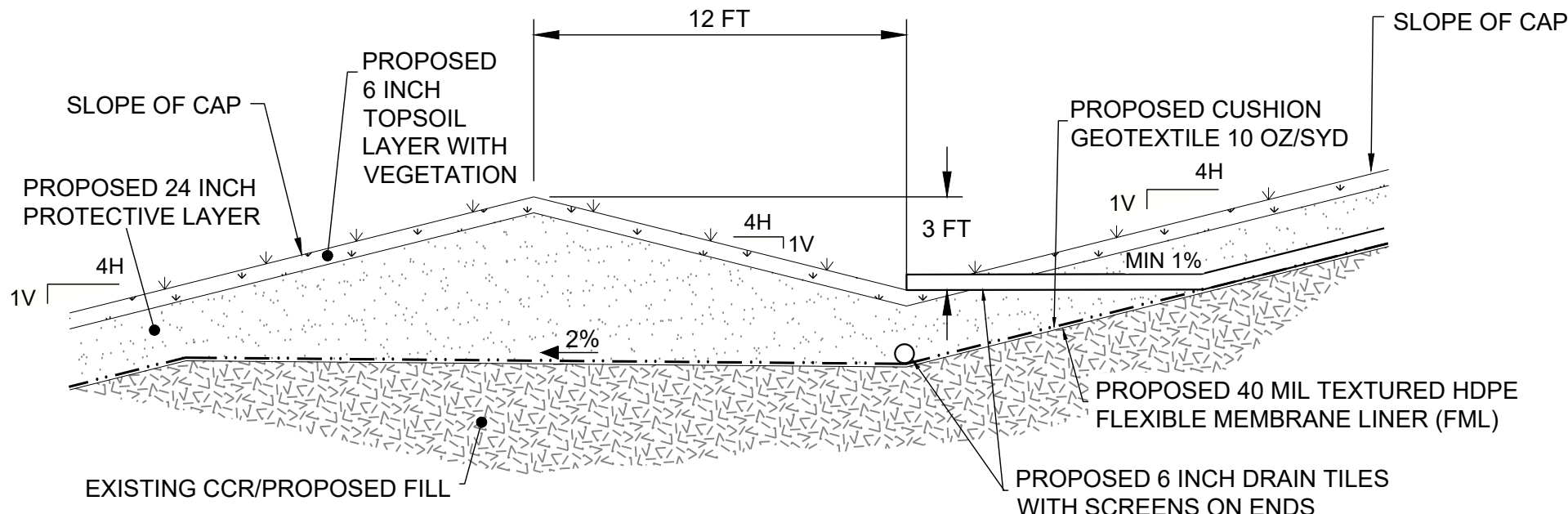
NOT TO SCALE **1**
9 TYPICAL BOLLARD DETAIL



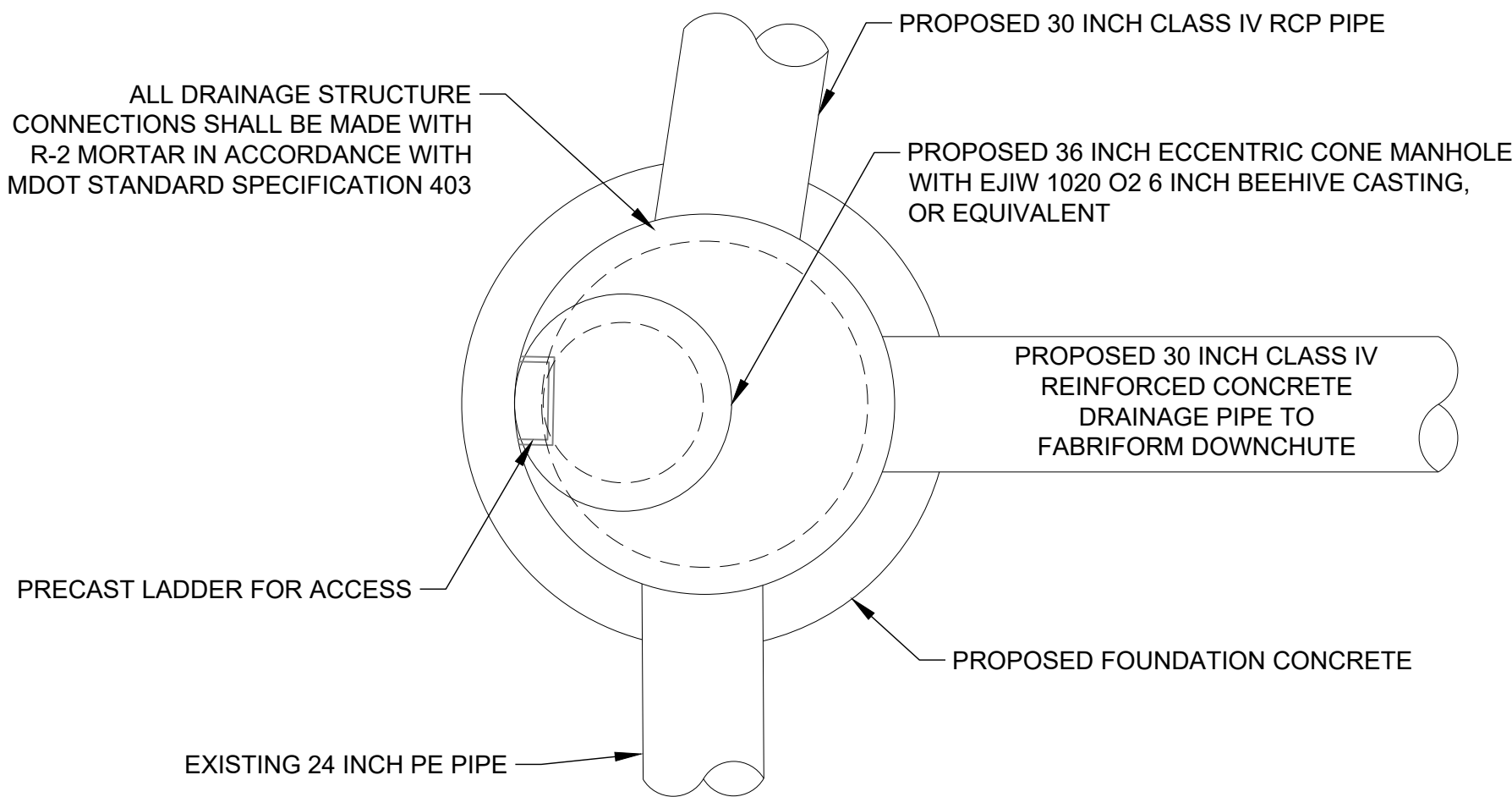
NOT TO SCALE **2**
9 TYPICAL SUBGRADE STABILIZATION DETAIL



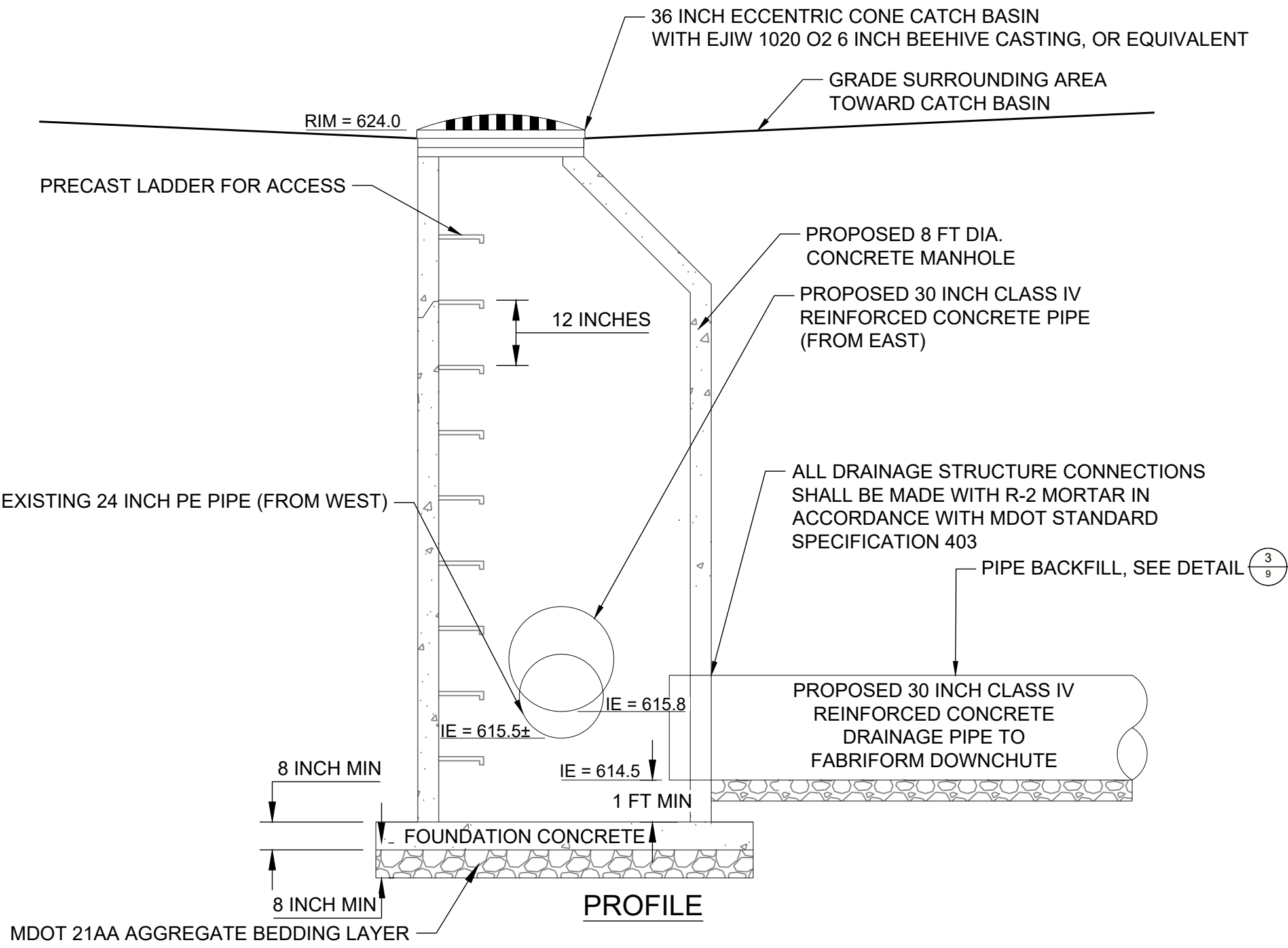
NOT TO SCALE **3**
9 TYPICAL DRAINAGE PIPE BACKFILL DETAIL



NOT TO SCALE **4**
9 TYPICAL POND A BENCH DRAIN DETAIL



PLAN



PROFILE

NOT TO SCALE **5**
9 PROPOSED 8 FT DIA. JUNCTION MANHOLE DETAIL

NOTE(S)
1. ALL DIMENSIONS SHOWN ARE NOMINAL OR APPROXIMATE UNLESS SPECIFIED OTHERWISE.

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APPENDIX B
CONSTRUCTION QUALITY ASSURANCE PLAN



CONSTRUCTION QUALITY ASSURANCE PLAN

J.H. CAMPBELL GENERATING FACILITY

POND A CONSTRUCTION QUALITY ASSURANCE (CQA) PLAN

West Olive, Michigan

Submitted To: Consumer Energy Company
1945 W. Parnall Road
Jackson, Michigan 49201

Submitted By: Golder Associates Inc.
15851 South US 27, Suite 50
Lansing, Michigan 48906

January 25, 2019

1667572





Table of Contents

1.0	INTRODUCTION.....	1
1.1	Summary	1
1.2	Purpose and Scope.....	1
1.3	Design Summary.....	1
2.0	RESPONSIBILITY AND AUTHORITY	2
2.1	Facility Owner/Operator	2
2.2	Regulatory Agency	2
2.3	Design Engineer.....	2
2.4	Construction Contractor	2
2.5	Construction Quality Assurance Officer	2
2.6	Construction Quality Assurance Technician(s)	3
2.7	Licensed Land Surveyor	3
2.8	Testing Laboratory	3
3.0	MEETINGS	4
3.1	Preconstruction Meeting	4
3.2	Progress Meetings	4
3.3	Special Meetings.....	5
4.0	CONSTRUCTION OBSERVATIONS.....	6
4.1	Daily Reports.....	6
4.2	Photographs	6
4.3	Test Data Sheets	7
4.4	Documentation and Record Storage.....	7
5.0	EARTHWORK OBSERVATIONS AND TESTING	8
5.1	Pond A CCR Grading and Fill Acceptance	8
5.2	Geosynthetic Subgrade Acceptance.....	8
5.3	Anchor Trenches.....	8
5.4	Protective Cover Soil Layer.....	9
5.5	Topsoil.....	10
6.0	GEOMEMBRANE LINER OBSERVATIONS AND TESTING	11
6.1	Geomembrane Rolls and Panels	11
6.2	Panel Placement	16
6.3	Geomembrane Field Seam Construction.....	16
6.4	Seam Repair	20
6.5	Documentation and Reporting	21
6.6	Stability.....	21
7.0	CUSHION GEOTEXTILE	23
7.1	Geotextile Rolls	23



7.2	Geotextile Seams and Overlaps	23
7.3	Geotextile Repairs.....	23
7.4	Geotextile Sampling	24
7.5	Documentation and Reporting	24
8.0	SITE RESTORATION	25
8.1	Erosion and Sediment Control	25
8.2	Seeding, Fertilizer, and Mulch.....	25
9.0	STORMWATER MANAGEMENT	26
9.1	Culverts and Drain Tile.....	26
9.2	Bench Drains and Perimeter Ditches	26
9.3	Documentation	26
10.0	CONSTRUCTION CERTIFICATION REPORT	27
10.1	Summary	27
11.0	REFERENCES.....	28

List of Tables

Table 6.1	HDPE Textured Polyethylene Geomembrane Properties and Testing Frequencies
Table 6.2	HDPE Smooth Polyethylene Geomembrane Properties and Testing Frequencies
Table 7.1	Geotextile Properties

List of Appendices

Appendix A	Example CQA Forms
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1.0 INTRODUCTION

1.1 Summary

The Construction Quality Assurance (CQA) program for the closure of Pond A at the Consumers Energy Company (CEC) J.H. Campbell Generating Facility (JH Campbell) in West Olive, Michigan is presented herein. This CQA Plan presents the methods to be followed during closure of the surface impoundment in accordance with the final cover design and regulatory requirements.

1.2 Purpose and Scope

The purpose of the CQA program is to provide minimum requirements for construction observation, testing, and documentation activities to be performed during closure and to verify that the constructed final cover meets or exceeds design requirements and specifications contained in the approved Pond A Closure Plan and achieves regulatory and local requirements. This plan details sampling and testing programs to be carried out during the final cover construction. The primary goal of the CQA Plan is to provide a means of evaluating the quality of the constructed final cover so that the intent of the design is achieved.

1.3 Design Summary

In general, the closure of Pond A includes the following major components:

- Dewatering
- Stabilizing existing coal combustion residuals (CCR) (if necessary)
- Placement of fill materials to establish proposed closure grading
- Preparation of the subgrade for placement of geomembrane
- Installation of a geosynthetic capping system (geomembrane and geotextile cushion)
- Placement of protective cover soils and installation of drain tile
- Placement of topsoil
- Final grading, seeding, mulching, and fertilizing to establish vegetation to protect the completed final cover system



2.0 RESPONSIBILITY AND AUTHORITY

2.1 Facility Owner/Operator

CEC is responsible for the design, construction, and operation of the facility in compliance with the regulatory requirements.

2.2 Regulatory Agency

The regulatory and licensing agency for this project is the Michigan Department of Environmental Quality (MDEQ), Office of Waste Management and Radiological Protection (Regulator).

2.3 Design Engineer

The Design Engineer (Engineer) has the responsibility of designing the final cover system to meet the permitted design and operational requirements of CEC. The Engineer will be onsite as needed during the Pond A closure construction and geosynthetics placement to assure quality is upheld and the intent of the closure design is met.

2.4 Construction Contractor

The Construction Contractor (Contractor) is responsible for construction of the final cover, which includes fill placement to meet closure grades as indicated on the contract drawings and in the CQA Plan. The Contractor may implement their own quality control program for purposes of monitoring their related construction. The CQA program presented in this document provides the minimum standards for the acceptance of the work and the regulatory agencies.

2.5 Construction Quality Assurance Officer

The Construction Quality Assurance Officer (CQA Officer) is a designated representative of CEC who is responsible for certificates of construction. The CQA Officer will be a professional engineer registered in the State of Michigan with experience in solid waste unit construction and closure. The CQA Officer is responsible for supervising all the inspection and testing quality assurance (QA) requirements of this section. The CQA Officer is also responsible for the preparation of a construction certification report following construction to document the completed observations, measurements, and testing. The report will include a certification statement signed by the CQA Officer that construction meets or exceeds design requirements and specifications contained in the Pond A Closure Plan and achieves regulatory and local requirements.

The specific responsibilities for administering the CQA program are the responsibility of the CQA Officer and will include the following, at a minimum:

- Reviewing plans and specifications for clarity, completeness, and compliance with the approved closure plan and applicable regulations



- Educating and training QA personnel on requirements and procedures outlined in the CQA program
- Scheduling and coordinating QA activities
- Supervising field personnel
- Confirming that QA data are accurately recorded and maintained
- Verifying that raw QA data are properly recorded, reduced, summarized, and interpreted
- Providing associated organizations with reports on CQA activities and results
- Identifying non-conforming construction and verifying corrective measures

2.6 Construction Quality Assurance Technician(s)

The Construction Quality Assurance Technician(s) [CQAT(s)], under the direct supervision of the CQA Officer, will be present to perform observations and testing during the following construction activities:

- Dewatering of Pond A
- Stabilizing existing CCR in Pond A (if required)
- Earthwork
- Inspection and acceptance of geosynthetic subgrade
- Survey of Pond A top of liner grades
- Installation, seaming, patching, and testing of the geomembrane
- Installation of the cushion geotextile
- Placement of drain tiles and protective cover soils over cushion geotextile
- Placement of topsoil, seed, fertilizer, and mulch
- Installation of stormwater features
- Site restoration
- Documentation of tests, work activities, and material deliveries

The CQAT(s) will document construction and CQA activities as described in Section 4.0 of this document.

2.7 Licensed Land Surveyor

The Licensed Land Surveyor shall provide equipment and personnel needed to perform surveying activities as required by the construction project. The Licensed Land Surveyor shall be licensed in the State of Michigan.

2.8 Testing Laboratory

The Testing Laboratory is responsible for providing soil and/or geosynthetic testing as required in the project's plans and specifications.



3.0 MEETINGS

The meeting requirements for the CQA program include a preconstruction meeting, construction progress meetings, and special meetings.

3.1 Preconstruction Meeting

A preconstruction meeting will be held prior to the start of construction and will be attended by all principle parties (CEC, Contractor, CQA Officer) involved in the project. MDEQ will be notified as soon as possible in advance of the preconstruction meeting in the event a representative wishes to attend. The purpose of the meeting is to:

- Exchange the following information: business addresses, phone numbers, and e-mail addresses of the Owner (CEC), Engineer, CQA Officer, and pertinent personnel for the Contractor
- Resolve any uncertainties following the award of the construction contract
- Review work scope
- Conduct a site walkthrough and inspection
- Discuss the Contractor's overall construction schedule and anticipated work hours
- Discuss project administration
- Review status of submittals required to be transmitted
- Discuss any appropriate design modifications or clarifications
- Discuss the Contractor's surface water and dust management plan
- Discuss the schedule and procedures of the geomembrane installation
- Discuss CEC's emergency notification and operating practices for emergency situations
- Review project methods, site security, and safety

3.2 Progress Meetings

Progress meetings will be held prior to the beginning of each major phase or on an "as needed" basis. The day of week and time of day will be determined and agreed upon by all parties prior to the meetings. The meetings will be conducted by CEC. The purpose of the meetings will be to:

- Review coordination of work
- Review schedule
- Review the previous work activities and accomplishments
- Review the status of the Contractor's submittals
- Identify the Contractor's personnel and equipment assignments for the upcoming work
- Discuss any existing or potential construction problems and their respective corrective actions
- Review non-conformance list



3.3 Special Meetings

Special meetings will be called at the discretion of CEC, Engineer, CQA Officer, or Contractor to resolve problems or other work-related issues.



4.0 CONSTRUCTION OBSERVATIONS

4.1 Daily Reports

The CQAT(s) collects samples and performs or observes the CQA testing required by the CQA Plan. A daily field report is prepared by each CQAT(s) for each day they are onsite observing the construction and kept in a record book which is to be made available to CEC on a daily basis. The report will contain (at a minimum) the following information:

- Date
- Type of observations
- Summary of weather conditions such as minimum and maximum temperatures, wind speed, and any precipitation
- Summary of any meetings held and attendees
- Equipment and personnel on the project
- Name and titles of Contractor supervisors and Quality Control personnel
- Summary of construction activities and locations
- Description of offsite materials received
- Calibration and recalibration of test equipment
- Description of procedures used
- Summary of all QA tests conducted
- Summary of samples collected
- Record of repairs to the liner system
- Personnel involved in daily observations and sampling activities
- Signature of the technician
- Description of delays in construction activities
- Description of any problems or non-conforming construction and resolution/alternatives for each situation
- Summary of failed testing and corrective actions completed
- Documentation of field modifications made if hot or cold weather placement procedures for liner installation are in effect

4.2 Photographs

The CQAT(s) will coordinate with CEC personnel to ensure sufficient photographs are taken to document construction problems, non-conforming work, and related repairs taken before and after the problem or non-conforming work is corrected.

Photographs approved by CEC security will be provided to the CQA Officer for inclusion in the Certification Report. At the end of the project, photographs will be retained by CEC.



4.3 Test Data Sheets

At a minimum, the CQAT(s) will record all field test data results on separate forms listed below:

- Daily field report
- Certificate of acceptance of prepared subgrade (geosynthetic subgrade)
- Certificate of acceptance of installed geosynthetic liner
- Initial roll inventory
- Panel placement summary
- Trial weld summary
- Panel seaming summary
- Repair summary
- Non-destructive test summary
- Destructive test summary - field
- Destructive test summary – laboratory

Independent consultants or laboratories engaged by the CQA Officer will submit their test results on forms acceptable to and approved by the CQA Officer.

4.4 Documentation and Record Storage

The daily records maintained during construction activities include but are not limited to the following:

- Daily observation reports
- Test data sheets
- Test data from independent consultants or laboratories (if any)
- Field book maintained by each CQAT(s)



5.0 EARTHWORK OBSERVATIONS AND TESTING

The following section summarizes the QA plan for testing and monitoring the earthwork required to close Pond A. The Contractor will provide Owner's acceptance criteria that documents all imported protective cover soil and topsoil provided for this project is from clean, uncontaminated sources. If the soil source is an established commercial sand/aggregate pit, then a letter from the commercial pit stating that the soil is virgin and non-contaminated will satisfy the testing requirement.

5.1 Pond A CCR Grading and Fill Acceptance

The CQAT(s) will observe CCR filling and grading and confirm it is subsequent to Pond A dewatering. Areas that exhibit excessive yielding or rutting shall be reworked or stabilized in accordance with the contract documents. CCR shall be placed in uniform horizontal lifts and compacted with equipment and methods that can achieve a surface that is sufficient to support subsequent lifts and the final cover system. The CQAT(s) is responsible for observing and documenting the dewatering and earthwork associated with Pond A closure until the geosynthetic subgrade is achieved.

5.2 Geosynthetic Subgrade Acceptance

Once the geosynthetic subgrade is obtained, the subgrade will be smooth drum rolled. Ruts or irregular surfaces, protruding stones larger than 0.75 inches, debris, and any existing dense vegetation will be eliminated prior to placement of the geomembrane. The geosynthetic subgrade will be documented by survey and compared to the design elevations. The maximum allowable difference from documented grades to design grades is +/- 1.0 foot per R4921(4)(d). If the documented top of geosynthetic subgrade differs from the design grades by more than allowed, the subgrade will be regraded and redocumented. Once acceptable, the CQAT will document subgrade acceptance with the certificate of soil surface acceptance form provided in Appendix A.

5.3 Anchor Trenches

QA associated with monitoring and testing of anchor trenches will include the following:

- Anchor trench excavation will be monitored for proper depth and location
- Geosynthetic panels extending into the anchor trench will be monitored for complete seaming into the anchor trench
- Anchor trench backfill operations will be monitored
- The depth of a typical anchor trench will be measured to conform to contract drawings
- Backfill will be placed to anchor the geosynthetics without causing damage



5.4 Protective Cover Soil Layer

Protective cover soils will be placed over geosynthetics. Protective cover soils must be either SM, SW, or SP. Since these soils are placed adjacent to the geosynthetics, there will be no protruding stones larger than 0.75 inches, and they will be free of materials that could harm the geosynthetics.

The soil source will be approved by CEC and free of contaminants prior to hauling onsite. Material will be spread to the thickness shown by the plans with low ground pressure equipment [not exceeding five pounds per square inch (psi)] and pushed up slope to prevent tensioning of the geosynthetics. Limited placement of protective cover soils down slope will be allowed only after submittal and approval by the Owner of a slope stability evaluation by the Contractor in accordance with Section 6.6. Temporary haul roads for normal ground pressure vehicles will be a minimum of 36 inches thick.

During protective cover soil placement, the CQAT(s) will observe the following:

- Placement procedures and equipment sizes
- Weather conditions to prevent placement of frozen material
- Removal of stones or other debris
- Confirmation that underlying 40 mil high-density polyethylene (HDPE) geomembrane and 10oz./sy geotextile remain in place and with a minimal amount of wrinkles
- Control of protective cover layer thickness over the geosynthetics in areas of hauling
- Evaluate degree of compaction by visual, qualitative means

The CQAT(s) will perform the following testing prior to and during protective cover placement:

- Collect one sample per source for contaminant testing at the request of CEC from potential borrow sites.
- Collect a minimum one sample per 5,000 cubic yards (cyd) of placed material and/or when the material source changes for grain size determination in accordance with ASTM D422 and Unified Soil Classification in accordance with ASTM D2487. The protective cover soil samples shall be collected and tested by the CQAT (s). The CQAT (s) will verify that the test results meet the requirements of the project specifications, drawings and CQA Plan.
- Document testing and observations in the daily report and with construction photographs in accordance with Section 4.2.
- The Licensed Land Surveyor shall survey the top of protective cover layer on a 100-foot grid system to verify the thickness. Alternately, direct depth checks may be used to determine the protective layer thickness. Locations where the protective layer thickness is less than that required on the engineering plans shall be increased to meet the project specifications. The CQA Officer will document the placement of additional soil material to meet the requirements of the CQA Plan. Elevations shall be referenced to NGVD29 datum. Grade tolerance is +0.2 to 0.0 at high design points (top of protective cover) from the engineering plans and maintaining slope minimums and protective soil thickness minimums indicated in the engineering plans and specifications.



5.5 Topsoil

The topsoil will be the final six inches of the final cover system. This material shall be locally available topsoil with a minimum 2.5 percent organic matter and pH between 6.4 and 7.5 to support the establishment of vegetation and retain moisture. Testing of the topsoil for organic content will be in accordance with ASTM D2974. The CQAT(s) will observe the topsoil placement and confirm it is generally placed at its designed thickness.

The CQAT(s) will perform the following testing prior to and during topsoil placement:

- Collect sample for contaminant testing at the request of CEC from potential borrow sites.
- Collect and test a minimum of one sample per five acres of material placed and/or when the material source changes for grain size determination in accordance with ASTM D422 for organic content and pH in accordance with ASTM D4972, "Standard Test Method for pH of Soils."
- Record observations in the daily report and with construction photographs in accordance with Section 4.2.
- The Licensed Land Surveyor shall survey the top of topsoil layer on a 100-foot grid system to verify the thickness. Alternately, direct depth checks may be used to determine the topsoil thickness. Locations where the topsoil thickness is less than that required on the engineering plans shall be increased to meet the project specifications. The CQA Officer will document the placement of additional topsoil material to meet the requirements of the CQA Plan. Elevations shall be referenced to NGVD29 datum. Grade tolerance is +0.2 to 0.0 at high design points (top of topsoil) from the engineering plans and maintaining slope minimums and protective soil thickness minimums indicated in the engineering plans and specifications.



6.0 GEOMEMBRANE LINER OBSERVATIONS AND TESTING

The geomembrane is the synthetic barrier layer of the final cover system. The geomembrane will be HDPE with a nominal thickness as shown on the contract documents. Textured geomembrane shall be placed on areas specified in the contract documents. Textured geomembranes can be used in lieu of smooth geomembranes provided they meet the nominal thickness requirements.

6.1 Geomembrane Rolls and Panels

All geomembrane materials will be approved by the CQA Officer before being used in construction. Approval will be based on the review of material data provided by the manufacturer and the inspection for defects of material as it is delivered to the site. All HDPE Flexible Membrane Liners (FML) will be in accordance with Geosynthetic Research Institute GRI GM 13 standard.

The CQA Officer will review Contractor submittals and monitor handling and deployment of the materials. These activities generally include:

- Monitoring and documenting the unloading of trucks delivering geomembrane rolls to the site:
 - Name of the manufacturer and fabricator
 - Name and type of liner
 - Thickness of liner
 - Batch code
 - Date of fabrication
 - Physical dimensions of rolls or fabricated panels
 - Panel number
 - Location and method of storage at the site
- Monitoring the handling and onsite storage of geomembrane rolls
- Recording the manufacturing roll and batch number of geomembrane rolls delivered to the site
- Reviewing the manufacturer's quality control testing for conformance with GRI GM 13 and the required testing in Table 6.1
- Fixing a code number to samples and recording the manufacturing numbers of the rolls from which samples are taken
- Labeling, packaging, and shipping samples to an offsite laboratory for conformance testing (if required)
- Interpreting laboratory test results in accordance with the specifications and accepting or rejecting delivered rolls based on results of offsite testing
- Observing and marking geomembrane as it is unrolled and deployed at the job site for uniformity, damage, and imperfections including holes, cracks, thin spots, tears, punctures, blisters, and foreign matter



- Reviewing documentation of the origin and identification of the raw materials used in the liner
- Reviewing copies of quality control certificates that are issued by the producer of the raw materials

**Table 6.1: HDPE Textured Polyethylene Geomembrane Properties and Testing Frequencies**

Properties	Test Method	Test Value 40 mils	Testing Frequency (minimum)
Thickness mils (min. ave.) ■ Lowest individual for any of the 10 values	D 5199	-10%	Per roll
Asperity Height mils (min. ave.) ¹	D 7466	16	Every second roll ²
Density (min. ave.)	D 1505/ D 792	0.940	200,000 pounds
Tensile Properties (min. ave.) ³ ■ Break strength –lb/in. ■ Break elongation - % ■ Yield strength –lb/in. ■ Yield elongation - %	D 6693 Type IV	60 100% 84 12%	20,000 pounds
Tear Resistance - lb (min. ave.)	D 1004	28	45,000 pounds
Puncture Resistance - lb (min. ave.)	D 4833	60	45,000 pounds
Stress Crack Resistance ⁴	D 5397 (App.)	500 hr	Per GRI GM10
Carbon Black Content - % (range)	D 4218 ⁵	2.0-3.0%	20,000 pounds
Carbon Black Dispersion	D 5596	Note ⁶	45,000 pounds
Oxidative Induction Time (OIT) (min. ave.) ⁷ (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	200,000 pounds
Oven Aging at 85°C ^{7,8} (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	55% 80%	Per each formulation
UV Resistance ⁹ (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs ¹¹	D 7238 D 3895 D 5885	N.R. ¹⁰ 50%	Per each formulation

¹Out of 10 readings; 8 out of 10 must be greater than 7 mils, and lowest individual reading must be less than 5 mils; see also Note 6.

²Alternate the measurement side for double sided textured sheet.

³Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of five test specimens each direction.

- Yield elongation is calculated using a gage length of 1.3 inches
- Break elongation is calculated using a gage length of 2.0 inches

⁴P-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for



the textured sheet materials. The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

⁵Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

⁶Carbon black dispersion (only near spherical agglomerates) for 10 different views:

- Nine in Categories 1 or 2 and one in Category 3

⁷The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

⁸It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

⁹The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

¹⁰Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

¹¹UV resistance is based on percent retained value regardless of the original HP-OIT value.

¹²Table and notes derived from GM13.

**Table 6.2: HDPE Smooth Polyethylene Geomembrane Properties and Testing Frequencies**

Properties	Test Method	Test Value 40 mils	Testing Frequency (minimum)
Thickness mils (min. ave.) ■ Lowest individual for any of the 10 values	D 5199	nom. -10%	Per roll
Density (min. ave.)	D 1505/ D 792	0.940	200,000 pounds
Tensile Properties (min. ave.) ¹ ■ Break strength –lb/in. ■ Break elongation - % ■ Yield strength –lb/in. ■ Yield elongation - %	D 6693 Type IV	152 700% 84 12%	20,000 pounds
Tear Resistance - lb (min. ave.)	D 1004	28	45,000 pounds
Puncture Resistance - lb (min. ave.)	D 4833	72	45,000 pounds
Stress Crack Resistance ²	D 5397 (App.)	500 hr	Per GRI GM10
Carbon Black Content - % (range)	D 4218 ³	2.0-3.0%	20,000 pounds
Carbon Black Dispersion	D 5596	Note ⁴	45,000 pounds
Oxidative Induction Time (OIT) (min. ave.) ⁵ (c) Standard OIT — or — (d) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	200,000 pounds
Oven Aging at 85°C ^{5,6} (c) Standard OIT (min. ave.) - % retained after 90 days — or — (d) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	55% 80%	Per each formulation
UV Resistance ⁷ (c) Standard OIT (min. ave.) — or — (d) High Pressure OIT (min. ave.) - % retained after 1600 hrs ⁹	D 7238 D 3895 D 5885	N.R. ⁸ 50%	Per each formulation

¹Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of five test specimens each direction.

- Yield elongation is calculated using a gage length of 1.3 inches
- Break elongation is calculated using a gage length of 2.0 inches

²The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

³Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

⁴Carbon black dispersion (only near spherical agglomerates) for 10 different views:

- Nine in Categories 1 or 2 and one in Category 3

⁵The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.



⁶It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

⁷The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

⁸Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

⁹UV resistance is based on percent retained value regardless of the original HP-OIT value.

¹⁰Table and notes derived from GM13.

6.2 Panel Placement

QA monitoring for panel placement includes:

- Obtaining written acceptance of the subgrade by the geomembrane installer, CQAT(s), and earthworks contractor
- Evaluating and documenting weather conditions (e.g., temperature, wind) for geomembrane placement and informing the CQAT(s) if requirements for weather conditions are not met so the CQAT(s) can decide whether or not to stop geomembrane placement
- Monitoring and documenting geomembrane placement as well as conditions of panels as placed
- Noting panel defects, tears, or other deformities
- Observing panel placement for proper overlap
- Measuring panel lengths
- Recording the locations of installed panels and checking that the panels have been installed in accordance with the design plan
- Assigning each panel a unique panel number and identifying that panel with the manufacturer's roll number
- Recording panel numbers and locations on a panel layout diagram
- Recording ambient air temperature (daily)

6.3 Geomembrane Field Seam Construction

Seam construction information includes:

- Seam Layout:
 - When possible, orient seams parallel to line of maximum slope, (i.e., oriented along, not across, slope).
 - Horizontal seams on slopes shall be reasonably minimized with no horizontal seams within five feet of an anchor trench or the toe of a slope.
 - No horizontal seams shall be within five feet of the crest of the subgrade.
 - Horizontal seams shall be diagonal and staggered.
 - In general, maximize lengths of field panels and minimize number of field seams.
 - Align geomembrane panels to have nominal overlap of three inches for extrusion welding and four to six inches for fusion welding. Final overlap will be sufficient to allow strength tests to be performed on seam.
 - Seams will be wiped free of moisture and debris prior to seaming.



- Where applicable, the panels will be shingled in a down slope fashion.
- Temporary Bonding:
 - Hot air device (Liestar) will be used to temporarily bond geomembrane panels to be extrusion welded.
 - Do not damage geomembrane when temporarily bonding adjacent panels. Apply minimal amount of heat to lightly tack geomembrane panels together. Control temperature of hot air at nozzle of any temporary welding apparatus to prevent damage to geomembrane.
 - Do not use solvent or adhesive.
- Seaming Methods:
 - Approved processes for field seaming are extrusion welding and double-wedge fusion welding methods. Proposed alternate processes will be documented and submitted to Owner for approval. Alternate procedures will be used only after being approved in writing by Owner.
 - Use double-wedge fusion welding as primary method of seaming adjacent field panels:
 - For cross seam tees associated with fusion welding, a minimum one-foot-by-one-foot patch is required. Extrusion welding of cross seam tees will only be permitted with approval of CQAT(s).
 - When subgrade conditions dictate, use movable protective layer (e.g., extra piece of geomembrane) directly below each overlap of geomembrane that is to be seamed to prevent buildup of moisture between sheets and prevent debris from collecting around pressure rollers. If protective layer is used, it will be removed after completion of seam.
 - Use extrusion welding as secondary method of seaming between adjacent panels and as primary method of welding for detail and repair work.
- Seaming procedures:
 - General seaming procedures ambient temperature between 32°F and 104°F (seaming outside of this temperature range may be allowed provided trial welds provide passing results and are approved by Owner):
 - Do not seam if dust is blowing because of excessive winds.
 - Align seams with fewest possible number of wrinkles and fishmouths.
 - Prior to seaming, ensure that seam area is clean and free of moisture, dust, dirt, debris, or foreign material.
 - At beginning and end of each seam, Contractor will record start time of weld, date, welder initials, identification number of seaming unit, seaming unit temperature, and speed.
 - T-welding of cross seams will not be permitted unless approved by CQAT(s).
 - Cold weather seaming procedures [ambient temperature below 32°F (5°C)]:
 - Sheet grinding may be performed before preheating, if applicable.
 - Trial seaming will be conducted under same ambient temperature and preheating conditions as actual seams. New trial seams will be conducted if ambient temperature drops by more than 10°F from initial trial seam test conditions. New trial seams will be conducted upon completion of seams in progress during temperature drop.



- CQAT(s) or Owner will inspect the geomembrane surfaces for the presence of frost or residual moisture prior and during the welding procedure. If either is present, Installer will make provisions for removal and sufficient drying.
- The CQAT(s) will describe the nature and time of the execution of cold weather welding procedures in the certification report as a means of notification to MDEQ.
- Warm weather procedures (ambient temperature above 104°F):
 - No seaming of geomembrane is permitted unless demonstrated to CQAT(s) that geomembrane seam quality will not be compromised.
 - At the option of CQAT(s), additional destructive seam tests may be required for any suspect areas.
- Repair procedures:
 - Repair portions of geomembrane exhibiting flaw or failing destructive or nondestructive test.
 - Final decision as to repair procedure will be agreed upon between Owner, Contractor, and CQAT(s).
 - Acceptable repair procedures may include following:
 - i. Patching: Piece of same geomembrane material welded into place. Use to repair large holes, tears, non-dispersed raw materials, and contamination by foreign matter.
 - ii. Capping: Strip of same geomembrane material extrusion welded into place over inadequate seam. Use to repair large lengths of failed seams.
 - iii. Removal and replacement: Remove bad seam and replace with strip of same geomembrane material welded into place. Use to repair large lengths of failed seams.

QA monitoring and testing to be conducted for seam construction includes:

- Monitoring trial test seams: Test seams will be made by each operator and seaming unit combination each day prior to commencing field seaming. These seams will be made on fragment pieces of geomembrane liner to observe that seaming conditions are adequate. Such test seams will be made at the beginning of each seaming period; at changes of equipment, equipment settings, or power supply interruption; at the discretion of the CQAT(s); and at least once every five hours or as directed by the CQAT(s) in accordance with temperature and weather conditions during continuous operation of each welding machine. Also, each operator and seaming unit combination will make at least one test seam each day prior to commencing seaming operations. Requirements for test seams are as follows:
 - The test seam sample will be at least three-feet (0.9 m)-long by one-foot (0.3 m)-wide, or as agreed with the seam centered lengthwise. Six adjoining specimens, one-inch (25 mm)-wide each, will be die cut from the test seam sample. These specimens will be tested in the field with a tensionmeter for both shear (three specimens) and peel (three specimens) for single-track fusion welds or extrusion welds. For dual-track fusion welds, the Contractor will test each track as if it were a single-track weld. Test seams will be tested by the Contractor under observation of the CQAT(s) or designated representative of CEC. The specimens will not fail in the weld. No strain measurements need to be obtained in the field. A passing fusion or extrusion welded test seam will be achieved when the criteria is met described in Table 1(a) of GRI GM 19, Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembrane. If a



test seam fails, the entire operation will be repeated. If the additional test seam fails, the seaming apparatus or seamer will not be accepted and will not be used for seaming until the deficiencies are corrected and two consecutive successful full test seams are achieved. Test seam failure is defined as failure of any one of the specimens tested in shear or peel. For double-weld seams, both weld tracks will meet the test seam criteria.

- The CQAT(s) will log the date, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description.

■ Non-destructive testing:

- Production seams will be tested by the Contractor continuously using non-destructive techniques. The Contractor will perform all pressure and vacuum testing. The CQAT(s) or CQA Officer shall document all testing and monitor the work on a procedural basis. Requirements for non-destructive testing are as follows:

- Extrusion weld seams:

- i. The Contractor will maintain and use equipment and personnel at the site to perform continuous vacuum box testing on all single weld production seams. The system will be capable of applying a vacuum of at least five psi (35 kPa). The vacuum will be held for a minimum of 10 seconds for each section of seam. If bubbles are present indicating leakage, the area will be marked clearly for repair. If the vacuum test indicates leakage, the area will be patched; or the entire seam will be capped.

- Double-wedge fusion weld seams:

- i. The Contractor will maintain and use equipment and personnel to perform air pressure testing of all double weld seams. The system will be capable of applying a pressure of at least 30 psi (207 kPa) for not less than five minutes. The seam will be cut at opposite end from the air pressure gauge to assure full continuity of the test. Pressure loss tests will be conducted in accordance with the procedures outlined in "Pressurized Air Channel Test for Dual Seamed Geomembranes," GRI Test Method GM 6. As outlined by the test method, the seam or portion thereof being tested will be pressurized to 30 psi and; following a two-minute pressurized stabilization period, pressure losses over a measurement period of five minutes will not exceed four psi for a 40-mil sheet. The Contractor will demonstrate the required pressure over the entire length of the seam. If pressure drops below the allowance, the test will be considered a failure, and the following procedures will be implemented: Check to determine if there is excessive seepage around the inflation needle; check both ends of the seam to ensure the flow channel is completely sealed off; walk the length of the seam; and look and listen for air leaks. If either of these procedures fails to identify the leak, trim the seam overlap and vacuum test the seam to locate the leak. Once the leak is identified, make the necessary repairs and retest the seam.

■ Destructive Testing:

- Destructive testing will be performed on at least one field-seamed sample per day per seaming crew and machine combination. The sampling and testing frequency will be at least one test every 500 linear feet (150 m) of production seam for fusion and extrusion welded seams. Minor repairs with less than 10 feet of seam length (measured in linear feet along the seam, not measured around the perimeter of the patch) are not included in the extrusion weld seam total. If the weather conditions are such that the ambient air temperature is less than 32°F, then the minimum frequency may be increased by CEC, CQAT(s), or CQA Officer. GRI Test Method GM 9, "Cold



Weather Seaming of Geomembrane” will be utilized for seaming under 32°F. The locations will be selected by the CQAT(s) or CQA Officer. Sufficient samples will be obtained by the Contractor to provide one sample to the archive, one sample to the CQAT(s) or CQA Officer for laboratory testing (if required), and one sample to be retained by the Contractor for field testing. The Contractor will mark each sample with the name of the person welding, date, time, ambient air temperature, temperature of heating element, speed of seaming, and identification number of seaming unit. The test seam sample will be a minimum of three-feet (0.9 m)-long-by-one-foot (0.3 m)-wide with the seam centered lengthwise. Testing requirements are as indicated in GRI standard GM 19, “Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembrane.” Final determination of sample sizes will be agreed upon at the preconstruction meeting.

- Seam destructive testing shall be observed by the CQAT(s) or CQA Officer on a procedural basis. The Contractor will test samples in the field. All tests will be performed using a calibrated, motor-driven, strain-controlled tensionmeter approved by the CQA Officer.
 - Peel will be measured for one sample (five specimens). Peel tests will be evaluated for the criteria described in GRI GM 19. For double track welders, peel tests (five specimens) will be evaluated for each track.
 - Shear will be measured for one sample (five specimens). Tests will be evaluated for the criteria described in GRI GM 19.
- The CQAT(s) or CQA Officer will observe all production seam field test procedures and will provide samples to a third party laboratory certified by “Geosynthetic Accreditation Institute – Laboratory Accreditation Program” for laboratory testing for both peel and shear and evaluate test results in accordance with GRI GM 19.
- The CQAT(s) or CQA Officer will be responsible for the archive specimen and will assign a number to the archive sample and mark the sample with the number and will also log the date, seam number, approximate location in the seam, and field test pass-or-fail description, if applicable.

6.4 Seam Repair

Damaged and sample areas of geomembrane will be repaired by the Contractor by construction of a cap strip. No repairs will be made to seams by application of an extrusion bead to a seam edge previously welded by fusion or extrusion methods. Repaired areas will be tested for seam integrity. Damaged materials are the property of the Contractor and will be removed from the site. The following QA monitoring and testing will be implemented to monitor defect repairs:

- Destructive test failure procedures: When a sample fails destructive testing, Contractor has the following options:
 - Repair seam between any two passing destructive test locations.
 - Trace welding path to intermediate point (10 feet minimum from point of failed test in each direction) and take a small sample with a one-inch-wide die for an additional field test at each location. If these additional samples pass test, then take a full size destructive sample for peel and shear testing in accordance with Section 6.3. If these samples pass tests, repair seam between these locations. If either sample fails, repeat the process to establish a zone in which seam should be repaired.



- Acceptable repaired seams will be bound by locations from which samples passing destructive tests have been taken. In cases exceeding 150 feet of repaired seam, the CQA Officer may have Contractor destructive test repair seam.
- When sample fails, CQA Officer or CQAT(s) may require additional testing of seams that were welded by same welder and/or welding apparatus during same time shift.
- Repair Verification:
 - The CQAT(s) will observe, number, and log each repair.
 - The CQAT(s) will observe and document non-destructive testing of each repair.
 - The CQAT(s) will document passing non-destructive test results as adequate repairs.
 - Repairs more than 150-feet-long may require destructive test sampling.

Failed destructive or non-destructive tests indicate that repair will be redone and retested until passing test results.

6.5 Documentation and Reporting

Documentation and reporting methods will be implemented to systematically record results of onsite monitoring and testing. Reporting forms will be used for roll and panel placement, trial weld construction, panel seaming, non-destructive seam testing, and destructive seam testing. Unique identifying numbers will be assigned to each panel and seam and used to reference the panel and seam location and test results. Copies of example QA forms are included in Appendix A.

Panel location and seam location diagrams will be kept showing the location of all panel and seams, repairs, and destructive sample test locations. These location diagrams will be updated on a daily basis and will be available for review.

Copies of test results for any offsite laboratory testing will be forwarded to the CQA Officer and CQAT(s). The laboratory test result documents will be maintained in a job file and submitted with the final certification report.

6.6 Stability

Limited deployment of protective cover soils down slope may be allowed by CEC pending a submittal of a slope stability evaluation by the Contractor for the specific deployment equipment, geosynthetics, and cover soils showing an acceptable factor of safety of 1.3 for veneer stability. A down slope cover deployment plan shall be submitted by the Contractor to CEC assuring the geosynthetics are not damaged and soil washout is minimized, including a revised veneer cover stability analysis and anchor trench pull out analysis, if applicable. Plans for protective cover soil deployment down slopes on grades of two percent to less than nine percent do not need to be submitted to the MDEQ. For slopes of nine percent or greater, a down slope cover deployment plan shall be submitted to the MDEQ by CEC, if acceptable by CEC, prior to construction for approval. Any equipment required to access final cover will maintain pressure below five



psi at the geomembrane. If larger equipment is required, access/haul roads may be needed to prevent damage to the geosynthetics.



7.0 CUSHION GEOTEXTILE

The following section defines the CQA program for installation of the geotextile cushion layer in the final cover system. Geotextile (10 oz/sy) for cushion will be installed over the 40-mil HDPE geomembrane.

7.1 Geotextile Rolls

Monitoring for geotextile cushion rolls includes the following:

- Monitoring the condition of the rolls following delivery and unloading
- Recording the roll number of rolls delivered to the site
- Reviewing manufacturer's quality control testing for conformance with the CQA Plan shown in Table 7.1
- Obtaining samples and recording the manufacturer roll numbers from which samples are taken
- Labeling, packaging, and shipping samples to an offsite laboratory for conformance testing (if required)
- Observing geotextile as it is installed for uniformity, damage, and imperfections including holes, tears, thin spots, punctures, and foreign matter

Table 7.1: Geotextile Properties

Property	Test Method	Frequency	Minimum Value
Mass per unit area, oz/yd ²	ASTM D 5261	100,000 ft ²	10
Puncture resistance, lb.	ASTM D 6241	500,000 ft ²	700
Grab tensile strength, lb. (elong. percent)	ASTM D 4632	100,000 ft ²	230 (50%)
Trapezoidal tear strength, lb.	ASTM D 4533	100,000 ft ²	95
UV resistance, percent	ASTM D 7238	Per Formulation	70%

Note: Alternative test methods must be approved by Engineer

7.2 Geotextile Seams and Overlaps

The geotextile will be continuously sewn with a double stitch seam. Overlaps will be at least three inches or as required to perform the proper seaming. An alternative single fusion wedge weld seaming method is also acceptable. Fusion welding will not be used in adverse weather conditions, in which case sewn seaming shall be the preferable method.

7.3 Geotextile Repairs

The geotextile will overlap the repair area by six inches to provide proper excess material to perform the sewing. On repairs smaller than six square feet, the geotextile may be repaired by overlapping the damaged area with new geotextile and heat bonding it into place.



7.4 Geotextile Sampling

CQA monitoring will include sampling of the geotextile at a rate of one sample per 90,000 square feet of delivered material. Samples may be forwarded to a laboratory for testing at the CQA Officer's discretion. Otherwise, the material will be archived. Extra samples of deployed material may be taken if the general material appearance is questioned by the CQA Officer or CEC.

7.5 Documentation and Reporting

Daily estimates of the amount of geotextile placed and seamed will be kept. This information will be included in the daily reports. A record of geotextile roll numbers delivered to the project site will be kept with a copy of the required manufacturer certifications.



8.0 SITE RESTORATION

The following section describes the CQA requirements for the site restoration such as final cover seeding, fertilizing, and mulching. Miscellaneous activities (i.e., road grading) required for complete site restoration are included in this section.

8.1 Erosion and Sediment Control

The CQAT(s) will monitor the installation of erosion and sediment control features. This includes the installation of temporary silt fencing, silt check dams, and temporary ditching.

8.2 Seeding, Fertilizer, and Mulch

The final cover topsoil will be prepared for seeding and mulching in accordance with typical Michigan Department of Transportation (MDOT) standards. Alternative seed mixtures may be proposed and approved by CEC. The CQAT(s) will monitor the seeding operation for general compliance with MDOT standards.



9.0 STORMWATER MANAGEMENT

This section describes the requirements for the CQAT(s) during construction of the stormwater control features associated with the Pond A closure. The final grading plan for Pond A is designed such that drain tiles, bench drains, and perimeter ditches convey stormwater to one of two outlet culverts. Stormwater is directed towards the recirculation pond, with ultimate discharge at the National Pollutant Discharge Elimination System (NPDES) permitted outfall.

9.1 Culverts and Drain Tile

Culverts and drain tile will be placed in the final cover as shown in the contract documents in accordance with manufacturer's recommendations for installation. The CQAT(s) will record the type, size, and quantity of the culverts and drain tile placed. The culverts and drain tile will be field verified by survey at junctions. Culverts and drain tile used in the project shall meet the requirements of the contract documents.

9.2 Bench Drains and Perimeter Ditches

Bench drains and perimeter ditches will be graded with protective cover soils to meet the lines and grades provided in the contract documents. Once bench drains and perimeter ditch grades meet tolerances required by the specifications, the bench drains and perimeter ditches will be overlain with six inches of topsoil and restored in accordance with Section 8.0 – Site Restoration.

9.3 Documentation

The final cover documentation report will provide a drawing that shows stormwater management features that were constructed. The report will contain information on methods for installation and the types of material used.



10.0 CONSTRUCTION CERTIFICATION REPORT

10.1 Summary

A Construction Certification Report will be prepared under the direction of the CQA Officer in accordance with Rule 921 of Part 115. The report will contain, at a minimum, the following information:

- Daily field reports
- Detailed narrative describing the construction activities in chronological order
- Analysis and discussion of QA testing performed with summaries of the test results
- Raw data and test reports performed during construction
- Discussion of any construction material or equipment which deviated from the engineering plan and reason for deviation
- Photographs documenting the construction methods
- Correspondence with MDEQ concerning rule exceptions or CQA changes
- Record drawings containing:
 - Existing site grades prior to construction
 - Geosynthetic subgrade elevations (contours)
 - Protective cover thickness and measurement locations
 - Pipe invert elevations
 - Geomembrane panel layout diagram including seam locations and types, repair locations, destructive sample locations, and anchor trench location
 - Locations of field tests
 - Final site grades

Based on review of the data and the CQA Officer's personal observations during construction, the CQA Officer will certify that the Pond A closure has been prepared and constructed in conformance with the engineering plans and specifications, the CQA Plan, and the requirements of applicable MDEQ rules.



11.0 REFERENCES

Geosynthetics Research Institute (GRI) GM 6 – Pressurized Air Channel Test for Dual Seamed Geomembranes.

GRI GM 9 - Cold Weather Seaming of Geomembranes.

GRI GM 13 - Test Methods, Test Properties, and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.

GRI GM 19 - Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes.

GRI Test Method GT 12(a) – ASTM – Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials.

APPENDIX A
SAMPLE CQA FORMS

- **Field Monitoring Report**
- **Geosynthetic Installation Monitoring Report**
- **Trial Weld Summary**
- **Certificate of Soil Surface Acceptance**
- **Initial Roll Inventory Summary**
- **Geosynthetic Deployment Summary**
- **Panel Seaming Summary**
- **Construction and Repair Summary**
- **Air Channel Pressure Test Summary**

FIELD MONITORING REPORT

FIELD MONITORING REPORT

PAGE _____ **OF** _____

PROJECT NUMBER: _____
OWNER: _____
LOCATION: _____

PROJECT TITLE: _____
CONTRACTOR: _____

DATE _____

--

S M T W T F S

THE FOLLOWING WAS NOTED: _____

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

SUBMITTED BY:

FIELD MONITORING SUMMARY

SHEET 1 OF 2

PROJECT NUMBER: _____

PROJECT TITLE: _____

OWNER: _____

CONTRACTOR: _____

LOCATION: _____

DATE:

--

S M T W T F S

WEATHER: _____ **TEMPERATURE:** **LOW:** _____ @ _____ **HIGH** _____ @ _____

CLOUD COVER _____ **PRECIPITATION** _____ **WIND** _____

GOLDER PERSONNEL ON SITE: _____

SUMMARY OF CONSTRUCTION PROGRESS: _____

GOLDER ACTIVITIES AND TEST RESULTS: _____

SUBMITTED BY:

GEOSYNTHETIC INSTALLATION MONITORING REPORT

GEOSYNTHETIC INSTALLATION MONITORING REPORT

PAGE ____ OF ____

PROJECT NUMBER: _____

PROJECT TITLE: _____

OWNER: _____

CONTRACTOR: _____

LOCATION: _____

DATE:

S M T W R F S

GEOSYNTHETIC DEPLOYMENT:

TRIAL SEAMING:

SEAMING:

NON-DESTRUCTIVE TESTING:

DESTRUCTIVE TESTING:

GENERAL REMARKS:

SUBMITTED BY:

TRIAL WELD SUMMARY

GEOMEMBRANE TRIAL SEAM LOG

PROJECT NUMBER: _____ PROJECT TITLE: _____
 OWNER: _____ CONTRACTOR: _____
 LOCATION: _____

TF - # = FUSION

DATE _____

TX - # = EXTRUSION

SHEET NUMBER _____

SAMPLE NUMBER	APPROX. TIME	WELDING MACHINE NUMBER	WELD TECH.	TEMPERATURES				TEST RESULTS			PASS OR FAIL	MON.	REMARKS **
				AMBIENT AIR TEMP.	PREHEAT OR MACHINE SPEED	EXTRUDER	NOZZLE OR WEDGE	INSIDE PEEL STRENGTH	OUTSIDE PEEL STRENGTH	SHEAR STRENGTH			
								/ /	/ /	/			
								/ /	/ /	/			
								/ /	/ /	/			
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NOTE: ADHESION FAILURE OF TRIAL SEAM SAMPLES SHALL BE NOTED IN THE REMARKS COLUMN
 FOR JOBS IN MICHIGAN, PUT DESTRUCTIVE SAMPLE NUMBER CORRESPONDING TO EACH MACHINE

GOLDER FORM: G12-TSS

REVIEWED BY: _____ DATE: _____

(August 2000)

GOLDER ASSOCIATES INC.

CERTIFICATE OF SOIL SURFACE ACCEPTANCE

**CERTIFICATE OF ACCEPTANCE OF SOIL SURFACE
BASED UPON VISUAL OBSERVATION ONLY**

COMPANY:

PROJECT NUMBER:

PROJECT TITLE:

LOCATION:

OWNER:

I, the Undersigned, the duly authorized representative of _____

do hereby accept the area of soil surface bounded by (Panels)

and shall be responsible for maintaining its integrity and suitability in accordance with the project specifications from this date to the completion of the installation.

NAME

SIGNATURE

TITLE

DATE

I, the Undersigned, the duly authorized representative of _____

do hereby accept the area of soil surface bounded by (Panels)

NAME

SIGNATURE

TITLE

DATE

I, the Undersigned, the duly authorized representative of the CQA Engineer, do hereby accept the area of soil surface bounded by (Panels)

NAME

SIGNATURE

TITLE

DATE

Reviewed/Approved by:

Date:

INITIAL ROLL INVENTORY SUMMARY

GEOSYNTHETIC INVENTORY CONTROL LOG

PROJECT NUMBER: _____

OWNER: _____

LOCATION: _____

PROJECT TITLE: _____

CONTRACTOR: _____

MATERIAL TYPE : GEOMEMBRANE GEONET GEOTEXTILE OTHER _____

DATE OF ARRIVAL: _____

MATERIAL MANUFACTURER: _____

PRODUCT IDENTIFICATION: _____

TRUCK TYPE: _____

DATE OF INVENTORY: _____

INVENTORY MONITOR: _____

CONDITION IN TRUCK: _____

UNLOADING METHOD: _____

	ROLL NUMBER	BATCH OR LOT NO.	MATERIAL DIMENSIONS			QC CERT Y / N	CONF. SAMP. Y / N	OTHER	REMARKS
			LENGTH	WIDTH	THICKNESS OR WEIGHT				
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
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24									
25									

Golder Form: G2

REVIEWED BY: _____

DATE: _____

(July 2000)

GOLDER ASSOCIATES INC.

GEOSYNTHETIC DEPLOYMENT SUMMARY

GEOSYNTHETIC PANEL DEPLOYMENT LOG

PROJECT NUMBER: _____
OWNER: _____
LOCATION: _____

PROJECT TITLE: _____
CONTRACTOR: _____

GEOMEMBRANE:	Secondary	Primary	Closure	Other: _____
SUBGRADE CONDITION:	(Surface Compaction	Protrusions	Dessiccation	Excessive Moisture)
REMARKS:	_____			

TRANSPORT EQUIPMENT: _____

[illegible]**Golder Form: G2-TSS**

REVIEWED BY: _____ **DATE:** _____

(August 2000)

GOLDER ASSOCIATES INC.

PANEL SEAMING SUMMARY

GEOMEMBRANE SEAM LOG

PROJECT NUMBER: _____
OWNER: _____
LOCATION: _____

PROJECT TITLE: _____
CONTRACTOR: _____

☐ FUSION
☐ EXTRUSION
 MACHINE # _____

PASSING TRIAL SEAMS

<input type="checkbox"/>	FUSION	NO.	TIME	TECH ID
<input type="checkbox"/>	EXTRUSION			
MACHINE # _____				

DESTRUCTIVE LENGTH CARRY-OVER
FROM PREVIOUS LOG

DATE _____

SHEET NUMBER

	SEAM NUMBER	SEAM SECTION*		APPROX. START TIME	AMB. AIR TEMP.	WELD TECH.	PREHEAT OR MACH. SPEED	MACHINE TEMPERATURES		APPROX. LENGTH WELDED	LENGTH FROM PREVIOUS DESTR.	DESTR. NUMBER	MON.	REMARKS	**	
		START POINT	FINISH POINT					DIGITAL SET	INDICATOR						NON-DESTRUCTIVE	
								WEDGE OR BARREL NOZZLE	WEDGE OR BARREL NOZZLE						TEST DATE	MON.
1	/	-					-	-								
2	/	-					-	-								
3	/	-					-	-								
4	/	-					-	-								
5	/	-					-	-								
6	/	-					-	-								
7	/	-					-	-								
8	/	-					-	-								
9	/	-					-	-								
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12	/	-					-	-								
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14	/	-					-	-								
15	/	-					-	-								
16	/	-					-	-								
17	/	-					-	-								

* REFERENCE SEAM ENDPOINTS FROM AN END OF SEAM (EOS),
A REPAIR NUMBER, OR A POINT LOCATION ON THE SEAM.

DAILY TOTAL
DESTRUCTIVE LENGTH CARRY-OVER

**** COLUMNS TO BE USED
BY THE DATA REVIEWER ONLY**

GOLDER FORM: G13-0699
(JUNE 1999)

REVIEWED BY: _____ DATE: _____

GOLDER ASSOCIATES INC.

CONSTRUCTION AND REPAIR SUMMARY

GEOMEMBRANE REPAIR LOG

PROJECT NUMBER _____
OWNER: _____
LOCATION: _____

PROJECT TITLE: _____
CONTRACTOR: _____

PASSING TRIAL SEAMS

NO.	TIME	TECH	NO.	TIME	TECH

MACHINE NUMBER: _____

DATE: _____

SHEET NO: _____

	DEFECT CODE	REPAIR DATE	APPRX. TIME	REPAIR TYPE	APPRX. DIM.	WELD TECH.	MON.	REMARKS
1								
2								
3								
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6								
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25								

	DEFECT CODE	REPAIR DATE	APPRX. TIME	REPAIR TYPE	APPRX. DIM.	WELD TECH.	MON.	REMARKS
26								
27								
28								
29								
30								
31								
32								
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50								

REPAIR TYPE: P - PATCH, C - CAP, RS - RECONSTRUCTED SEAM, G&W - GRIND WELD

REVIEWED BY: _____ DATE _____

GOLDER FORM: G19-tss
(August 2000)

GOLDER ASSOCIATES INC.

AIR CHANNEL PRESSURE TEST SUMMARY

GEOMEMBRANE SEAM NON-DESTRUCTIVE TEST LOG

PROJECT NUMBER: _____
 OWNER: _____
 LOCATION: _____

PROJECT TITLE: _____
 CONTRACTOR: _____

DATE: _____
 SHEET NUMBER: _____

	SEAM NUMBER	SEAM SECTION *		VACUUM OR PRESSURE	TECH ID	TIME		PRESSURE		OBS. TEST	RESULTS PASS/ FAIL	SEAM COMPLETE		MON.	REMARKS
		FROM	TO			START	FINISH	INITIAL	FINAL			NO	YES		
1	/	-				:		:							
2	/	-				:		:							
3	/	-				:		:							
4	/	-				:		:							
5	/	-				:		:							
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19	/	-				:		:							
20	/	-				:		:							

* REFERENCE SEAM ENDPOINTS FROM AND END OF SEAM (EOS), A REPAIR NUMBER,
 OR A POINT LOCATION ON THE SEAM (i.e., REFERENCE POINT, DISTANCE, DIRECTION FROM REF. PT.)

GOLDER FORM: G16-tss
 (August 2000)

REVIEWED BY: _____ DATE: _____

GOLDER ASSOCIATES INC.

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South America	+ 56 2 2616 2000

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Fax: (517) 482-2460



Engineering Earth's Development, Preserving Earth's Integrity

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APPENDIX C
J.H. CAMPBELL FUGITIVE DUST CONTROL PLAN



**J.H. Campbell Electric Generating Complex
17000 Croswell
West Olive, MI
SRN: B2835**

**Fugitive Dust Control Plan
For
Coal Combustion Residuals (CCR)**

Date: 12/15/16
Rev: 01

Table of Contents

1.0	Introduction.....	3
2.0	CCR Operations	3
2.1	Dry Fly Ash (DFA) Handling System	3
2.2	Dry Fly Ash Landfill Operations	4
2.2.1	Silo Operation/Truck Loading.....	4
2.2.2	Ash - placement and storage.....	4
2.3	Wet Ash - Bottom Ash Handling.....	5
2.4	Roads.....	6
3.0	Monitoring/Recordkeeping	6
4.0	Citizen Complaints.....	7
5.0	Plan Assessments/Amendments.....	7
6.0	Annual Reporting.....	7
7.0	Certifications	8
8.0	Revision History.....	9

1.0 INTRODUCTION

The purpose of this Fugitive Dust Control Plan (FDCP) is to describe the measures adopted at the J.H. Campbell (JHC) electric generating complex for minimizing fugitive dust emissions from coal combustion residual (CCR) handling operations (also known as ash handling operations). The JHC facility is located at 17000 Croswell in West Olive, Michigan and is a coal fired electric generating power plant consisting of three boilers, Units 1, 2, and 3. This plan has been developed in accordance with the CCR regulations stipulated in 40 CFR Part 257.80. The scope of this plan includes active CCR units as well as their corresponding roads, handling and control equipment, and associated activities therein. A site Fugitive Dust Plan Coordinator (FDPC) has been appointed and is responsible for ensuring adequate resources are provided for controlling fugitive dust, as well as implementing the monitoring and recordkeeping requirements of this plan. This FDCP has been certified by a qualified professional engineer and is placed in the facility's CCR operating record and on the Consumers Energy website. The initial FDCP was posted and made available to the public on October 19, 2015. All revisions of this document shall be posted to the operating record and public website, with a notification sent to the Michigan Department of Environmental Quality (MDEQ) within thirty (30) days of that posting.

The CCR facility consists of separate dry and wet ash handling systems and the CCR disposal area is divided into two primary components:

- Wet ash ponds
 - Wet ash, comprised of bottom ash from the main burner area of the boilers, is sluiced by water into the bottom ash ponds
 - Wet ash, comprised of particulate matter (PM) that falls out from the economizer and air heater portions of the Unit 1 and 2 boilers is sluiced to a channel that leads to A-Pond
- Dry ash disposal facility (i.e. landfill).
 - Dry fly ash (DFA) from Units 1, 2, and 3 and Economizer ash from Unit 3 is conveyed to the dry ash silos
 - DFA consists of coal ash that has been collected from the pulse jet fabric filters (PJFF) from each boiler, which are used as the PM control devices for the boiler units
 - DFA is either sold for beneficial re-use (dependent upon ash characteristics) or disposed of in the on-site landfill.
 - The dry ash disposal facility is a permitted landfill and includes two (2) leachate contact water retention ponds that cover an area of approximately five (5) acres.

The appropriate control activities selected for the site are based on good engineering practices that were developed in accordance with Michigan's Fugitive Dust Regulations under Act 451 of 1994, Rule 324.5524, as required by the site's Renewable Operating Permit and the Engineering Plans for ponds A-K (2015, operating license 9446) and landfill cells 1-7 (1996, construction permit 0299) as required for solid waste disposal licensing under MDEQ. The following sections outline the FDCP.

2.0 CCR OPERATIONS

2.1 DFA HANDLING SYSTEM

The DFA handling system consists of a pneumatic collection system that transfers the DFA from the collection hoppers to storage silos. The ash handling system is comprised of four (4) transfer tanks,

vacuum and pressure conveying systems, three (3) ash disposal silos (A,B, and C) and three (3) ash sales silos (operated by a third party). From the PJFF dust collection hoppers, the DFA is pneumatically conveyed through hard piping under vacuum through filter separators to transfer tanks. The DFA is then pneumatically pressure transferred to either the disposal silos (A, B, or C) or the ash sales silos. PM emissions from the transfer process and tank displacement are controlled by bin vent filters. The DFA is held in the disposal storage silos until transferred to the on-site licensed landfill, or in the ash sales silos until shipped off-site for beneficial re-use. Silo B or A may also be used as a sales silo. The DFA evacuation system is not operated unless the equipment and control systems are installed and operating properly.

2.2 Dry Fly Ash Landfill Operations

2.2.1 SILO OPERATION/TRUCK LOADING

From disposal Silos A, B, or C, the DFA is conditioned with water and/or other approved suppressant. Silos A and B are equipped with a fogging system that may be utilized during the truck loading as needed to control fugitive PM. Proper conditioning of the DFA with water and/or suppressant is to achieve a moisture content that will prevent wind dispersal and provide proper stability characteristics for the landfill, but will not result in free liquids. A vacuum fan is located on the mixer floor of the silos, which draws PM from the mixing activity as well near the loading chute. The air/dust mix is discharged back into the controlled storage silo. The truck loading station shall not be operated unless adequate PM emission controls are employed. Any ash spillage shall be cleaned up and disposed of properly to minimize track-out. The following operational controls are also in place:

- The appropriate moisture characteristics shall be maintained during the truck loading process.
- Transport truck bodies will be maintained in good condition and properly closed to prevent leakage.
- Truck bodies will be filled in a manner that minimizes fugitive emissions during transport (minimize exposed peaks from top of truck bed rail).
- Transport operations will be suspended if the current conditions indicate that operations cannot be conducted in a controlled manner.

DFA may also be hauled off-site for beneficial re-use from Silo B, A, and the ash sales facility silos. The haul trucks are pneumatically loaded from the silos through a chute that is gasket sealed to the truck hatch, which is equipped with a vacuum fan to recover displacement air and send back into the silo. The contractor is responsible for cleaning up any spills that may occur during the loading process.

2.2.2 ASH - PLACEMENT AND STORAGE

Conditioned ash is placed in the active landfill cell by haul trucks and further wetted as required to minimize dusting during spreading by bulldozer. The conditioned ash piles are to be flattened and compacted as they are deposited, utilizing water as necessary. A bulldozer may also be used for shaping the piles/slopes. All dumping, dozing, and excavating activities are visually monitored for dusting and

activities are suspended if there is excessive dusting or when there are exceptionally high wind speeds. The following operational controls are utilized for ash placement and storage:

- Active areas will be limited to approximately five (5) acres in size. When a work area expands beyond this limit, the procedures for inactive work areas will be implemented.
- Water application will be the primary means of fugitive dust control on active areas. Water may be applied by water truck, water cannon, or irrigation system.
- Commercial dust control additives may be used subject to review and approval by Consumers Energy and the MDEQ.
- Ash dozing, loading, unloading and placement will be suspended when the current conditions indicate that such activities cannot be conducted in a controlled manner.
- Where possible, active areas will be located to take advantage of protective berms to reduce wind velocity over the active area.
- Bottom ash may be applied over compacted fly ash as a temporary measure to control fugitive dust.

The following general procedures are in place for fugitive dust control of inactive cell areas:

- Inactive areas are formerly active areas that will be inactive for three (3) months or more.
- Fugitive dust control will be provided for inactive areas through means such as irrigation, bottom ash, straw mat, or vegetative cover installation, stabilization and maintenance.
- After an area becomes inactive, then the entire area is wetted and covered with straw matting which is then staked into the surface. When dry, the area then forms a crust which lowers potential for wind erosion and fugitive emissions.

2.3 WET ASH - BOTTOM ASH HANDLING

The wet ash handling system consists of a conveying system and the active ash ponds labeled "A," "Units 1-2 Bottom Ash Ponds," and "Unit 3 Bottom Ash Ponds." Bottom ash from all three boilers is water sluiced to the corresponding bottom ash pond. Ash from the Units 1 and 2 economizers and air heaters is pulled from the associated hoppers and is discharged to a ditch that leads to A-Pond. The overflow of the bottom ash ponds discharges into A-Pond. From A-Pond, the effluent water travels through a channel, the recirculation pond, and then eventually is discharged through an NPDES permitted outfall (002A) into the Pigeon River. The ash ponds are generally in a wet condition and do not usually require active fugitive dust control; however, the plant has the ability to switch which ponds the wet CCR is sent to as a fugitive dust control measure in the event that one of the ponds is dry. The Units 1 and 2 bottom ash ponds do have irrigation control available for wetting if necessary.

Solids from the bottom ash ponds are sold for beneficial reuse or are placed in the licensed landfill (can be used for cover). These solids may be pushed out of the pond with a bulldozer, or removed using a long-armed excavator, into a pile for de-watering prior to transferring into haul trucks for transport to

landfill or re-use destination. The ash is kept in a wet condition during this transfer activity. Activities may be suspended in high wind conditions and the site will wet the material if it becomes dry. Measures to control fugitive dust from the roads surrounding the ponds are addressed in the next section.

2.4 ROADS

Fugitive PM emissions may be generated from trucks and other heavy equipment traveling on the site haul roads and entering/exiting the site. A water truck is used to wet roads as needed to minimize fugitive PM emissions from truck travel on the site roadways. Routinely accessed un-paved roadways have been improved with an aggregate cover (21AA) in order to minimize dusting and track-out. There is a site wide speed limit of 25 mph on non-paved roads to minimize PM generation.

3.0 MONITORING/RECORDKEEPING

3.1 MONITORING

The entire CCR system is monitored through visual checks of process equipment and the corresponding particulate matter control devices. The following monitoring is conducted to ensure conformance to the previously stated operational controls:

- All alarms from the dry fly ash collection system bin vent filters shall be responded to promptly.
- Daily:
 - The transfer tank bin vent filter exhaust and the vacuum pump exhaust breather shall be inspected for signs of dust and the ash equipment building and the transfer tanks shall be inspected for signs of fly ash leaks
 - With the DFA system in operation, all pressure piping from the transfer tanks to the valve located on the Unit 3 and Units 1&2 ash trestle shall be inspected
 - With the DFA system in operation, the vacuum piping from the PM control devices to the transfer tanks shall be inspected
 - With the DFA system in operation, all pressure piping from the point at which the piping exits the Unit 3 and Units 1&2 ash trestle to the point it enters the ash silos shall be inspected
 - All PM control device exhaust stacks shall be monitored for visible emissions
- Twice per week, all pressure piping from the transfer tank to the ash sales facility shall be inspected.
- Weekly, pressure gauge differential readings for the particulate matter control devices shall be recorded.
- Results of all inspections shall be recorded. If PM is visible from any vacuum or pressure piping, the maintenance department shall be promptly notified and a maintenance request notification shall be submitted and the FDPC shall be notified. The site maintains spare parts for routine repairs of the control and monitoring equipment.

The following control measures are utilized for the landfill operations:

- Active landfill cell areas will be visually inspected daily to determine if the ash surface requires moisture to prevent fugitive dust formation.
- Records of all dust inspections will be retained.
- If water application is indicated by the inspection, water will be applied at a rate sufficient to control dust emissions.
- A fugitive dust record is maintained that includes events of visible emissions that are observed reaching the landfill or site boundary, as well as of suspended activities. The date, cause and corrective action taken shall be logged relative to suspended activities.
- Fugitive dust control techniques and/or activities which are used for any of the various site activities to control fugitive dust are documented.

3.2 RECORDKEEPING

The following records will be retained for a period of at least five (5) years:

- All actions taken to control CCR fugitive dust
- Record of all citizen complaints
- Summary of any corrective measures taken

4.0 CITIZEN COMPLAINTS

All complaints, concerns and/or inquiries that result in an action being taken shall be documented in the site External Communication Log. Any complaint will be acted upon through internal communication procedures. Environmental Services and Legal shall be notified of any citizen complaint regarding CCR fugitive dust. In accordance with the CCR regulation, the complaint log and resultant actions will be summarized in the annual report.

5.0 PLAN ASSESSMENTS/AMENDMENTS

The FDPC will be audited utilizing Consumers Energy Compliance Assurance guidance once per year, coordinated by the site FDPC in order to periodically assess the effectiveness of the control plan. Results of the audit shall be reported to site management, Environmental Services, and legal counsel as necessary.

This FDPC may be amended at any time provided that revisions are logged and the revised plan is placed in the facility's operating record. The FDPC is responsible for amending the written plan whenever there is a change in site conditions that would substantially affect the written plan in effect. All amendments to the fugitive dust control plan must be certified by a qualified professional engineer. A notice shall be sent to the MDEQ (Waste Division) within 30 days of when the plan is revised.

6.0 ANNUAL REPORTING

The FDPC will prepare an annual CCR fugitive dust control report that includes a description of the actions taken by plant personnel or contractors to control CCR fugitive dust, a record of all citizen complaints, and a summary of any corrective actions taken. The report shall be reviewed by site management, Environmental Services, and Legal prior to posting to the operating record. The first annual report is due no later than 14 months after placing the plan in the facility's operating record and

subsequent plans shall be completed one year after the date of posting the previous report. A notice will be sent to MDEQ (Waste Division) within 30 days of posting the annual report.

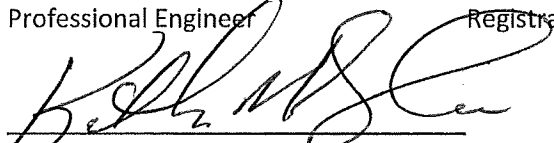
7.0 CERTIFICATIONS

CCR Fugitive Dust Plan, Professional Engineer Certification:

By means of this certification, I attest that I am familiar with the requirements of provisions of 40 CFR Part 257.80, that I or my designated agent have visited and examined the facility, that this CCR FDP has been prepared in accordance with good engineering practices, including consideration of applicable industry standards, and with the requirements of this Part, that procedures for required fugitive dust minimization activities, monitoring, and reporting have been established and that the Plan is adequate for the facility.

Kathryn M. Cunningham
Professional Engineer

44447
Registration Number (MI)


Professional Engineer (Signature)

12/15/14
Date of Plan Certification:

CCR Fugitive Dust Plan Management Approval:

This Plan is certified as being prepared in accordance with good engineering practices. Thus, this Plan has the full approval of Consumers Energy Company Management. I am at a level of sufficient authority to commit the necessary resources to implement this Plan as described. I have appointed the following representative as the Fugitive Dust Plan Coordinator: Kevin D. Starken


Neil J. Dziedzic
Plant Business Manager

15 DEC 2016
Date

8.0 REVISION HISTORY

[illegible]

APPENDIX D
GEOTECHNICAL CALCULATIONS

FINAL COVER VENEER STABILITY CALCULATIONS

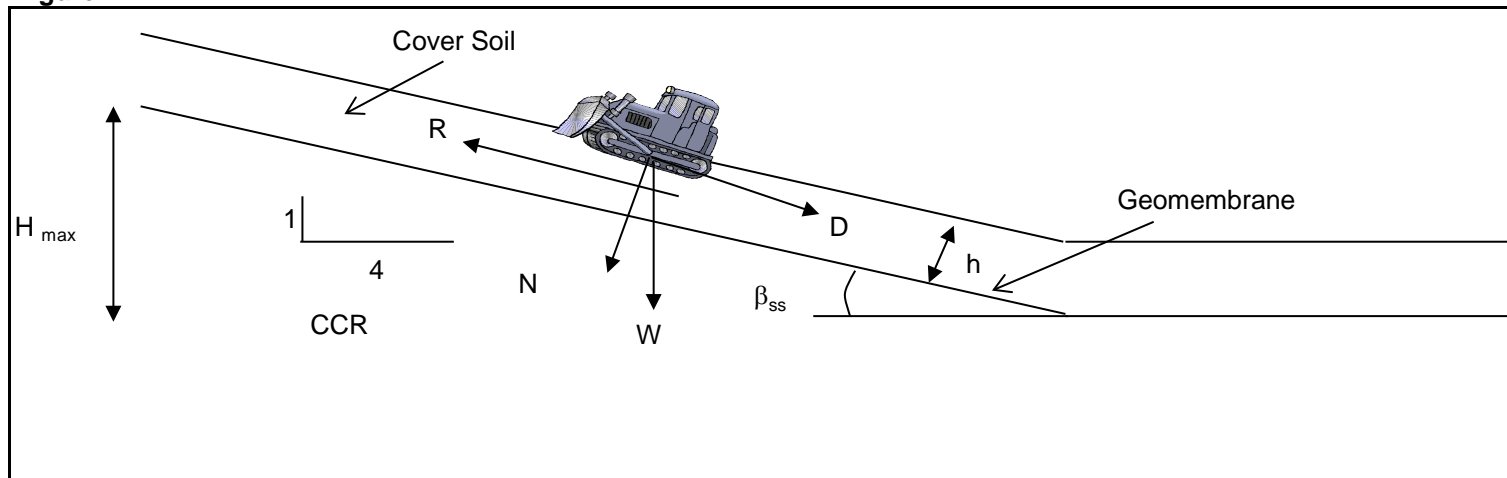
Date:	Aug-18	Made by:	MMJ
Project No.:	1667572.0003	Checked by:	JRP
3H:1V FINAL COVER STABILITY - SHORT TERM WITH EQUIPMENT FORCES			
Subject:		Reviewed by:	DL
Project Short Title: JH Campbell Pond A Closure Plan			

1.0 OBJECTIVE

Analyze the short-term static stability of the cap system at JH Campbell Pond A, considering peak low normal load shear strengths with regards to wedge/block failure and sliding due to equipment forces and considering water within the protective cover and topsoil layer.

2.0 GEOMETRY

Figure 1.



The worst case slope is 3 feet horizontal to 1 foot vertical (3H:1V)

2.0 ASSUMPTIONS

- 1.) The proposed Final Cover system consists of (from top to bottom):
 - 6-inch (in) topsoil layer
 - 24-in protective cover
 - 10 ounce per square yard (oz/sy) 100-mil thick nonwoven geotextile (GT)
 - 40-mil thick High Density Polyethylene (HDPE) textured geomembrane (TGM).
- 2.) Material Properties used for the analysis are shown in Table 1 along with assumptions used to clarify estimated properties of materials where applicable.
- 3.) The final cover slopes are designed to be a maximum 3 horizontal to 1 vertical (3H:1V) along the perimeter ditch.
- 4.) Maximum slope length along the 3H:1V slope is approximately 31.5 feet (ft).
- 5.) This calculation is valid for equipment moving up the slope only.

3.0 METHODS

- 1.) **Use method outlined in R.M. Koerner and T. Soong's method, Reference 2. Please see Figure 1 for Equations and Parameter definitions for the calculations performed below.**
- 2.) Allow a minimum interim factor of safety of 1.3, when saturated conditions are considered, and peak interface friction angles are used.
- 3.) Interface friction angles were taken as averages of representative lab data for similar materials, residual strengths. (These friction angles are conservative and for design purposes. The owner may choose to purchase materials with interface friction angles greater than those used in the design.)

CALCULATIONS

Date:	Aug-18	Made by:	MMJ
Project No.:	1667572.0003	Checked by:	JRP
3H:1V FINAL COVER STABILITY - SHORT TERM WITH EQUIPMENT FORCES			
Subject:		Reviewed by:	DL
Project Short Title: JH Campbell Pond A Closure Plan			

4.0 CALCULATIONS

Calculate Factor of Safety using Koerner's Method for short term stability with equipment loads;
(See attached Reference 2, GRI Report #18, for method)

Uniform Cover Soil Thickness with the Incorporation of Equipment Loads

thickness of cover soil =	h =	2.5	ft	
soil slope angle beneath the geomembrane =	β =	18.43	degrees	Slope = 3H : 1V
length of slope measured along the geosynthetics =	L =	31.5	ft	Maximum slope length
unit wt. of cover soil =	γ =	120	pcf	Assume saturated conditions
friction angle of cover soil =	φ =	28	degrees	
cohesion of cover soil =	c =	0	psf	C = 0 lb
interface frict. between GT and 40-mil TGM =	δ =	25	degrees peak low normal load	
adhesion between GT and 40-mil TGM =	ca =	0	psf	Ca = 0.00 lb

Dozer Specifications	(Ref 3)
D6R LGP Track- type tractor	39,222 lb
Track	128 inches long
	33 inches wide

thickness of cover soil =	h =	2.5	ft	b/h= 1.1
equipment ground pressure (=wt. of equip./(2*w*b)) =	q =	668.56	psf	We = q*w*I = 6824.6 lb/ft
length of equipment track =	w =	10.67	ft	Ne = Wecosβ = 6474.6 lb/ft
width of equipment track =	b =	2.75	ft	Fe=We*a/g*I= 457.2 lb
influence factor at Geotextile interface =	I =	0.96	See Ref 2, Fig 7.	
acceleration of bulldozer =	a =	0.07	g	Assume Cat D6R LGP dozer accelerating to 3 mph in approx. 2 sec. (accel. = 0.07 g)

W _A	7,074.39	lb
N _A	6,711.55	lb
W _p	1,250.29	lb
$FS = \frac{R}{D} = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$	a	4,602.48
	b	-7,313.71
	c	1,033.60
FS		1.43

CALCULATIONS

Date:	Aug-18	Made by:	MMJ
Project No.:	1667572.0003	Checked by:	JRP
3H:1V FINAL COVER STABILITY - SHORT TERM WITH EQUIPMENT FORCES			
Subject:		Reviewed by:	DL
Project Short Title: JH Campbell Pond A Closure Plan			

4.0 CALCULATIONS CONT.

Uniform Cover Soil Thickness Seepage Forces with Parallel-to-Slope Buildup

(See attached Figure 1 depicting seepage forces with parallel-to-slope buildup)

- 1) Assume maximum 100-mil of head on geotextile.

thickness of cover soil =	$h =$	2.5	ft	
soil slope angle beneath the geomembrane =	$\beta =$	18.43	degrees	Slope = 3H : 1V
length of slope measured along the geosynthetics =	$L =$	31.5	ft	Maximum slope length
vertical height of slope measured from toe =	$H =$	10	ft	
depth of water over geomembrane =	$h_w =$	0.01	ft	100-mil
parallel submergence ratio =	$PSR =$	4.00E-03		$PSR = \frac{\text{depth of water on TGM}}{\text{thickness of cover soil}}$
dry unit wt. of cover soil =	$\gamma_d =$	115	pcf	
saturated unit wt. of cover soil =	$\gamma_{sat} =$	120	pcf	
unit wt. of water =	$\gamma_w =$	62.4	pcf	
friction angle of drainage soil =	$\phi =$	28	degrees	
interface frict. between GT and 40-mil TGM =	$\delta =$	25	degrees	peak low normal load

W_A	7,859.6	lb
U_n	18.6	lb
U_h	0.0	lb
N_A	7,437.9	lb
W_p	1,198.2	lb
U_v	0.0	lb

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

a	2,357.3
b	-4,345.2
c	583.0

FS	1.70
-----------	-------------

CALCULATIONS

Date:	Aug-18	Made by:	MMJ
Project No.:	1667572.0003	Checked by:	JRP
Subject:	3H:1V FINAL COVER STABILITY - SHORT TERM WITH EQUIPMENT FORCES	Reviewed by:	DL
Project Short Title: JH Campbell Pond A Closure Plan			

5.0 CONCLUSIONS

The evaluation of this short-term condition considering equipment forces and water within the protective layer and topsoil layer is found to be acceptable with the Factors of Safety being greater than 1.3. Since it was a short-term condition, peak low normal load shear strengths were applied.

6.0 REFERENCES

- 1.) Koerner, R.M., *Designing with Geosynthetics*, Prentice Hall, New Jersey, 1998.
- 2.) Koerner, R.M. and Soong, T., "Analysis and design of veneer cover soils"
Geosynthetics International, 2005, 12, No.1.
- 3.) Ritchiespecs, Specification Summary, D6N LGP Crawler Tractor.

CALCULATIONS

Date:	Aug-18	Made by:	MMJ
Project No.:	1667572.0003	Checked by:	JRP
Subject:	3H:1V FINAL COVER STABILITY - LONG TERM	Reviewed by:	DL
Project Short Title:	JH Campbell Pond A Closure Plan		

1.0 OBJECTIVE

Analyze a "worst case" scenario and determine the long-term stability of the final cover system considering long term normal load shear strengths with regards to wedge/block failure and sliding due to water seepage forces within the protective layer and topsoil layer while considering seismic forces.

2.0 ASSUMPTIONS

- 1.) The proposed Final Cover system consists of (from top to bottom):
 - 6-inch (in) topsoil layer
 - 24-in protective layer
 - 10 ounce per square yard (oz/sy) 100-mil thick nonwoven geotextile (GT)
 - 40-mil thick High Density Polyethylene (HDPE) textured geomembrane (TGM).
- 2.) Material Properties used for the analysis are shown in Table 1 along with assumptions used to clarify estimated properties of materials where applicable.
- 3.) The worst case final cover slopes are designed to be a maximum 3 horizontal to 1 vertical (3H:1V) along the perimeter ditch.
- 4.) Maximum slope length along the 3H:1V slope is approximately 31.5 feet (ft).
- 5.) The peak interface friction angle has been used because settlement of the CCR will be negligible and HDPE geomembrane will be used.

3.0 METHODS

- 1.) **Use method outlined in R.M. Koerner and T. Soong's method, Reference 2. Please see Figure 1 for Equations and Parameter definitions for the calculations performed below.**
- 2.) Allow a minimum interim factor of safety of 1.1, with seismic when saturated conditions are considered, and residual interface friction angles are used and calculate the maximum safe slope length for each condition.
- 3.) Interface friction angles were taken as averages of representative lab data for similar materials, residual strengths. (These friction angles are conservative and for design purposes. The owner may choose to purchase materials with interface friction angles greater than those used in the design.)

CALCULATIONS

Date:	Aug-18	Made by:	MMJ
Project No.:	1667572.0003	Checked by:	JRP
Subject:	3H:1V FINAL COVER STABILITY - LONG TERM	Reviewed by:	DL
Project Short Title:	JH Campbell Pond A Closure Plan		

4.0 CALCULATIONS

Calculate Factor of Safety using Koerner's Method for long term stability with wet conditions (i.e. water on the liner); (See attached GRI Report #18)

Uniform Cover Soil Thickness Seismic and Seepage Forces with Parallel-to-Slope Buildup

(See attached Figure 1 depicting seepage forces with parallel-to-slope buildup)

- 1) Assume maximum 100-mil of head (geotextile thickness)

thickness of cover soil =	$h =$	2.5	ft	
soil slope angle beneath the geomembrane =	$\beta =$	18.43	degrees	Slope = 3H : 1V
length of slope measured along the geosynthetics =	$L =$	31.5	ft	Length between drainage outfalls.
vertical height of slope measured from toe =	$H =$	10	ft	
depth of water over geotextile =	$h_w =$	0.01	ft	Assume 100 mil of head (GT thickness)
parallel submergence ratio =	$PSR =$	4.00E-03		$PSR = \frac{\text{depth of water on TGM}}{\text{thickness of cover soil}}$
dry unit wt. of cover soil =	$\gamma_d =$	115	pcf	
saturated unit wt. of cover soil =	$\gamma_{sat} =$	120	pcf	
unit wt. of water =	$\gamma_w =$	62.4	pcf	
friction angle of cover soil =	$\phi =$	28	degrees	
peak interface frict. between GT and 40-mil TGM =	$\delta =$	25	degrees	peak low normal load

- 2) Determine seismic coefficient following FHWA (2011) and AASHTO (2009) guidelines.
Pond A classifies as site class D - "Stiff Soil". See USGS Design Map Summary Report (Reference 6) for site factors and seismic design values used below.

AASHTO peak ground acceleration site factor =	$F_{pga} =$	1.6		
USGS mapped acceleration coefficient =	$PGA =$	0.023	g	
maximum possible seismic coefficient =	$k_{max} =$	0.037	g	$k_{max} = F_{pga} * PGA$
spectral acceleration at 1 second for site class B =	$S_1 =$	0.026	g	
AASHTO site factor for the spectral acceleration at 1 second =	$F_v =$	2.4		
	$B =$	1.70		$B = F_v * S_1 / k_{max}$
slope height reduction factor =	$\alpha =$	0.985		$\alpha = 1 + 0.01 * H(0.5B - 1)$
average peak acceleration	$k_{av} =$	0.036	g	$k_{av} = \alpha * k_{max}$
seismic coefficient =	$C_s =$	0.018	g	$C_s = 0.5 * k_{av}$

W_A	7,859.6	lb
U_n	18.6	lb
U_h	0.0	lb
N_A	116.5	lb
W_p	1,198.2	lb
U_v	0.0	lb

With Seismic

W_A (lb)	142.43
W_p (lb)	21.71

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

a	42.7
b	-70.6
c	9.1

FS	1.5
-----------	------------

CALCULATIONS

Date:	Aug-18	Made by:	MMJ
Project No.:	1667572.0003	Checked by:	JRP
Subject:	3H:1V FINAL COVER STABILITY - LONG TERM	Reviewed by:	DL
Project Short Title:	JH Campbell Pond A Closure Plan		

5.0 CONCLUSIONS

Considering the use of seismic loading, peak low normal load shear strengths, and saturated conditions, the long-term "worst case" stability evaluation results are considered acceptable with a factor of safety = 1.1.

6.0 REFERENCES

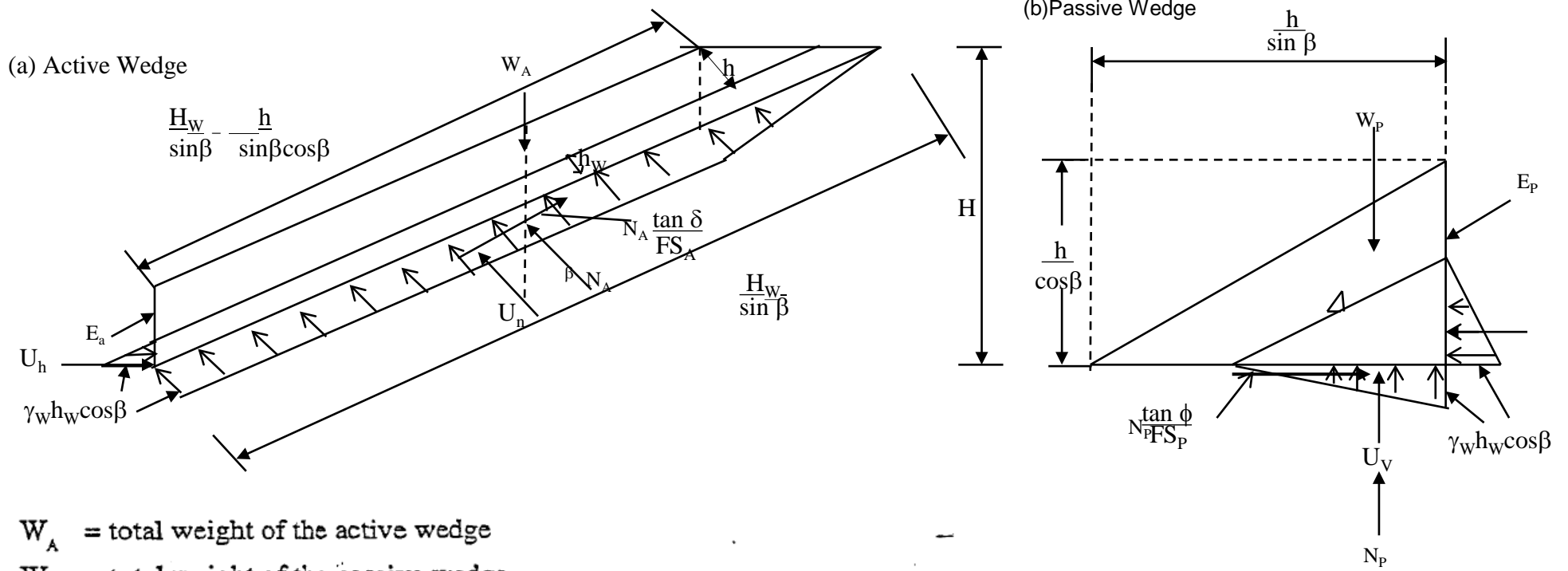
- 1.) Koerner, R.M., *Designing with Geosynthetics*, Prentice Hall, New Jersey, 1998.
- 2.) Koerner, R.M. and Soong, T., "Analysis and design of veneer cover soils"
Geosynthetics International, 2005, 12, No.1.
- 3.) Ritchiespecs, Specification Summary, D6N LGP Crawler Tractor.
- 4.) FHWA, "LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations", 2011.
- 5.) AASHTO, "Guide Specifications for LRFD Seismic Bridge Design", 2009.
- 6.) USGS, Design Map Summary Report for JH Campbell Pond A, generated from
<http://earthquake.usgs.gov/designmaps/us/application.php> on January 18, 2017.

TABLE 1 - Material Properties

Symbol	Definition and assumptions for the purpose of this calculation
$h =$	<i>Thickness of the cover soil</i> - In all cases the protective cover will be 2.0 feet thick and the topsoil will be 0.5 feet thick for a total of 2.5 feet.
$\beta =$	<i>Soil slope angle beneath the geomembrane</i> - A 3H:1V slope exhibits an angle of soil beneath the geomembrane of 18.43°. This slope is present on the side slopes and represents a "worst case" scenario.
$L =$	<i>Length of slope measured along the geomembrane</i> - The maximum 3H:1V slope length anticipated is 31.5 feet.
$\gamma_d =$	<i>Weighted dry unit weight of final cover soil</i> - The protective cover and topsoil are both assumed to contain a mix of sandy soils with varying amounts of fines. In place unit weight is assumed to be 115 pounds per cubic foot (pcf).
$\phi =$	<i>Minimum friction angle of final cover soil</i> - A friction angle of 28 degrees is assumed for protective cover and topsoil materials for this calculation.
$c =$	<i>Cohesion of the cover soil</i> - Cohesion is assumed to be zero because cover soils may be sand.
$\delta =$	<i>Critical Interface friction angle within the final cover system</i> - The critical interface will be between a 40 mil textured HDPE geomembrane and 100-mil, 10oz/sy geotextile. The estimated peak friction angle between these materials is 25 degrees. The estimated residual friction angle between these materials is 17 degrees.
$c_a =$	<i>Adhesion between cover soil of the active wedge and the geomembrane</i> - Adhesion is assumed to be zero because cover soils may be sand.
$\gamma_{sat} =$	<i>Saturated unit weight of final cover soil</i> - The unit weight of saturated final cover soils is assumed to be 120 pcf for this calculation.
$C_s =$	<i>Average seismic coefficient</i> - The average horizontal component seismic coefficient for the Ottawa County area is 0.018 gravity. Calculation shown on page 6.
$I =$	<i>Influence factor at geocomposite interface</i> - The influence factor at the geomembrane interface and width of the dozer track divided by the thickness of cover soil show $I = 0.96$ for this case (Reference 2, Figure 7).

FIGURE 1

**Uniform Cover Soil Thickness
Seepage Forces with Parallel-to-Slope Buildup**



- W_A = total weight of the active wedge
 W_P = total weight of the passive wedge
 N_A = effective force normal to the failure plane of the active wedge
 N_P = effective force normal to the failure plane of the passive wedge
 γ = unit weight of the cover soil
 h = thickness of the cover soil
 L = length of slope measured along the geomembrane
 β = soil slope angle beneath the geomembrane
 ϕ = friction angle of the cover soil
 δ = interface friction angle between cover soil and geomembrane
 C_a = adhesive force between cover soil of the active wedge and the geomembrane
 c_a = adhesion between cover soil of the active wedge and the geomembrane
 C = cohesive force along the failure plane of the passive wedge
 c = cohesion of the cover soil
 E_A = interwedge force acting on the active wedge from the passive wedge
 E_P = interwedge force acting on the passive wedge from the active wedge
 FS = factor-of-safety against cover soil sliding on the geomembrane

$$W_A = \gamma h^2 \left(\frac{L}{2} - \frac{1}{\sin 2\beta} - \frac{1}{2 \tan \beta} \right)$$

$$a(FS)^2 + b(FS) + c = 0$$

$$N_A = W_A \cos \beta$$

$$a = (W_A - N_A \cos \beta) \cos \beta$$

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$

$$b = -[(W_A - N_A \cos \beta) \sin \beta \tan \phi + (N_A \tan \delta + C_a) \sin \beta \cos \beta + \sin \beta (C + W_P \tan \phi)]$$

$$N_P = W_P + E_P \sin \beta$$

$$c = (N_A \tan \delta + C_a) \sin^2 \beta \tan \phi$$


$$C = \frac{(c)(h)}{\sin \beta}$$

AND:

$$E_P \cos \beta = \frac{C + N_P \tan \phi}{FS}$$

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

GLOBAL STABILITY CALCULATIONS

	SUBJECT: Stability Analyses - Closure Plan J.H. Campbell Pond A	
	Job No.: 1667572.0003.02	Prepared: MJ
	Ref.: Consumers/Campbell Pond A Closure/MI	Checked: JRP
	Date: Aug-16-2018	Reviewed: DL

Slope Stability Analyses for the Proposed Closure Plan of J.H. Campbell Pond A in Ottawa County, Michigan

Objective:

Analyze the short term psuedo-static and long term static stability of the proposed closure conditions for Consumers Energy Corporation (Consumers) J.H. Campbell Pond A in Ottawa County, Michigan.

Analysis Methods:

The static stability of the proposed closure conditions for J.H. Campbell Pond A in Ottawa County, Michigan was evaluated using the computer program SLIDE 2018 Version 8.016 (Rocscience, 2018). Generalized limit equilibrium method of stability analysis developed by Morgenstern and Price (Abramson et al., 2002) was utilized for the analysis. Block and circular search patterns were utilized to find failure surfaces that resulted in the minimum calculated factor of safety. Depending on the analyzed section, block search patterns were used to search for slip surfaces within a specific layer (e.g. CCR, sand-clay interface).

Minimum required factors of safety (FoS) for this analysis were taken as 1.5 for permanent loading conditions (long-term, drained) and 1.0 for temporary loading conditions (end of construction, undrained, seismic). A groundwater elevation of 600.7 feet was assumed within the pond area decreasing to an elevation of 594 feet at the exterior southern drainage channel to account for mounded water during short term conditions at end of construction. During long term conditions, groundwater was assumed at the historic grounwater elevation of 590 feet. All elevations presented are based on plant datum (NGVD29).

Global slip surfaces or those impacting the crest of the slope were considered "Critical" surfaces that may compromise the stability of the impoundment. Shallow or surficial slip surfaces along the slope surface (i.e., not global or impacting the crest of the slope) with factors of safety lower than the "Critical" surface were often generated during the analyses; the shallow slip surfaces were considered "Non-Critical" and issues that could likely be addressed by maintenance (e.g. local regrading, riprap armoring, etc.). Both "Critical" and "Non-Critical" surfaces (as required) are shown on the stability output figures.

Analysis Sections:

Two (2) cross-sections were selected to evaluate the stability of the entire area of Pond A. Section B was considered the most critical and was utilized for this analysis. Figure 1 provides an overview of the section locations.

Analysis Cases:


The following stability cases were analyzed for the current analysis:

- Proposed Fill Conditions - Short-term Strength Parameters (Undrained Conditions with Seismic)
- Proposed Fill Conditions - Long-term Strength Parameters (Drained Conditions)

Material Properties:

The material properties used for this analysis are provided in the table below.

Material	Unit Weight (pcf)		Strength Properties		
	Dry	Saturated	Peak ϕ' (°)	Cohesion (psf)	Undrained Shear Strength (psf)
Cover Material	115	120	28	-	-
CCR	75	100	28	-	-
Fill Sand	110	115	36	-	-
Native Sand	105	120	34	-	-
Native Clay	115	125	27	-	1950

	SUBJECT: Stability Analyses - Closure Plan J.H. Campbell Pond A	
	Job No.: 1667572.0003.02	Prepared: MJ Checked: JRP Reviewed: DL
	Ref.: Consumers/Campbell Pond A Closure/MI	
	Date: Aug-16-2018	

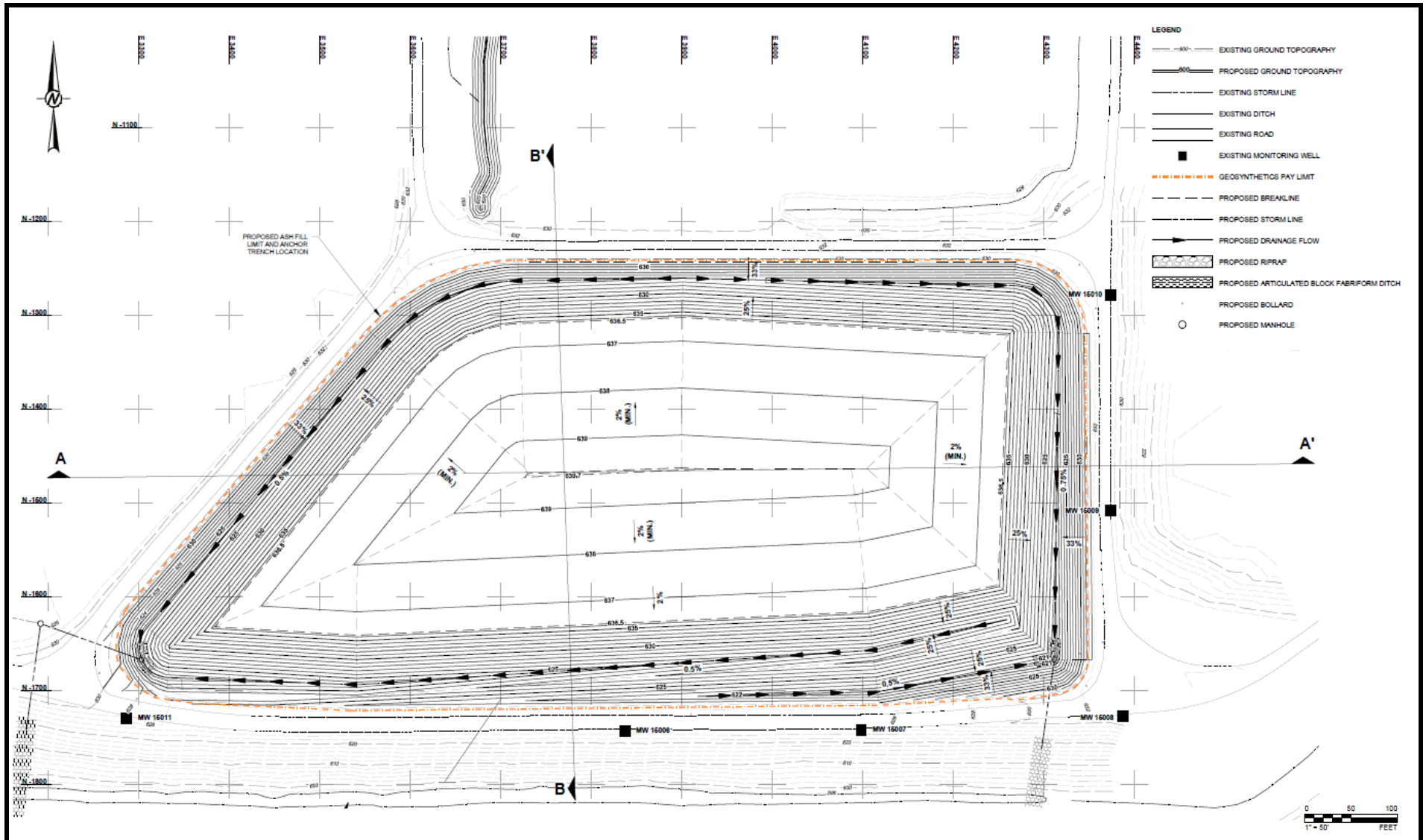
Summary of Stability Analyses Results



Cross-Section B-B

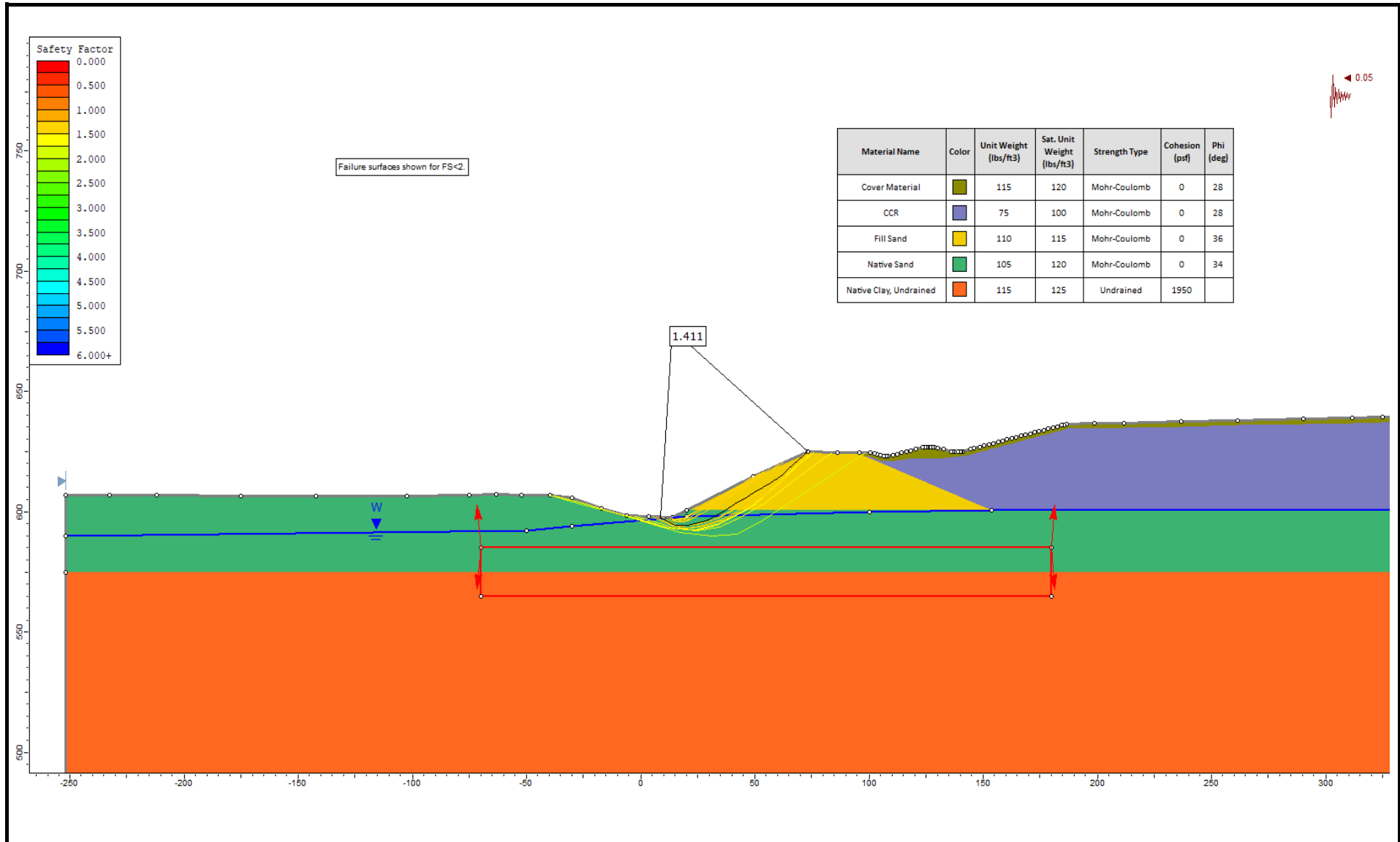
Analysis	Method	Calculated Value	Required FoS	Evaluation	Figure
PROPOSED CONDITIONS - Pond A with 1:3 side slopes (18.43 degrees)					
Pseudo-Static, Short-Term	Block	1.4	1.0	OK	1A
	Circular	2.2	1.0	OK	1B
Static, Long-Term	Block	1.7	1.5	OK	1C
	Circular	4.7	1.5	OK	1D

References:

1. Rocscience (2018), SLIDE 2018 Version 8.016
2. Abramson, L.W., T.S. Lee, S. Sharma, and G.M. Boyce (2002), Slope Stability and Stabilization Methods, 2nd edition, John Wiley & Sons, New York.



 <div>Golder Associates Golder Associates Inc.</div>		SCALE	AS SHOWN	TITLE	Stability Cross-Section Location Plan		
		DATE	Aug 2018				
		MADE BY	MJ				
		CAD	DS				
FILE		STABILITY	CHECK	JRP	 Consumers Energy Corporation	FIGURE	1
PROJECT No.	1667572.0003	REV.	2	REVIEW		DL	



SCALE AS SHOWN
DATE Aug 2018
MADE BY MJ
CAD DS

TITLE

Cross-Section B-B - Pseudo-Static, Short-Term, End of Construction Condition - Block Failure Search

FILE STABILITY

CHECK JRP

PROJECT No. 1667572.0003 REV. 2

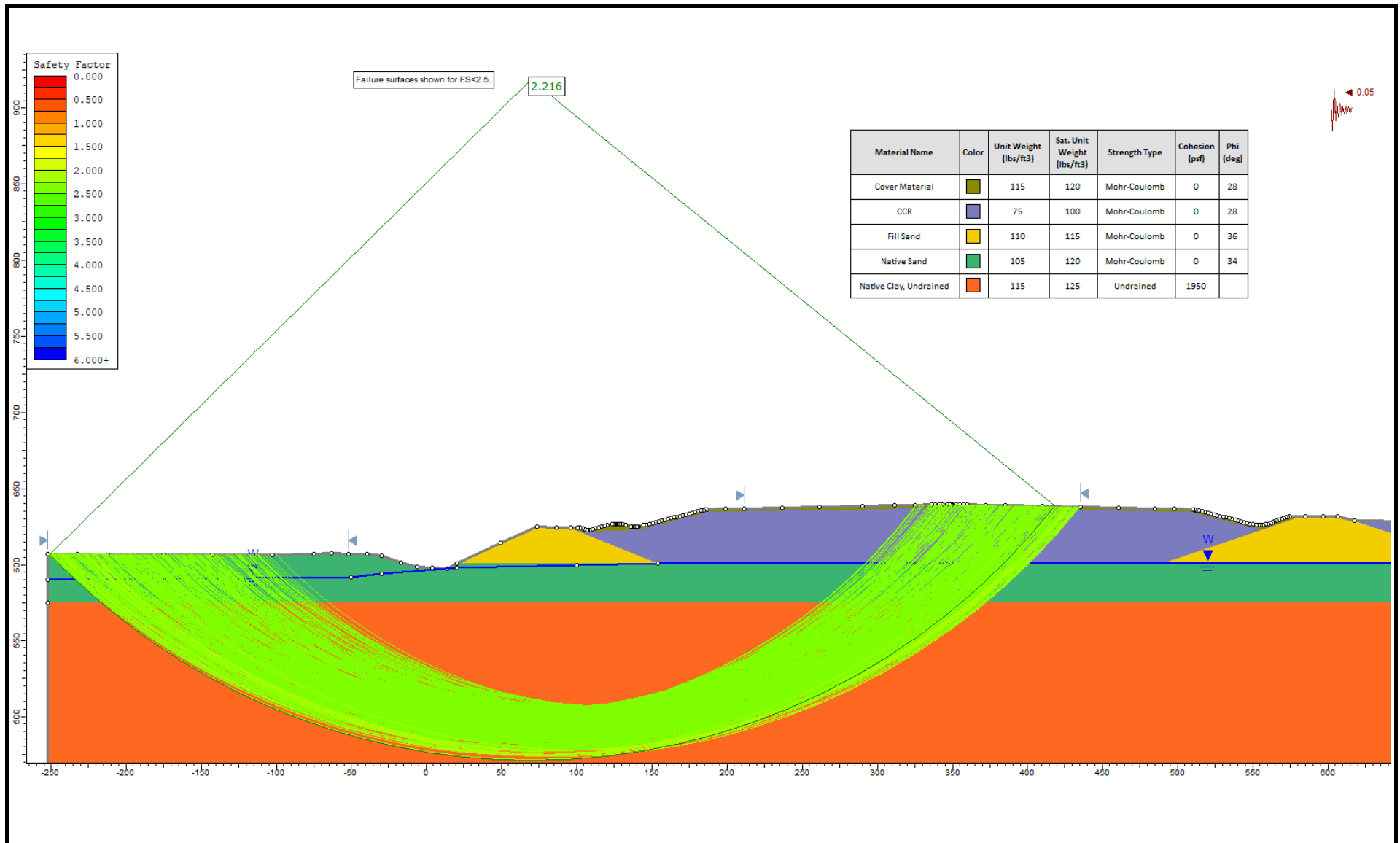
REVIEW DL



Consumers Energy Corporation

FIGURE

1A



SCALE AS SHOWN

DATE Aug 2018

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CAD DS

TITLE

Cross-Section B-B - Pseudo-Static, Short-Term, End of Construction Condition - Circular Failure

FILE STABILITY

CHECK JRP

PROJECT No. 1667572.0003

REV. 2

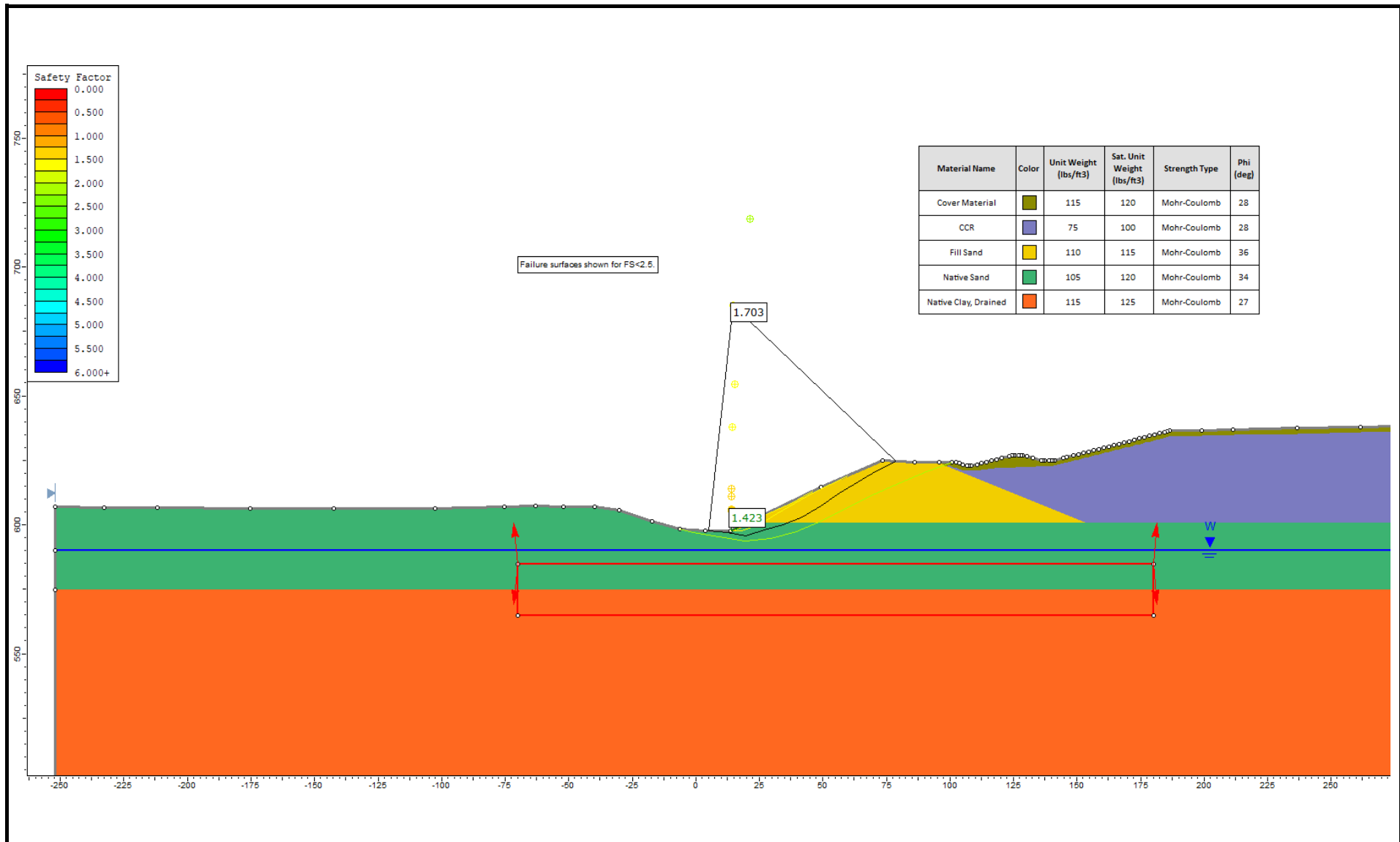
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Consumers Energy Corporation

FIGURE

1B



SCALE AS SHOWN
DATE Aug 2018
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CAD DS

TITLE

Cross-Section B-B - Static, Long-Term Condition - Block Failure Search

FILE STABILITY

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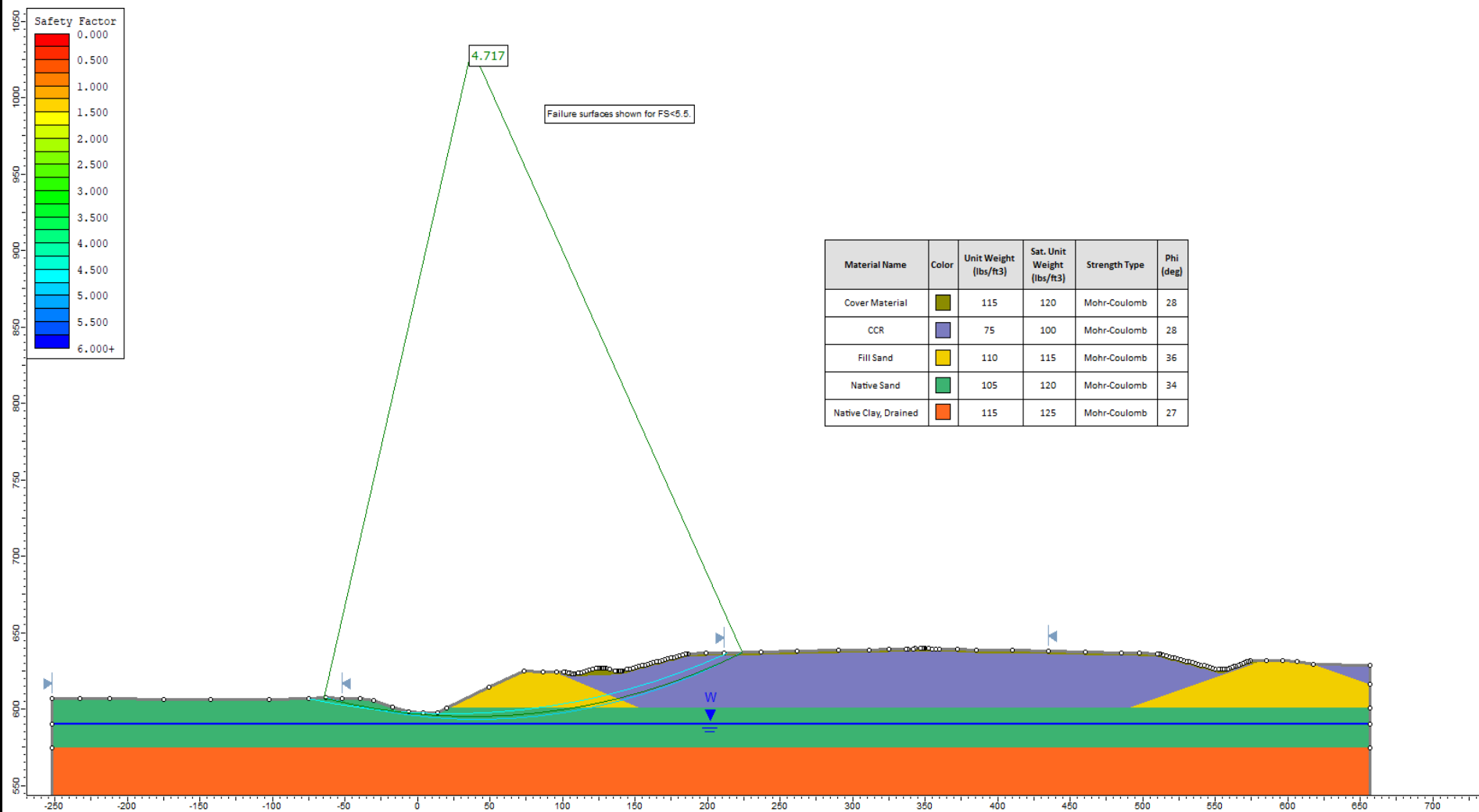
FIGURE

1C

PROJECT No. 1667572.0003

REV. 2

REVIEW DL



SCALE AS SHOWN
DATE Aug 2018
MADE BY MJ
CAD DS

TITLE

Cross-Section B-B - Static, Long-Term Condition - Circular Failure

FILE STABILITY

CHECK JRP

PROJECT No. 1667572.0003 REV. 2

REVIEW DL



Consumers Energy Corporation

FIGURE

1D

SETTLEMENT CALCULATIONS

Date: August 2018
Project No. 1667572.0003.02
Short Name: JH Campbell Pond A Closure
Subject **SETTLEMENT ANALYSIS OF POND A FINAL COVER**

Made by: MMJ
Checked by JRP
Reviewed by: DL

1.0 OBJECTIVE

A settlement analysis was completed to estimate total settlement across the final cover of Pond A at the JH Campbell site and assure anticipated settlements will not cause backflow and ponding of water on the cover system. The final cover is currently designed such that water will flow to bench drains and perimeter drain and directed to the Recirculation Pond through a network of culverts and ditches. Water will ultimately be discharged at the National Pollutant Discharge Elimination System (NPDES) permitted outfall.

2.0 METHODOLOGY

The software program Settle3D (version 4.016) was used to estimate total settlement across the final cover of Pond A. Total settlement was determined at 6 points along the edges and center of the final cover where the Coal Combustion Residual (CCR) thickness is at a minimum and maximum, respectively. A plan view showing the locations of the calculation points is provided in Figure 1. Final elevations were calculated using total settlement results to confirm positive drainage will be maintained across the final cover and prevent ponding of water. Results from Settle3D were verified using hand calculations at Point 4.

2.1 Soil Profile and Material Properties

The subsurface soil profile was established using boring logs from the following subsurface investigations:

- Conetec, 2016 (Cone Penetrometer test (CPT) investigation)
- Golder, 2016 (Sonic/direct push investigation)
- Golder, 2015 (Standard Penetration test (SPT) investigation)
- Engineering and Environmental Solutions, Inc. (E&ES), 2012 (SPT investigation)

Laboratory test results obtained from the Golder, 2016; Golder, 2015; and E&ES, 2012 investigations were used with CPT data to estimate material properties. The subsurface soil profile beneath the proposed CCR landfill is summarized in the table below:



CALCULATIONS

Page 2 of 8

Project No.:	1667572.0003.02	Made by:	MMJ
Site Name:	JH Campbell	Checked by:	JRP
Date:	August 2018	Reviewed by:	DL

Summary of Soil Profile					
Location on Final Cover	Top Elevation of Final Cover ¹ (feet)	Base Elevation of Pond A (feet)	CCR Thickness (feet)	Native Sand Thickness (feet)	Native Clay Thickness ² (feet)
Point 1	636.0	600.7	32.8	25	50
Point 2	636.0		32.8		
Point 3	639.7		36.5		
Point 4	639.7		36.5		
Point 5	636.0		32.8		
Point 6	636.0		32.8		

Elevation datum = NGVD29 US Feet

¹Final cover thickness is 2.5 feet

²Depth of clay is unknown. A thickness of 50 feet was assumed for the model.

Material properties estimated for each soil layer mentioned above include: unit weight; elastic modulus (E_s) for cohesionless soils; compression index (C_c), recompression index (C_r), initial void ratio (e_o), coefficient of consolidation (c_v), and overconsolidation ratio (OCR) for cohesive soils. Material properties are summarized in the table below:

Material Properties								
Material	Unit Weight (pcf)		E_s (ksf)	C_c	C_r	c_v (ft ² /d)	e_o	OCR
	Dry	Saturated						
CCR	75	100	-	-	-	-	-	-
Native sand	105	120	600	-	-	-	-	-
Native clay	115	125	-	0.225	0.023	0.1	0.50	2

Notes:

pcf = pounds per cubic foot

ksf = kips per cubic foot

ft²/d = square feet per day

CCR saturated unit weight used to determine load applied to underlying native sand and clay.

Unit weights for the CCR and native soils were selected based on laboratory results and blow counts (N-value) from the SPT investigations listed above.

The elastic modulus for the native sand was estimated using the following correlation (Ref. 1):

$$E_s = 500 \text{ kPa} * (N_{55} + 15)$$

$$N_{55} = \frac{E_m}{0.55} * N$$

CALCULATIONS

Page 3 of 8

Project No.:	1667572.0003.02	Made by:	MMJ
Site Name:	JH Campbell	Checked by:	JRP
Date:	August 2018	Reviewed by:	DL

where N_{55} is the corrected blow count for hammer efficiency, N is the blow count or N-value, and E_m is the hammer efficiency. The average N-value measured for the native sand is 30 and assuming a hammer efficiency of 80%:

$$N_{55} = \frac{0.8}{0.55} * 30 = 43.6$$

$$E_s = 500 \text{ kPa} * (43.6 + 15) = 29318 \text{ kPa} = 612 \text{ ksf} \approx 600 \text{ ksf}$$

Consolidation properties for the native clay were estimated based on Atterberg limits and natural water content (w) from index testing performed during the Golder 2015 and E&ES 2012 investigations. The following equations were used to determine the consolidation properties (Ref. 2):

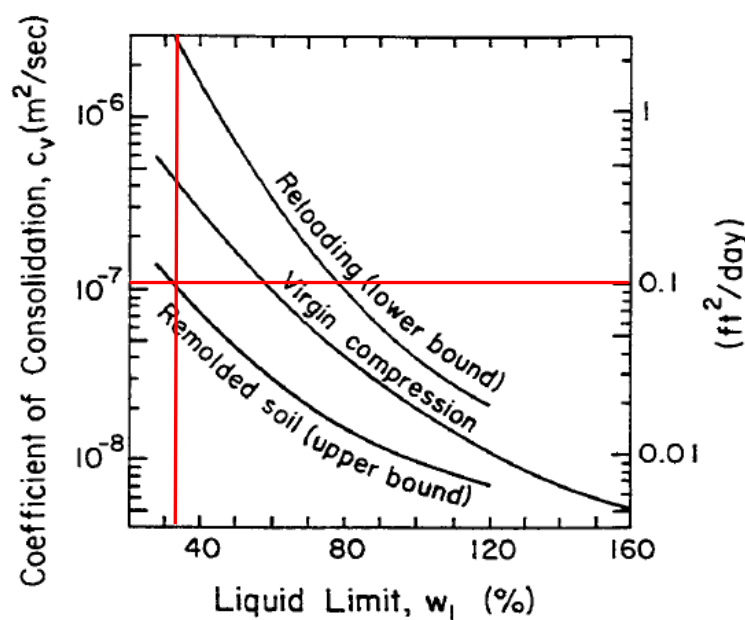
$$C_c = 0.009 * (LL - 10)$$

$$C_r = 0.1C_c$$

$$e_o = G_s * w \text{ (Assumes 100\% saturation)}$$

where LL is the liquid limit and G_s is the specific gravity (assumed to be 2.7 for clay). Average values from laboratory results were used for LL and w . With $LL = 35\%$ and $w = 18.5\%$, C_c is 0.225, C_r is 0.023, and e_o is 0.50.

The value for c_v was estimated using a graphical correlation between c_v and LL provided in the chart shown below (Ref. 2). The same average value of LL (35%) was used to determine a c_v value of 0.1 ft²/d.



CALCULATIONS

Page 4 of 8

Project No.:	1667572.0003.02	Made by:	MMJ
Site Name:	JH Campbell	Checked by:	JRP
Date:	August 2018	Reviewed by:	DL

2.2 Groundwater

The current groundwater elevation at the site is at an approximate elevation of 600 feet (NGVD29) as provided in the Pond A Annual Groundwater Monitoring Report by TRC Environmental Corporation (Ref. 3). The settlement analysis conducted in Settle3D was performed assuming groundwater is at the base of the pond at an elevation of 600.7 feet (NGVD29).

3.0 RESULTS

The settlement analysis was primarily performed using Settle3D. Hand calculations were performed at Point 4 to verify total settlement results obtained from Settle3D.

3.1 Settle3D

The settlement analysis results from Settle3D are summarized in the table below with final top of cover elevations assuming a “worst case scenario” (i.e., largest total settlement occurs):

Location on Final Cover	Total Settlement (inches)	Final Top of Cover Elevation
Point 1	2.5 to 3.0	635.8
Point 2	2.5 to 3.0	635.8
Point 3	8.5 to 9.5	638.9
Point 4	8.5 to 9.5	638.9
Point 5	2.5 to 3.0	635.8
Point 6	2.5 to 3.0	635.8

Elevation datum = NGVD29 US Feet

The analysis considered elastic settlement of the sand and consolidation of the native clay due to the loading of the CCR fill. Since the CCR is anticipated to be compacted during placement, the settlement within the CCR was considered to be negligible compared to the settlement of the underlying native material.

Output from the Settle3D analysis provided in Figure 2 indicates where the largest settlement is anticipated to occur and shows the distribution of total settlement throughout the final cover.

3.2 Hand Calculation for Point 4

The total settlement at Point 4 was calculated by adding the elastic settlement of the native sand and the consolidation settlement of the native clay.

The elastic settlement of the native sand was calculated using the following equations (Ref. 2):

CALCULATIONS

Page 5 of 8

Project No.:	1667572.0003.02	Made by:	MMJ
Site Name:	JH Campbell	Checked by:	JRP
Date:	August 2018	Reviewed by:	DL

$$S_e = \left(\frac{\Delta\sigma}{M_s} \right) * H_0$$

$$M_s = \frac{E_s(1 - \nu_s)}{(1 + \nu_s)(1 - 2 * \nu_s)}$$

Where;

S_e= elastic settlement of soil layer (ft)

H₀=initial thickness of soil layer (ft)

Δσ=increment of vertical effective stress (tsf)

M_s=constrained modulus of soil (tsf)

ν_s=Poisson's ratio of soil

Assuming ν_s = 0.3 and E_s = 600 ksf → M_s = 808 ksf

The thickness of CCR fill at Point 4 is approximately 39 feet; therefore, the increment of vertical effective stress will be:

$$\Delta\sigma = \gamma * H = 100 * 36.5 = 3.65 \text{ ksf}$$

$$S_e = \left(\frac{3.65 \text{ ksf}}{808 \text{ ksf}} \right) * 25 \text{ feet} = \mathbf{1.36 \text{ inch}}$$

The primary consolidation of the native clay (OCR = 2) can be calculated using the following equation (Ref. 2):

$$S_c = \frac{C_r H_o}{1 + e_o} \log \left(\frac{\sigma'_{v,c}}{\sigma'_o} \right) + \frac{C_c H_o}{1 + e_o} \log \left(\frac{\sigma'_o + \Delta\sigma}{\sigma'_o} \right)$$

Where

S_c= consolidation settlement of soil layer (ft)

σ'_{v,c}=preconsolidation stress (psf)

σ'_o=initial vertical effective stress (psf)

In the middle of the native clay layer:

$$\sigma'_o = (H_{sand} \gamma_{sand} + 0.5 H_{clay} \gamma_{clay}) - \gamma_w (H_{sand} + 0.5 H_{clay})$$

$$\sigma'_o = (25 \text{ feet} * 120 \text{ pcf} + 0.5 * 50 \text{ feet} * 125 \text{ pcf}) - 62.4 \text{ pcf} (25 \text{ feet} + 0.5 * 50 \text{ feet}) = 3005 \text{ psf}$$

The OCR for the native clay was used to estimate σ'_{v,c}:

$$\sigma'_{v,c} = \sigma'_o * OCR = 3005 \text{ psf} * 2 = 6010 \text{ psf}$$

$$S_c = \frac{0.023 * 50 \text{ feet}}{1 + 0.5} * \log \left(\frac{6010 \text{ psf}}{3005 \text{ psf}} \right) + \frac{0.225 * 50 \text{ feet}}{1 + 0.5} * \log \left(\frac{3005 \text{ psf} + 3650 \text{ psf}}{6010 \text{ psf}} \right) = \mathbf{6.75 \text{ inch}}$$

CALCULATIONS

Page 6 of 8

Project No.:	1667572.0003.02	Made by:	MMJ
Site Name:	JH Campbell	Checked by:	JRP
Date:	August 2018	Reviewed by:	DL

Total settlement will be:

$$S = S_e + S_c = 1.36 + 6.75 = \mathbf{8.1\ inch}$$

The 8.1 inches of total settlement generally agrees with the total settlement determined by Settle3D (8.5 to 9.0 inches), therefore a total settlement between 8.5 to 9.0 inches is a reasonable expectation.

4.0 DISCUSSION

Approximately 8.5 to 9.0 inches of total settlement can be expected at the center of the pond area where CCR is thickest. Total settlement along the edge of the pond area is anticipated to range from 2.5 to 3.0 inches. The final elevations of the final cover post-settlement indicate positive drainage will still be present and prevent ponding of water. The highest elevations along the final cover will remain at the center of Pond A causing water to drain to the side slopes, as currently designed.

5.0 REFERENCES

1. Bowles, J.E., 1995. Foundation Analysis and Design.
2. Naval Facilities Engineering Command (NAVFAC), Design Manual 7.01, 1986.
3. TRC Environmental Corporation, 2018. Annual Groundwater Monitoring Report: JH Campbell Power Plant Pond A CCR Unit.

CALCULATIONS
Page 7 of 8

Project No.:	1667572.0003.02	Made by:	MMJ
Site Name:	JH Campbell	Checked by:	JRP
Date:	August 2018	Reviewed by:	DL

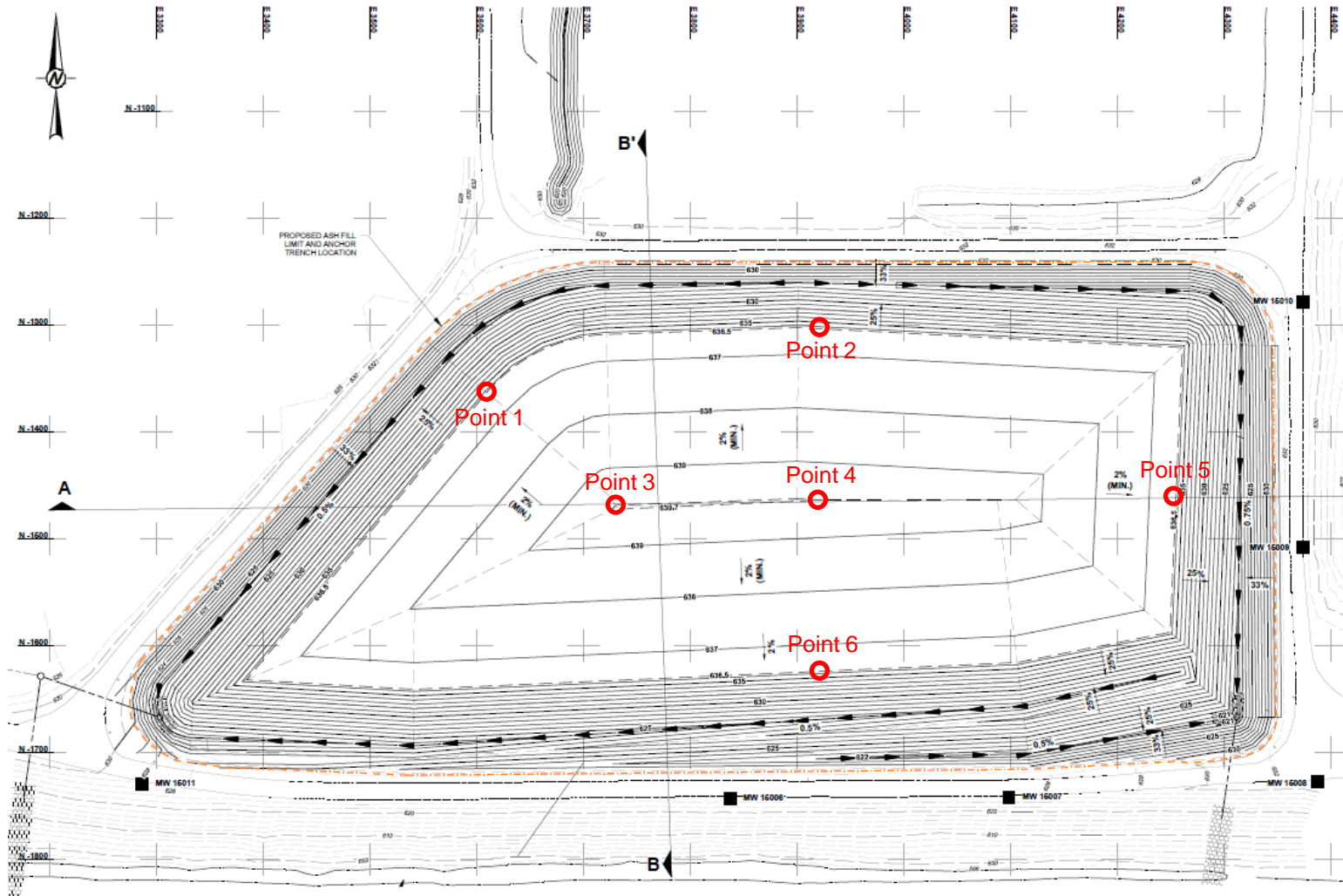


Figure 1

CALCULATIONS
Page 8 of 8

Project No.:	1667572.0003.02	Made by:	MMJ
Site Name:	JH Campbell	Checked by:	JRP
Date:	August 2018	Reviewed by:	DL

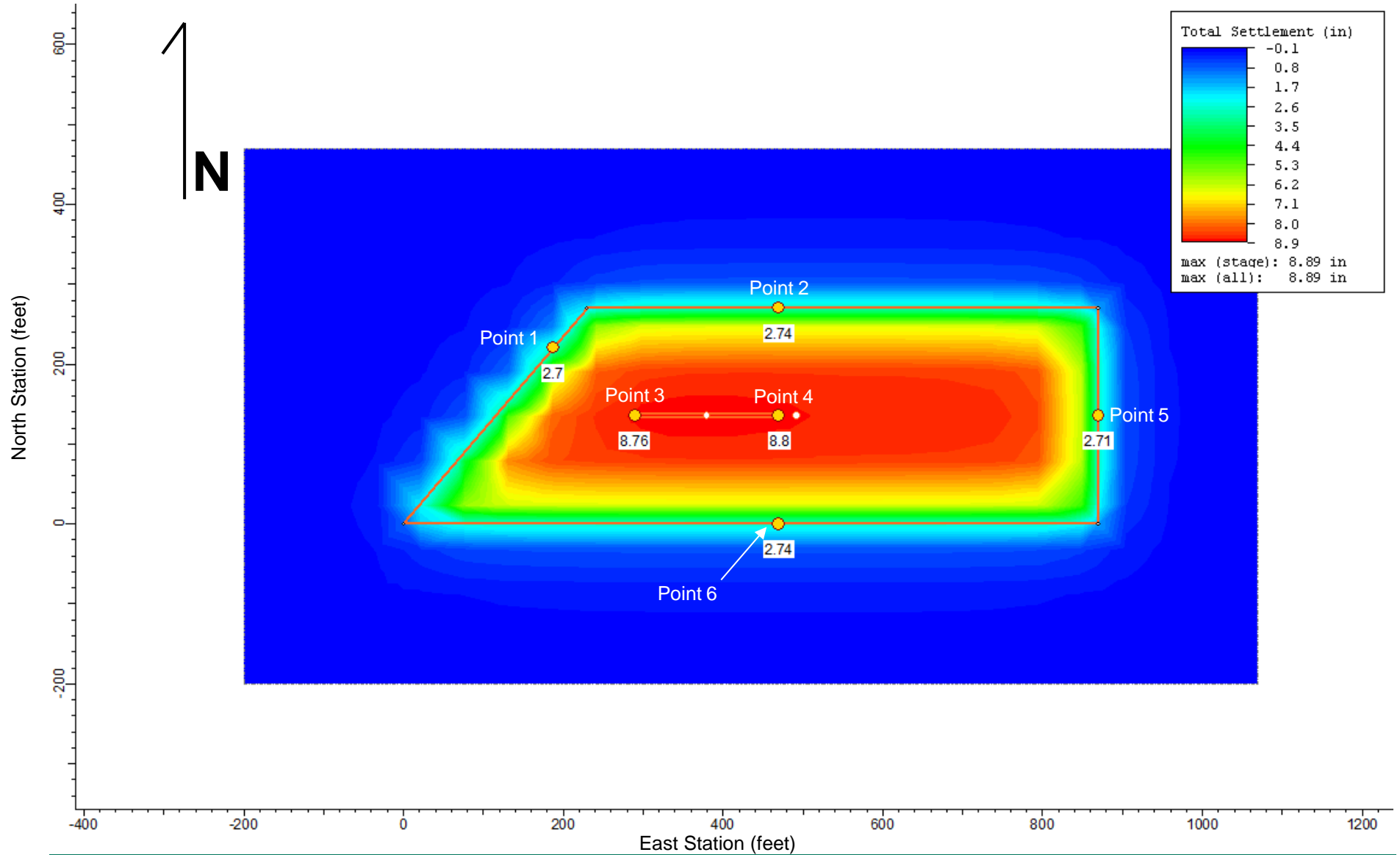


Figure 2

APPENDIX E
HYDROLOGIC AND HYDRAULIC CALCULATIONS

HYDROLOGIC PARAMETERS

CALCULATION SHEET

Page 1 Of 2

Client	CEC	Subject	Hydrologic	Prepared By	JSH	Date	07/12/18
Project	J.H. Campbell	Parameters		Reviewed By	JDP	Date	01/24/19
Pond A				Approved By	DL	Date	01/25/19

HYDROLOGIC PARAMETERS

Objective

Determine hydrologic parameters (curve number, rainfall depth and rainfall distribution) and design criteria to be used to design and evaluate the surface water management system.

Design Criteria and Assumptions

1. Curve numbers were calculated using the Soil Conservation Service ("SCS") methodology.
2. Times of concentration were computed by HydroCAD, a hydrologic and hydraulic modeling software program using methodology developed by the SCS.
3. Rainfall depths are provided in Attachment 1. Depths for rainfall distributions are based on the NOAA Atlas 14, Volume 8, Version 2, Point Precipitation Frequency Estimates.
4. HydroCAD was used to calculate the peak flow and velocity into channels and the outfall, and compute peak surface water discharge from Pond A. Storage-Indication-Translation Method routing techniques were used to route surface water through the surface water management system. The antecedent moisture condition specifies the moisture level in the ground immediately prior to the storm. A value of "2" for normal conditions is used in the analyses.
5. The stormwater management system is designed to meet the following criteria:
 - o The perimeter drains will collect and control run-off from the SCS Type II, 100-year, 24-hour storm event without overflow, which exceeds MI DEQ R 299.4435(b) requirement for a 25-year, 24-hour storm.
 - o The interior bench drains will collect and control run-off from the SCS Type II, 100-year 24-hour storm event without overflow.
 - o All proposed culverts were modeled with a manning's n value of 0.013 for HDPE pipe with smooth interiors. Alternative culverts types may be used with equal hydraulic performance.

Calculations

Curve Numbers

A Curve Number ("CN") was applied to the final cover drainage areas. A summary of the curve number used throughout the calculations is provided in Table 1 shown below. The TR-55 Tables 2-2a was used to develop the curve number summary and is provided in Attachment 2.

CALCULATION SHEET

Page 2 Of 2

Client CEC Subject Hydrologic
Project J.H. Campbell Parameters Prepared By JSH Date 07/12/18
Pond A Reviewed By JDP Date 01/24/19
 Approved By DL Date 01/25/19

TABLE 1- CURVE NUMBER SUMMARY

Study Area Cover Description	TR-55 Cover Type and Hydrologic Condition	Hydrologic Soil Group	Curve Number
Final Cover	Grassland in good condition	C	74

Note: Although cover material will most like be a type B soil, type C was used to be conservative

Rainfall Depth

Rainfall depths for storm events used in the analyses are provided in Attachment 1. The rainfall depths used in the analyses are summarized in Table 2, below.

Table 2- Summary of Rainfall Depths

Rainfall Event	Duration (hours)	Depth (inches)
SCS Type II 25-yr	24	4.97
SCS Type II 100-yr	24	6.95

Conclusions

CNs for the final cover conditions were determined using standard SCS methods. Rainfall depths for storm events are summarized in Table 2. These hydrologic parameters will be used to design the surface water management system for Pond A.

ATTACHMENT 1



NOAA Atlas 14, Volume 8, Version 2
Location name: West Olive, Michigan, US*
Latitude: 42.9081°, Longitude: -86.1972°
Elevation: 606 ft*
 * source: Google Maps



POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffrey Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

[PF tabular](#) | [PF graphical](#) | [Maps & aeriels](#)

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)¹										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.307 (0.251–0.382)	0.362 (0.296–0.451)	0.459 (0.373–0.572)	0.544 (0.440–0.682)	0.671 (0.526–0.877)	0.776 (0.591–1.03)	0.886 (0.650–1.20)	1.01 (0.704–1.39)	1.17 (0.786–1.66)	1.30 (0.848–1.87)
10-min	0.450 (0.368–0.560)	0.531 (0.433–0.661)	0.671 (0.546–0.838)	0.797 (0.644–0.999)	0.982 (0.771–1.28)	1.14 (0.866–1.50)	1.30 (0.952–1.75)	1.47 (1.03–2.04)	1.71 (1.15–2.44)	1.91 (1.24–2.74)
15-min	0.549 (0.449–0.683)	0.647 (0.528–0.806)	0.819 (0.666–1.02)	0.972 (0.786–1.22)	1.20 (0.940–1.57)	1.39 (1.06–1.83)	1.58 (1.16–2.14)	1.79 (1.26–2.49)	2.09 (1.40–2.97)	2.33 (1.51–3.34)
30-min	0.768 (0.628–0.955)	0.907 (0.741–1.13)	1.15 (0.937–1.44)	1.37 (1.11–1.72)	1.69 (1.33–2.21)	1.96 (1.49–2.59)	2.24 (1.64–3.03)	2.54 (1.78–3.52)	2.96 (1.99–4.22)	3.30 (2.15–4.74)
60-min	0.999 (0.817–1.24)	1.18 (0.962–1.47)	1.50 (1.22–1.87)	1.79 (1.44–2.24)	2.22 (1.75–2.92)	2.59 (1.98–3.43)	2.98 (2.19–4.03)	3.40 (2.39–4.72)	4.00 (2.69–5.69)	4.48 (2.91–6.43)
2-hr	1.23 (1.01–1.52)	1.45 (1.19–1.79)	1.84 (1.51–2.28)	2.20 (1.80–2.74)	2.75 (2.18–3.58)	3.21 (2.48–4.23)	3.71 (2.75–4.99)	4.26 (3.01–5.87)	5.03 (3.41–7.11)	5.66 (3.71–8.05)
3-hr	1.38 (1.14–1.69)	1.62 (1.34–1.99)	2.06 (1.70–2.53)	2.47 (2.02–3.05)	3.10 (2.48–4.03)	3.64 (2.82–4.77)	4.23 (3.15–5.67)	4.87 (3.46–6.69)	5.79 (3.94–8.16)	6.54 (4.31–9.27)
6-hr	1.66 (1.38–2.01)	1.93 (1.61–2.34)	2.45 (2.03–2.98)	2.94 (2.43–3.60)	3.72 (3.01–4.81)	4.40 (3.44–5.73)	5.14 (3.87–6.86)	5.97 (4.29–8.16)	7.17 (4.93–10.0)	8.15 (5.41–11.5)
12-hr	1.95 (1.64–2.34)	2.26 (1.90–2.71)	2.85 (2.39–3.44)	3.44 (2.86–4.16)	4.36 (3.56–5.61)	5.18 (4.09–6.70)	6.08 (4.62–8.05)	7.09 (5.14–9.63)	8.56 (5.94–11.9)	9.78 (6.54–13.6)
24-hr	2.26 (1.91–2.68)	2.60 (2.20–3.09)	3.26 (2.75–3.89)	3.92 (3.28–4.70)	4.97 (4.09–6.34)	5.91 (4.71–7.58)	6.95 (5.32–9.12)	8.11 (5.93–10.9)	9.82 (6.87–13.6)	11.2 (7.58–15.5)
2-day	2.60 (2.23–3.07)	2.96 (2.53–3.49)	3.67 (3.13–4.34)	4.38 (3.70–5.20)	5.51 (4.58–6.96)	6.53 (5.24–8.29)	7.65 (5.91–9.96)	8.91 (6.57–11.9)	10.8 (7.60–14.7)	12.3 (8.37–16.9)
3-day	2.86 (2.45–3.34)	3.23 (2.77–3.78)	3.96 (3.38–4.65)	4.68 (3.97–5.52)	5.83 (4.86–7.31)	6.86 (5.54–8.66)	8.01 (6.21–10.4)	9.29 (6.88–12.3)	11.2 (7.91–15.2)	12.7 (8.69–17.4)
4-day	3.06 (2.64–3.57)	3.45 (2.97–4.02)	4.20 (3.60–4.91)	4.93 (4.20–5.79)	6.09 (5.09–7.59)	7.13 (5.77–8.95)	8.27 (6.43–10.6)	9.54 (7.09–12.6)	11.4 (8.11–15.5)	13.0 (8.88–17.6)
7-day	3.58 (3.10–4.13)	4.01 (3.48–4.64)	4.82 (4.16–5.59)	5.59 (4.79–6.51)	6.78 (5.68–8.31)	7.80 (6.34–9.68)	8.93 (6.98–11.3)	10.2 (7.58–13.3)	11.9 (8.54–16.0)	13.4 (9.25–18.1)
10-day	4.05 (3.53–4.65)	4.53 (3.94–5.21)	5.40 (4.68–6.23)	6.20 (5.34–7.18)	7.41 (6.21–9.00)	8.44 (6.87–10.4)	9.54 (7.48–12.0)	10.7 (8.04–13.9)	12.4 (8.92–16.6)	13.8 (9.59–18.6)
20-day	5.50 (4.83–6.25)	6.11 (5.36–6.95)	7.15 (6.25–8.16)	8.05 (6.99–9.23)	9.34 (7.85–11.1)	10.4 (8.50–12.5)	11.5 (9.04–14.2)	12.6 (9.49–16.1)	14.2 (10.2–18.6)	15.4 (10.8–20.6)
30-day	6.76 (5.97–7.64)	7.49 (6.61–8.47)	8.69 (7.64–9.86)	9.69 (8.47–11.1)	11.1 (9.34–13.0)	12.2 (10.0–14.6)	13.3 (10.5–16.3)	14.4 (10.9–18.2)	15.9 (11.5–20.7)	17.0 (12.0–22.6)
45-day	8.39 (7.45–9.43)	9.29 (8.23–10.4)	10.7 (9.47–12.1)	11.9 (10.4–13.5)	13.4 (11.3–15.6)	14.6 (12.0–17.3)	15.7 (12.5–19.1)	16.8 (12.7–21.1)	18.3 (13.2–23.6)	19.3 (13.6–25.5)
60-day	9.80 (8.73–11.0)	10.9 (9.66–12.2)	12.5 (11.1–14.0)	13.8 (12.2–15.6)	15.5 (13.1–17.9)	16.8 (13.8–19.7)	17.9 (14.3–21.7)	19.1 (14.5–23.8)	20.4 (14.9–26.3)	21.4 (15.2–28.2)

¹ Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS). Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values. Please refer to NOAA Atlas 14 document for more information.

[Back to Top](#)

PF graphical

ATTACHMENT 2

Table 2-2a Runoff curve numbers for urban areas ^{1/}

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area ^{2/}	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) ^{3/} :					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) ^{4/}		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) ^{5/}		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

¹ Average runoff condition, and $I_a = 0.2S$.² The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.³ CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.⁴ Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.⁵ Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

HYDRAULIC CALCULATIONS

CALCULATION SHEET

Page 1 Of 3

Client CEC

Subject Design

Project J.H. Campbell

Calculations

Prepared By JSH

Date 07/12/18

Pond A

Reviewed By JDP

Date 01/24/19

Approved By DL

Date 01/25/19

Objective

Design the stormwater management system for J.H. Campbell Pond A. Pond A is shown on Figure 01 in Attachment 1.

Design Criteria and Assumptions

1. HydroCAD was used to design and evaluate the stormwater management system for Pond A.
2. The perimeter drains will collect and manage run-off from the SCS Type II, 100-year, 24-hour storm event without overflow, which exceeds MI DEQ R 299.4435(b) requirement for a 25-year, 24-hour storm.
3. Maximum channel side slopes will be 2H:1V.
4. Channels will be designed with flow velocities under 5 fps for the 25-year, 24-hour event. Velocities exceeding 5 fps have the capability to erode grass lined channels.
5. Downslope channels with flow velocities greater than 5 fps for the 25-year, 24 –hour event will be designed using Fabriform lining.

Calculations

Subbasin Delineations

Subbasins were delineated based on the grading of Pond A which is provided on Figure 01.

Curve Numbers

Curve Numbers are summarized in Appendix E-1 Hydrologic Parameters.

Times of Concentration

Calculations for the times of concentrations of each subbasin are shown in the HydroCAD outputs as provided in Attachment 1. Maximum sheet flow lengths of 100 feet were used in the calculations.

Rainfall Depths

Rainfall depths used in this analysis are provided in Appendix E-1 Hydrologic Parameters.

Flow Rate Calculations

HydroCAD was used to design and evaluate the stormwater management structures for Pond A. HydroCAD outputs are provided in Attachment 1. A summary of the stormwater channels and culverts are provided in Tables 1 and 2 below.

Stormwater management system structure labels are shown on Figure 01. The HydroCAD output files, which include all input parameters are provided in Attachment 1.

CALCULATION SHEET

Page 2 Of 3

Client CEC Subject Design
Project J.H. Campbell Calculations
Pond A

Prepared By JSH Date 07/12/18
Reviewed By JDP Date 01/24/19
Approved By DL Date 01/25/19

Table 1 – Proposed Channel Reach Summary

Channel I.D.	Channel Type	Length (feet)	25-year In-Flow (cfs)	Slope (%)	Depth (feet)		25-year Velocity (fps)	100-year Flow Depth
					25-year Flow Depth	Design (min)		
1R	V-Ditch	782	10.51	0.51	1.08	4.0	2.15	1.34
2R	V-Ditch	970	12.69	0.52	1.08	3.0	2.16	1.34
3R	V-Ditch	385	3.75	0.50	0.75	3.0	1.66	0.92
4R	V-Ditch	791	10.98	0.76	1.03	3.0	2.53	1.28
5R	V-Ditch	53	10.41	30.19	0.48	3.0	15.18	0.59
6R	V-ditch	70	35.51	25.43	0.78	3.0	19.33	0.98

A summary of the proposed outfall is described in Tables 2 below.

Table 2 – Culvert Summary

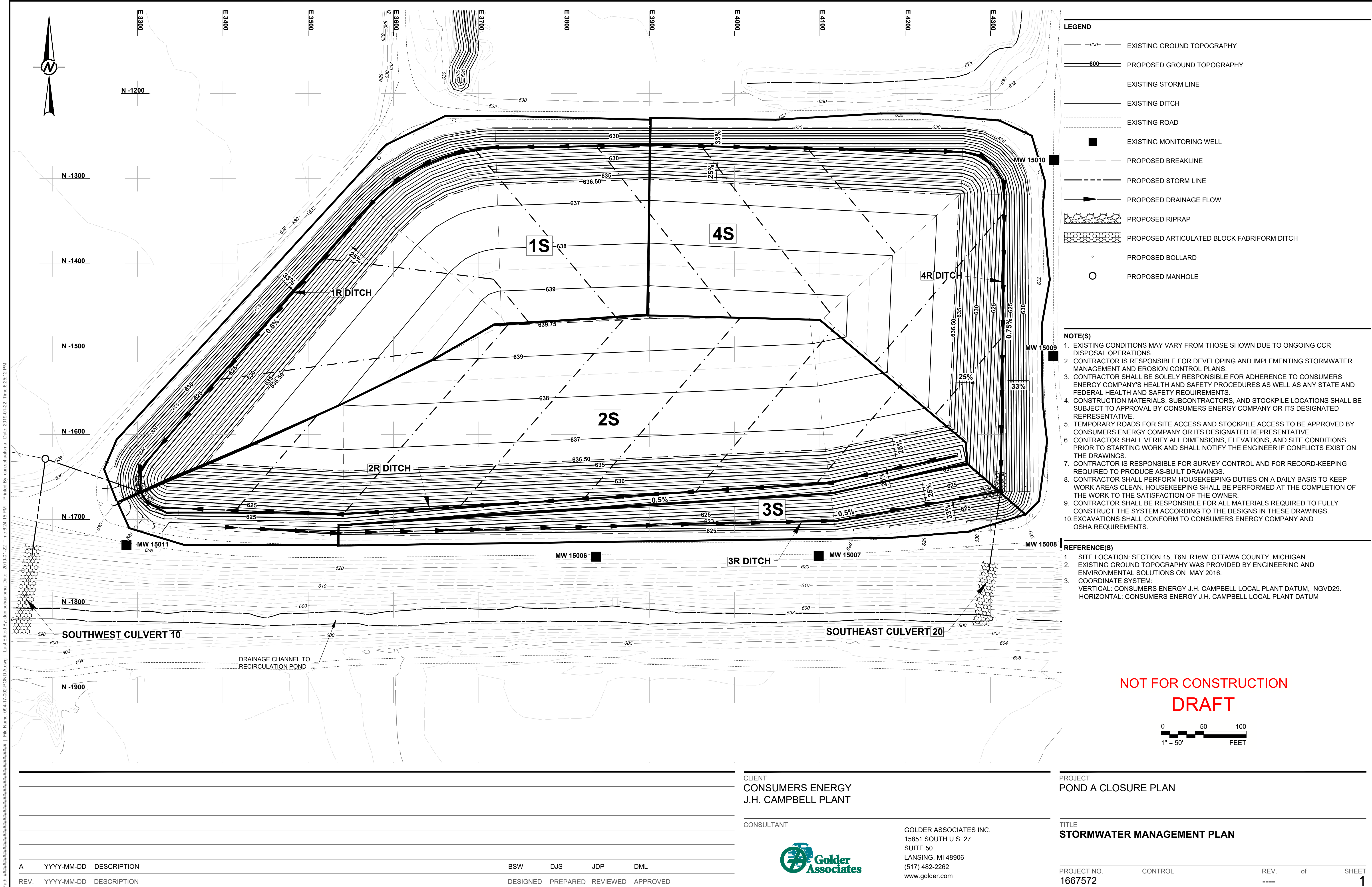
Culvert ID	Number of Culverts	Culvert Diameter (in)	Culvert Length (ft)	Culvert Slope (%)	Design Inlet Invert Elevation (MSL)	Design Outlet Invert Elevation (MSL)	Top of Road (MSL)	25-year Storm Headwater Elevation (MSL)	100-year Storm Headwater Elevation (MSL)
1O	1	30	115	1.04	617.00	615.80	628.9	622.61	623.93
1Oa	1	30	112	1.07	615.00	613.80	630.0	618.51	623.81
2O	1	30	95	1.05	615.00	614.00	631.0	620.19	620.59

NOTE: Proposed culverts were modeled with a Manning's n value of 0.012. Concrete, CMP or PE pipe with smooth interiors may be used.

Conclusions

The stormwater management system for J.H. Campbell Pond A has been designed to manage flows from the 25-year and 100-year events meeting or exceeding MI DEQ requirements R 299.4435(b).

FIGURE 1



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A		YYYY-MM-DD	DESCRIPTION	BSW				DJS	JDP	DML
REV.		YYYY-MM-DD	DESCRIPTION	DESIGNED				PREPARED	REVIEWED	APPROVED

CLIENT
CONSUMERS ENERGY
J.H. CAMPBELL PLANT

CONSULTANT



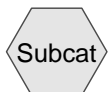
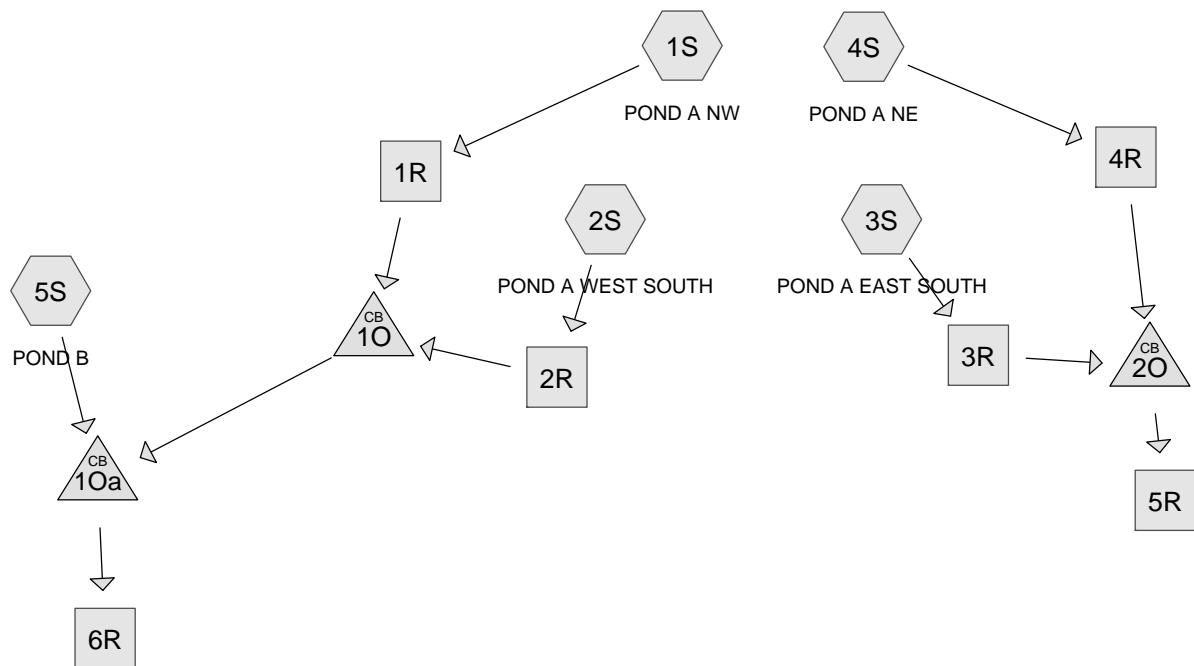
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PROJECT
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TITLE
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PROJECT NO.	CONTROL	REV.	of	SHEET
1667572		----		1

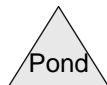
ATTACHMENT 1



Subcat



Reach



Pond



Link

Drainage Diagram for Pond A Stormwater_7-12-18

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Pond A Stormwater_7-12-18

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Page 2

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
8.850	69	50-75% Grass cover, Fair, HSG B (5S)
10.833	74	>75% Grass cover, Good, HSG C (1S, 2S, 3S, 4S)
19.683		TOTAL AREA

Pond A Stormwater_7-12-18

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Page 3

Soil Listing (selected nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
8.850	HSG B	5S
10.833	HSG C	1S, 2S, 3S, 4S
0.000	HSG D	
0.000	Other	
19.683		TOTAL AREA

Pond A Stormwater_7-12-18

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Page 4

Pipe Listing (selected nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)
1	1O	617.00	615.80	115.0	0.0104	0.012	30.0	0.0
2	1Oa	615.00	613.80	112.0	0.0107	0.012	30.0	0.0
3	2O	615.00	614.00	95.0	0.0105	0.012	30.0	0.0

Pond A Stormwater_7-12-18*Type II 24-hr 25-YEAR Rainfall=4.97"*

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Page 5

Time span=0.00-30.00 hrs, dt=0.05 hrs, 601 points

Runoff by SCS TR-20 method, UH=SCS

Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: POND A NWRunoff Area=3.075 ac 0.00% Impervious Runoff Depth=2.34"
Flow Length=135' Tc=11.1 min CN=74 Runoff=10.51 cfs 0.600 af**Subcatchment 2S: POND A WEST SOUTH**Runoff Area=3.725 ac 0.00% Impervious Runoff Depth=2.34"
Flow Length=173' Tc=11.2 min CN=74 Runoff=12.69 cfs 0.726 af**Subcatchment 3S: POND A EAST SOUTH**Runoff Area=0.832 ac 0.00% Impervious Runoff Depth=2.34"
Flow Length=35' Slope=0.2500 '/ Tc=1.7 min CN=74 Runoff=3.75 cfs 0.162 af**Subcatchment 4S: POND A NE**Runoff Area=3.201 ac 0.00% Impervious Runoff Depth=2.34"
Flow Length=131' Tc=11.0 min CN=74 Runoff=10.98 cfs 0.624 af**Subcatchment 5S: POND B**Runoff Area=8.850 ac 0.00% Impervious Runoff Depth=1.94"
Flow Length=100' Slope=0.0050 '/ Tc=20.9 min CN=69 Runoff=18.04 cfs 1.427 af**Reach 1R:**Avg. Depth=1.08' Max Vel=2.15 fps Inflow=10.51 cfs 0.600 af
n=0.032 L=782.0' S=0.0051 '/ Capacity=287.48 cfs Outflow=8.78 cfs 0.600 af**Reach 2R:**Avg. Depth=1.08' Max Vel=2.16 fps Inflow=12.69 cfs 0.726 af
n=0.032 L=970.0' S=0.0052 '/ Capacity=154.13 cfs Outflow=9.84 cfs 0.726 af**Reach 3R:**Avg. Depth=0.75' Max Vel=1.66 fps Inflow=3.75 cfs 0.162 af
n=0.032 L=385.0' S=0.0050 '/ Capacity=131.80 cfs Outflow=3.13 cfs 0.162 af**Reach 4R:**Avg. Depth=1.03' Max Vel=2.53 fps Inflow=10.98 cfs 0.624 af
n=0.032 L=791.0' S=0.0076 '/ Capacity=162.55 cfs Outflow=9.33 cfs 0.624 af**Reach 5R:**Avg. Depth=0.48' Max Vel=15.18 fps Inflow=10.41 cfs 0.787 af
n=0.020 L=53.0' S=0.3019 '/ Capacity=1,394.49 cfs Outflow=10.39 cfs 0.787 af**Reach 6R:**Avg. Depth=0.78' Max Vel=19.33 fps Inflow=35.51 cfs 2.754 af
n=0.020 L=70.0' S=0.2543 '/ Capacity=1,279.84 cfs Outflow=35.48 cfs 2.754 af**Pond 10:**Peak Elev=622.61' Inflow=18.49 cfs 1.326 af
Outflow=18.49 cfs 1.326 af**Pond 10a:**Peak Elev=618.51' Inflow=35.51 cfs 2.754 af
30.0" Round Culvert n=0.012 L=112.0' S=0.0107 '/ Outflow=35.51 cfs 2.754 af**Pond 20:**Peak Elev=620.19' Inflow=10.41 cfs 0.787 af
Outflow=10.41 cfs 0.787 af**Total Runoff Area = 19.683 ac Runoff Volume = 3.540 af Average Runoff Depth = 2.16"**
100.00% Pervious = 19.683 ac 0.00% Impervious = 0.000 ac

Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 6

Summary for Subcatchment 1S: POND A NW

Runoff = 10.51 cfs @ 12.03 hrs, Volume= 0.600 af, Depth= 2.34"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

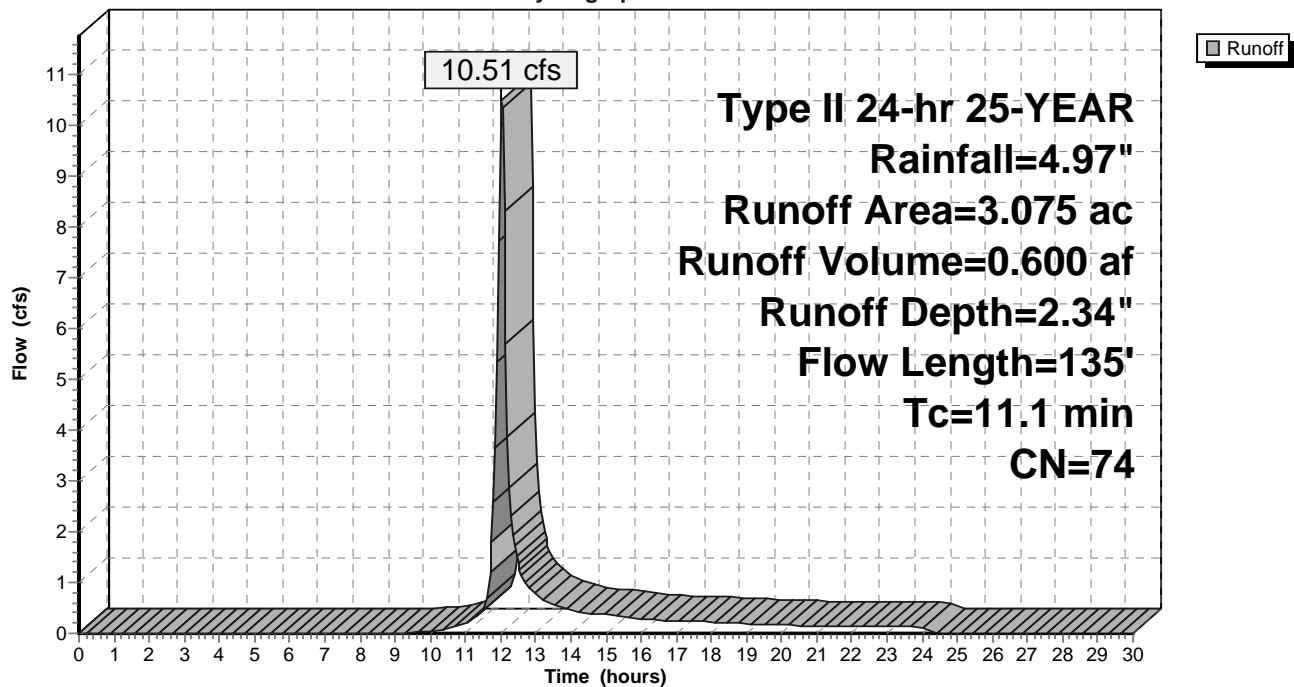
Type II 24-hr 25-YEAR Rainfall=4.97"

Area (ac)	CN	Description
3.075	74	>75% Grass cover, Good, HSG C
3.075		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.9	100	0.0200	0.15		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.2	35	0.2500	3.50		Shallow Concentrated Flow, Short Grass Pasture Kv= 7.0 fps
11.1	135	Total			

Subcatchment 1S: POND A NW

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 7

Summary for Subcatchment 2S: POND A WEST SOUTH

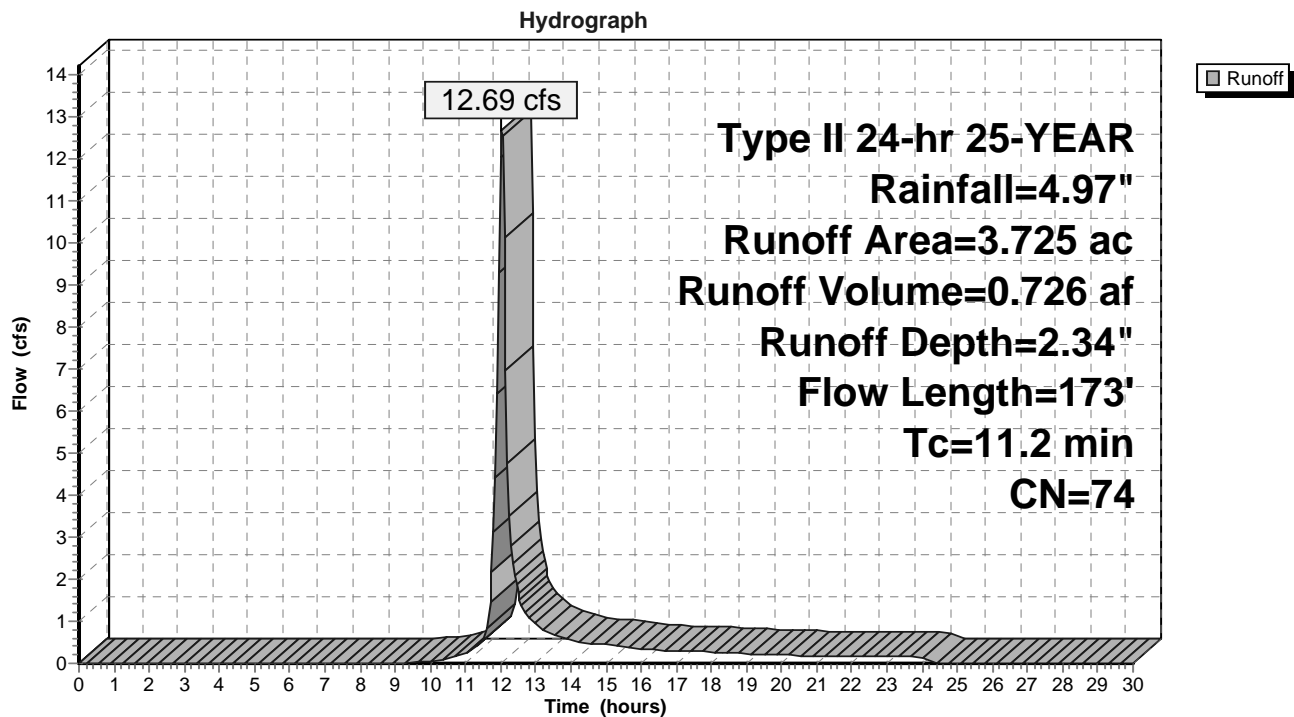
Runoff = 12.69 cfs @ 12.03 hrs, Volume= 0.726 af, Depth= 2.34"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Type II 24-hr 25-YEAR Rainfall=4.97"

Area (ac)	CN	Description
3.725	74	>75% Grass cover, Good, HSG C
3.725		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.9	100	0.0200	0.15		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.3	73	0.2500	3.50		Shallow Concentrated Flow, Short Grass Pasture Kv= 7.0 fps
11.2	173	Total			

Subcatchment 2S: POND A WEST SOUTH

Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 8

Summary for Subcatchment 3S: POND A EAST SOUTH

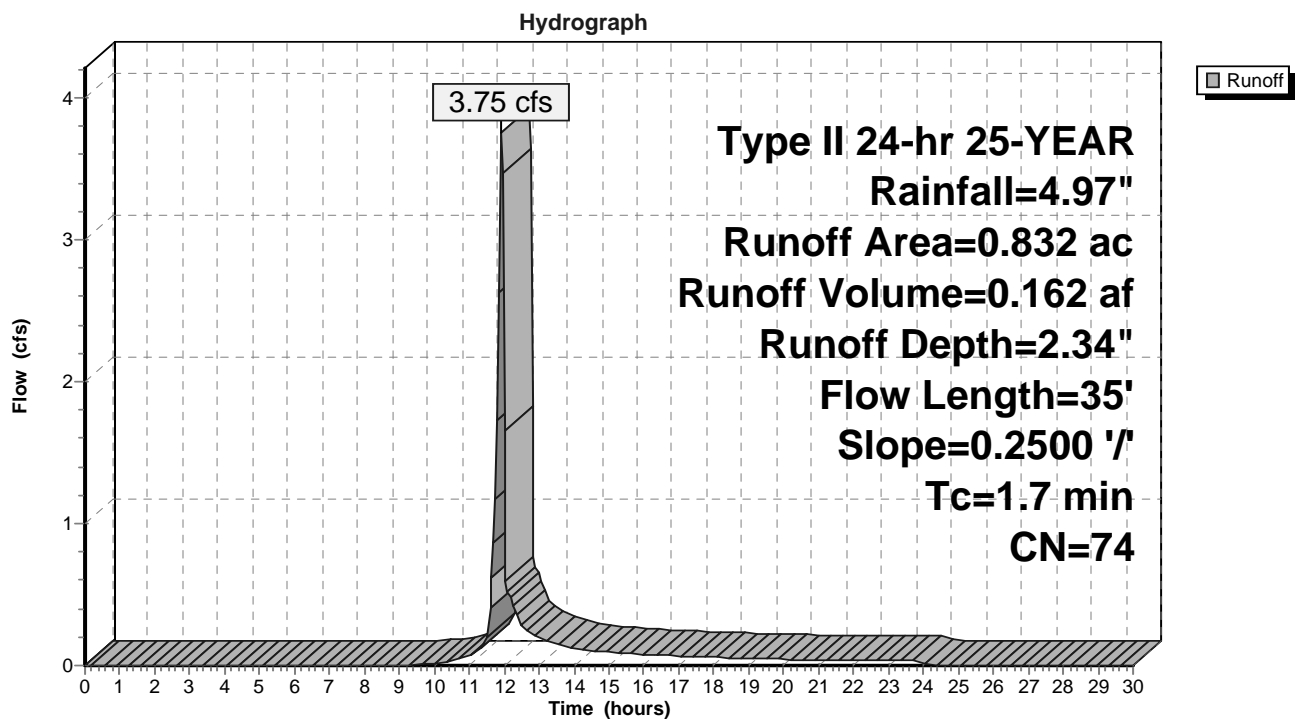
Runoff = 3.75 cfs @ 11.92 hrs, Volume= 0.162 af, Depth= 2.34"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Type II 24-hr 25-YEAR Rainfall=4.97"

Area (ac)	CN	Description
0.832	74	>75% Grass cover, Good, HSG C
0.832		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.7	35	0.2500	0.34		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment 3S: POND A EAST SOUTH

Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 9

Summary for Subcatchment 4S: POND A NE

Runoff = 10.98 cfs @ 12.03 hrs, Volume= 0.624 af, Depth= 2.34"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

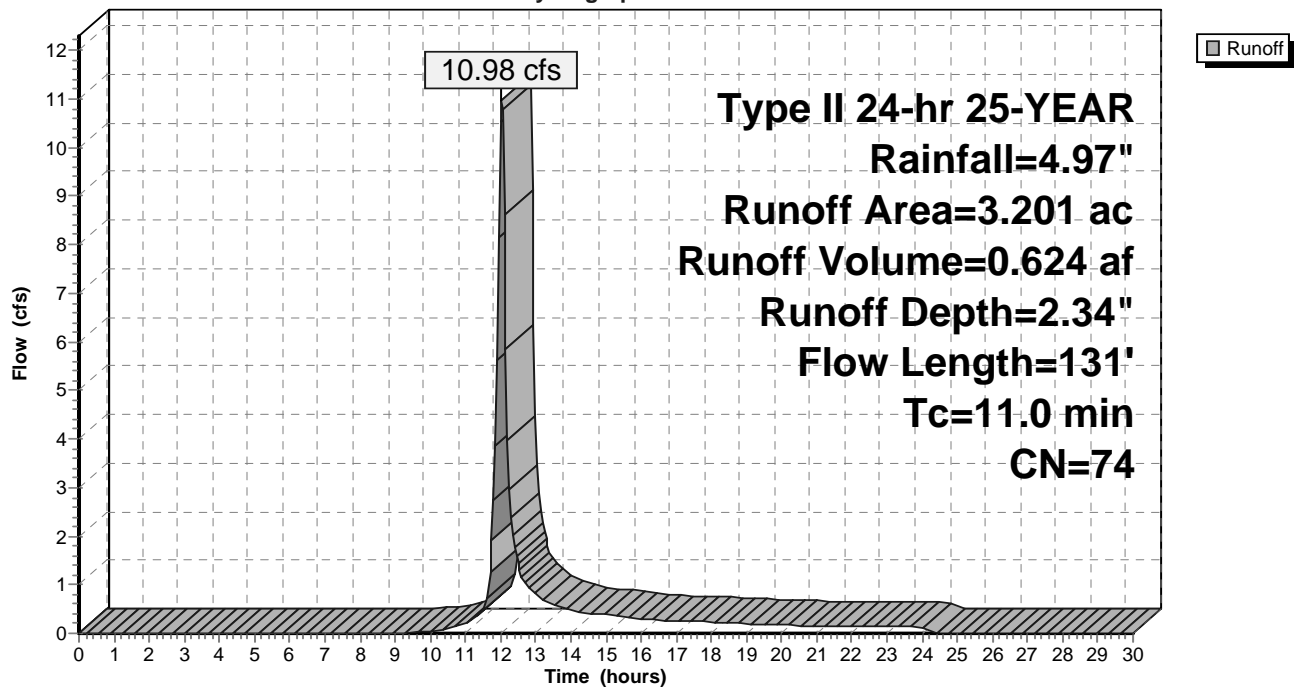
Type II 24-hr 25-YEAR Rainfall=4.97"

Area (ac)	CN	Description
3.201	74	>75% Grass cover, Good, HSG C
3.201		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.9	100	0.0200	0.15		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.1	31	0.2500	3.50		Shallow Concentrated Flow, Short Grass Pasture Kv= 7.0 fps
11.0	131	Total			

Subcatchment 4S: POND A NE

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 10

Summary for Subcatchment 5S: POND B

Runoff = 18.04 cfs @ 12.15 hrs, Volume= 1.427 af, Depth= 1.94"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

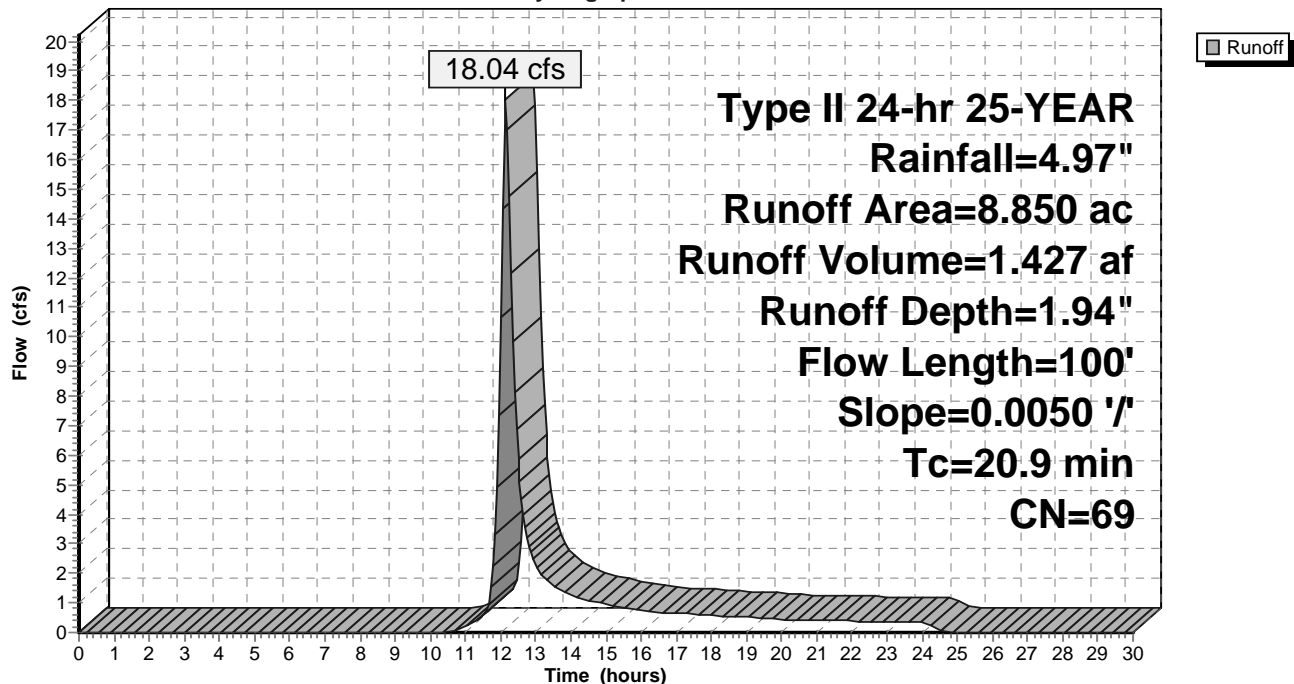
Type II 24-hr 25-YEAR Rainfall=4.97"

Area (ac)	CN	Description
8.850	69	50-75% Grass cover, Fair, HSG B
8.850		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.9	100	0.0050	0.08		Sheet Flow, Cultivated: Residue>20% n= 0.170 P2= 2.60"

Subcatchment 5S: POND B

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 11

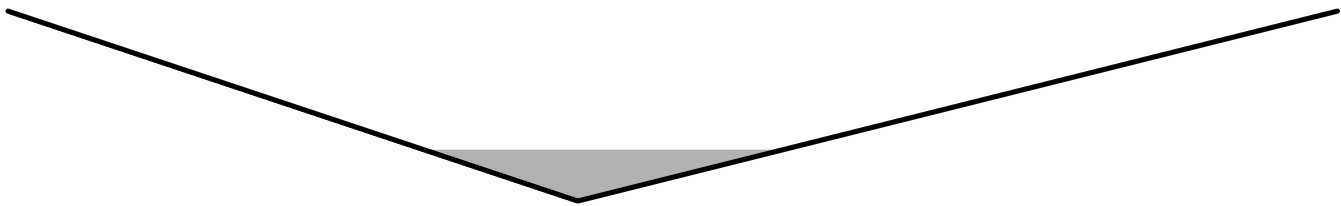
Summary for Reach 1R:

Inflow Area = 3.075 ac, 0.00% Impervious, Inflow Depth = 2.34" for 25-YEAR event
Inflow = 10.51 cfs @ 12.03 hrs, Volume= 0.600 af
Outflow = 8.78 cfs @ 12.20 hrs, Volume= 0.600 af, Atten= 17%, Lag= 9.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.15 fps, Min. Travel Time= 6.1 min
Avg. Velocity = 0.73 fps, Avg. Travel Time= 17.9 min

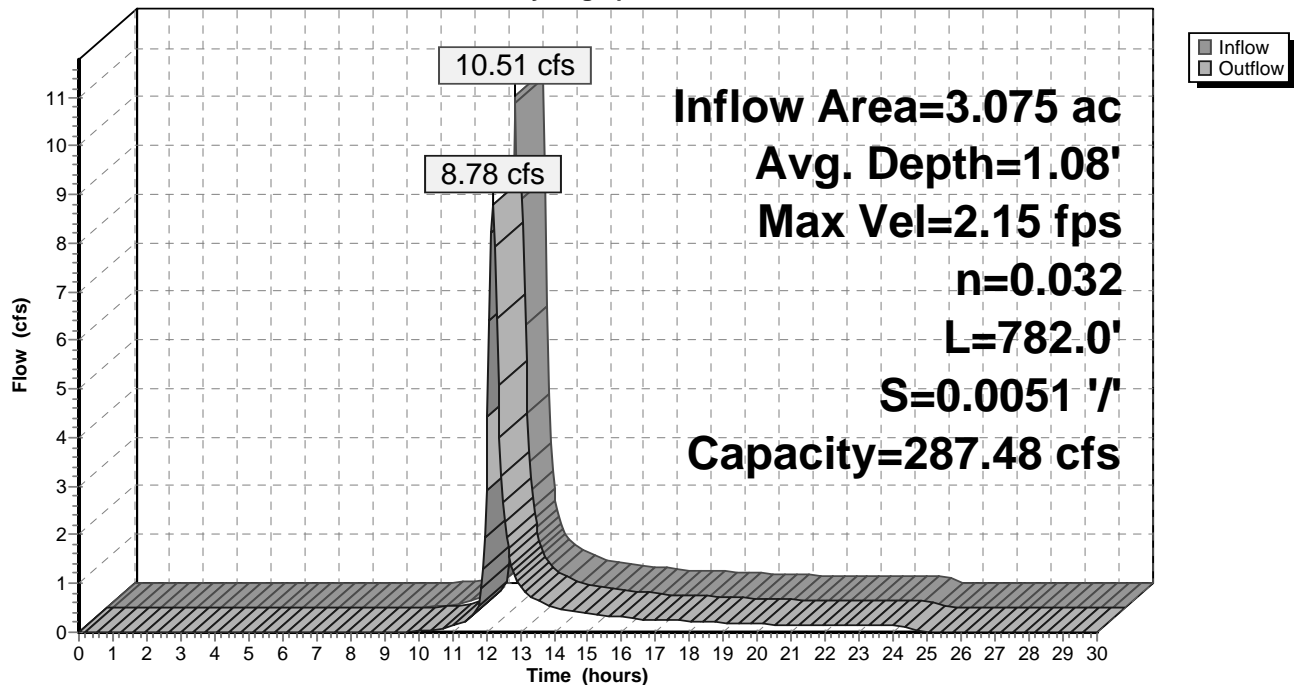
Peak Storage= 3,203 cf @ 12.09 hrs, Average Depth at Peak Storage= 1.08'
Bank-Full Depth= 4.00', Capacity at Bank-Full= 287.48 cfs

0.00' x 4.00' deep channel, n= 0.032
Side Slope Z-value= 3.0 4.0 '/' Top Width= 28.00'
Length= 782.0' Slope= 0.0051 '/'
Inlet Invert= 626.00', Outlet Invert= 622.00'



Reach 1R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 12

Summary for Reach 2R:

Inflow Area = 3.725 ac, 0.00% Impervious, Inflow Depth = 2.34" for 25-YEAR event
Inflow = 12.69 cfs @ 12.03 hrs, Volume= 0.726 af
Outflow = 9.84 cfs @ 12.23 hrs, Volume= 0.726 af, Atten= 22%, Lag= 11.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Max. Velocity= 2.16 fps, Min. Travel Time= 7.5 min

Avg. Velocity = 0.73 fps, Avg. Travel Time= 22.1 min

Peak Storage= 4,517 cf @ 12.10 hrs, Average Depth at Peak Storage= 1.08'

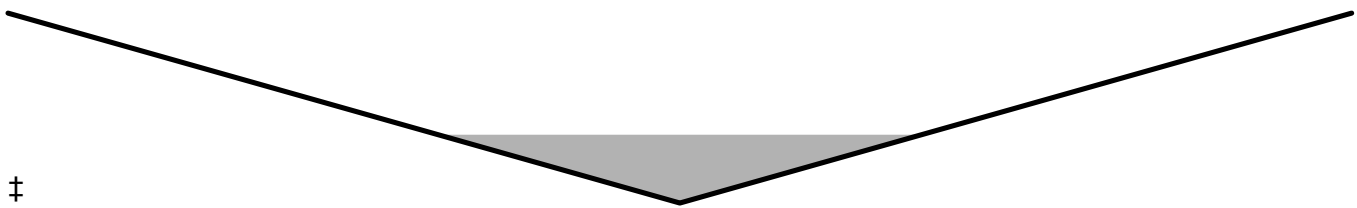
Bank-Full Depth= 3.00', Capacity at Bank-Full= 154.13 cfs

0.00' x 3.00' deep channel, n= 0.032

Side Slope Z-value= 4.0 '/ Top Width= 24.00'

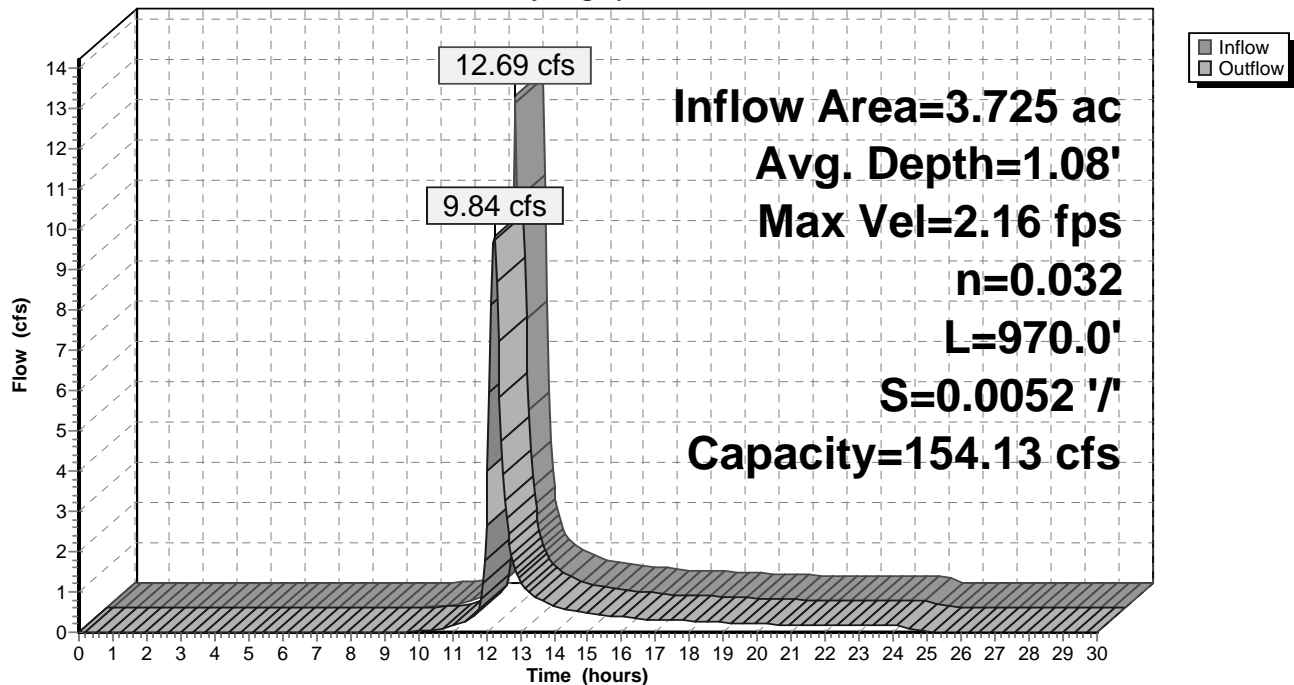
Length= 970.0' Slope= 0.0052 '/

Inlet Invert= 627.00', Outlet Invert= 622.00'



Reach 2R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 13

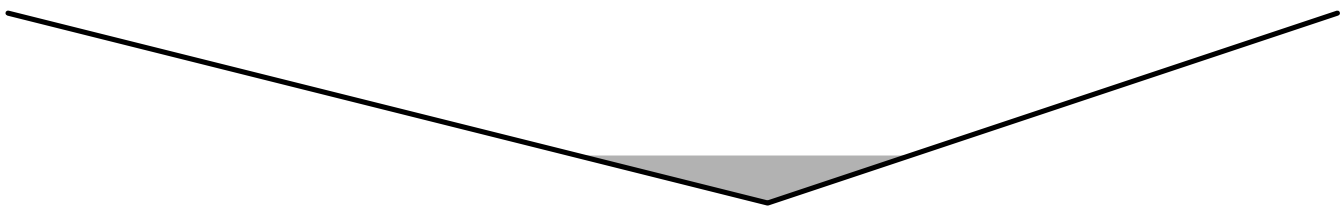
Summary for Reach 3R:

Inflow Area = 0.832 ac, 0.00% Impervious, Inflow Depth = 2.34" for 25-YEAR event
Inflow = 3.75 cfs @ 11.92 hrs, Volume= 0.162 af
Outflow = 3.13 cfs @ 12.02 hrs, Volume= 0.162 af, Atten= 17%, Lag= 5.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.66 fps, Min. Travel Time= 3.9 min
Avg. Velocity = 0.57 fps, Avg. Travel Time= 11.3 min

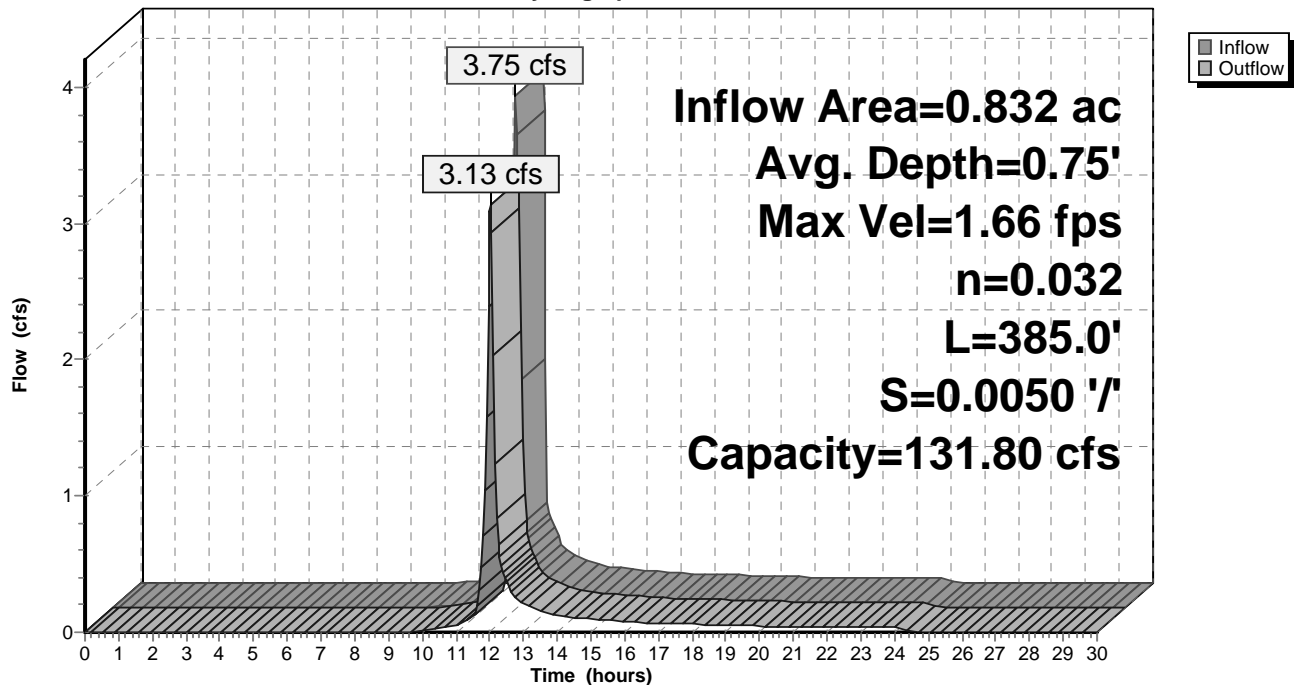
Peak Storage= 758 cf @ 11.95 hrs, Average Depth at Peak Storage= 0.75'
Bank-Full Depth= 3.00', Capacity at Bank-Full= 131.80 cfs

0.00' x 3.00' deep channel, n= 0.032
Side Slope Z-value= 4.0 3.0 '/' Top Width= 21.00'
Length= 385.0' Slope= 0.0050 '/'
Inlet Invert= 621.92', Outlet Invert= 620.00'



Reach 3R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 14

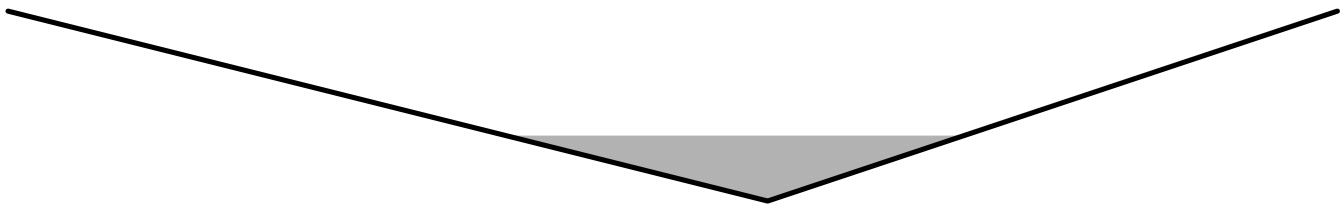
Summary for Reach 4R:

Inflow Area = 3.201 ac, 0.00% Impervious, Inflow Depth = 2.34" for 25-YEAR event
Inflow = 10.98 cfs @ 12.03 hrs, Volume= 0.624 af
Outflow = 9.33 cfs @ 12.17 hrs, Volume= 0.624 af, Atten= 15%, Lag= 8.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.53 fps, Min. Travel Time= 5.2 min
Avg. Velocity = 0.85 fps, Avg. Travel Time= 15.4 min

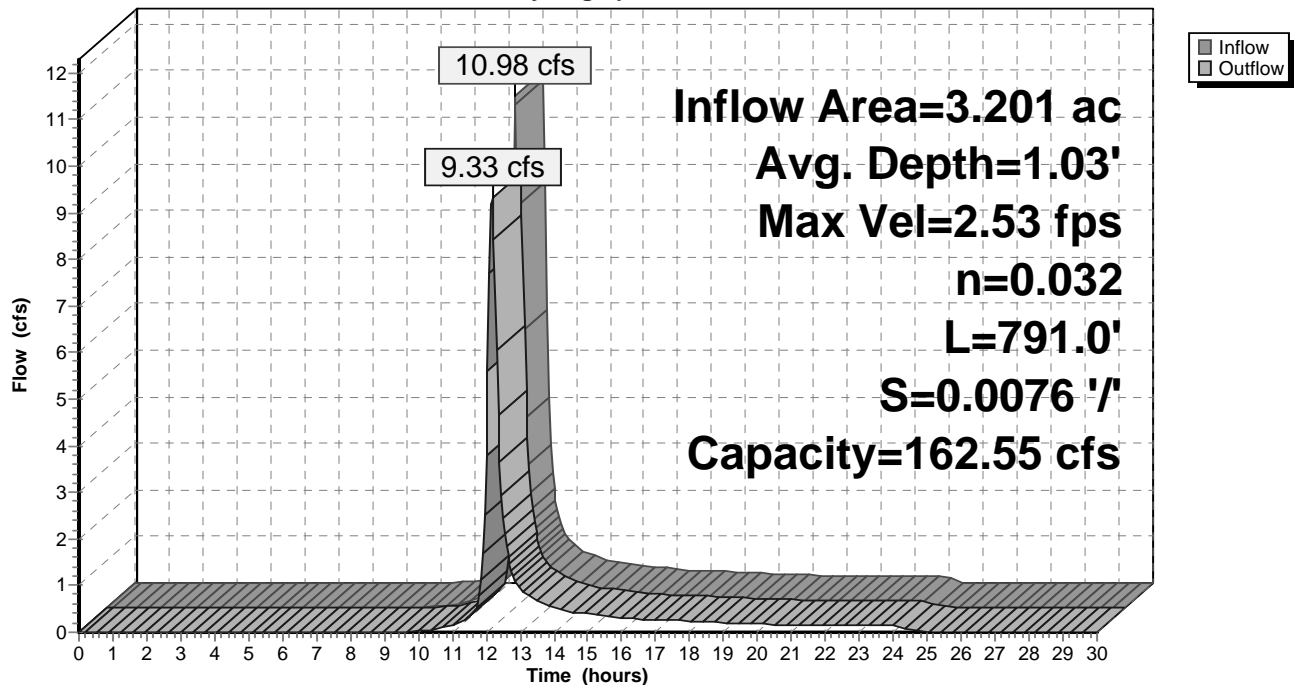
Peak Storage= 2,957 cf @ 12.09 hrs, Average Depth at Peak Storage= 1.03'
Bank-Full Depth= 3.00', Capacity at Bank-Full= 162.55 cfs

0.00' x 3.00' deep channel, n= 0.032
Side Slope Z-value= 4.0 3.0 '/' Top Width= 21.00'
Length= 791.0' Slope= 0.0076 '/'
Inlet Invert= 626.00', Outlet Invert= 620.00'



Reach 4R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 15

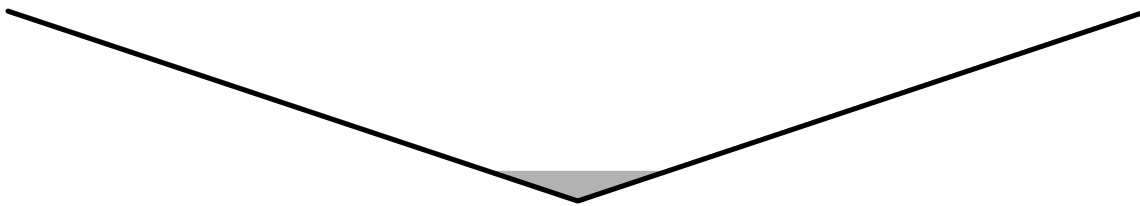
Summary for Reach 5R:

Inflow Area = 4.033 ac, 0.00% Impervious, Inflow Depth = 2.34" for 25-YEAR event
Inflow = 10.41 cfs @ 12.15 hrs, Volume= 0.787 af
Outflow = 10.39 cfs @ 12.16 hrs, Volume= 0.787 af, Atten= 0%, Lag= 0.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 15.18 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 5.86 fps, Avg. Travel Time= 0.2 min

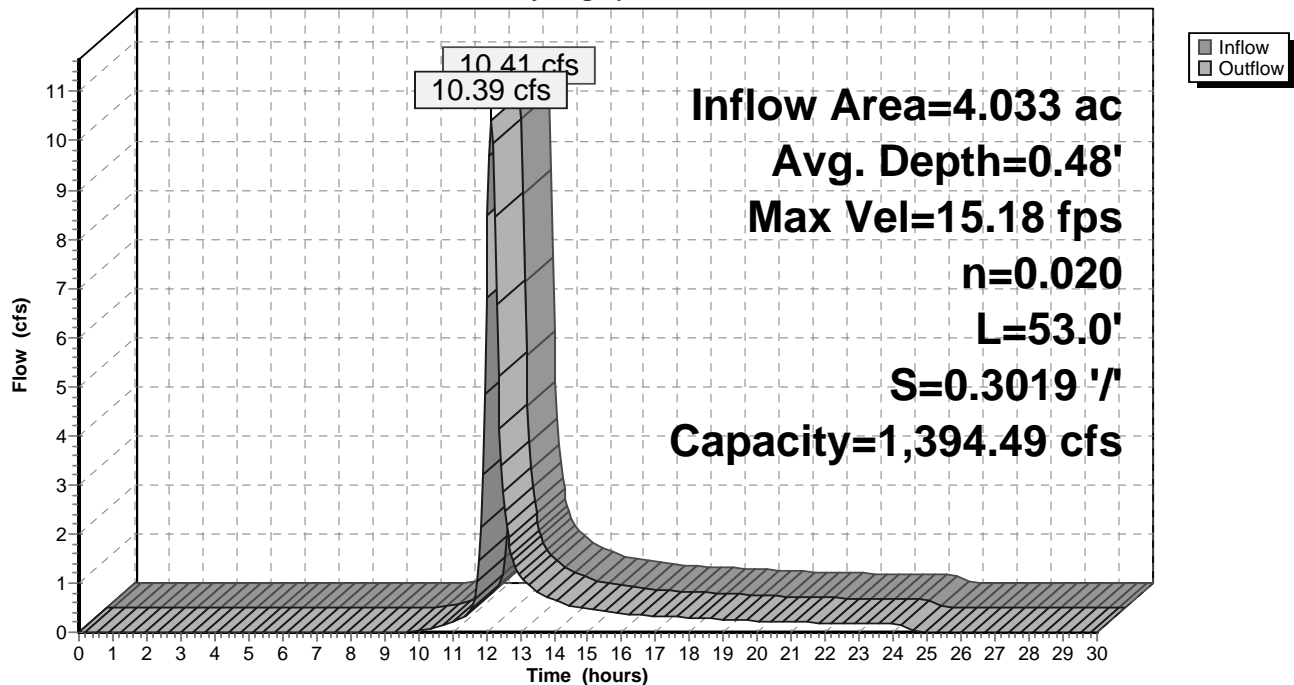
Peak Storage= 36 cf @ 12.16 hrs, Average Depth at Peak Storage= 0.48'
Bank-Full Depth= 3.00', Capacity at Bank-Full= 1,394.49 cfs

0.00' x 3.00' deep channel, n= 0.020 Concrete, unfinished
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 53.0' Slope= 0.3019 '/'
Inlet Invert= 614.00', Outlet Invert= 598.00'



Reach 5R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 16

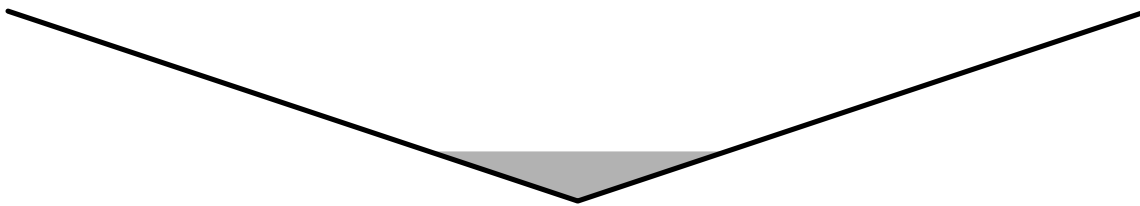
Summary for Reach 6R:

Inflow Area = 15.650 ac, 0.00% Impervious, Inflow Depth = 2.11" for 25-YEAR event
Inflow = 35.51 cfs @ 12.19 hrs, Volume= 2.754 af
Outflow = 35.48 cfs @ 12.19 hrs, Volume= 2.754 af, Atten= 0%, Lag= 0.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 19.33 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 6.88 fps, Avg. Travel Time= 0.2 min

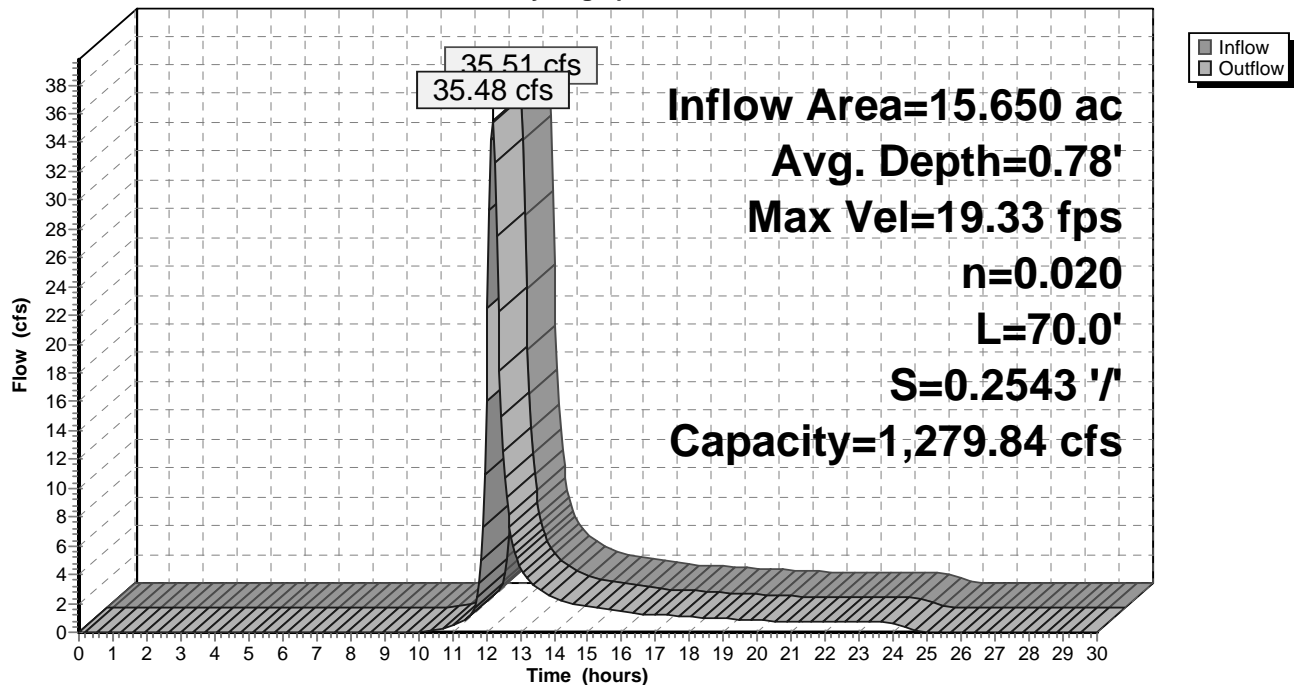
Peak Storage= 129 cf @ 12.19 hrs, Average Depth at Peak Storage= 0.78'
Bank-Full Depth= 3.00', Capacity at Bank-Full= 1,279.84 cfs

0.00' x 3.00' deep channel, n= 0.020 Concrete, unfinished
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 70.0' Slope= 0.2543 '/'
Inlet Invert= 613.80', Outlet Invert= 596.00'



Reach 6R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 17

Summary for Pond 10:

Inflow Area = 6.800 ac, 0.00% Impervious, Inflow Depth = 2.34" for 25-YEAR event
Inflow = 18.49 cfs @ 12.21 hrs, Volume= 1.326 af
Outflow = 18.49 cfs @ 12.21 hrs, Volume= 1.326 af, Atten= 0%, Lag= 0.0 min
Primary = 18.49 cfs @ 12.21 hrs, Volume= 1.326 af

Routing by Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Peak Elev= 622.61' @ 12.21 hrs

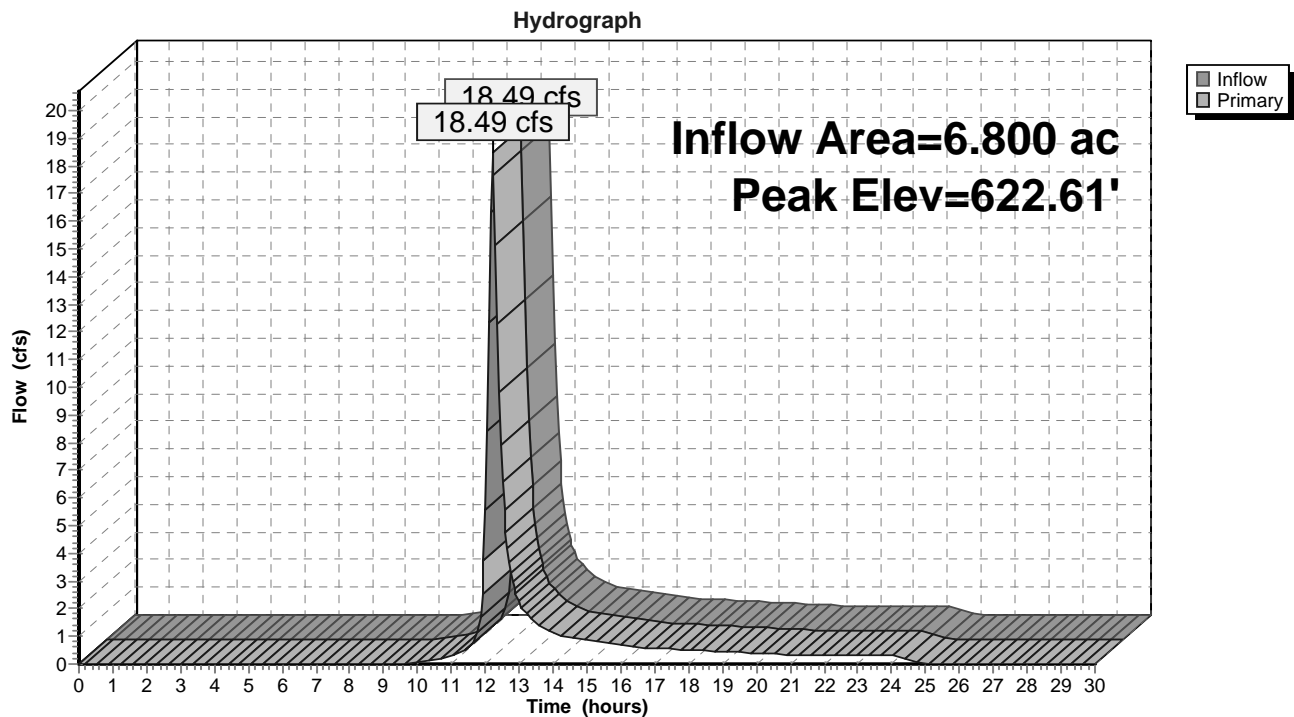
Device	Routing	Invert	Outlet Devices
#1	Primary	617.00'	30.0" Round Culvert L= 115.0' CPP, square edge headwall, Ke= 0.500 Outlet Invert= 615.80' S= 0.0104 '/ Cc= 0.900 n= 0.012
#2	Device 1	622.00'	30.0" Horiz. Orifice/Grate C= 0.600

Primary OutFlow Max=18.23 cfs @ 12.21 hrs HW=622.60' (Free Discharge)

1=Culvert (Passes 18.23 cfs of 49.27 cfs potential flow)

2=Orifice/Grate (Orifice Controls 18.23 cfs @ 3.71 fps)

Pond 10:



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 18

Summary for Pond 10a:

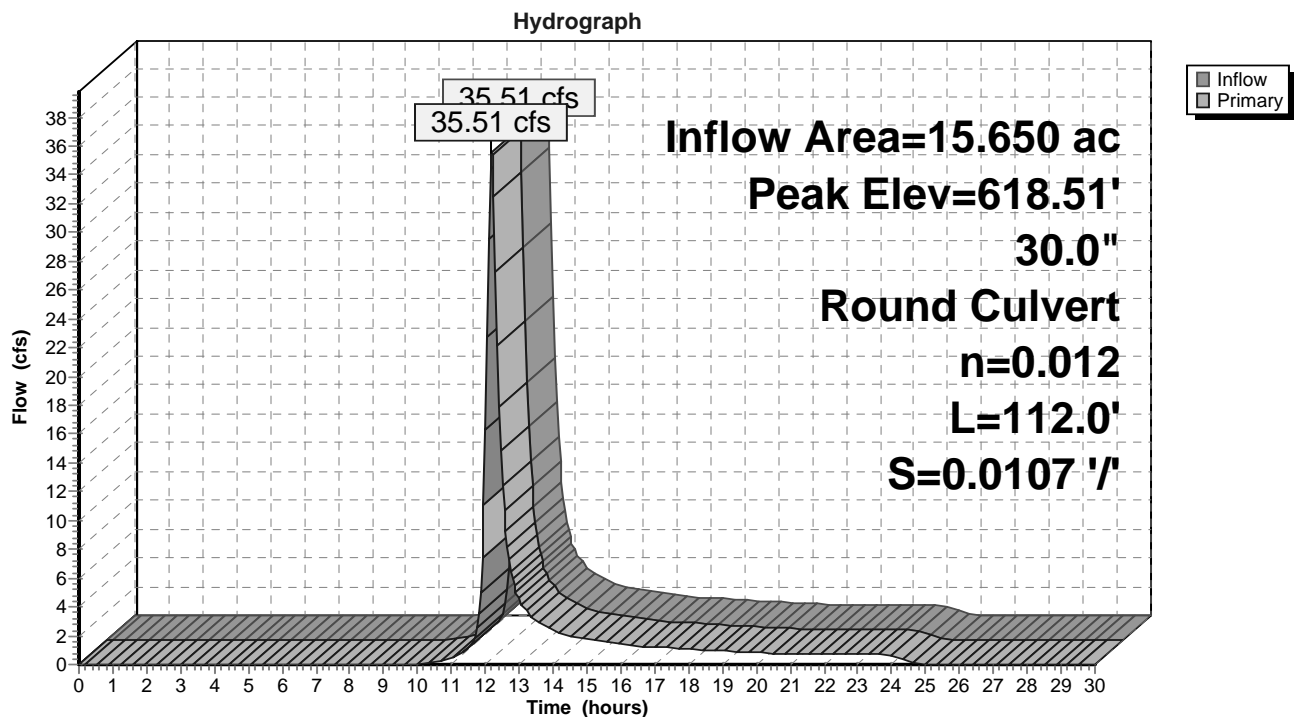
Inflow Area = 15.650 ac, 0.00% Impervious, Inflow Depth = 2.11" for 25-YEAR event
Inflow = 35.51 cfs @ 12.19 hrs, Volume= 2.754 af
Outflow = 35.51 cfs @ 12.19 hrs, Volume= 2.754 af, Atten= 0%, Lag= 0.0 min
Primary = 35.51 cfs @ 12.19 hrs, Volume= 2.754 af

Routing by Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Peak Elev= 618.51' @ 12.19 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	615.00'	30.0" Round Culvert L= 112.0' RCP, end-section conforming to fill, Ke= 0.500 Outlet Invert= 613.80' S= 0.0107 '/ Cc= 0.900 n= 0.012 Concrete pipe, finished

Primary OutFlow Max=35.15 cfs @ 12.19 hrs HW=618.46' (Free Discharge)
↑ **1=Culvert** (Inlet Controls 35.15 cfs @ 7.16 fps)

Pond 10a:



Pond A Stormwater_7-12-18

Type II 24-hr 25-YEAR Rainfall=4.97"

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Page 19

Summary for Pond 20:

Inflow Area = 4.033 ac, 0.00% Impervious, Inflow Depth = 2.34" for 25-YEAR event
Inflow = 10.41 cfs @ 12.15 hrs, Volume= 0.787 af
Outflow = 10.41 cfs @ 12.15 hrs, Volume= 0.787 af, Atten= 0%, Lag= 0.0 min
Primary = 10.41 cfs @ 12.15 hrs, Volume= 0.787 af

Routing by Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Peak Elev= 620.19' @ 12.15 hrs

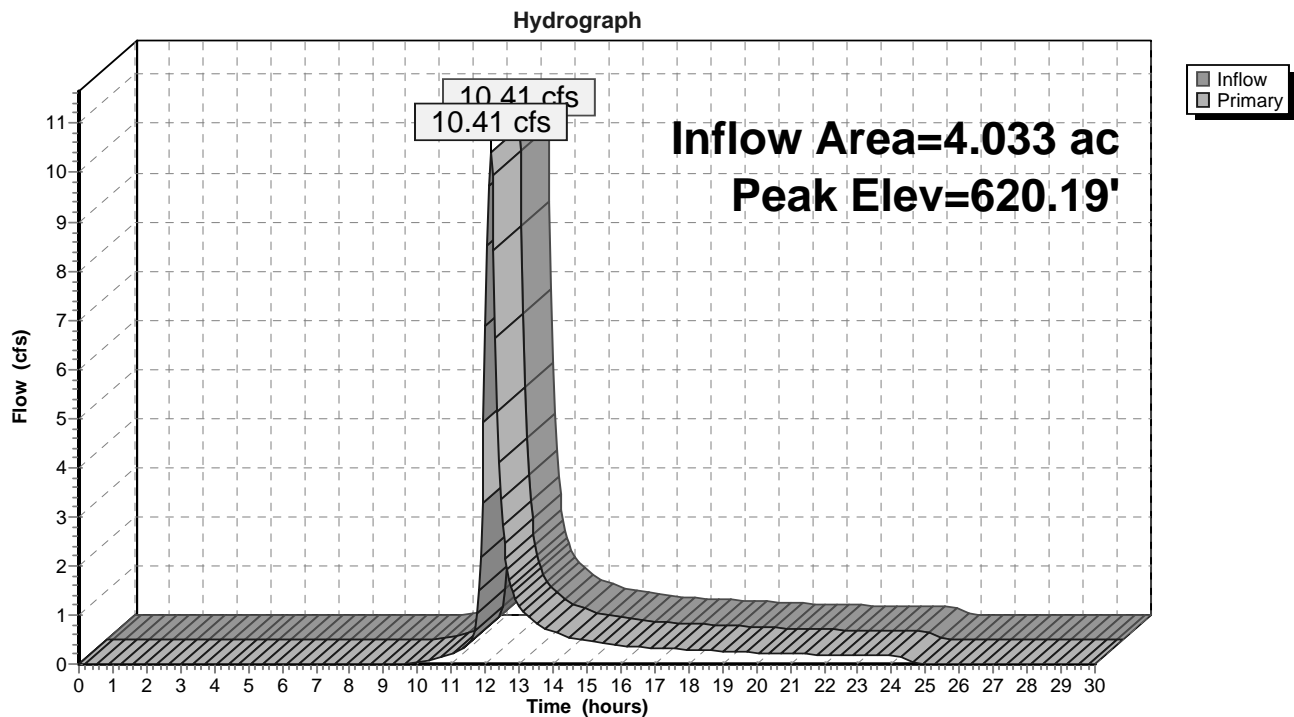
Device	Routing	Invert	Outlet Devices
#1	Primary	615.00'	30.0" Round Culvert L= 95.0' CPP, square edge headwall, Ke= 0.500 Outlet Invert= 614.00' S= 0.0105 '/ Cc= 0.900 n= 0.012
#2	Device 1	620.00'	30.0" Horiz. Orifice/Grate C= 0.600

Primary OutFlow Max=10.38 cfs @ 12.15 hrs HW=620.19' (Free Discharge)

1=Culvert (Passes 10.38 cfs of 46.93 cfs potential flow)

2=Orifice/Grate (Orifice Controls 10.38 cfs @ 2.11 fps)

Pond 20:



Pond A Stormwater_7-12-18*Type II 24-hr 100-YEAR Rainfall=6.95"*

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Page 20

Time span=0.00-30.00 hrs, dt=0.05 hrs, 601 points

Runoff by SCS TR-20 method, UH=SCS

Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: POND A NWRunoff Area=3.075 ac 0.00% Impervious Runoff Depth=4.00"
Flow Length=135' Tc=11.1 min CN=74 Runoff=17.87 cfs 1.025 af**Subcatchment 2S: POND A WEST SOUTH**Runoff Area=3.725 ac 0.00% Impervious Runoff Depth=4.00"
Flow Length=173' Tc=11.2 min CN=74 Runoff=21.59 cfs 1.241 af**Subcatchment 3S: POND A EAST SOUTH**Runoff Area=0.832 ac 0.00% Impervious Runoff Depth=4.00"
Flow Length=35' Slope=0.2500 '/' Tc=1.7 min CN=74 Runoff=6.32 cfs 0.277 af**Subcatchment 4S: POND A NE**Runoff Area=3.201 ac 0.00% Impervious Runoff Depth=4.00"
Flow Length=131' Tc=11.0 min CN=74 Runoff=18.66 cfs 1.067 af**Subcatchment 5S: POND B**Runoff Area=8.850 ac 0.00% Impervious Runoff Depth=3.47"
Flow Length=100' Slope=0.0050 '/' Tc=20.9 min CN=69 Runoff=33.09 cfs 2.561 af**Reach 1R:**Avg. Depth=1.34' Max Vel=2.47 fps Inflow=17.87 cfs 1.025 af
n=0.032 L=782.0' S=0.0051 '/' Capacity=287.48 cfs Outflow=15.29 cfs 1.025 af**Reach 2R:**Avg. Depth=1.34' Max Vel=2.50 fps Inflow=21.59 cfs 1.241 af
n=0.032 L=970.0' S=0.0052 '/' Capacity=154.13 cfs Outflow=17.79 cfs 1.241 af**Reach 3R:**Avg. Depth=0.92' Max Vel=1.91 fps Inflow=6.32 cfs 0.277 af
n=0.032 L=385.0' S=0.0050 '/' Capacity=131.80 cfs Outflow=5.57 cfs 0.277 af**Reach 4R:**Avg. Depth=1.28' Max Vel=2.90 fps Inflow=18.66 cfs 1.067 af
n=0.032 L=791.0' S=0.0076 '/' Capacity=162.55 cfs Outflow=16.30 cfs 1.067 af**Reach 5R:**Avg. Depth=0.59' Max Vel=17.41 fps Inflow=18.13 cfs 1.344 af
n=0.020 L=53.0' S=0.3019 '/' Capacity=1,394.49 cfs Outflow=18.12 cfs 1.344 af**Reach 6R:**Avg. Depth=0.98' Max Vel=22.46 fps Inflow=65.04 cfs 4.827 af
n=0.020 L=70.0' S=0.2543 '/' Capacity=1,279.84 cfs Outflow=64.96 cfs 4.827 af**Pond 1O:**Peak Elev=623.93' Inflow=32.82 cfs 2.266 af
Outflow=32.82 cfs 2.266 af**Pond 1Oa:**Peak Elev=623.81' Inflow=65.04 cfs 4.827 af
30.0" Round Culvert n=0.012 L=112.0' S=0.0107 '/' Outflow=65.04 cfs 4.827 af**Pond 2O:**Peak Elev=620.59' Inflow=18.13 cfs 1.344 af
Outflow=18.13 cfs 1.344 af**Total Runoff Area = 19.683 ac Runoff Volume = 6.171 af Average Runoff Depth = 3.76"**
100.00% Pervious = 19.683 ac 0.00% Impervious = 0.000 ac

Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 21

Summary for Subcatchment 1S: POND A NW

Runoff = 17.87 cfs @ 12.03 hrs, Volume= 1.025 af, Depth= 4.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

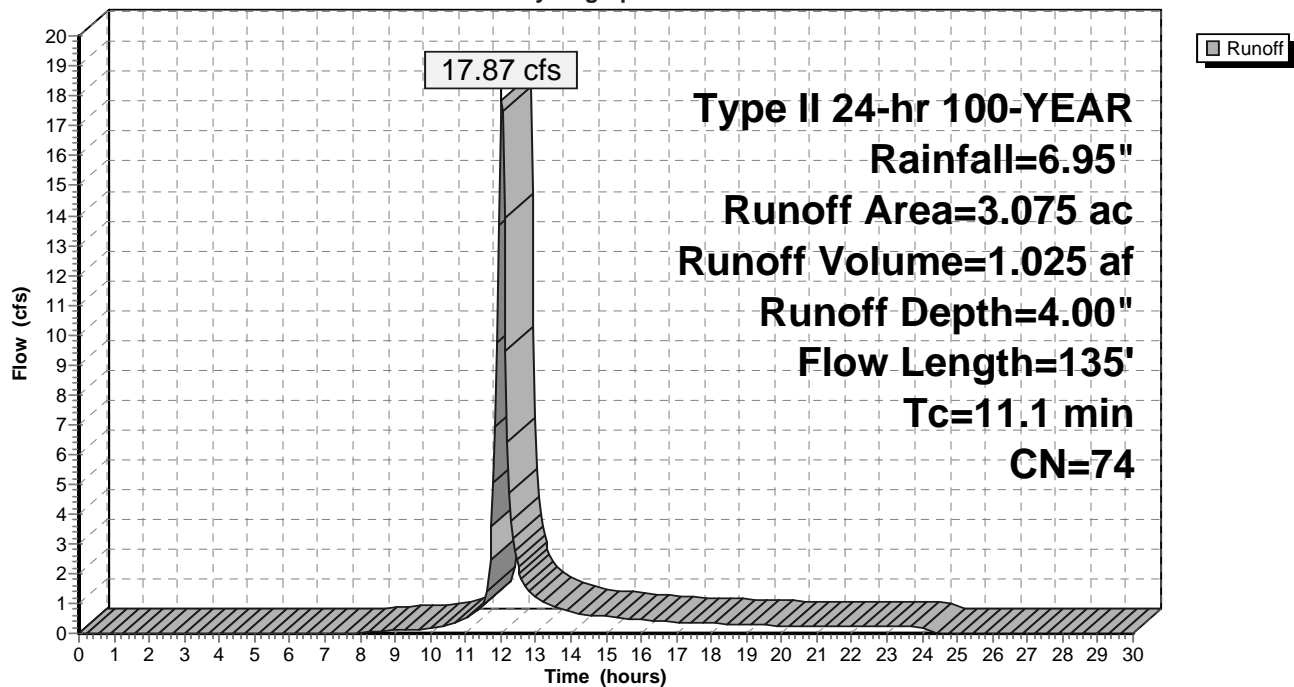
Type II 24-hr 100-YEAR Rainfall=6.95"

Area (ac)	CN	Description
3.075	74	>75% Grass cover, Good, HSG C
3.075		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.9	100	0.0200	0.15		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.2	35	0.2500	3.50		Shallow Concentrated Flow, Short Grass Pasture Kv= 7.0 fps
11.1	135	Total			

Subcatchment 1S: POND A NW

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 22

Summary for Subcatchment 2S: POND A WEST SOUTH

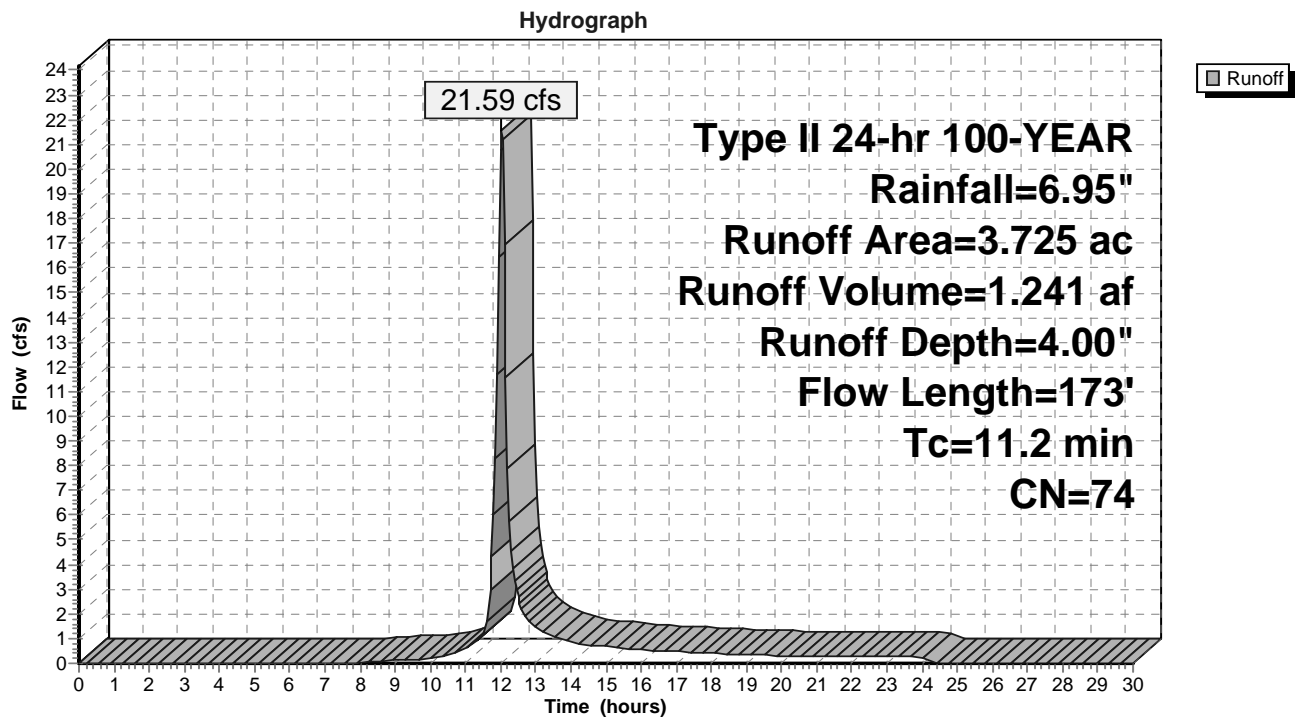
Runoff = 21.59 cfs @ 12.03 hrs, Volume= 1.241 af, Depth= 4.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Type II 24-hr 100-YEAR Rainfall=6.95"

Area (ac)	CN	Description
3.725	74	>75% Grass cover, Good, HSG C
3.725		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.9	100	0.0200	0.15		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.3	73	0.2500	3.50		Shallow Concentrated Flow, Short Grass Pasture Kv= 7.0 fps
11.2	173	Total			

Subcatchment 2S: POND A WEST SOUTH

Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 23

Summary for Subcatchment 3S: POND A EAST SOUTH

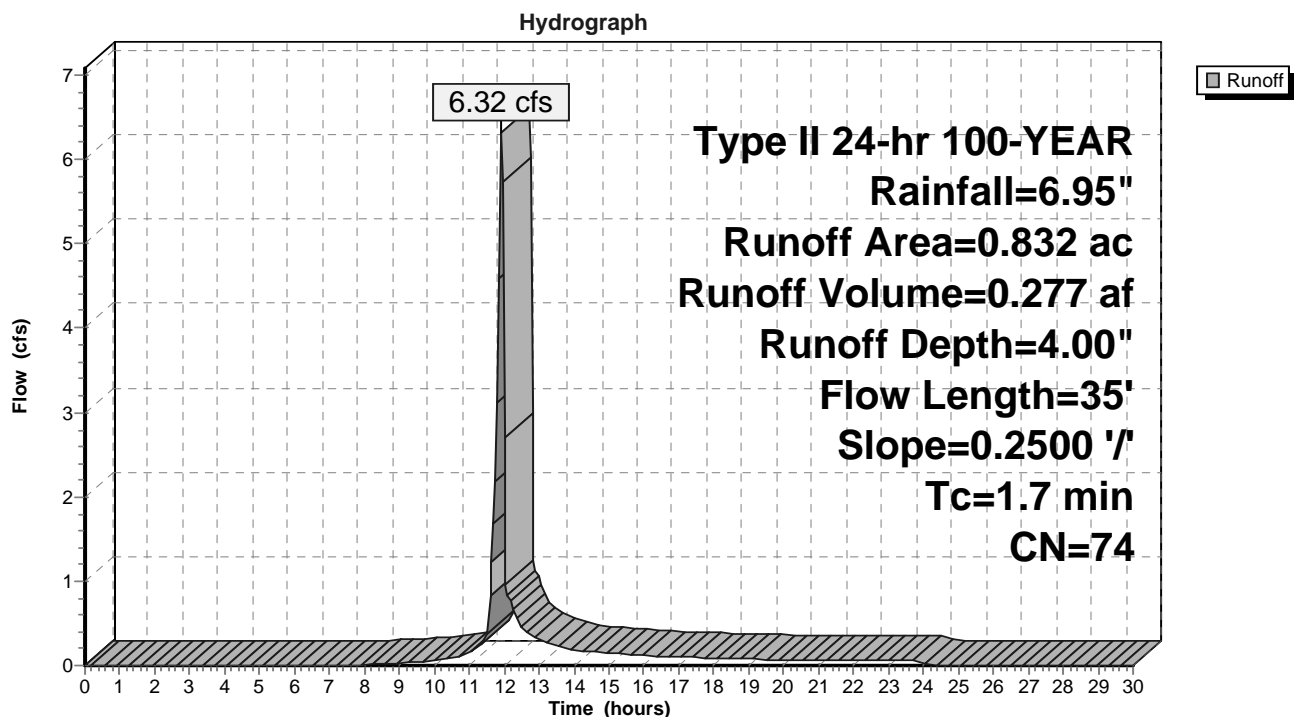
Runoff = 6.32 cfs @ 11.91 hrs, Volume= 0.277 af, Depth= 4.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Type II 24-hr 100-YEAR Rainfall=6.95"

Area (ac)	CN	Description
0.832	74	>75% Grass cover, Good, HSG C
0.832		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.7	35	0.2500	0.34		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment 3S: POND A EAST SOUTH

Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 24

Summary for Subcatchment 4S: POND A NE

Runoff = 18.66 cfs @ 12.03 hrs, Volume= 1.067 af, Depth= 4.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

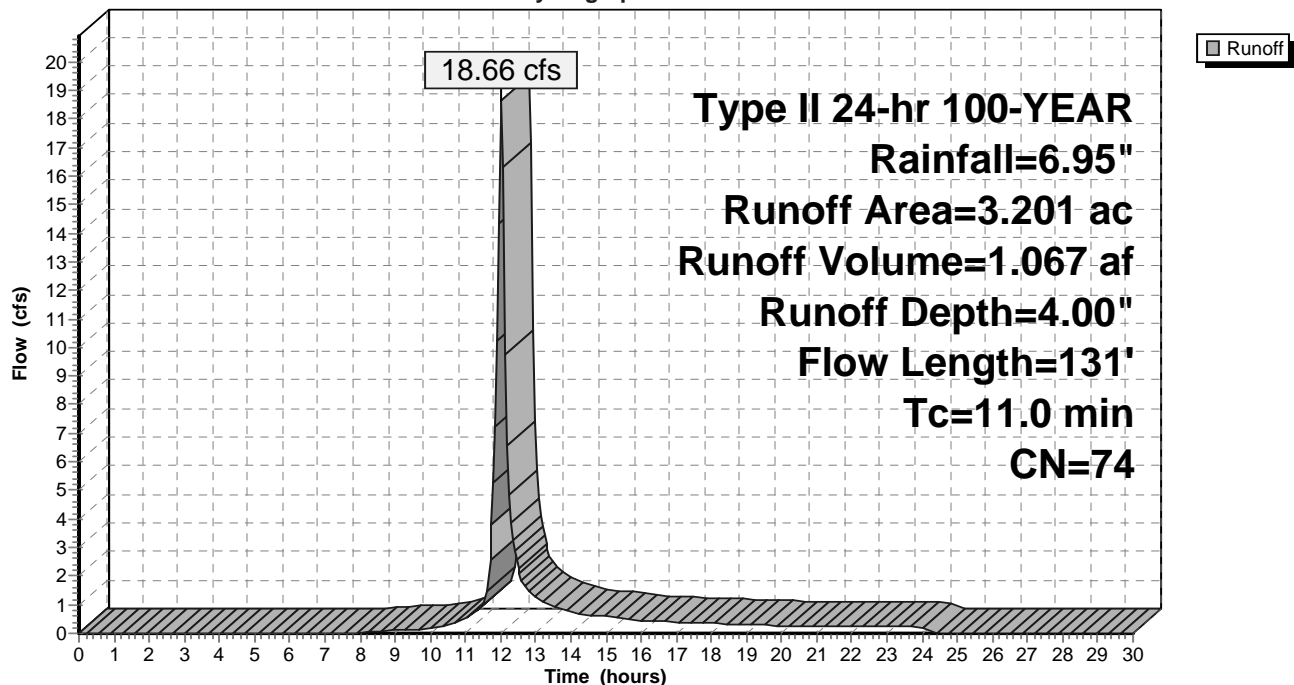
Type II 24-hr 100-YEAR Rainfall=6.95"

Area (ac)	CN	Description
3.201	74	>75% Grass cover, Good, HSG C
3.201		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.9	100	0.0200	0.15		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.1	31	0.2500	3.50		Shallow Concentrated Flow, Short Grass Pasture Kv= 7.0 fps
11.0	131	Total			

Subcatchment 4S: POND A NE

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 25

Summary for Subcatchment 5S: POND B

Runoff = 33.09 cfs @ 12.14 hrs, Volume= 2.561 af, Depth= 3.47"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

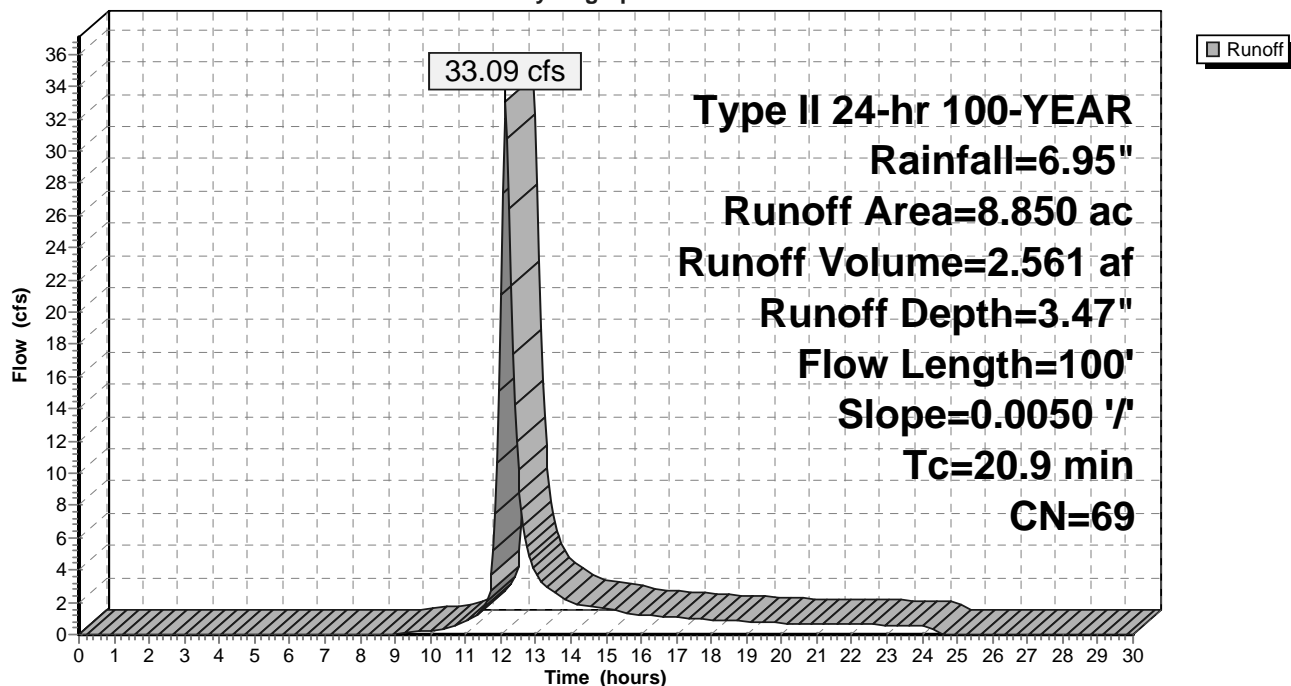
Type II 24-hr 100-YEAR Rainfall=6.95"

Area (ac)	CN	Description
8.850	69	50-75% Grass cover, Fair, HSG B
8.850		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.9	100	0.0050	0.08		Sheet Flow, Cultivated: Residue>20% n= 0.170 P2= 2.60"

Subcatchment 5S: POND B

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 26

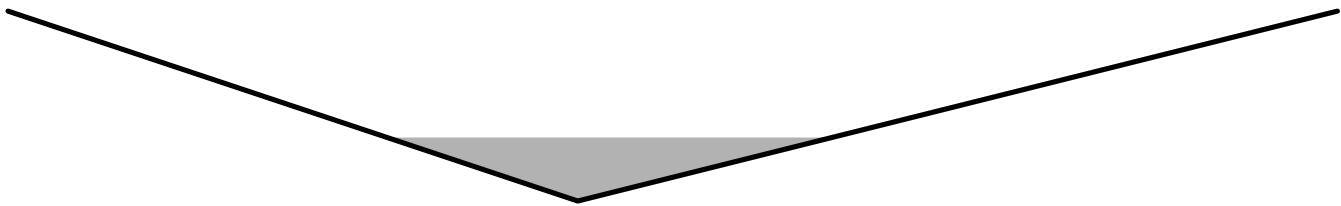
Summary for Reach 1R:

Inflow Area = 3.075 ac, 0.00% Impervious, Inflow Depth = 4.00" for 100-YEAR event
Inflow = 17.87 cfs @ 12.03 hrs, Volume= 1.025 af
Outflow = 15.29 cfs @ 12.17 hrs, Volume= 1.025 af, Atten= 14%, Lag= 8.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.47 fps, Min. Travel Time= 5.3 min
Avg. Velocity = 0.80 fps, Avg. Travel Time= 16.2 min

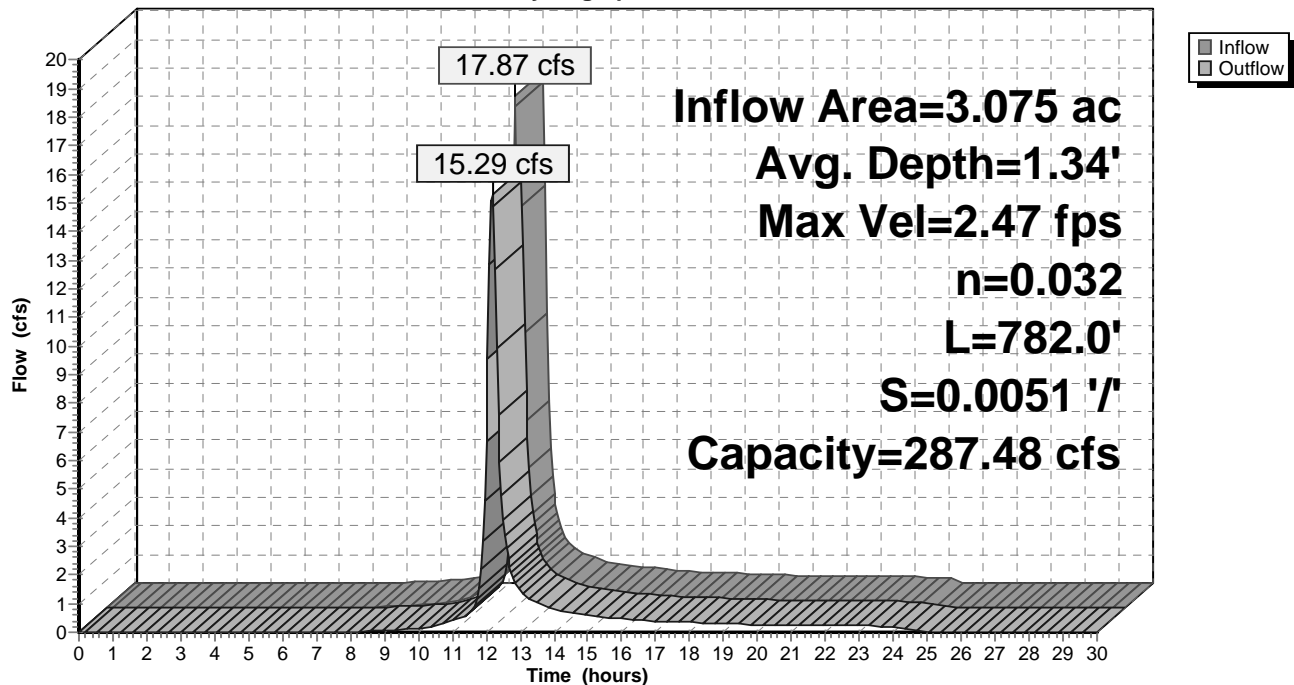
Peak Storage= 4,903 cf @ 12.08 hrs, Average Depth at Peak Storage= 1.34'
Bank-Full Depth= 4.00', Capacity at Bank-Full= 287.48 cfs

0.00' x 4.00' deep channel, n= 0.032
Side Slope Z-value= 3.0 4.0 '/' Top Width= 28.00'
Length= 782.0' Slope= 0.0051 '/'
Inlet Invert= 626.00', Outlet Invert= 622.00'



Reach 1R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 27

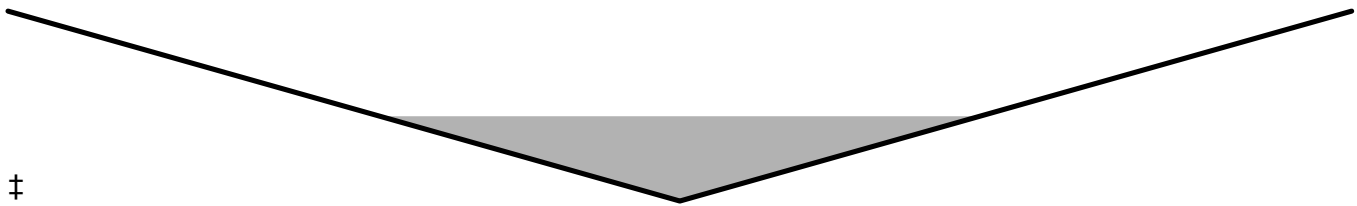
Summary for Reach 2R:

Inflow Area = 3.725 ac, 0.00% Impervious, Inflow Depth = 4.00" for 100-YEAR event
Inflow = 21.59 cfs @ 12.03 hrs, Volume= 1.241 af
Outflow = 17.79 cfs @ 12.20 hrs, Volume= 1.241 af, Atten= 18%, Lag= 10.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.50 fps, Min. Travel Time= 6.5 min
Avg. Velocity = 0.81 fps, Avg. Travel Time= 20.0 min

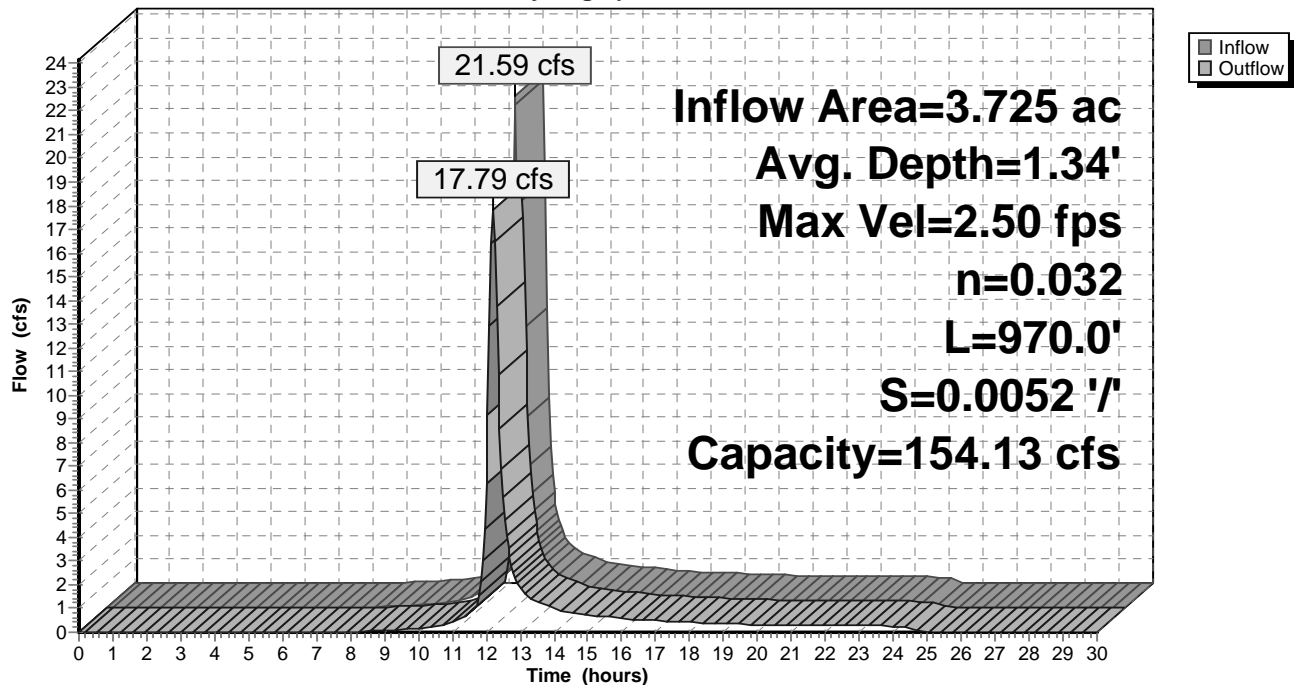
Peak Storage= 6,966 cf @ 12.09 hrs, Average Depth at Peak Storage= 1.34'
Bank-Full Depth= 3.00', Capacity at Bank-Full= 154.13 cfs

0.00' x 3.00' deep channel, n= 0.032
Side Slope Z-value= 4.0 '/' Top Width= 24.00'
Length= 970.0' Slope= 0.0052 '/'
Inlet Invert= 627.00', Outlet Invert= 622.00'



Reach 2R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 28

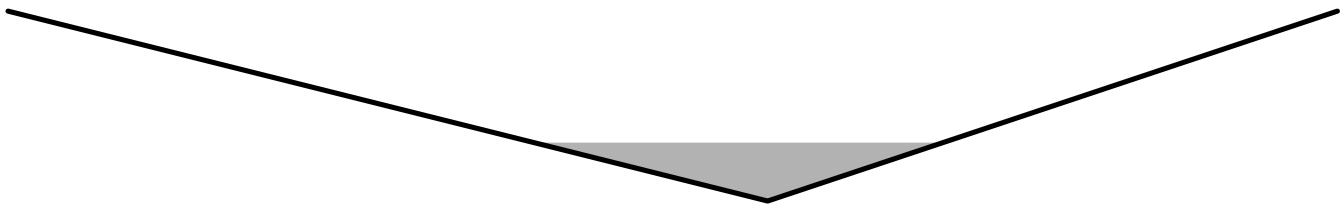
Summary for Reach 3R:

Inflow Area = 0.832 ac, 0.00% Impervious, Inflow Depth = 4.00" for 100-YEAR event
Inflow = 6.32 cfs @ 11.91 hrs, Volume= 0.277 af
Outflow = 5.57 cfs @ 12.00 hrs, Volume= 0.277 af, Atten= 12%, Lag= 5.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.91 fps, Min. Travel Time= 3.4 min
Avg. Velocity = 0.63 fps, Avg. Travel Time= 10.2 min

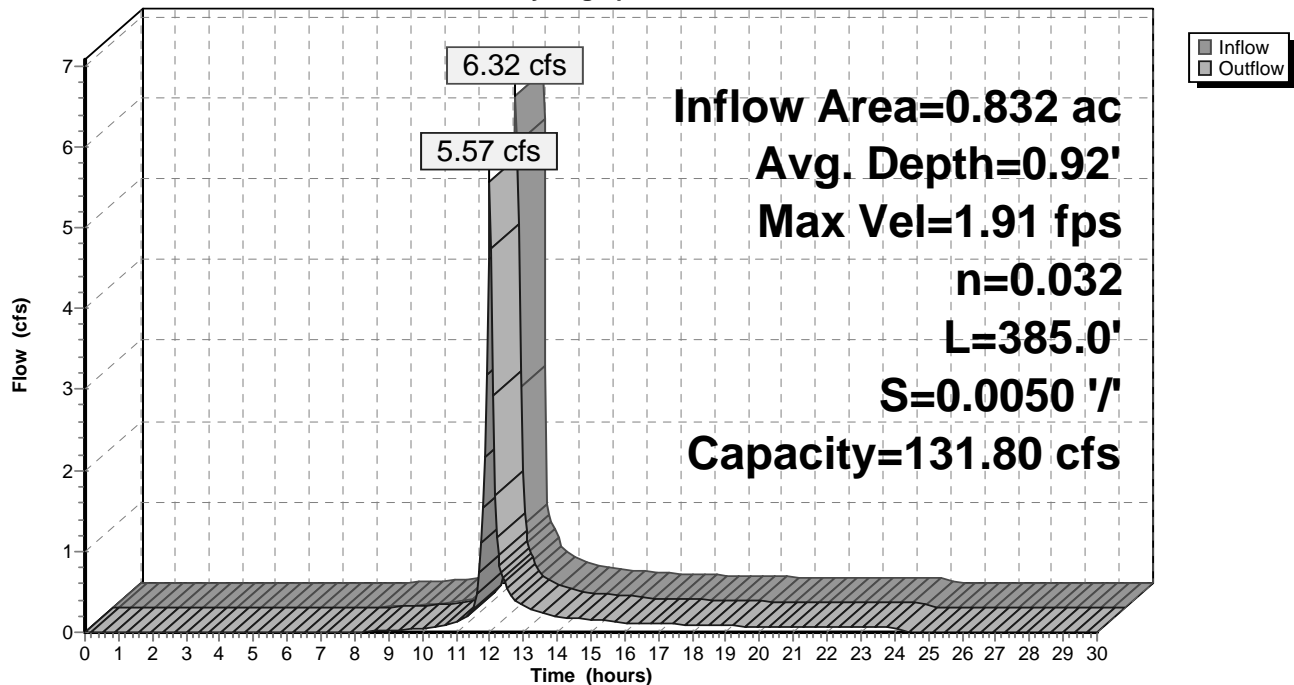
Peak Storage= 1,147 cf @ 11.95 hrs, Average Depth at Peak Storage= 0.92'
Bank-Full Depth= 3.00', Capacity at Bank-Full= 131.80 cfs

0.00' x 3.00' deep channel, n= 0.032
Side Slope Z-value= 4.0 3.0 '/' Top Width= 21.00'
Length= 385.0' Slope= 0.0050 '/'
Inlet Invert= 621.92', Outlet Invert= 620.00'



Reach 3R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 29

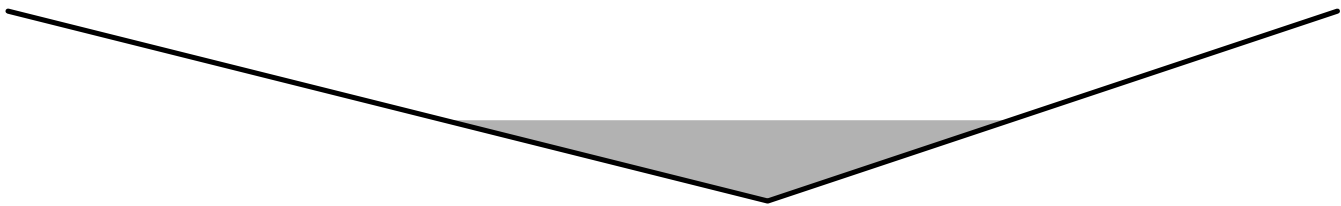
Summary for Reach 4R:

Inflow Area = 3.201 ac, 0.00% Impervious, Inflow Depth = 4.00" for 100-YEAR event
Inflow = 18.66 cfs @ 12.03 hrs, Volume= 1.067 af
Outflow = 16.30 cfs @ 12.15 hrs, Volume= 1.067 af, Atten= 13%, Lag= 7.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.90 fps, Min. Travel Time= 4.5 min
Avg. Velocity = 0.94 fps, Avg. Travel Time= 14.0 min

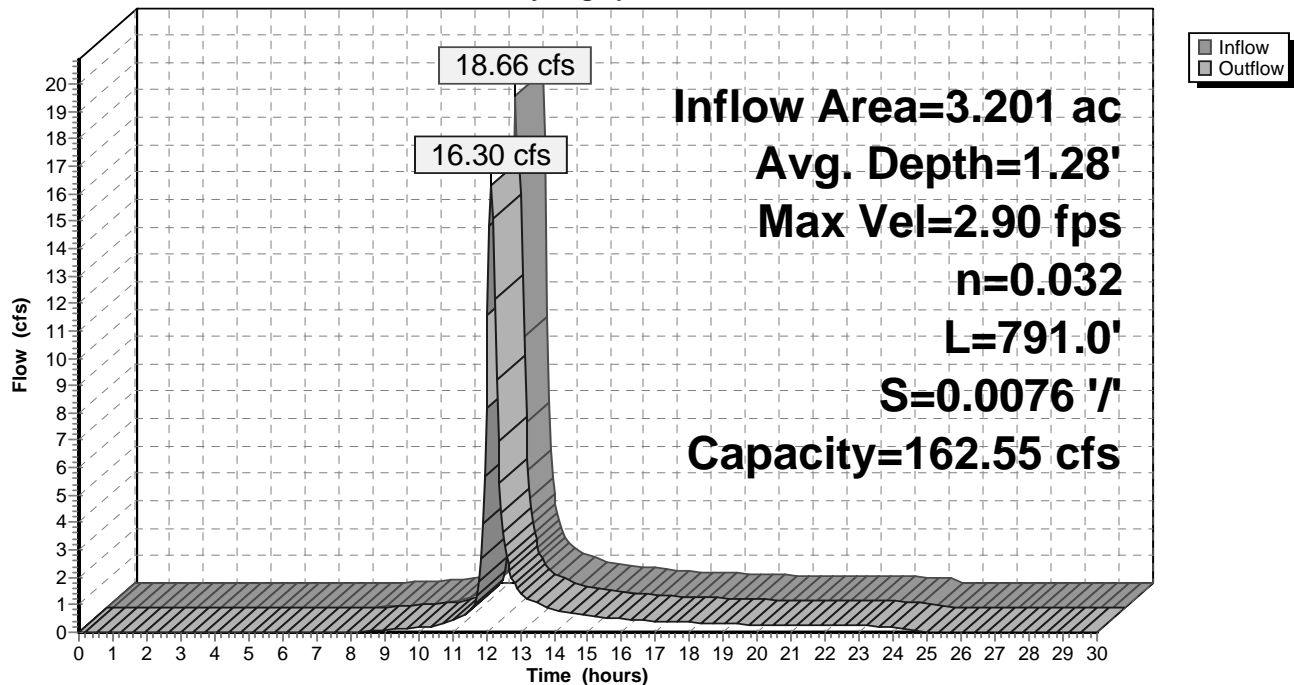
Peak Storage= 4,506 cf @ 12.08 hrs, Average Depth at Peak Storage= 1.28'
Bank-Full Depth= 3.00', Capacity at Bank-Full= 162.55 cfs

0.00' x 3.00' deep channel, n= 0.032
Side Slope Z-value= 4.0 3.0 '/' Top Width= 21.00'
Length= 791.0' Slope= 0.0076 '/'
Inlet Invert= 626.00', Outlet Invert= 620.00'



Reach 4R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 30

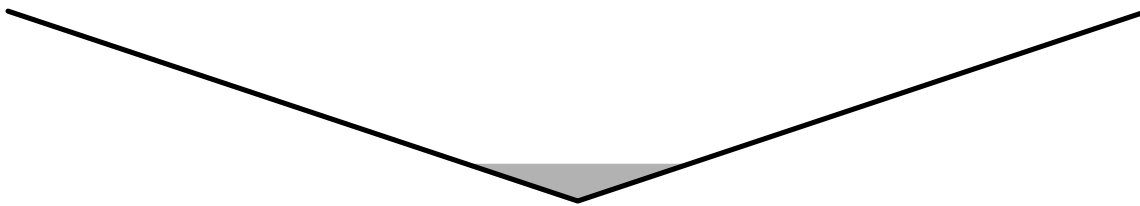
Summary for Reach 5R:

Inflow Area = 4.033 ac, 0.00% Impervious, Inflow Depth = 4.00" for 100-YEAR event
Inflow = 18.13 cfs @ 12.13 hrs, Volume= 1.344 af
Outflow = 18.12 cfs @ 12.13 hrs, Volume= 1.344 af, Atten= 0%, Lag= 0.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 17.41 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 6.41 fps, Avg. Travel Time= 0.1 min

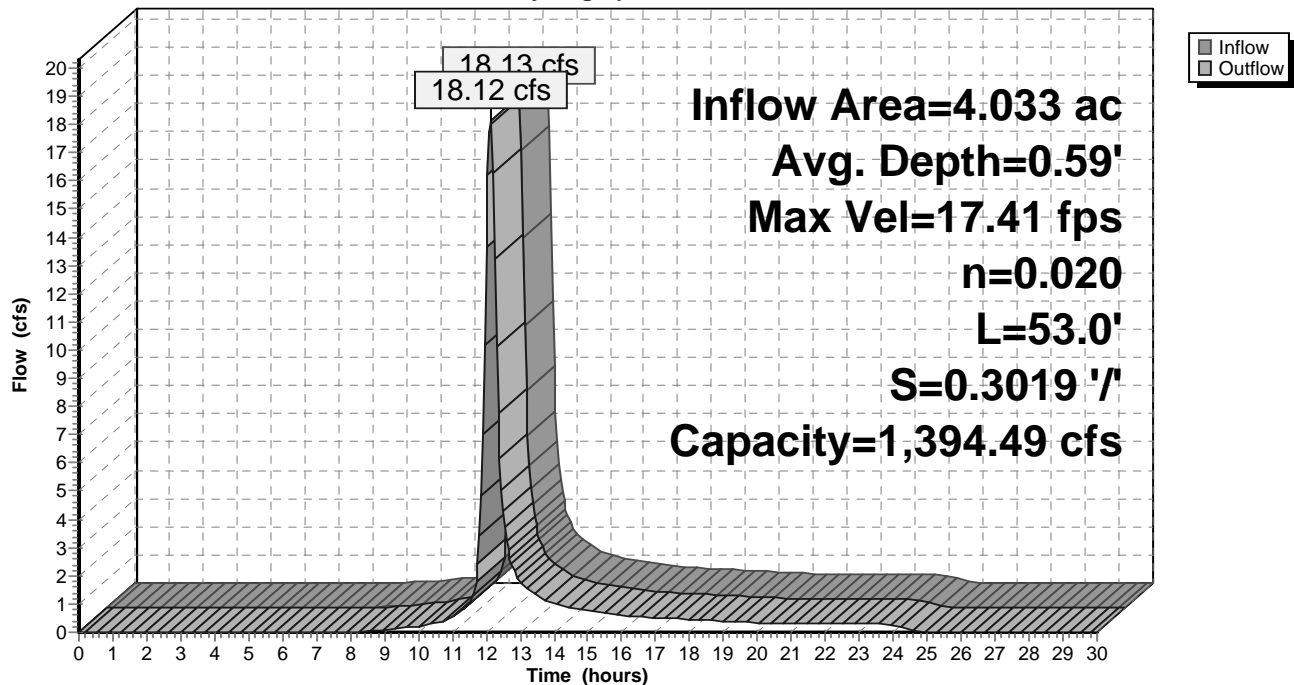
Peak Storage= 55 cf @ 12.13 hrs, Average Depth at Peak Storage= 0.59'
Bank-Full Depth= 3.00', Capacity at Bank-Full= 1,394.49 cfs

0.00' x 3.00' deep channel, n= 0.020 Concrete, unfinished
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 53.0' Slope= 0.3019 '/'
Inlet Invert= 614.00', Outlet Invert= 598.00'



Reach 5R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 31

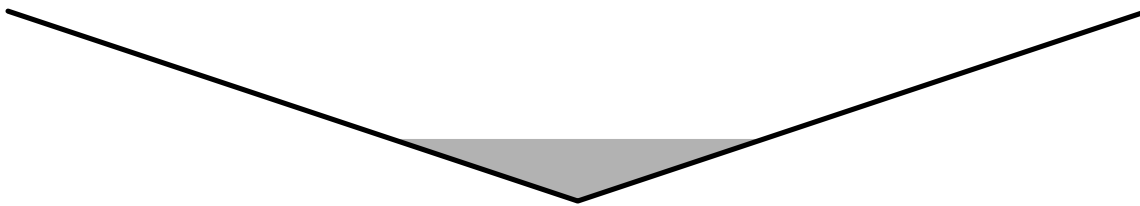
Summary for Reach 6R:

Inflow Area = 15.650 ac, 0.00% Impervious, Inflow Depth = 3.70" for 100-YEAR event
Inflow = 65.04 cfs @ 12.17 hrs, Volume= 4.827 af
Outflow = 64.96 cfs @ 12.17 hrs, Volume= 4.827 af, Atten= 0%, Lag= 0.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Max. Velocity= 22.46 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 7.61 fps, Avg. Travel Time= 0.2 min

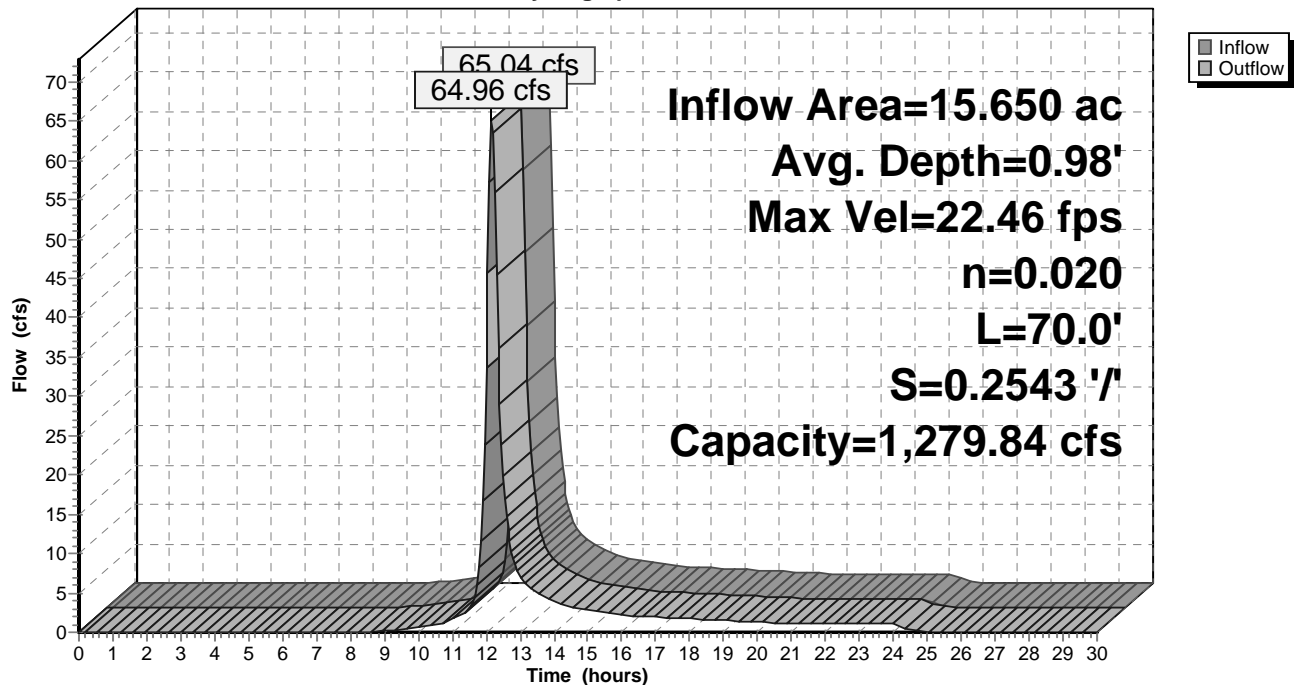
Peak Storage= 202 cf @ 12.17 hrs, Average Depth at Peak Storage= 0.98'
Bank-Full Depth= 3.00', Capacity at Bank-Full= 1,279.84 cfs

0.00' x 3.00' deep channel, n= 0.020 Concrete, unfinished
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 70.0' Slope= 0.2543 '/'
Inlet Invert= 613.80', Outlet Invert= 596.00'



Reach 6R:

Hydrograph



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 32

Summary for Pond 10:

Inflow Area = 6.800 ac, 0.00% Impervious, Inflow Depth = 4.00" for 100-YEAR event
Inflow = 32.82 cfs @ 12.19 hrs, Volume= 2.266 af
Outflow = 32.82 cfs @ 12.19 hrs, Volume= 2.266 af, Atten= 0%, Lag= 0.0 min
Primary = 32.82 cfs @ 12.19 hrs, Volume= 2.266 af

Routing by Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Peak Elev= 623.93' @ 12.19 hrs

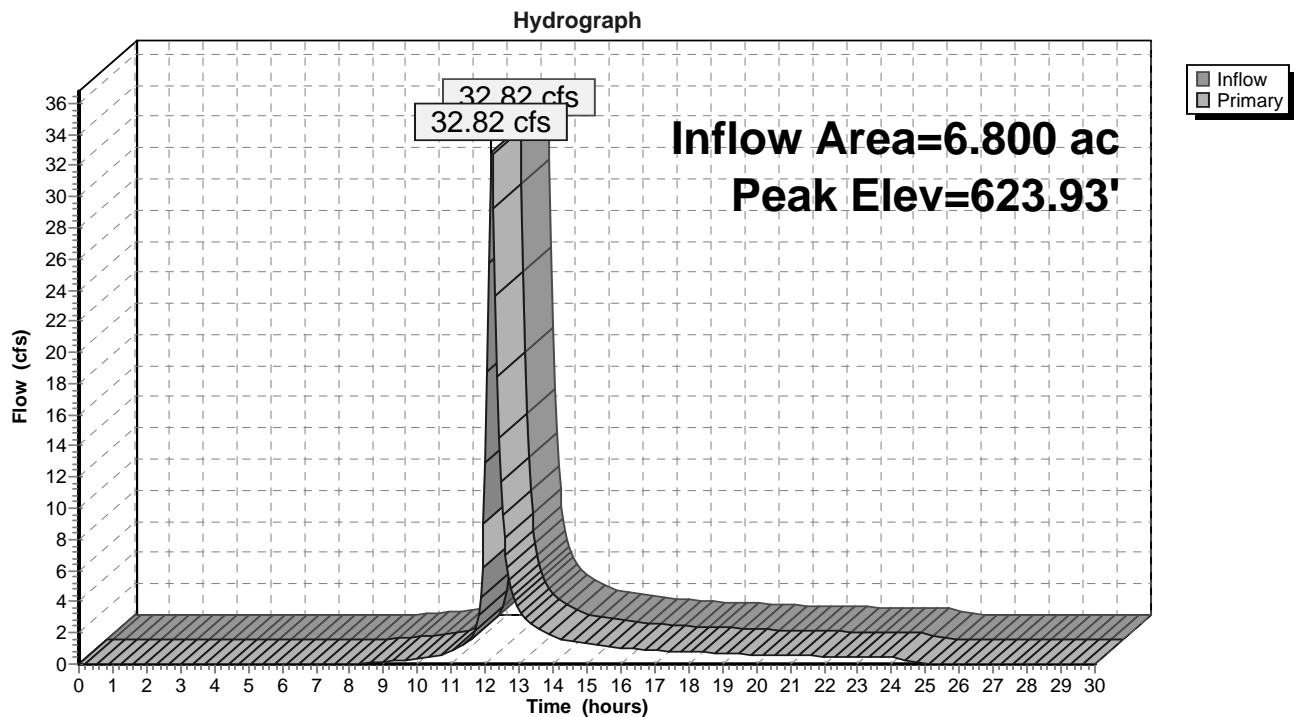
Device	Routing	Invert	Outlet Devices
#1	Primary	617.00'	30.0" Round Culvert L= 115.0' CPP, square edge headwall, Ke= 0.500 Outlet Invert= 615.80' S= 0.0104 '/' Cc= 0.900 n= 0.012
#2	Device 1	622.00'	30.0" Horiz. Orifice/Grate C= 0.600

Primary OutFlow Max=32.39 cfs @ 12.19 hrs HW=623.88' (Free Discharge)

1=Culvert (Passes 32.39 cfs of 56.07 cfs potential flow)

2=Orifice/Grate (Orifice Controls 32.39 cfs @ 6.60 fps)

Pond 10:



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 33

Summary for Pond 10a:

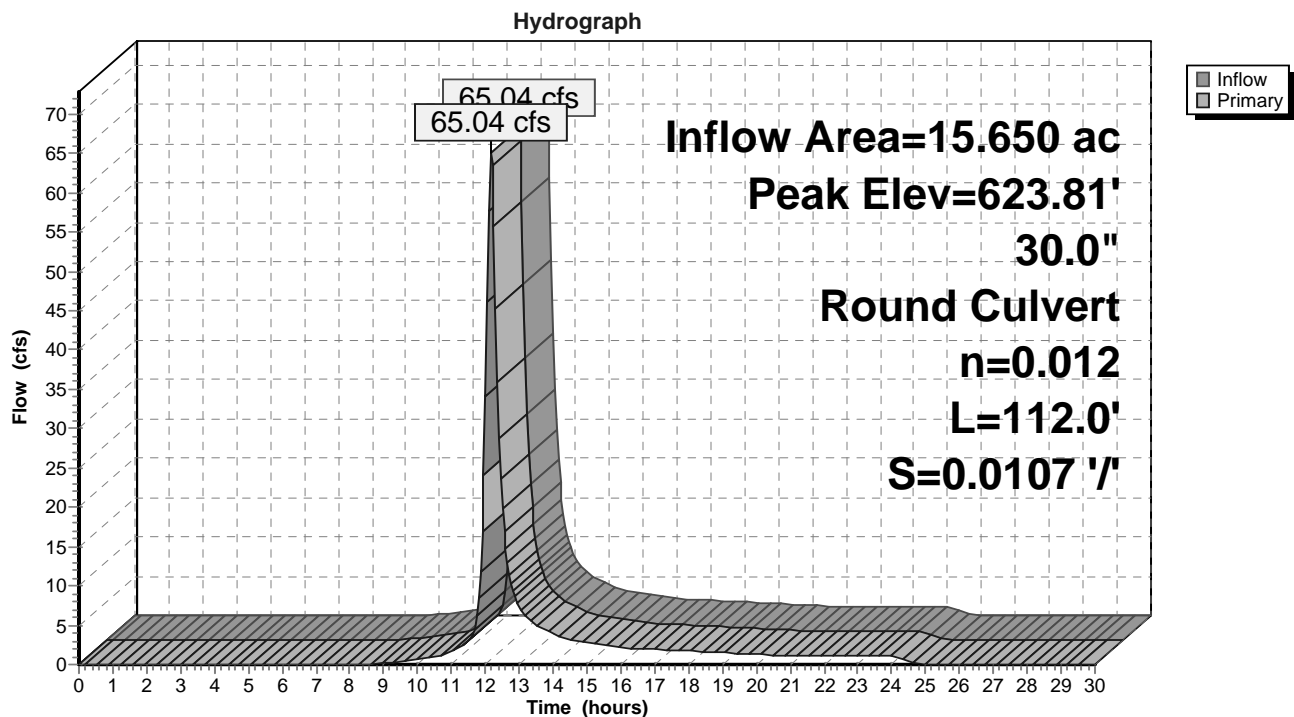
Inflow Area = 15.650 ac, 0.00% Impervious, Inflow Depth = 3.70" for 100-YEAR event
Inflow = 65.04 cfs @ 12.17 hrs, Volume= 4.827 af
Outflow = 65.04 cfs @ 12.17 hrs, Volume= 4.827 af, Atten= 0%, Lag= 0.0 min
Primary = 65.04 cfs @ 12.17 hrs, Volume= 4.827 af

Routing by Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Peak Elev= 623.81' @ 12.17 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	615.00'	30.0" Round Culvert L= 112.0' RCP, end-section conforming to fill, Ke= 0.500 Outlet Invert= 613.80' S= 0.0107 '/' Cc= 0.900 n= 0.012 Concrete pipe, finished

Primary OutFlow Max=64.12 cfs @ 12.17 hrs HW=623.61' (Free Discharge)
↑**1=Culvert** (Inlet Controls 64.12 cfs @ 13.06 fps)

Pond 10a:



Pond A Stormwater_7-12-18

Type II 24-hr 100-YEAR Rainfall=6.95"

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Page 34

Summary for Pond 20:

Inflow Area = 4.033 ac, 0.00% Impervious, Inflow Depth = 4.00" for 100-YEAR event
Inflow = 18.13 cfs @ 12.13 hrs, Volume= 1.344 af
Outflow = 18.13 cfs @ 12.13 hrs, Volume= 1.344 af, Atten= 0%, Lag= 0.0 min
Primary = 18.13 cfs @ 12.13 hrs, Volume= 1.344 af

Routing by Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Peak Elev= 620.59' @ 12.13 hrs

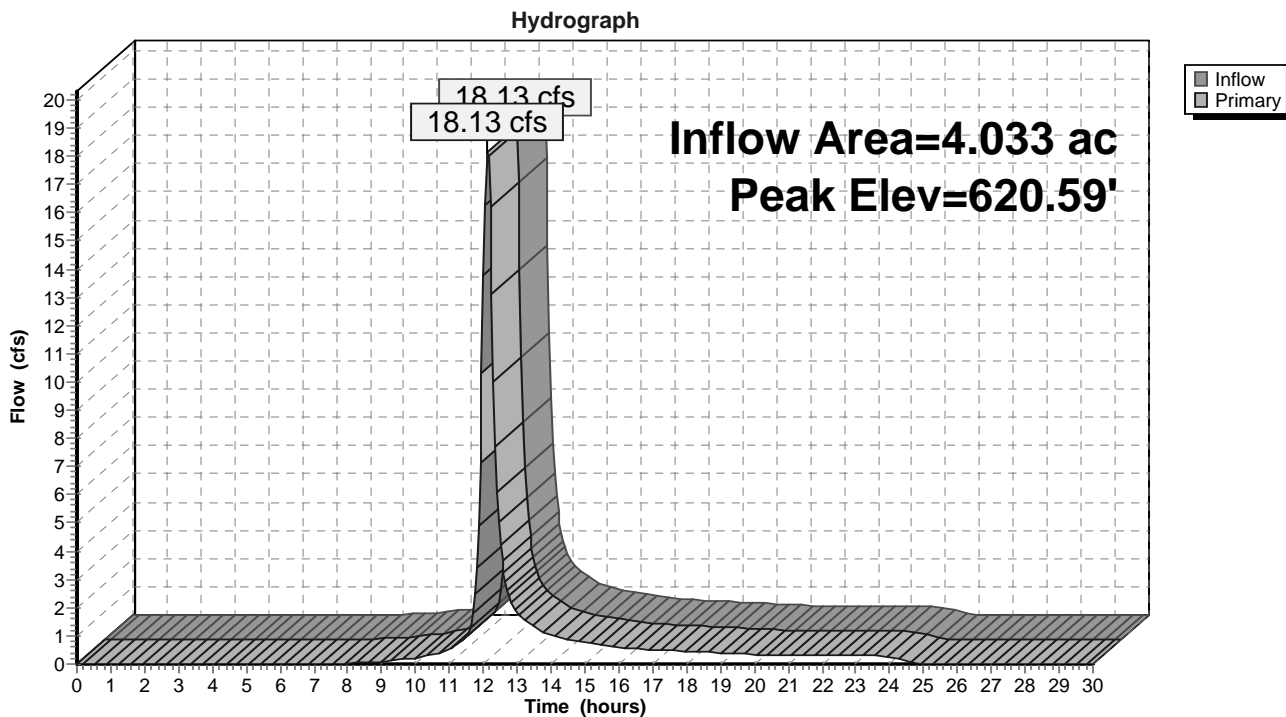
Device	Routing	Invert	Outlet Devices
#1	Primary	615.00'	30.0" Round Culvert L= 95.0' CPP, square edge headwall, Ke= 0.500 Outlet Invert= 614.00' S= 0.0105 '/' Cc= 0.900 n= 0.012
#2	Device 1	620.00'	30.0" Horiz. Orifice/Grate C= 0.600

Primary OutFlow Max=17.90 cfs @ 12.13 hrs HW=620.57' (Free Discharge)

1=Culvert (Passes 17.90 cfs of 49.15 cfs potential flow)

2=Orifice/Grate (Orifice Controls 17.90 cfs @ 3.65 fps)

Pond 20:



EROSION CALCULATIONS

J.H. Campbell Pond A
1667572.0003.02
FINAL COVER - EROSION EVALUATION

Required: Determine expected soil loss for Pond A final cover.

Method: Expected soil loss is calculated using the Universal Soil Loss Equation. Minimum erosion layer thickness is determined by adding the minimum thickness allowed by MDEQ to the expected soil loss.

References:

1. SCS National Engineering Handbook, Section 3 - Sedimentation, Chapter 3 - Erosion.
2. Michigan Department of Natural Resources, Surface Water Quality Division, *Guidebook of Best Management Practices for Michigan Watersheds*.
3. United States Department of Agriculture, Soil Conservation Service, *Soil Survey of Ottawa County, Michigan*, 1980.
4. United States Environmental Protection Agency, *Solid Waste Disposal Facility Criteria Technical Manual*, 1993.

Solution: 1. Soil loss equation: $A = RKL_sCP$

Where:

A =	Soil loss (tons/ac/yr)
R =	Rainfall factor
K =	Soil erodibility factor
L_s =	Slope length / slope gradient factor
C =	Plant cover or cropping management factor
P =	Erosion control practice factor

The rainfall factor, R, represents the average intensity for the maximum intensity, 30 minute storms over a 22 year period of record compiled by the SCS. Using Exhibit 4B, Rainfall Erosion Factors To Be Used With The Universal Soil Loss Equation (Ref 2, p. 2D-5), the R factor for Ottawa County is:

$$R = 110$$

The soil erodibility, K, factor represents the resistance of a soil surface to erosion as a function of the soil's physical and chemical properties. Use Ref. 3 to determine the K factor for the site.

$$K = 0.02$$

The slope length / slope gradient factor, L_s , represents the erosion of the soil due to both slope length and degree of slope. The slopes of interest are the typical sideslope and topslope conditions.

1. Typical sideslope	2. Typical topslope
slope = 25 %	slope = 4 %
length = 85 ft	length = 130 ft

J.H. Campbell Pond A
1667572.0003.02
FINAL COVER - EROSION EVALUATION

Using the above information and Exhibit 4D (Ref 2, p. 2D-16), the L_s factors are determined.

1. Typical Sideslope L_s = 5.56
2. Typical Topslope L_s = 0.46

The plant cover or cropping management factor, C, represents the percentage of soil loss that would occur if the surface were partially protected by some combination of cover and management practices. Using the values given in Ref. 2 (p.2D-1), a C factor is selected for weeds and wild grass cover over existing areas.

$$C = 0.12$$

The conservation practice factor, P, is used to account for the positive impacts of such agricultural management practices as planting on the contour, strip cropping, and use of terraces. Since this land is not cropped, the primary conservation practice factors of interest will be cross slope drainage berms. These drainage berms reduce the slope length, and sometimes the slope steepness that, in turn, reduce the L and S factors in the USLE. Thus, the P factor is taken to be 1.0.

$$P = 1.0$$

2. Soil loss calculations:

Slope Condition	R	K	L_s	C	P	A (tons/ac/yr)
1. Typical Sideslope 25% slope 82 ft length	110	0.02	5.56	0.12	1.0	1.47
2. Typical Topslope 4% slope 130 ft (average) length	110	0.02	0.46	0.12	1.0	0.12

3. Erosion layer thickness calculations:

$$T_{el} = 6 \text{ in} + \frac{AYF(2000 \text{ lb/ton})(12 \text{ in/ft})}{w(43,560 \text{ sf/ac})}$$

Where: T_{el} = Erosion layer thickness (in)
A = Soil loss (ton/ac)
Y = Postclosure period (yr)
F = Factor of safety
w = Specific weight of soil (pcf)

Y = 30 yr
F = 2
w = 110 pcf

1. Typical Sideslope Thickness:

Required thickness = 6.4 in
Specified thickness = 24.0 in

2. Typical Topslope Thickness:

Required thickness = 6.0 in
Specified thickness = 24.0 in

Note: All thicknesses include 6 inch minimum required.

4. Summary:

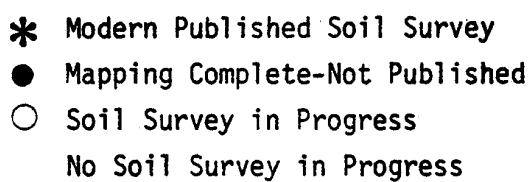
Calculated erosion loss, A, is less than 2 tons/acre/year. As noted in the permit drawings, the erosion layer will be a minimum of 24 inches thick.

REFERENCES

Slop-Effect Table (Topographic Factor, LS)

Slope Length in feet	LS Value (% Slope)														
	4	6	8	10	12	14	16	18	20	25	30	35	40	45	50
50	.3	.5	.7	1.0	1.3	1.6	2.0	2.4	3.0	4.3	6.0	7.9	10.1	12.6	15.4
100	.4	.7	1.0	1.4	1.8	2.3	2.8	3.4	4.2	6.1	8.5	11.2	14.4	17.9	21.7
150	.5	.8	1.2	1.6	2.2	2.8	3.5	4.2	5.1	7.5	10.4	13.8	17.6	21.9	26.6
200	.6	.9	1.4	1.9	2.6	3.3	4.1	4.8	5.9	8.7	12.0	15.9	20.3	25.2	30.7
250	.7	1.0	1.6	2.2	2.9	3.7	4.5	5.4	6.6	9.7	13.4	17.8	22.7	28.2	34.4
300	.7	1.2	1.7	2.4	3.1	4.0	5.0	5.9	7.2	10.7	14.7	19.5	24.9	30.9	37.6
350	.8	1.2	1.8	2.6	3.4	4.3	5.4	6.4	7.8	11.5	15.9	21.0	26.9	33.4	40.6
400	.8	1.3	2.0	2.7	3.6	4.6	5.7	6.8	8.3	12.3	17.0	22.5	28.7	35.7	43.5
450	.9	1.4	2.1	2.9	3.8	4.9	6.1	7.2	8.9	13.1	18.0	23.8	30.5	37.9	46.1
500	.9	1.5	2.2	3.1	4.0	5.2	6.4	7.6	9.3	13.7	19.0	25.1	32.1	39.9	48.6
550	1.0	1.6	2.3	3.2	4.2	5.4	6.7	8.0	9.8	14.4	19.9	26.4	33.7	41.9	50.9
600	1.0	1.6	2.4	3.3	4.4	5.7	7.0	8.3	10.2	15.1	20.8	27.5	35.2	43.7	53.2
650	1.1	1.7	2.5	3.5	4.6	5.9	7.3	8.7	10.6	15.7	21.7	28.7	36.6	45.5	55.4
700	1.1	1.8	2.6	3.6	4.8	6.1	7.6	9.0	11.1	16.3	22.5	29.7	38.0	47.2	57.5
750	1.1	1.8	2.7	3.7	4.9	6.3	7.9	9.3	11.4	16.8	23.3	30.8	39.3	48.9	59.5
800	1.2	1.9	2.8	3.8	5.1	6.5	8.1	9.6	11.8	17.4	24.1	31.8	40.6	50.5	61.4
900	1.2	2.0	3.0	4.1	5.4	6.9	8.6	10.2	12.5	18.5	25.5	33.7	43.1	53.5	65.2
1000	1.3	2.1	3.1	4.3	5.7	7.3	9.1	10.8	13.2	19.5	26.9	35.5	45.4	56.4	68.7

Appendix 2C



Appendix 2D

Use of The Universal Soil Loss Equation

In Developing Areas

WATER EROSION--SHEET

The following procedure is commonly used to estimate soil loss from construction sites and other developing areas. It is a method adopted from the Universal Soil Loss Equation as presented in Agricultural Handbook No. 282, Rainfall-Erosion Losses from Cropland East of the Rocky Mountains. A more precise computation can be made by using the full procedures given in the publication. This method is used to calculate soil eroded by water and causing sheet erosion. Use Exhibit 5 of this Appendix to calculate soil eroded by gullies. Contact the Soil Conservation Service for information on calculating soil lost by wind erosion.

To predict soil losses in developing areas, the simplified form of the equation is: $A = RCKLS$

A - is the computed soil loss per acre per year in tons. This quantity may be converted to cubic yards by using the conversion factors found in Exhibit 4A. (See attached example problem). All soil loss computations will be made using full years as the unit of time, that is 1-year, 2-year, etc.

R - is the average annual rainfall erosion index which is a measure of the erosive force of rainfall. The "R" value for urban areas is the same as that for agricultural lands and should be used in predicting annual soil losses on construction sites. Exhibit 4B gives "R" values for each county in Michigan.

C - is the ratio of soil loss from land cropped under specified conditions to the corresponding loss from tilled, continuous fallow. For developing areas the following three values will represent conditions in most cases:

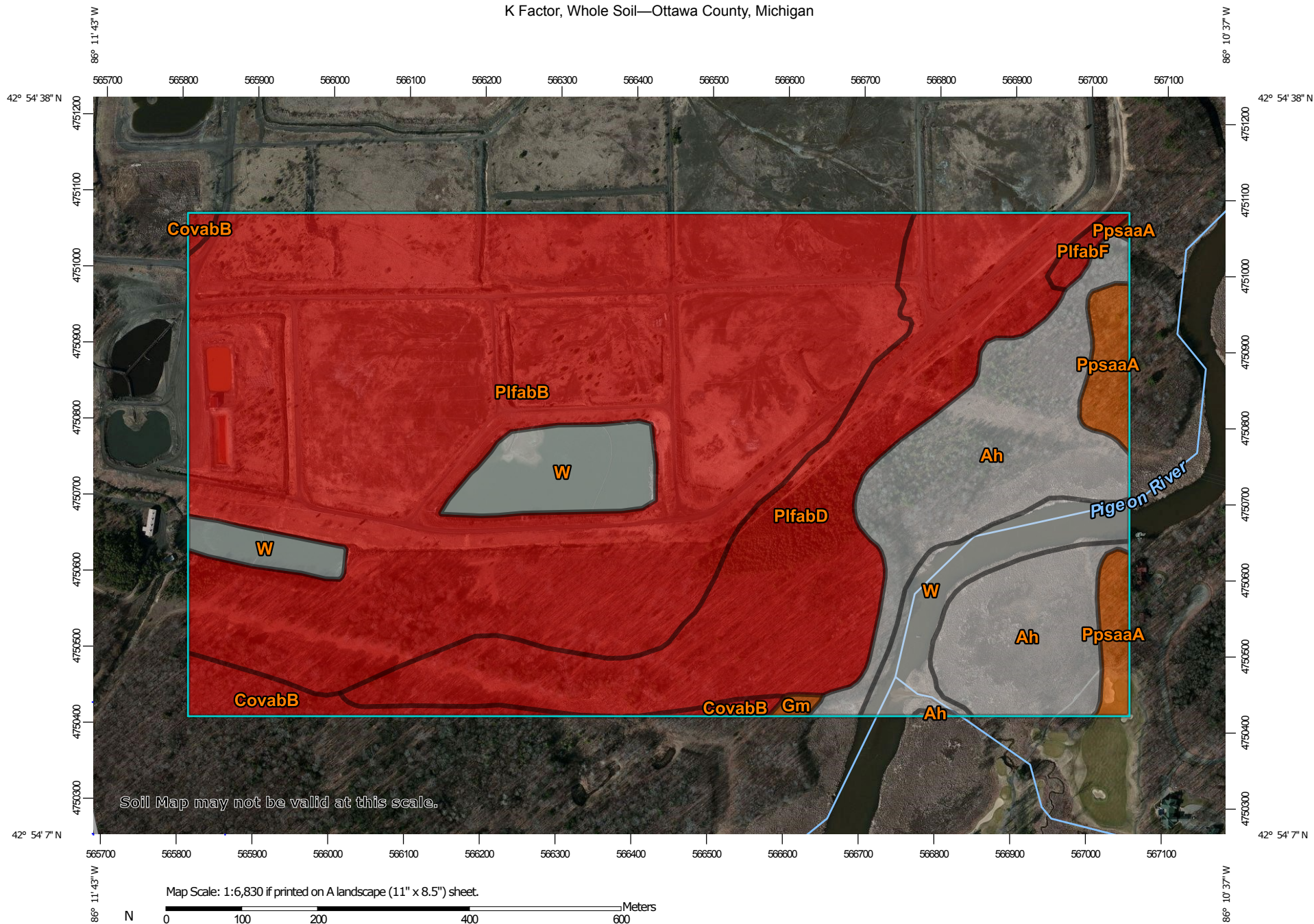
Well established grass or grass-legume cover	C = 0.006
Weeds and wild grass cover	C = 0.120
Bare or disturbed area	C = 1.000

If more than one condition exists on a site, more than one C value will need to be used per each length-slope ration (see "LS" and the example problem, below).

K - is the soil erodibility factor. On construction sites, substrata materials are often exposed to water erosion so that appropriate "K" values must be used. Exhibit 4C (attached) gives "K" values for the surface soil and for the substrata material if it differs significantly from the surface.

Limited research data show that infiltration rates and erosion losses from compacted fills do not differ greatly from those on "cuts" when slopes and surface materials are the same.

K Factor, Whole Soil—Ottawa County, Michigan




Natural Resources
Conservation Service

Web Soil Survey
National Cooperative Soil Survey

6/29/2017
Page 1 of 4
















MAP LEGEND

Area of Interest (AOI)







 Area of Interest (AOI)










Soils

Soil Rating Polygons
















	.02
	.05
	.10
	.15
	.17
	.20
	.24
	.28
	.32
	.37
	.43
	.49
	.55
	.64
	Not rated or not available

Soil Rating Lines









	.02
	.05
	.10
	.15
	.17
	.20

	.24
	.28
	.32
	.37
	.43
	.49
	.55
	.64
	Not rated or not available

Soil Rating Points

	.02
	.05
	.10
	.15
	.17
	.20
	.24
	.28
	.32
	.37
	.43
	.49
	.55
	.64
	Not rated or not available

Water Features

	Streams and Canals
	Rails
	Interstate Highways
	US Routes
	Major Roads
	Local Roads
	Background
	Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Ottawa County, Michigan
Survey Area Data: Version 11, Sep 26, 2016

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 13, 2012—Apr 6, 2012

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

K Factor, Whole Soil

K Factor, Whole Soil— Summary by Map Unit — Ottawa County, Michigan (MI139)				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Ah	Houghton-Adrian mucks, 0 to 1 percent slopes		29.5	14.5%
CovabB	Covert-Pipestone sands, 0 to 6 percent slopes	.02	4.6	2.2%
Gm	Granby loamy sand, lake plain, 0 to 2 percent slopes	.05	0.4	0.2%
PlfabB	Plainfield sand, lake plain, 0 to 6 percent slopes	.02	110.7	54.2%
PlfabD	Plainfield sand, lake plain, 6 to 18 percent slopes	.02	36.8	18.0%
PlfabF	Plainfield sand, high ecological site, 30 to 50 percent slopes	.02	0.9	0.5%
PpsaaA	Pipestone-Covert-Saugatuck sands, 0 to 3 percent slopes	.05	5.0	2.4%
W	Water		16.3	8.0%
Totals for Area of Interest			204.1	100.0%

Description

Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity (Ksat). Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

"Erosion factor Kw (whole soil)" indicates the erodibility of the whole soil. The estimates are modified by the presence of rock fragments.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Layer Options (Horizon Aggregation Method): Surface Layer (Not applicable)

HELP MODEL

Campbell HELP Model Aug 2018.txt

```
*****
**
**
**      HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE      **
**      HELP MODEL VERSION 3.07 (1 NOVEMBER 1997)           **
**      DEVELOPED BY ENVIRONMENTAL LABORATORY               **
**      USAE WATERWAYS EXPERIMENT STATION                  **
**      FOR USEPA RISK REDUCTION ENGINEERING LABORATORY     **
**
*****
*****
```

PRECIPITATION DATA FILE: C:\input\CEC\PC.D4
TEMPERATURE DATA FILE: C:\input\CEC\PC.D7
SOLAR RADIATION DATA FILE: C:\input\CEC\PC.D13
EVAPOTRANSPIRATION DATA: C:\input\CEC\PC.D11
SOIL AND DESIGN DATA FILE: C:\input\CEC\PC3.D10
OUTPUT DATA FILE: C:\output\PC3.OUT

TIME: 11:42 DATE: 8/ 9/2018

```
*****
TITLE: CEC Campbell - Post Closure
*****
```

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
WERE SPECIFIED BY THE USER.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7
THICKNESS = 6.00 INCHES
POROSITY = 0.4730 VOL/VOL
FIELD CAPACITY = 0.2220 VOL/VOL
WILTING POINT = 0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4051 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.520000001000E-03 CM/SEC
NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 4.90
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

Campbell HELP Model Aug 2018.txt

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 1

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4170	VOL/VOL
FIELD CAPACITY	=	0.0450	VOL/VOL
WILTING POINT	=	0.0180	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2949	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999978000E-02	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.11	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.8500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	2.00	PERCENT
DRAINAGE LENGTH	=	500.0	FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.04	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3	- GOOD

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 30

THICKNESS	=	360.00	INCHES
POROSITY	=	0.5410	VOL/VOL
FIELD CAPACITY	=	0.1870	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1870	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.499999987000E-04	CM/SEC

Campbell HELP Model Aug 2018.txt
 GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
 SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A
 GOOD STAND OF GRASS, A SURFACE SLOPE OF 2.0%
 AND A SLOPE LENGTH OF 500. FEET.

SCS RUNOFF CURVE NUMBER	=	65.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	20.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	6.559	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.676	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.876	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	76.922	INCHES
TOTAL INITIAL WATER	=	76.922	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
 GRAND RAPIDS MICHIGAN

STATION LATITUDE	=	42.53	DEGREES
MAXIMUM LEAF AREA INDEX	=	4.00	
START OF GROWING SEASON (JULIAN DATE)	=	123	
END OF GROWING SEASON (JULIAN DATE)	=	283	
EVAPORATIVE ZONE DEPTH	=	20.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.80	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	77.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
 COEFFICIENTS FOR GRAND RAPIDS MICHIGAN

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
-----	-----	-----	-----	-----	-----
1.91	1.53	2.48	3.56	3.03	3.86
3.02	3.45	3.14	2.89	2.93	2.55

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
 COEFFICIENTS FOR GRAND RAPIDS MICHIGAN

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
-----	-----	-----	-----	-----	-----
22.00	23.70	33.10	46.30	57.50	67.10
71.40	69.60	62.10	50.90	38.50	27.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
 COEFFICIENTS FOR GRAND RAPIDS MICHIGAN
 AND STATION LATITUDE = 42.53 DEGREES

ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	34.36	124726.812	100.00
RUNOFF	4.465	16208.640	13.00
EVAPOTRANSPIRATION	22.580	81966.344	65.72
DRAINAGE COLLECTED FROM LAYER 3	8.1664	29644.119	23.77
PERC./LEAKAGE THROUGH LAYER 4	0.195198	708.569	0.57
AVG. HEAD ON TOP OF LAYER 4	6.6607		
PERC./LEAKAGE THROUGH LAYER 5	0.187413	680.310	0.55
CHANGE IN WATER STORAGE	-1.039	-3772.628	-3.02
SOIL WATER AT START OF YEAR	79.166	287371.312	
SOIL WATER AT END OF YEAR	78.126	283598.687	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.034	0.00

ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	35.11	127449.344	100.00
RUNOFF	6.169	22394.875	17.57
EVAPOTRANSPIRATION	18.479	67080.531	52.63
DRAINAGE COLLECTED FROM LAYER 3	10.1869	36978.539	29.01
PERC./LEAKAGE THROUGH LAYER 4	0.263529	956.611	0.75

AVG. HEAD ON TOP OF LAYER 4	9.1203		
PERC./LEAKAGE THROUGH LAYER 5	0.204532	742.451	0.58
CHANGE IN WATER STORAGE	0.070	252.943	0.20
SOIL WATER AT START OF YEAR	78.126	283598.687	
SOIL WATER AT END OF YEAR	76.708	278449.219	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.488	5402.413	4.24
ANNUAL WATER BUDGET BALANCE	0.0000	0.005	0.00

ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	36.63	132966.891	100.00
RUNOFF	7.818	28378.223	21.34
EVAPOTRANSPIRATION	21.297	77308.125	58.14
DRAINAGE COLLECTED FROM LAYER 3	8.5335	30976.598	23.30
PERC./LEAKAGE THROUGH LAYER 4	0.207712	753.994	0.57
AVG. HEAD ON TOP OF LAYER 4	7.1105		
PERC./LEAKAGE THROUGH LAYER 5	0.217107	788.099	0.59
CHANGE IN WATER STORAGE	-1.235	-4484.207	-3.37
SOIL WATER AT START OF YEAR	76.708	278449.219	
SOIL WATER AT END OF YEAR	75.738	274930.344	
SNOW WATER AT START OF YEAR	1.488	5402.413	4.06
SNOW WATER AT END OF YEAR	1.222	4437.067	3.34
ANNUAL WATER BUDGET BALANCE	0.0000	0.050	0.00

ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
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PRECIPITATION	31.19	113219.687	100.00
RUNOFF	5.458	19813.691	17.50
EVAPOTRANSPIRATION	17.777	64530.617	57.00
DRAINAGE COLLECTED FROM LAYER 3	7.3424	26653.086	23.54
PERC./LEAKAGE THROUGH LAYER 4	0.167005	606.229	0.54
AVG. HEAD ON TOP OF LAYER 4	5.6506		
PERC./LEAKAGE THROUGH LAYER 5	0.224547	815.107	0.72
CHANGE IN WATER STORAGE	0.388	1407.160	1.24
SOIL WATER AT START OF YEAR	75.738	274930.344	
SOIL WATER AT END OF YEAR	76.705	278440.562	
SNOW WATER AT START OF YEAR	1.222	4437.067	3.92
SNOW WATER AT END OF YEAR	0.643	2334.007	2.06
ANNUAL WATER BUDGET BALANCE	0.0000	0.028	0.00

ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	32.46	117829.781	100.00
RUNOFF	5.461	19823.217	16.82
EVAPOTRANSPIRATION	17.895	64958.145	55.13
DRAINAGE COLLECTED FROM LAYER 3	8.2336	29887.975	25.37
PERC./LEAKAGE THROUGH LAYER 4	0.197249	716.016	0.61
AVG. HEAD ON TOP OF LAYER 4	6.7345		
PERC./LEAKAGE THROUGH LAYER 5	0.177198	643.230	0.55
CHANGE IN WATER STORAGE	0.693	2517.219	2.14
SOIL WATER AT START OF YEAR	76.705	278440.562	
SOIL WATER AT END OF YEAR	78.042	283291.781	
SNOW WATER AT START OF YEAR	0.643	2334.007	1.98
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.002	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	32.93	119535.930	100.00
RUNOFF	3.689	13391.647	11.20
EVAPOTRANSPIRATION	21.824	79219.578	66.27
DRAINAGE COLLECTED FROM LAYER 3	9.1540	33228.875	27.80
PERC./LEAKAGE THROUGH LAYER 4	0.228534	829.577	0.69
AVG. HEAD ON TOP OF LAYER 4	7.8733		
PERC./LEAKAGE THROUGH LAYER 5	0.223889	812.715	0.68
CHANGE IN WATER STORAGE	-1.961	-7116.910	-5.95
SOIL WATER AT START OF YEAR	78.042	283291.781	
SOIL WATER AT END OF YEAR	74.094	268960.969	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.987	7213.907	6.03
ANNUAL WATER BUDGET BALANCE	0.0000	0.019	0.00

ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	35.83	130062.922	100.00
RUNOFF	7.928	28778.057	22.13
EVAPOTRANSPIRATION	21.763	78998.656	60.74
DRAINAGE COLLECTED FROM LAYER 3	6.6143	24009.820	18.46
PERC./LEAKAGE THROUGH LAYER 4	0.147183	534.275	0.41
AVG. HEAD ON TOP OF LAYER 4	4.9818		
PERC./LEAKAGE THROUGH LAYER 5	0.171936	624.128	0.48

CHANGE IN WATER STORAGE	-0.647	-2347.754	-1.81
SOIL WATER AT START OF YEAR	74.094	268960.969	
SOIL WATER AT END OF YEAR	75.434	273827.125	
SNOW WATER AT START OF YEAR	1.987	7213.907	5.55
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.010	0.00

ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	42.67	154892.078	100.00
RUNOFF	4.792	17396.406	11.23
EVAPOTRANSPIRATION	24.822	90103.180	58.17
DRAINAGE COLLECTED FROM LAYER 3	10.4320	37868.195	24.45
PERC./LEAKAGE THROUGH LAYER 4	0.271371	985.076	0.64
AVG. HEAD ON TOP OF LAYER 4	9.3720		
PERC./LEAKAGE THROUGH LAYER 5	0.196155	712.043	0.46
CHANGE IN WATER STORAGE	2.428	8812.315	5.69
SOIL WATER AT START OF YEAR	75.434	273827.125	
SOIL WATER AT END OF YEAR	76.545	277859.656	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.317	4779.800	3.09
ANNUAL WATER BUDGET BALANCE	0.0000	-0.057	0.00

ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	33.64	122113.211	100.00
RUNOFF	2.832	10278.604	8.42

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EVAPOTRANSPIRATION	23.003	83502.602	68.38
DRAINAGE COLLECTED FROM LAYER 3	8.2831	30067.744	24.62
PERC./LEAKAGE THROUGH LAYER 4	0.199236	723.226	0.59
AVG. HEAD ON TOP OF LAYER 4	6.8169		
PERC./LEAKAGE THROUGH LAYER 5	0.200240	726.873	0.60
CHANGE IN WATER STORAGE	-0.678	-2462.609	-2.02
SOIL WATER AT START OF YEAR	76.545	277859.656	
SOIL WATER AT END OF YEAR	75.427	273801.719	
SNOW WATER AT START OF YEAR	1.317	4779.800	3.91
SNOW WATER AT END OF YEAR	1.756	6375.103	5.22
ANNUAL WATER BUDGET BALANCE	0.0000	-0.001	0.00

ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	25.52	92637.617	100.00
RUNOFF	1.968	7145.483	7.71
EVAPOTRANSPIRATION	17.125	62163.402	67.10
DRAINAGE COLLECTED FROM LAYER 3	7.6075	27615.154	29.81
PERC./LEAKAGE THROUGH LAYER 4	0.176158	639.454	0.69
AVG. HEAD ON TOP OF LAYER 4	5.9885		
PERC./LEAKAGE THROUGH LAYER 5	0.250480	909.243	0.98
CHANGE IN WATER STORAGE	-1.431	-5195.714	-5.61
SOIL WATER AT START OF YEAR	75.427	273801.719	
SOIL WATER AT END OF YEAR	74.208	269376.687	
SNOW WATER AT START OF YEAR	1.756	6375.103	6.88
SNOW WATER AT END OF YEAR	1.544	5604.420	6.05
ANNUAL WATER BUDGET BALANCE	0.0000	0.046	0.00

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	26.96	97864.844	100.00
RUNOFF	2.368	8595.687	8.78
EVAPOTRANSPIRATION	17.157	62278.117	63.64
DRAINAGE COLLECTED FROM LAYER 3	6.2046	22522.521	23.01
PERC./LEAKAGE THROUGH LAYER 4	0.128486	466.403	0.48
AVG. HEAD ON TOP OF LAYER 4	4.3049		
PERC./LEAKAGE THROUGH LAYER 5	0.128546	466.624	0.48
CHANGE IN WATER STORAGE	1.102	4001.892	4.09
SOIL WATER AT START OF YEAR	74.208	269376.687	
SOIL WATER AT END OF YEAR	75.096	272598.125	
SNOW WATER AT START OF YEAR	1.544	5604.420	5.73
SNOW WATER AT END OF YEAR	1.759	6384.892	6.52
ANNUAL WATER BUDGET BALANCE	0.0000	0.006	0.00

ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	30.01	108936.305	100.00
RUNOFF	3.951	14341.287	13.16
EVAPOTRANSPIRATION	17.190	62401.227	57.28
DRAINAGE COLLECTED FROM LAYER 3	7.9640	28909.375	26.54
PERC./LEAKAGE THROUGH LAYER 4	0.188063	682.668	0.63
AVG. HEAD ON TOP OF LAYER 4	6.3990		
PERC./LEAKAGE THROUGH LAYER 5	0.157633	572.209	0.53
CHANGE IN WATER STORAGE	0.747	2712.187	2.49
SOIL WATER AT START OF YEAR	75.096	272598.125	

SOIL WATER AT END OF YEAR	77.517	281385.375	
SNOW WATER AT START OF YEAR	1.759	6384.892	5.86
SNOW WATER AT END OF YEAR	0.085	309.827	0.28
ANNUAL WATER BUDGET BALANCE	0.0000	0.025	0.00

ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	29.87	108428.133	100.00
RUNOFF	1.586	5758.045	5.31
EVAPOTRANSPIRATION	19.963	72467.328	66.83
DRAINAGE COLLECTED FROM LAYER 3	9.3829	34060.074	31.41
PERC./LEAKAGE THROUGH LAYER 4	0.236466	858.373	0.79
AVG. HEAD ON TOP OF LAYER 4	8.1415		
PERC./LEAKAGE THROUGH LAYER 5	0.231779	841.357	0.78
CHANGE IN WATER STORAGE	-1.294	-4698.723	-4.33
SOIL WATER AT START OF YEAR	77.517	281385.375	
SOIL WATER AT END OF YEAR	75.353	273532.937	
SNOW WATER AT START OF YEAR	0.085	309.827	0.29
SNOW WATER AT END OF YEAR	0.954	3463.549	3.19
ANNUAL WATER BUDGET BALANCE	0.0000	0.050	0.00

ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	28.84	104689.211	100.00
RUNOFF	3.527	12804.308	12.23
EVAPOTRANSPIRATION	18.870	68496.883	65.43
DRAINAGE COLLECTED FROM LAYER 3	6.6456	24123.588	23.04

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PERC./LEAKAGE THROUGH LAYER 4	0.143850	522.176	0.50
AVG. HEAD ON TOP OF LAYER 4	4.8351		
PERC./LEAKAGE THROUGH LAYER 5	0.178800	649.043	0.62
CHANGE IN WATER STORAGE	-0.381	-1384.660	-1.32
SOIL WATER AT START OF YEAR	75.353	273532.937	
SOIL WATER AT END OF YEAR	74.888	271842.281	
SNOW WATER AT START OF YEAR	0.954	3463.549	3.31
SNOW WATER AT END OF YEAR	1.038	3769.540	3.60
ANNUAL WATER BUDGET BALANCE	0.0000	0.045	0.00

ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
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PRECIPITATION	37.39	135725.703	100.00
RUNOFF	2.470	8967.048	6.61
EVAPOTRANSPIRATION	23.873	86658.844	63.85
DRAINAGE COLLECTED FROM LAYER 3	7.6070	27613.492	20.35
PERC./LEAKAGE THROUGH LAYER 4	0.177914	645.826	0.48
AVG. HEAD ON TOP OF LAYER 4	6.0721		
PERC./LEAKAGE THROUGH LAYER 5	0.129527	470.184	0.35
CHANGE IN WATER STORAGE	3.310	12016.148	8.85
SOIL WATER AT START OF YEAR	74.888	271842.281	
SOIL WATER AT END OF YEAR	78.806	286066.844	
SNOW WATER AT START OF YEAR	1.038	3769.540	2.78
SNOW WATER AT END OF YEAR	0.430	1561.135	1.15
ANNUAL WATER BUDGET BALANCE	0.0000	-0.017	0.00

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ANNUAL TOTALS FOR YEAR 16

	INCHES	CU. FEET	PERCENT
PRECIPITATION	35.73	129699.883	100.00
RUNOFF	4.648	16871.758	13.01
EVAPOTRANSPIRATION	24.714	89713.297	69.17
DRAINAGE COLLECTED FROM LAYER 3	9.6366	34980.832	26.97
PERC./LEAKAGE THROUGH LAYER 4	0.244798	888.615	0.69
AVG. HEAD ON TOP OF LAYER 4	8.4217		
PERC./LEAKAGE THROUGH LAYER 5	0.243263	883.046	0.68
CHANGE IN WATER STORAGE	-3.512	-12749.035	-9.83
SOIL WATER AT START OF YEAR	78.806	286066.844	
SOIL WATER AT END OF YEAR	74.905	271905.125	
SNOW WATER AT START OF YEAR	0.430	1561.135	1.20
SNOW WATER AT END OF YEAR	0.819	2973.814	2.29
ANNUAL WATER BUDGET BALANCE	0.0000	-0.014	0.00

ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	41.90	152097.000	100.00
RUNOFF	2.089	7583.081	4.99
EVAPOTRANSPIRATION	24.977	90667.586	59.61
DRAINAGE COLLECTED FROM LAYER 3	8.9758	32582.229	21.42
PERC./LEAKAGE THROUGH LAYER 4	0.222109	806.255	0.53
AVG. HEAD ON TOP OF LAYER 4	7.6426		
PERC./LEAKAGE THROUGH LAYER 5	0.233901	849.061	0.56
CHANGE IN WATER STORAGE	5.624	20415.061	13.42
SOIL WATER AT START OF YEAR	74.905	271905.125	
SOIL WATER AT END OF YEAR	79.267	287738.125	
SNOW WATER AT START OF YEAR	0.819	2973.814	1.96

SNOW WATER AT END OF YEAR	2.082	7555.867	4.97
ANNUAL WATER BUDGET BALANCE	0.0000	-0.011	0.00

ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.71	144147.312	100.00
RUNOFF	12.032	43674.562	30.30
EVAPOTRANSPIRATION	23.022	83569.609	57.98
DRAINAGE COLLECTED FROM LAYER 3	9.3535	33953.062	23.55
PERC./LEAKAGE THROUGH LAYER 4	0.235164	853.646	0.59
AVG. HEAD ON TOP OF LAYER 4	8.0896		
PERC./LEAKAGE THROUGH LAYER 5	0.235500	854.863	0.59
CHANGE IN WATER STORAGE	-4.932	-17904.811	-12.42
SOIL WATER AT START OF YEAR	79.267	287738.125	
SOIL WATER AT END OF YEAR	76.036	276009.344	
SNOW WATER AT START OF YEAR	2.082	7555.867	5.24
SNOW WATER AT END OF YEAR	0.380	1379.846	0.96
ANNUAL WATER BUDGET BALANCE	0.0000	0.026	0.00

ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	32.02	116232.641	100.00
RUNOFF	5.038	18288.838	15.73
EVAPOTRANSPIRATION	19.722	71592.320	61.59
DRAINAGE COLLECTED FROM LAYER 3	7.5969	27576.916	23.73
PERC./LEAKAGE THROUGH LAYER 4	0.175960	638.736	0.55
AVG. HEAD ON TOP OF LAYER 4	5.9769		

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PERC./LEAKAGE THROUGH LAYER 5	0.213587	775.319	0.67
CHANGE IN WATER STORAGE	-0.551	-2000.781	-1.72
SOIL WATER AT START OF YEAR	76.036	276009.344	
SOIL WATER AT END OF YEAR	75.169	272863.750	
SNOW WATER AT START OF YEAR	0.380	1379.846	1.19
SNOW WATER AT END OF YEAR	0.695	2524.657	2.17
ANNUAL WATER BUDGET BALANCE	0.0000	0.030	0.00

ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.82	148176.594	100.00
RUNOFF	6.253	22696.719	15.32
EVAPOTRANSPIRATION	21.874	79401.758	53.59
DRAINAGE COLLECTED FROM LAYER 3	9.0897	32995.723	22.27
PERC./LEAKAGE THROUGH LAYER 4	0.226589	822.518	0.56
AVG. HEAD ON TOP OF LAYER 4	7.7672		
PERC./LEAKAGE THROUGH LAYER 5	0.140327	509.388	0.34
CHANGE IN WATER STORAGE	3.464	12572.998	8.49
SOIL WATER AT START OF YEAR	75.169	272863.750	
SOIL WATER AT END OF YEAR	79.328	287961.406	
SNOW WATER AT START OF YEAR	0.695	2524.657	1.70
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.012	0.00

ANNUAL TOTALS FOR YEAR 21

	INCHES	CU. FEET	PERCENT
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PRECIPITATION	28.99	105233.750	100.00
RUNOFF	3.273	11881.725	11.29
EVAPOTRANSPIRATION	20.548	74588.695	70.88
DRAINAGE COLLECTED FROM LAYER 3	8.9026	32316.404	30.71
PERC./LEAKAGE THROUGH LAYER 4	0.220225	799.416	0.76
AVG. HEAD ON TOP OF LAYER 4	7.5627		
PERC./LEAKAGE THROUGH LAYER 5	0.211806	768.855	0.73
CHANGE IN WATER STORAGE	-3.945	-14321.955	-13.61
SOIL WATER AT START OF YEAR	79.328	287961.406	
SOIL WATER AT END OF YEAR	75.383	273639.437	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.024	0.00

ANNUAL TOTALS FOR YEAR 22

	INCHES	CU. FEET	PERCENT
PRECIPITATION	37.19	134999.703	100.00
RUNOFF	4.994	18127.654	13.43
EVAPOTRANSPIRATION	21.454	77879.047	57.69
DRAINAGE COLLECTED FROM LAYER 3	7.1023	25781.525	19.10
PERC./LEAKAGE THROUGH LAYER 4	0.162363	589.379	0.44
AVG. HEAD ON TOP OF LAYER 4	5.5232		
PERC./LEAKAGE THROUGH LAYER 5	0.253487	920.158	0.68
CHANGE IN WATER STORAGE	3.386	12291.280	9.10
SOIL WATER AT START OF YEAR	75.383	273639.437	
SOIL WATER AT END OF YEAR	74.803	271534.969	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	3.966	14395.745	10.66
ANNUAL WATER BUDGET BALANCE	0.0000	0.046	0.00

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ANNUAL TOTALS FOR YEAR 23

	INCHES	CU. FEET	PERCENT
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PRECIPITATION	28.45	103273.516	100.00
RUNOFF	5.695	20673.646	20.02
EVAPOTRANSPIRATION	19.019	69039.789	66.85
DRAINAGE COLLECTED FROM LAYER 3	6.3780	23152.303	22.42
PERC./LEAKAGE THROUGH LAYER 4	0.135080	490.339	0.47
AVG. HEAD ON TOP OF LAYER 4	4.5282		
PERC./LEAKAGE THROUGH LAYER 5	0.138887	504.159	0.49
CHANGE IN WATER STORAGE	-2.781	-10096.408	-9.78
SOIL WATER AT START OF YEAR	74.803	271534.969	
SOIL WATER AT END OF YEAR	75.910	275552.687	
SNOW WATER AT START OF YEAR	3.966	14395.745	13.94
SNOW WATER AT END OF YEAR	0.078	281.639	0.27
ANNUAL WATER BUDGET BALANCE	0.0000	0.026	0.00

ANNUAL TOTALS FOR YEAR 24

	INCHES	CU. FEET	PERCENT
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PRECIPITATION	32.05	116341.500	100.00
RUNOFF	4.166	15124.127	13.00
EVAPOTRANSPIRATION	22.022	79938.305	68.71
DRAINAGE COLLECTED FROM LAYER 3	7.5143	27276.889	23.45
PERC./LEAKAGE THROUGH LAYER 4	0.172973	627.890	0.54
AVG. HEAD ON TOP OF LAYER 4	5.8580		
PERC./LEAKAGE THROUGH LAYER 5	0.172979	627.913	0.54
CHANGE IN WATER STORAGE	-1.825	-6625.665	-5.70

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SOIL WATER AT START OF YEAR	75.910	275552.687	
SOIL WATER AT END OF YEAR	74.162	269208.656	
SNOW WATER AT START OF YEAR	0.078	281.639	0.24
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.073	0.00

ANNUAL TOTALS FOR YEAR 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	30.08	109190.422	100.00
RUNOFF	2.928	10627.025	9.73
EVAPOTRANSPIRATION	18.563	67383.125	61.71
DRAINAGE COLLECTED FROM LAYER 3	5.7910	21021.486	19.25
PERC./LEAKAGE THROUGH LAYER 4	0.123267	447.459	0.41
AVG. HEAD ON TOP OF LAYER 4	4.1379		
PERC./LEAKAGE THROUGH LAYER 5	0.123182	447.152	0.41
CHANGE IN WATER STORAGE	2.675	9711.603	8.89
SOIL WATER AT START OF YEAR	74.162	269208.656	
SOIL WATER AT END OF YEAR	75.473	273968.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.364	4951.991	4.54
ANNUAL WATER BUDGET BALANCE	0.0000	0.025	0.00

ANNUAL TOTALS FOR YEAR 26

	INCHES	CU. FEET	PERCENT
PRECIPITATION	35.58	129155.391	100.00
RUNOFF	5.913	21463.152	16.62

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EVAPOTRANSPIRATION	18.148	65877.414	51.01
DRAINAGE COLLECTED FROM LAYER 3	8.7057	31601.617	24.47
PERC./LEAKAGE THROUGH LAYER 4	0.213224	774.002	0.60
AVG. HEAD ON TOP OF LAYER 4	7.3089		
PERC./LEAKAGE THROUGH LAYER 5	0.191991	696.927	0.54
CHANGE IN WATER STORAGE	2.622	9516.324	7.37
SOIL WATER AT START OF YEAR	75.473	273968.250	
SOIL WATER AT END OF YEAR	78.294	284208.437	
SNOW WATER AT START OF YEAR	1.364	4951.991	3.83
SNOW WATER AT END OF YEAR	1.165	4228.144	3.27
ANNUAL WATER BUDGET BALANCE	0.0000	-0.044	0.00

ANNUAL TOTALS FOR YEAR 27

	INCHES	CU. FEET	PERCENT
PRECIPITATION	33.80	122694.008	100.00
RUNOFF	3.175	11526.576	9.39
EVAPOTRANSPIRATION	22.568	81920.453	66.77
DRAINAGE COLLECTED FROM LAYER 3	9.5229	34567.980	28.17
PERC./LEAKAGE THROUGH LAYER 4	0.240881	874.400	0.71
AVG. HEAD ON TOP OF LAYER 4	8.3103		
PERC./LEAKAGE THROUGH LAYER 5	0.223534	811.427	0.66
CHANGE IN WATER STORAGE	-1.689	-6132.432	-5.00
SOIL WATER AT START OF YEAR	78.294	284208.437	
SOIL WATER AT END OF YEAR	77.770	282304.156	
SNOW WATER AT START OF YEAR	1.165	4228.144	3.45
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.008	0.00

Campbell HELP Model Aug 2018.txt

ANNUAL TOTALS FOR YEAR 28

	INCHES	CU. FEET	PERCENT
PRECIPITATION	26.59	96521.719	100.00
RUNOFF	2.555	9273.872	9.61
EVAPOTRANSPIRATION	16.530	60004.422	62.17
DRAINAGE COLLECTED FROM LAYER 3	8.1898	29728.871	30.80
PERC./LEAKAGE THROUGH LAYER 4	0.195820	710.828	0.74
AVG. HEAD ON TOP OF LAYER 4	6.6753		
PERC./LEAKAGE THROUGH LAYER 5	0.234426	850.965	0.88
CHANGE IN WATER STORAGE	-0.919	-3336.440	-3.46
SOIL WATER AT START OF YEAR	77.770	282304.156	
SOIL WATER AT END OF YEAR	75.077	272528.656	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.774	6439.042	6.67
ANNUAL WATER BUDGET BALANCE	0.0000	0.031	0.00

ANNUAL TOTALS FOR YEAR 29

	INCHES	CU. FEET	PERCENT
PRECIPITATION	24.01	87156.312	100.00
RUNOFF	2.639	9578.358	10.99
EVAPOTRANSPIRATION	18.299	66423.594	76.21
DRAINAGE COLLECTED FROM LAYER 3	6.1071	22168.645	25.44
PERC./LEAKAGE THROUGH LAYER 4	0.125306	454.861	0.52
AVG. HEAD ON TOP OF LAYER 4	4.1975		
PERC./LEAKAGE THROUGH LAYER 5	0.125347	455.009	0.52
CHANGE IN WATER STORAGE	-3.160	-11469.334	-13.16
SOIL WATER AT START OF YEAR	75.077	272528.656	
SOIL WATER AT END OF YEAR	73.341	266229.469	

Campbell HELP Model Aug 2018.txt

SNOW WATER AT START OF YEAR	1.774	6439.042	7.39
SNOW WATER AT END OF YEAR	0.350	1268.895	1.46
ANNUAL WATER BUDGET BALANCE	0.0000	0.040	0.00

ANNUAL TOTALS FOR YEAR 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	34.16	124000.852	100.00
RUNOFF	2.311	8387.658	6.76
EVAPOTRANSPIRATION	22.376	81226.578	65.50
DRAINAGE COLLECTED FROM LAYER 3	6.8181	24749.562	19.96
PERC./LEAKAGE THROUGH LAYER 4	0.162429	589.618	0.48
AVG. HEAD ON TOP OF LAYER 4	5.5575		
PERC./LEAKAGE THROUGH LAYER 5	0.162286	589.100	0.48
CHANGE IN WATER STORAGE	2.493	9047.865	7.30
SOIL WATER AT START OF YEAR	73.341	266229.469	
SOIL WATER AT END OF YEAR	76.064	276110.906	
SNOW WATER AT START OF YEAR	0.350	1268.895	1.02
SNOW WATER AT END OF YEAR	0.120	435.347	0.35
ANNUAL WATER BUDGET BALANCE	0.0000	0.087	0.00

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.87 2.81	1.45 3.03	2.46 3.10	3.90 2.94	2.80 2.64	3.63 2.52

	Campbell HELP Model Aug 2018.txt					
STD. DEVIATIONS	0.60	0.58	1.11	1.50	0.99	1.74
	1.43	1.65	1.81	1.43	1.27	0.76
RUNOFF						

TOTALS	0.369	0.588	1.812	1.554	0.012	0.000
	0.000	0.000	0.000	0.000	0.000	0.070
STD. DEVIATIONS	0.572	0.680	1.198	1.407	0.065	0.000
	0.000	0.001	0.000	0.000	0.000	0.142
EVAPOTRANSPIRATION						

TOTALS	0.437	0.394	0.399	2.079	3.314	3.614
	2.970	2.614	2.146	1.289	0.848	0.478
STD. DEVIATIONS	0.090	0.080	0.160	0.952	0.767	1.337
	1.168	1.423	0.822	0.272	0.197	0.125
LATERAL DRAINAGE COLLECTED FROM LAYER 3						

TOTALS	0.6199	0.4566	0.4072	0.6959	1.0614	0.8371
	0.7291	0.6365	0.5603	0.6152	0.6856	0.7634
STD. DEVIATIONS	0.1992	0.1498	0.1557	0.2593	0.2017	0.1074
	0.0825	0.0841	0.1154	0.2354	0.2943	0.2871
PERCOLATION/LEAKAGE THROUGH LAYER 4						

TOTALS	0.0142	0.0093	0.0074	0.0171	0.0290	0.0216
	0.0178	0.0147	0.0123	0.0139	0.0165	0.0189
STD. DEVIATIONS	0.0065	0.0047	0.0043	0.0086	0.0068	0.0036
	0.0028	0.0028	0.0039	0.0079	0.0099	0.0097
PERCOLATION/LEAKAGE THROUGH LAYER 5						

TOTALS	0.0157	0.0137	0.0124	0.0121	0.0171	0.0214
	0.0231	0.0208	0.0156	0.0130	0.0128	0.0150
STD. DEVIATIONS	0.0082	0.0089	0.0098	0.0090	0.0072	0.0034
	0.0048	0.0068	0.0060	0.0063	0.0072	0.0068

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)						

DAILY AVERAGE HEAD ON TOP OF LAYER 4						

AVERAGES	5.6739	4.0350	2.8670	7.2031	11.9150	9.1192
	7.1851	5.8676	5.0487	5.5658	6.8923	7.6749
STD. DEVIATIONS	2.7383	2.0990	1.7237	3.6938	2.8709	1.5796
	1.1743	1.1961	1.6971	3.3496	4.3273	4.0842

Campbell HELP Model Aug 2018.txt
 AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	33.15 (4.771)	120333.3	100.00
RUNOFF	4.406 (2.2201)	15995.13	13.292
EVAPOTRANSPIRATION	20.582 (2.5525)	74711.99	62.088
LATERAL DRAINAGE COLLECTED FROM LAYER 3	8.06807 (1.25920)	29287.105	24.33832
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.19280 (0.04139)	699.881	0.58162
AVERAGE HEAD ON TOP OF LAYER 4	6.587 (1.469)		
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.19281 (0.04046)	699.899	0.58163
CHANGE IN WATER STORAGE	-0.099 (2.5105)	-360.84	-0.300

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30	(INCHES)	(CU. FT.)
PRECIPITATION	3.16	11470.801
RUNOFF	2.404	8728.0107
DRAINAGE COLLECTED FROM LAYER 3	0.05534	200.89204
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.001662	6.03193
AVERAGE HEAD ON TOP OF LAYER 4	21.225	
MAXIMUM HEAD ON TOP OF LAYER 4	29.359	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	154.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.001540	5.58856
SNOW WATER	5.58	20264.4355
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4250
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0438

*** Maximum heads are computed using McEnroe's equations. ***

Campbell HELP Model Aug 2018.txt
Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

FINAL WATER STORAGE AT END OF YEAR 30		
LAYER	(INCHES)	(VOL/VOL)
1	1.2718	0.2120
2	5.1344	0.2139
3	0.0935	0.8500
4	0.0000	0.0000
5	67.3199	0.1870
SNOW WATER	0.120	

MOUNDING CALCULATIONS



Date:	8/9/2018	Made by:	BSW
Project No.:	1667572	Checked by:	MMJ
Subject:	MOUNDING FOR ABOVE CAP DRAINS		
Project			
Short Title:	J.H. CAMPBELL GENERATING FACILITY - POND A CAPPING SYSTEM		

OBJECTIVE:

Evaluate the maximum mounding anticipated within the above cap drain system.

ASSUMPTIONS:

- 1) The above cap pipes will serve as a conduit to transfer water that drains through the cap soils to the storm water collection ditches. The above cap pipes are designed as 6 inch diameter ADS N-12 (or equal) smooth interior corrugated plastic pipes (CPPs). The pipes are spaced at 200 feet on centers and will be sloped on average 2.0%.
- 2) The cap design includes the following layers from top to bottom:
 - 6 inch thick layer of clean imported topsoil
 - 24 inch thick layer of clean imported protective soil (assumed 0.001 centimeters per second (cm/s) average permeability)
 - 6 inch diameter perforated corrugated plastic pipe, smooth interior cap drain system
 - 10 ounce per square yard (oz/sy) non-woven geotextile
 - 40-mil textured HDPE geomembrane liner
 - Graded existing surface
- 3) The percolation rate will be derived from the average annual totals calculated by the HELP Model in a separate calculation. The infiltration is calculated as the Total Precipitation minus Runoff minus Evapotranspiration.

METHODS:

- 1) Two methods will be used to calculate mounding, Giroud 2000, and McEnroe's 93 (Ref. 1) using the HELP Model predictions for infiltration.
- 2) Per the HELP Model, the average annual totals are:

Precipitation	=	33.15	inches per acre per year
Runoff	=	4.406	inches per acre per year
Evapotranspiration	=	20.582	inches per acre per year
Infiltration to pipes	=	0.1928	inches per acre per year

- 3) Convert infiltration to gallons per acre per day:

Infiltration to pipes	=	0.1928	inches per acre per year
Infiltration to pipes	=	14.34	gallons per acre per day (gpad)

CALCULATIONS:

See following worksheet for calculating the head using the two methods noted above. The results indicate a maximum head at 2.1 inches which is less than 6 inches - the diameter of the pipes.

CONCLUSIONS:

Assuming the HELP model infiltration rate, 6 inch perforated pipes and a cover soil with 0.001 cm/s average permeability, the 6 inch pipes will be able to route infiltration that makes it through the cap cover soils and route it to the perimeter ditch which is in an open channel flow freely draining condition.

REFERENCES:

- 1) Qian, Xuede; Donald Gray, and Robert M. Koerner, "Estimation of Maximum Liquid Head over Landfill Barriers", Journal of Geotechnical and Geoenvironmental Engineering, ASCE, May 2004.

FACILITY:	J.H Campbell Generating Facility- Pond A
CELL / UNIT:	Final Cover Slope Drains


6-inch Dia. HDPE Perforated pipes (ADS N-12)

Design Variables for input					
Calculated Values					
		Units		Units	Notation
Slope to Pipe	0.0200	ft/ft	2.00%		S1
Slope of Pipe	0.0100	ft/ft	1.00%		S2
Combined Slope	0.0224	ft/ft	2.24%		S
Slope Angle	0.022	radians	1.28	degrees	a
Max. Perp. Length to Pipe ⁽¹⁾	200	feet	2400	inches	
Adjusted Flow Length	224	feet	2683	inches	L
Cover soil Thickness	2.50	feet	30.0	inches	
Permeability	1.00E-03	cm/sec	34	in/day	K sand
Effective Permeability	5.80E-03	cm/s	34	in/day	K avg.
Average Percolation Rate	14	gpad	0.0005	ipad	r

Predicted Head on Liner				
Method	Modeled Design			
Giroud 2000	2.1	inches	≤ 6 inches	OK
McEnroe's 93	1.7	inches	≤ 6 inches	OK

R =	0.0311	
A =	0.9358	
B =	N/A	
R < 0.25	0.029	Y max
	1.715	y max
R = 0.25	N/A	Y max
	N/A	y max
R > 0.25	N/A	Y max
	N/A	y max

PUNCTURE RESISTANCE CALCULATION

	SUBJECT			
	PUNCTURE RESISTANCE OF GEOMEMBRANE			
	Job No.:	1667572	Made By	BSW
	Ref.:	Pond A Geomembrane	Checked	MMJ
		Puncture Resistance	Reviewed	
			Date	8/15/2018
			Sheet	1 of 1

OBJECTIVE:

To evaluate the puncture resistance of 40 mil thick HDPE textured geomembrane when overlain by a geotextile protection (or cushion) layer of 10 oz/yd².

METHODS:

There are many situations where geomembranes are placed on or beneath soils containing relatively large-sized stones. For example, poorly prepared soil subgrade with stones protruding from the surface, and cases where crushed-stoned drainage layers are to be placed above the geomembrane. In all of these situations, a nonwoven needle-punched geotextile can provide significant puncture protection to the geomembrane (Ref 1).

The method presented herein (Koerner, 2005) focuses on the protection of 40 mil (1.0 mm) thick HDPE textured geomembrane. The method uses the design by function approach.

$$FS = P_{\text{allow}} / P_{\text{actual}}$$

where:

FS = factor of safety against geomembrane puncture.

P_{actual} = actual pressure due to the pond contents or surface impoundment.

P_{allow} = allowable pressure using different types of geotextiles and site specific conditions.

The allowable pressure, P_{allow} is determined by the following equation:

$$P_{\text{allow}} = [50 + 0.00045 * (M/H^2)] * [1/(MF_s * MF_{PD} * MF_A)] * [1/(RF_{CR} * RF_{CBD})]$$

where:

P_{allow} = allowable pressure (kPa)

M = geotextile mass per unit area (g/m²)

H = protrusion height (m)

MF_s = modification factor for protrusion shape

MF_{PD} = modification factor for packing density

MF_A = modification factor for arching in solids

RF_{CR} = reduction factor for long-term creep

RF_{CBD} = reduction factor for long-term chemical/biological degradation

ASSUMPTIONS/CALCULATIONS:

Evaluate the factor of safety against geomembrane puncture when an 10 oz/sy nonwoven geotextile overlies the geomembrane of the base liner system.



SUBJECT						PUNCTURE RESISTANCE OF GEOMEMBRANE					
Job No.:		1667572		Made By		BSW		Date		8/15/2018	
Ref.:		Pond A Geomembrane		Checked		MMJ		Sheet		1 of 1	
		Puncture Resistance		Reviewed							

ASSUMPTIONS/CALCULATIONS Cont.:

Table 1 - Modification Factors and Reduction Factors for Geomembrane Protection Design.

MF _s		MF _{PD}		MF _A	
Angular:	1	Isolated	1	Hydrostatic	1
Subrounded:	0.5	Dense, 38 mm	0.83	Geostatic, shallow	0.75
Rounded:	0.25	Dense, 25 mm	0.67	Geostatic, mod.	0.5
		Dense, 12mm	0.5	Geostatic, deep	0.25
RF _{CBD}		RF _{CR}			
		Mass per unit area (g/m ²)	Protrusion (mm)		
			38	25	12
Mild leachate	1.1	Geomembrane alone	N/R	N/R	N/R
Moderate leachate	1.3	270	N/R	N/R	>1.5
Harsh leachate	1.5	550	N/R	1.5	1.3
		1100	1.3	1.2	1.1
		>1100	1.2	1.1	1

- Geotextile mass per unit area, M = 335 g/m² (10 oz/yd²)
- Depth of material on top of geomembrane, d = 0.762 m (30 inches)
- Unit weight of material on top of geomembrane, γ = 19.6 kN/m³ (125 pcf)
- Vehicle Loading = 21.2 psi = 146.2 kPa
- Protrusion height, H = 0.0254 m (1 inch)
- Modification and Reduction Factors:

MF _S =	1
MF _{PD} =	1
MF _A =	1
RF _{CR} =	1.5
RF _{CBD} =	1.1

$$P_{\text{allow}} = \{50 + 0.00045 \cdot [335/0.0254]^2\} \cdot [1/(1 \cdot 1 \cdot 1)] \cdot [1/(1.5 \cdot 1.1)]$$

$$P_{\text{allow}} = 192 \text{ kPa}$$

$$P_{\text{soil}} = d \cdot \gamma = 0.762 \times 19.6 = 15 \text{ kPa}$$

$$P_{\text{vehicle}} = 146.2 \text{ kPa}$$

$$FS = \frac{192}{161} = 1.2 \text{ (OK)}$$

CONCLUSION:

The results show a factor of safety against Geomembrane Puncture of 1.2, when the geomembrane is overlaid by an 10 oz/sy nonwoven geotextile.

REFERENCES:

- 1- Koerner, R.M. (2005), *Designing with Geosynthetics*, Prentice Hall Publishing Co., Englewood Cliffs, NJ, 5th edition.
- 2- GSE manufacturer data sheet for nonwoven geotextile, 2009.

APPENDIX F
J.H. CAMPBELL GENERATING FACILITY POND A POST-CLOSURE PLAN



Post-Closure Plan

J.H. CAMPBELL GENERATING FACILITY

POND A POST-CLOSURE PLAN

West Olive, Michigan

Pursuant to 40 CFR 257.104

Submitted To: Consumers Energy Company
1945 W. Parnall Road
Jackson, Michigan 49201

Submitted By: Golder Associates Inc.
15851 South US 27, Suite 50
Lansing, Michigan 48906

October 2016

1654923

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**CERTIFICATION****Professional Engineer Certification Statement [40 CFR 257.104(d)(4)]**

I hereby certify that, having reviewed the attached documentation and being familiar with the provisions of Title 40 of the Code of Federal Regulations Section 257.104 (40 CFR Part 257.104), I attest that this Post-Closure Plan is accurate and has been prepared in accordance with good engineering practices, including the consideration of applicable industry standards, and with the requirements of 40 CFR Part 257.104.

Golder Associates Inc.

Signature

October 14, 2016

Date of Report Certification

Jeffrey R. Piaskowski, PE
Name

6201061033
Professional Engineer Certification Number



10/14/16



Table of Contents

CERTIFICATION.....	C-1
Professional Engineer Certification Statement [40 CFR 257.104(d)(4)].....	C-1
1.0 INTRODUCTION.....	1
2.0 FACILITY CONTACT [40 CFR 257.104(d)(1)(ii)]	2
3.0 MONITORING AND MAINTENANCE ACTIVITIES [40 CFR 257.104(d)(1)(i, iii)]	3
3.1 Site Maintenance [40 CFR 257.104(d)(1)(i)].....	3
3.2 Periodic Inspection Requirements [40 CFR 257.104(d)(1)(i)].....	3
3.3 Site Use Restrictions [40 CFR 257.104(d)(1)(iii)].....	4
3.4 Groundwater Monitoring.....	4
4.0 REFERENCES.....	7

List of Tables

Table 3.4.1	Groundwater Detection Monitoring Constituents
Table 3.4.2	Groundwater Assessment Monitoring Constituents

List of Figures

Figure 1	Site Location Map
Figure 2	Site Map

List of Appendices

Appendix A	General Site Inspection Sheet
Appendix B	Groundwater Sampling Analysis and Procedure Plan



1.0 INTRODUCTION

On April 17, 2015, the United States Environmental Protection Agency (EPA) issued the Coal Combustion Residual (CCR) Resource Conservation and Recovery Act (RCRA) Rule (40 CFR 257 Subpart D) (“CCR RCRA Rule”) to regulate the beneficial use and disposal of CCR materials generated at coal-fired electrical power generating complexes. In accordance with the CCR RCRA Rule, any CCR surface impoundment or CCR landfill that was actively receiving CCRs on the effective date of the CCR RCRA Rule (October 19, 2015) was deemed to be an “Existing CCR Unit” on that date and subject to self-implementing compliance standards and schedules. Consumers Energy Company (CEC) identified three existing CCR surface impoundments at the J.H. Campbell Generating Facility (JH Campbell):

- Bottom Ash Ponds 1-2
- Bottom Ash Pond 3
- Pond A

JH Campbell is located in West Olive, Michigan as presented on Figure 1 – Site Location Map. The location of Pond A is presented on Figure 2 – Site Map.

This post-closure plan is limited to Pond A at JH Campbell; a separate, identical post-closure plan was developed for Bottom Ash Ponds 1-2. In accordance with 40 CFR 257.104(a)(2), a post-closure plan is not required for Bottom Ash Pond 3 because the surface impoundment will be closed with CCR in place as provided by 40 CFR 257.102(c). The intent of the post-closure plan is to assure that integrity and effectiveness of the final cover is maintained over the 30-year post-closure care period. Pond A is anticipated to be certified closed by January 1, 2024, which would result in the 30-year post-closure care period lasting through 2053 if the site is operating under detection monitoring.



2.0 FACILITY CONTACT [40 CFR 257.104(d)(1)(ii)]

The post-closure point of contact for Pond A at JH Campbell is:

Michelle Marion
1945 W Parnall Road
Jackson, Michigan 49201
(517) 788-5824
michelle.marion@cmsenergy.com



3.0 MONITORING AND MAINTENANCE ACTIVITIES [40 CFR 257.104(d)(1)(i, iii)]

3.1 Site Maintenance [40 CFR 257.104(d)(1)(i)]

The following general site maintenance and monitoring will be conducted to ensure the integrity and effectiveness of the final cover system:

- Fertilizer will be applied in areas of stressed or poor quality cover vegetation as needed.
- Vegetative cover will be mowed as needed to restrict uncontrolled woody plant establishment on the cover for the remainder of the 30-year post-closure period (estimated through 2053). This includes mowing the side slopes around the perimeter of Pond A.
- Areas of erosion, including erosion from run-off or vehicle use, will be repaired by restoring the thickness of the protective cover and topsoil and seeding as necessary upon discovery.
- Erosion repairs will utilize clean soils. Typically, repair is expected to involve minor regrading, spreading of small amounts of additional soil, and reseeding. Areas of repeated erosion will be evaluated to determine if additional protection, such as erosion blankets or riprap, should be added.
- Groundwater monitoring system will be maintained in accordance with applicable requirements from 40 CFR 257.90 to 40 CFR 257.98.
- Differential settlement will be repaired as follows:
 - Minor differential settlement in which no ponding can occur or in which the subsurface drainage will not be compromised shall be repaired by stripping topsoil, adding sandy soil, and replacing topsoil to attain a smooth surface before seeding.
 - If differential settlement has occurred to the extent that drainage is compromised, surface soils shall be removed in the area to expose the geomembrane. The geomembrane shall be cut back and sand added to attain the line grade. Geomembrane, protective soil, and topsoil shall be replaced and seeded with repair certification maintained in the site files.

Areas requiring repair due to erosion or settlement will be identified during annual site inspections which are detailed below in Section 3.2.

3.2 Periodic Inspection Requirements [40 CFR 257.104(d)(1)(i)]

Periodic site inspections verifying the integrity and effectiveness of the final cover system will be conducted throughout the 30-year post-closure period (estimated through 2053) on no less than an annual basis. When and if items requiring construction and/or maintenance are identified during an inspection, CEC will schedule and conduct repairs promptly while noting the risk associated with the deficiency. During site inspections, the inspector will walk the entire closed Pond A area and document the problematic items on the "General Site Inspection Sheet" provided in Appendix A.

If maintenance is required, only low ground-pressure tire or track equipment should be utilized to correct the deficiencies on closed portions of Pond A. Larger equipment can be used, but the equipment loading cannot exert more than five pounds per square inch (psi) on the liner material. The exterior dike is not



being capped, as it will serve as an access road around the site during construction of the final cover system.

If repairs to the geosynthetics (e.g., geomembrane, geotextile, etc.) are necessary, a certified geosynthetic installer must conduct the repairs under the direction of a quality assurance representative. Repairs will be documented in a report, and a copy will be placed in the site's operating record.

3.3 Site Use Restrictions [40 CFR 257.104(d)(1)(iii)]

Currently, the identified end use for Pond A at JH Campbell has been limited to securing the area and maintaining the site as described in Sections 3.1 and 3.2. If the area is to be developed in the future, the integrity of the geomembrane cover liner shall be confirmed with the proposed use; and institutional controls for maintaining the integrity of the geomembrane cover will be provided through an update to the post-closure plan. Once closed, the owner or operator must record a notation on the deed to the property. The notation on the deed must in perpetuity notify any potential purchaser of the property that:

- The land has been used as a CCR unit; and
- Its use is restricted under the post-closure care requirements as provided by Section 257.104(d)(1)(iii).

Use of the site will be restricted by either fencing and gating or procedure to prohibit access other than for performing inspections, maintenance, and monitoring; established easements; and to restrict the use of intrusive vehicles and activities at the site.

3.4 Groundwater Monitoring

Fourteen groundwater monitoring wells were installed around Pond A to establish a groundwater monitoring system under 40 CFR 257.91(e)(1) during the fourth quarter of 2015. The groundwater monitoring well locations are provided on Figure 2 – Site Map. Groundwater monitoring wells will be used to collect data to develop an initial annual groundwater monitoring and corrective action report that is required to be certified by a qualified professional engineer (QPE) and posted in the operating record by January 31, 2018 per 40 CFR 257.90(e). In conformance with 40 CFR 257.93, a groundwater sampling and analysis procedure plan was developed for the groundwater monitoring program. The plan is included in Appendix B – Groundwater Sampling Analysis and Procedure Plan and includes direction on how to perform or acquire the following:

- | | |
|---|---|
| ■ Groundwater elevations | ■ Sample preservation and shipment |
| ■ Sample collection and handling procedures | ■ Quality assurance/Quality control (QA/QC) |
| ■ Equipment decontamination procedures | ■ Investigation derived waste (IDW) |
| ■ Chain of custody control | |



- Field documentation
- Analytical suite and procedures
- Optional additional analyses
- Data evaluation

Once the CCR unit is certified closed, post-closure periodic groundwater samples will be collected at least semi-annually and analyzed for 30 years for the following constituents in Table 3.4.1 – Groundwater Detection Monitoring Constituents.

Table 3.4.1 – Groundwater Detection Monitoring Constituents

Common Name	
Boron	Fluoride
Calcium	Sulfate
Chloride	Total Dissolved Solids (TDS)
pH	-

If a statistically significant increase over background levels for one or more of the constituents listed in Table 3.4.1 is detected during groundwater detection monitoring, then CEC will follow the procedures outlined in 40 CFR 257.93(h) and 257.94(e). If required by 40 CFR 257.94(e), an assessment groundwater monitoring program will be established meeting the requirements of 40 CFR 257.95 for the constituents presented in Table 3.4.2 – Groundwater Assessment Monitoring Constituents. The data will be presented in an annual groundwater monitoring and corrective action report per 40 CFR 257.90(e).

Table 3.4.2 – Groundwater Assessment Monitoring Constituents

Common Name		
Antimony	Chromium	Mercury
Arsenic	Cobalt	Molybdenum
Barium	Fluoride	Selenium
Beryllium	Lead	Thallium
Cadmium	Lithium	Radium 226 and 228 combined



The annual groundwater monitoring and corrective action reports will be:

- Maintained in the JH Campbell operating record per 40 CFR 257.105(h)(1)
- Submitted to the Michigan Department of Environmental Quality (MDEQ) per the notification requirement in 40 CFR 257.106(h)(1)
- Posted on a publicly accessible internet website per 40 CFR 257.107(h)(1)

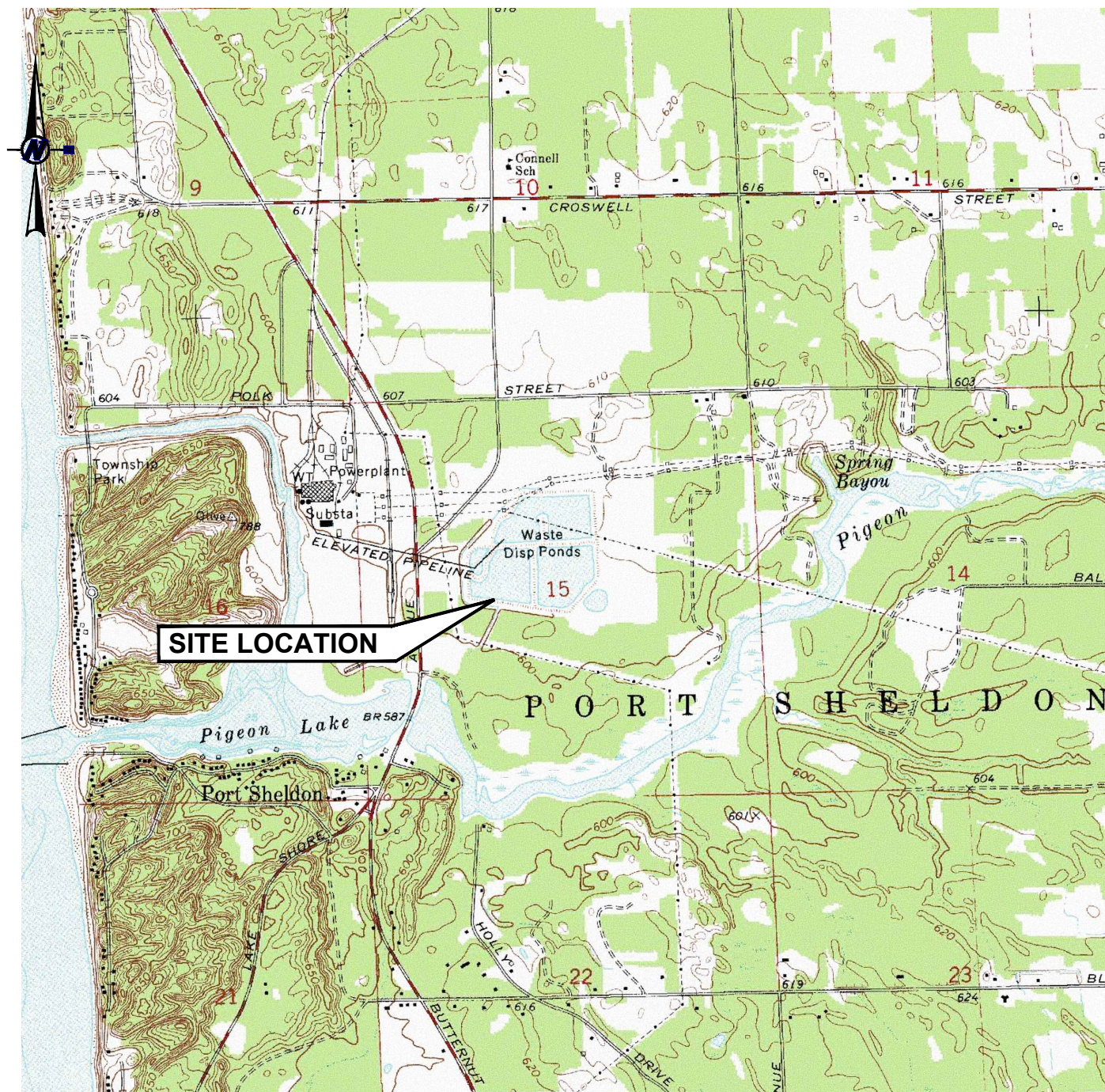
If additional notification is warranted, CEC will notify appropriate parties per 40 CFR 257.106(h).



4.0 REFERENCES

"Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments," Title 40 – Protection of the Environment Part 257 – Criteria for Classification of Solid Waste Disposal Facilities and Practices Subpart D – Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments.

FIGURES



REFERENCE(S)

1. BASE MAP TAKEN FROM 7.5 MINUTE U.S.G.S. QUADRANGLES OF PORT SHELDON MICHIGAN, DOWNLOADED FROM MICHIGAN DNR WEBSITE JUNE 2016.



CLIENT
CONSUMERS ENERGY COMPANY
17000 CROSWELL ST.
WEST OLIVE, MI 49460

CONSULTANT



YYYY-MM-DD 2016-06-06

DESIGNED BAL

PREPARED ARM

REVIEWED DJS

APPROVED MAB

PROJECT
J.H. CAMPBELL GENERATING FACILITY POND A
POST-CLOSURE PLAN

TITLE

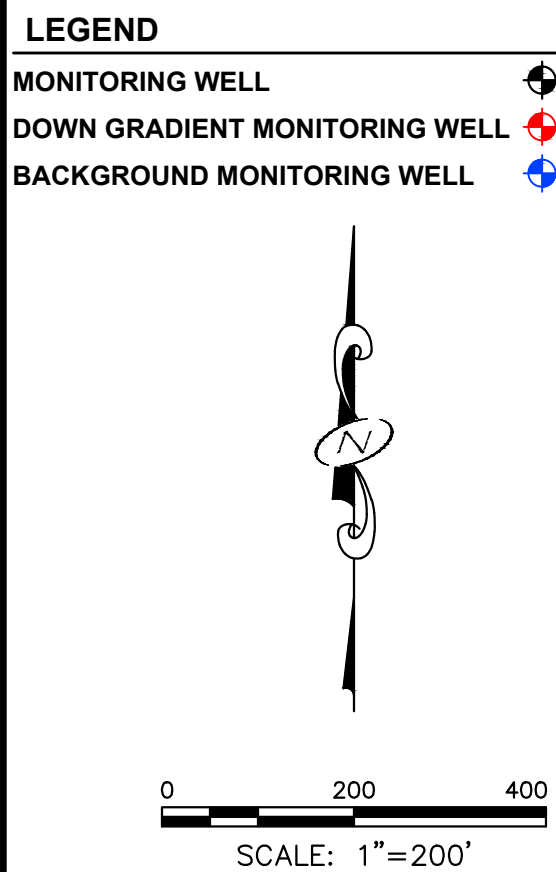
SITE LOCATION MAP

PROJECT NO.
1654923

REV.
#

FIGURE
1

1. CONTOURS SHOWN ARE FROM APRIL 2012 AERIAL SURVEY.

[illegible]

APPENDIX A
GENERAL SITE INSPECTION SHEET



GENERAL SITE INSPECTION J.H. CAMPBELL WET ASH POND CLOSURE AREA

Inspector:	Inspection Date:
Post Closure Manager:	Review Date:

SITE CONDITIONS	
Weather:	Temperature:
Precipitation:	Wind:

INSPECTION TASKS
1) Note areas of erosion (gullies exceeding 6 inches deep).
2) Note areas of sedimentation.
3) Note areas of settlement that have compromised surface drainage controls.
4) Note areas of ponding.
5) Note areas of vegetative stress.
6) Note areas of woody plant growth.
7) Note location of animal burrows.
8) Condition of ditches, culverts, and channels.



GENERAL SITE INSPECTION
J.H. CAMPBELL WET ASH POND CLOSURE AREA

9) Condition of site access road(s), silt fences surrounding the site.
10) Condition of fencing and gates.
11) Proper site restriction signage.
12) Miscellaneous findings.

ADDITIONAL COMMENTS

CORRECTIVE ACTION PLAN (To Be Completed by Post Closure Manager)

APPENDIX B
GROUNDWATER SAMPLING ANALYSIS AND PROCEDURE PLAN

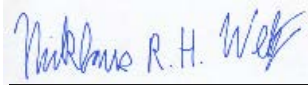
Consumers Energy Company

ELECTRIC GENERATION FACILITIES RCRA CCR DETECTION MONITORING PROGRAM

JH Campbell Monitoring Program
Sample and Analysis Plan
West Olive, Michigan

May 18, 2016

**ELECTRIC GENERATION
FACILITIES RCRA CCR
DETECTION MONITORING
PROGRAM**



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JH Campbell Monitoring Program
Sample and Analysis Plan

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DE000722.0002.00004

Date:

May 18, 2016

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CONTENTS

1	Introduction	1
2	Purpose and Objectives	1
3	Implementation and Sampling Schedule	1
4	Sample Collection and Handling Procedures	2
4.1	Groundwater Elevations	2
4.2	Groundwater Sample Collection	3
4.3	Sample Preservation and Shipment	4
4.4	Quality Assurance/Quality Control (QA/QC)	4
4.5	Equipment Decontamination Procedures	5
4.6	Investigation Derived Waste (IDW)	5
4.7	Field Documentation	5
5	Analytical Suite and Procedures	6
5.1	Optional Additional Analyses	7
6	Data Evaluation	8

TABLES

Table 1	Monitoring Well Construction Details
---------	--------------------------------------

FIGURES

Drawing SG-22345 – Campbell Plant Monitoring Wells, CCR Monitoring

APPENDICES

- A Low Stress (Low Flow) Purging and Sampling of Groundwater Monitoring Wells SOP (Procedure CHEM-2.7.06)
- B Chain-of-Custody, Handling, Packing and Shipping SOP (Procedure CHEM-1.2.04)

1 INTRODUCTION

ARCADIS has prepared this Groundwater Sampling and Analysis Plan (SAP) to evaluate background and downgradient groundwater quality at the JH Campbell electric generation facility (JHC), located in West Olive, Michigan (Site). The collection of groundwater data will be completed to achieve compliance under the recently published 40 CFR Part 257, Subpart D – Standards for the Disposal of Coal Combustion Residuals (CCR) in Landfills and Surface Impoundments. The methodologies outlined in this SAP are consistent with the regulations, general federal and state guidance, ARCADIS and Consumers Energy (CE) Standard Operating Procedures (SOPs), and industry standards.

2 PURPOSE AND OBJECTIVES

The groundwater monitoring and corrective action compliance requirements for existing CCR units are set forth in 40 CFR 257.90 through 257.98. The groundwater sampling and analysis requirements detailed in 40 CFR 257.93, and require the development of a SAP which details the sampling and analysis procedures that will be utilized to provide an accurate representation of groundwater quality at the background and downgradient wells. As per, 40 CFR 257.93 a) this SAP includes a description of the procedures and techniques that will be implemented for:

- Sample collection
- Sample preservation and shipment
- Analytical procedures
- Chain of custody control
- Quality assurance and quality control

3 IMPLEMENTATION AND SAMPLING SCHEDULE

As set forth in 40 CFR 257.93, eight (8) background detection monitoring events must be completed by October 17, 2017. Establishment of a groundwater monitoring system is necessary for the JH Campbell Cells 1-4 (CCR Landfill) and Bottom Ash Ponds 1-2, N/S, Bottom Ash Ponds 1-2, N/S, and Pond A (CCR Surface Impoundments). Background and detection monitoring events will be completed concurrently by comparison of data from monitoring wells located both away from (background) and downgradient of any impoundments still receiving ash as of the implementation date of the rule (October 19, 2015).

The sampling events will be distributed to account for seasonal variability and will be spaced at least 30 days apart to be considered statistically independent. The following is a general schedule to be followed assuming a quarterly sampling interval beginning December 2015 and ending September 2017. Minor modification to the timing of sampling events can be made as long as the requirements listed above are still met. This schedule may be shifted to start in the fourth quarter of 2015 pending timing of well installation and development.

- Event 1 – 4th Quarter 2015 (December)

- Event 2 – 1st Quarter 2016 (March)
- Event 3 – 2nd Quarter 2016 (June)
- Event 4 – 3rd Quarter 2016 (September)
- Event 5 – 4th Quarter 2016 (December)
- Event 6 – 1st Quarter 2017 (March)
- Event 7 – 2nd Quarter 2017 (June)
- Event 8 – 3rd Quarter 2017 (September)

Resampling of a well due to an anomalous result, either relative to data collected from other monitoring wells of similar type, or relative to other time-series data at an individual monitoring well may be completed at any time. The timing of the resampling event, and the reason for additional data collection will determine if events are statistically dependent and inform the appropriate method for addressing interpretation or inclusion of data. Additional analytes may also be required pending the results of the quarterly monitoring events (in accordance with Section 257.94(e)). This document does not cover collection and analysis of such additional data.

4 SAMPLE COLLECTION AND HANDLING PROCEDURES

The following sections address the methods and procedures associated with the collection and handling of groundwater samples at the Site. The monitoring well locations are shown in Drawing SG-22345, and relevant construction details and monitoring purpose (e.g. background or downgradient) provided in Table 1. A total of thirty-seven (37) monitoring wells were installed at the JH Campbell facility to assess groundwater quality within the uppermost aquifer, which consists of a shallow aquifer approximately 5-35 feet below ground surface. Eight (8) monitoring wells are designated as background monitoring wells with the remaining wells to monitor downgradient groundwater quality for comparison (Drawing SG-22345). Of the 37 monitoring wells, three (3) wells are existing monitoring wells, designated as follows:

Historical Well Name	RCRA Well Name
MW-B4	JRW MW-15035
MW-B6	JRW MW-15036
MW-B7	JRW MW-15037

4.1 Groundwater Elevations

Groundwater level data will be collected from all monitoring wells during each sampling event, prior to sampling. The monitoring well locations are depicted on Drawing SG-22345. Groundwater level monitoring will be conducted in accordance with Section 9.2 of the Low Stress (Low Flow) Purging and Sampling of Groundwater Monitoring Wells SOP presented in Appendix A.

Upon arrival at the site, all monitoring wells will be opened and allowed to equilibrate with ambient air pressures prior to measuring the depths to water. Groundwater level measurements will then be made to the nearest 0.01 foot with an electronic water level indicator from the entire monitoring well network prior to sampling – monitoring wells that constitute a groundwater monitoring system for a CCR Unit shall be preferentially sampled in order to further minimize water level elevational changes relative to the CCR Unit.. The entire monitoring well network shall be gauged on the same day to minimize temporal bias of measured groundwater elevation changes for the monitoring well network.

Depth to water will be measured from established top of casing reference points. Groundwater levels, well conditions, and any pertinent observations will be recorded on the depth to water level measurements field log provided in Appendix A.

The measured hydraulic gradient will be used along with previously completed hydraulic conductivity testing to estimate the apparent groundwater gradient during each sampling event.

4.2 Groundwater Sample Collection

Groundwater samples will be collected from the monitoring wells following Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures (US EPA, 1996), as detailed in the Low Stress (Low Flow) Purging and Sampling of Groundwater Monitoring Wells SOP (Appendix A). Low flow sampling will commence with the installation of either a peristaltic, stainless-steel 12-volt submersible impeller pump or bladder pump to a depth representing the middle of the saturated screen interval. An appropriate length of polyethylene tubing will be connected to the pump discharge prior to pump placement. The discharge line will be connected to a flow-cell and multi-meter to collect water quality indicator parameters (described below) during well purging to determine water quality stabilization.

The pump will be operated at a flow rate that will ensure low volatilization and low well disturbance. Water quality indicator parameters and depth to water will be recorded at 3 to 5 minute intervals during the purging process and recorded on the sampling worksheet provided in Appendix B. Purging and sampling will proceed at a low pumping rate, expected to be 0.5 liters per minute or less, such that the water column in the well is not lowered more than 0.3 feet below the initial static depth to water measurement. The subject well will be considered ready to sample when three consecutive water quality measurements meet the stabilization criteria presented below.

Parameter	Stabilization Criteria
pH	3 readings within +/- 0.1 standard units (SU)
Specific Conductance	3 readings within +/- 3% millisiemens per centimeter (mS/cm)
Temperature	For Information Only
Turbidity	+/- 10% Nephelometric Turbidity Unit (NTU) variance between three consecutive readings and a turbidity less than 10 NTU
Oxygen Reduction Potential (ORP)	3 readings within +/- 10 millivolts (mV)
Dissolved Oxygen (DO)	3 readings within +/- 0.3 milligrams per liter (mg/L)

If the well is dry, no attempt at sampling will be conducted, as the aquifer is not considered to have sufficient quantity at that location. Additionally, if the well is pumped dry during low-flow monitoring activity, the well will be left overnight to accumulate water, then a sample collected assuming the NTU criteria can be met. Prior to use, all equipment will be calibrated in accordance with the manufactures recommendations. Calibration information will be recorded in the field book.

4.3 Sample Preservation and Shipment

Samples will be collected immediately following stabilization of field parameters as set forth in the preceding section. Groundwater samples will be collected into the laboratory provided sample containers required for the analyses specified in the following section. The groundwater samples will be collected from the discharge tubing upstream of the water quality meter flow cell. Care will be taken to allow for a non-turbulent filling of laboratory containers. Routine samples will not be filtered in the field to provide a measure of total recoverable metals that will include both the dissolved and particulate fractions of metals as per the rule.

If a more detailed understanding of the source of metals concentrations in groundwater is required for select monitoring wells, field filtered samples may be analyzed in addition to routine analysis. Field filtering may also be completed on highly turbid samples (greater than 10 NTU). Field filtering will be completed using a 0.45 micron filter. If required, an attempt will be made to redevelop any monitoring wells that produce highly turbid samples prior to the subsequent sampling event. Where samples are filtered, a corresponding, unfiltered sample will also be collected.

The samples will be labelled, stored and transported to the laboratory according to the Chain-of-Custody, Handling, Packing and Shipping SOP presented in Appendix C. Following collection, samples will be immediately labelled, logged on the chain-of-custody, and placed in a cooler with ice. Sample coolers transported to the laboratory via overnight or next day air freight will be sealed with packing tape and a signed Chain-of-Custody seal. Sample coolers transported to the laboratory directly must be secured to ensure sample integrity is maintained. The samples will be packaged and shipped according to U. S. Department of Transportation and EPA regulations. The documentation of actual sample storage and transport will be by the use of chain-of-custody procedures. A laboratory provided chain-of-custody record will contain the dates and times of collection, receipt, and completion of all the analyses on a particular set of samples. The laboratory will return a copy of the chain-of-custody with the analytical report.

4.4 Quality Assurance/Quality Control (QA/QC)

Quality assurance/quality control (QA/QC) samples will be collected to ensure sample containers are free of analytes of interest, assess the variability of the sampling and laboratory methods, and monitor the effectiveness of decontamination protocols. The following QA/QC samples will be collected during each groundwater sampling event:

- Field duplicates will be collected at a frequency of one duplicate sample per 10 groundwater samples with at least one duplicate collected from each Unit. The field duplicates will be collected at the same time and in the same manner as the original sample. The duplicates will be labeled as a blind sample and noted on the sampling form of the designated well.

- Matrix spike/matrix spike duplicate (MS/MSD) samples will be collected at a frequency of one MS/MSD sample per 20 groundwater samples with at least one MS/MSD from each Unit. Duplicate and MS/MSD samples will be collected from different monitoring wells.
- Field blanks will be collected at a frequency of one field blank per 20 groundwater samples with at least one field blank collected from each Unit.
- Equipment blanks will be collected at a frequency of one equipment blank per 10 groundwater samples with at least one equipment blank collected from each Unit. The equipment blank will be collected by pouring distilled or deionized water over the decontaminated static water level meter or low flow pump and into the laboratory supplied containers.

Based on the number of Units at the Campbell facility (five Units) and wells per Unit, a total of 5 field duplicates, 5 MS/MSD, 5 field blanks, and 5 equipment blanks will be collected during each sample event. The QA/QC samples will be submitted to the laboratory for the routine analyses specified in Section 5 and in Appendix III and IV to Part 257. The laboratory should provide adequate documentation of laboratory reporting and QA/QC procedures.

4.5 Equipment Decontamination Procedures

All non-dedicated equipment will be decontaminated prior to use and between samples, following procedures presented in paragraph 9.6 of the SOP in Appendix A. Non-dedicated equipment will include a water level meter and low flow sampling pump (submersible). Each item will be cleaned using distilled or deionized water, and when necessary, non-phosphate detergent wash followed by a distilled or deionized water rinse. When a peristaltic pump is used for low flow sampling, decontamination is not required, only replacement of the pump head tubing.

All dedicated equipment will be disposed of after each sampling point. Dedicated equipment will include polyethylene tubing and bladders if a bladder pump is used for low-flow sampling.

The flow-cell and water quality multi-meter (sonde) will be decontaminated at the completion of low-flow sampling. All sample collection will occur upstream of this device and therefore will not affect groundwater sample analytical results.

4.6 Investigation Derived Waste (IDW)

All waste created during monitoring well sampling will remain on site. All purge water from wells installed within the CCR Units will be discharged back onto the ground near the well it was purged from. All purge water from wells installed outside of a CCR Unit will be discharged to the ground in a manner that it doesn't directly enter a surface water or drain. All IDW will be handled according to details provided in paragraphs 9.3.8 and 9.4.10 of the SOP provided in Appendix A.

4.7 Field Documentation

All information pertinent to the field activities and sampling efforts will be recorded in a log or notebook, following the documentation procedures presented in section 5.4 of the SOP in Appendix B. Field logs

are provided in the Attachments to Appendix A. At a minimum, entries in the sample logs will include the following:

- Property details and location
- Type of sample (for example, groundwater, surface water, waste)
- Number and volume of samples taken
- Sampling methodology
- Date and time of collection
- Sample identification number(s)
- Field observations including weather
- Any field measurements made (for example, pH, temperature, water depth and air monitoring data)
- Personnel present

Records shall contain sufficient information so that the sampling activity can be reconstructed without relying on the collector's memory. The sample logs will be preserved in electronic format.

5 ANALYTICAL SUITE AND PROCEDURES

As required for existing CCR units, all groundwater samples collected at the JHC facility will be submitted to the laboratory for the analyses specified in Appendix III and IV to Part 257. The analytical methods and reporting limits for each constituent are summarized below. If required, and in consultation with the laboratory, a comparable analytical method may be substituted for the analytical method recommended below. All groundwater samples will be submitted to Consumers Energy Trail Street Laboratory. If any analyses are subsequently subcontracted to another accredited laboratory, the samples will be shipped using appropriate methods and COC documentation. All analyses will be performed within required hold times and consistent with the data quality objectives of this SAP.

Appendix III to Part 257—Constituents

Constituent	Analytical method	Preservation	Hold Time (Days)	Reporting Limit (µg/L)
Boron	EPA 6020B	HNO ₃ , pH <2	180	20
Calcium	EPA 6020B	HNO ₃ , pH <2	180	1,000
Chloride	EPA 300.0	None, <6°C	28	1,000
Fluoride [#]	EPA 300.0	None	28	1,000
pH	Stabilized field measurement	NA	NA	0.1 standard units
Sulfate	EPA 300.0	None, <6°C	28	2,000
Total Dissolved Solids	SM 2540C	None, <6°C	7	1,000

HNO₃ – Nitric acid

NA – Not applicable

Appendix IV to Part 257—Constituents

Constituent	Analytical method	Preservation	Hold Time (Days)	Reporting Limit (µg/L)
Antimony	EPA 6020B	HNO ₃ , pH <2	180	1
Arsenic	EPA 6020B	HNO ₃ , pH <2	180	1
Barium	EPA 6020B	HNO ₃ , pH <2	180	5
Beryllium	EPA 6020B	HNO ₃ , pH <2	180	1
Cadmium	EPA 6020B	HNO ₃ , pH <2	180	0.2
Chromium, total	EPA 6020B	HNO ₃ , pH <2	180	1
Cobalt	EPA 6020B	HNO ₃ , pH <2	180	15
Fluoride [#]	EPA 300	None, <6°C	28	1,000
Lead	EPA 6020B	HNO ₃ , pH <2	180	1
Lithium	EPA 6020B	HNO ₃ , pH <2	180	10
Mercury	EPA 7470A	HNO ₃ , pH <2	28	0.2
Molybdenum	EPA 6020B	HNO ₃ , pH <2	180	5
Selenium	EPA 6020B	HNO ₃ , pH <2	180	1
Thallium	EPA 6020B	HNO ₃ , pH <2	180	2
Radium 226 and 228 combined [^]	EPA 903.1/904.0	HNO ₃ , pH <2	None	1 picocurie per liter

[#] Listed in both Appendix III and Appendix IV[^]Requires a larger sample volume (minimum 2 liter)**5.1 Optional Additional Analyses**

To interpret groundwater monitoring data and determine the appropriate statistical methods for use in comparison of background and downgradient data sets, an understanding of aquifer connectivity and water types may be required. To determine if samples are collected from comparable aquifer units the predominant water type will be determined using Piper and Stiff diagrams.

Piper and Stiff diagrams are a graphical representation of the major anion and cation composition of a water sample and are useful in establishing if groundwater samples are from the same or a similar aquifer unit. To generate Piper and Stiff diagrams additional analytical data beyond that collected during routine sampling will be required. The additional analytical requirements are shown in the table below.

Constituent	Analytical method	Preservation	Hold Time (Days)	Reporting Limit (µg/L)
Bicarbonate, carbonate and total alkalinity	ASM 2320B	None, 6°C	14	10,000
Magnesium	EPA 6020B	HNO ₃ , pH <2	180	1,000
Sodium	EPA 6020B	HNO ₃ , pH <2	180	1,000
Potassium	EPA 6020B	HNO ₃ , pH <2	180	500

6 DATA EVALUATION

In accordance with 40 CFR 257.93 data collected from eight samples from each background well will be used to calculate background concentrations for each constituent at each site. Background concentrations for each constituent will be calculated using an appropriate statistical method for each background well and constituent pair at the site, selected based on the distribution of the data in accordance with 40 CFR 257.93.

The data collected from background and downgradient monitoring wells will be compared using an appropriate statistical method, to be determined based on the distribution of data for each constituent, to assess if downgradient concentrations are consistent with background concentrations for each constituent. The statistical method used for this analysis will be one, or a combination, of the four statistical methods described below and in 40 CFR 257.93(f) and will meet the performance standards outlined in 40 CFR 257.93(g).

A combination of statistical methods may be applied depending on the statistical distribution observed for each specified constituent in each monitoring well. The four specific statistical procedures provided in 40 CFR 257.93(f) are: (1) a parametric analysis of variance followed by multiple comparison procedures to identify statistically significant evidence of contamination; (2) an analysis of variance based on ranks followed by multiple comparison procedures to identify statistically significant evidence of contamination; (3) a tolerance or prediction interval procedure; and (4) a control chart approach.

The potential for seasonal and spatial variability as well as temporal trends will be considered when selecting the statistical method for comparison. Data will also be displayed graphically using box-and-whisker plots to aid in interpretation of the statistical analysis.

In order to select the appropriate method for statistical analysis for each constituent at each monitoring well, the distribution type for each constituent/well pair will be calculated. Normally distributed data will use parametric methods for comparisons and non-normally distributed data will use non-parametric methods, consistent with the requirements outlined in 40 CFR 257.93(g).

Statistical comparisons will be performed using a confidence level of 99 percent (alpha of 0.01) for comparisons of individual data point to background concentrations, and a confidence level of 95 percent (alpha of 0.05) where multiple data points will be compared to background, consistent with 40 CFR 257.93(g).

TABLES



Table 1
Monitoring Well Construction Summary
Consumers Energy Co.
J.H. Campbell Generating Facility
West Olive, Michigan

MW ID	Former MW ID	Site Coordinates				Date Installed	Geologic Unit of Screen Interval	Well Construction	Well Screen Length (ft)	Screen Interval (ft bgs)	Static DTW (ft below TOC)	Total Depth
		Northing	Easting	TOC	Ground Elevation							
Pond A Downgradient MW												
JHC MW-15006	---	517535.73	12635481.66	624.74	627.58	9/18/2015	Silty Sand / Sand	2" PVC, 10 slot	10	25 - 35	28.90	38.02
JHC MW-15007	---	517540.50	12635742.72	624.82	627.70	9/21/2015	Sand	2" PVC, 10 slot	10	22 - 32	29.28	34.75
JHC MW-15008	---	517560.39	12636031.25	632.43	635.30	9/21/2015	Sand	2" PVC, 10 slot	10	28 - 38	38.25	40.76
JHC MW-15009	---	517779.13	12636014.80	632.33	635.32	9/22/2015	Sand	2" PVC, 10 slot	10	30 - 40	37.14	42.88
JHC MW-15010	---	518009.36	12636011.46	632.55	635.57	9/23/2015	Sand	2" PVC, 10 slot	10	30 - 40	36.57	42.88
JHC MW-15011	---	517540.50	12634931.59	627.71	630.83	9/23/2015	Sand	2" PVC, 10 slot	10	27 - 37	34.45	40.12
CCR Landfill (Cells 1,2,3, and 4) Downgradient MW												
JHC MW-15017	---	521074.31	12635685.32	613.69	616.61	9/29/2015	Sand	2" PVC, 10 slot	10	10 - 20	15.56	22.98
JHC MW-15018	---	521075.54	12635979.61	614.26	617.02	9/28/2015	Sand	2" PVC, 10 slot	10	10 - 20	16.23	22.95
JHC MW-15019	---	521058.67	12636352.00	609.81	612.86	9/29/2015	Sand	2" PVC, 10 slot	10	6 - 16	12.78	19.11
JHC MW-15020	---	521059.97	12636589.95	609.04	611.90	9/30/2015	Sand	2" PVC, 10 slot	10	6 - 16	12.25	18.97
JHC MW-15021	---	521065.93	12636839.06	610.70	613.65	9/30/2015	Sand	2" PVC, 10 slot	10	6 - 16	14.38	18.30
JHC MW-15022	---	520479.72	12638430.24	620.92	623.79	9/30/2015	Sand	2" PVC, 10 slot	10	23 - 33	29.37	36.30
JHC MW-15031	---	520118.00	12637801.51	632.94	635.87	10/5/2015	Sand	2" PVC, 10 slot	10	33 - 43	43.19	46.17
JHC MW-15032	---	520779.28	12638667.93	611.32	614.29	10/6/2015	Sand	2" PVC, 10 slot	10	13 - 23	17.81	26.04
JHC MW-15033	---	521075.81	12638598.12	618.08	620.99	10/6/2015	Sand	2" PVC, 10 slot	10	16 - 26	22.93	28.78
JHC MW-15034	---	521335.83	12638568.90	612.90	615.97	10/6/2015	Sand	2" PVC, 10 slot	10	11 - 21	16.81	23.98
JHC MW-15035	MW-B5	520112.93	12637510.26	632.53	634.28	3/14/2001	Sand	2" PVC, 10 slot	10	33 - 43	NA	NA
JHC MW-15036	MW-B6	520099.80	12638094.34	617.94	618.34	3/13/2001	Sand	2" PVC, 10 slot	10	20 - 30	NA	NA
JHC MW-15037	MW-B7	520083.04	12638436.69	614.28	616.06	8/29/2001	Sand	2" PVC, 10 slot	10	23 - 28	NA	NA
Bottom Ash Pond Unit 1-2N/1-2S Downgradient MW												
JHC MW-15001	---	518586.88	12633422.01	607.02	609.53	9/16/2015	Sand	2" PVC, 10 slot	5	3.5 - 8.5	9.31	11.72
JHC MW-15002	---	518378.92	12633974.82	625.97	628.87	9/16/2015	Sand	2" PVC, 10 slot	10	28 - 38	24.51	41.05
JHC MW-15003	---	518069.86	12633990.37	628.31	630.63	9/17/2015	Sand	2" PVC, 10 slot	10	28 - 38	30.57	40.12
JHC MW-15004	---	517864.56	12633547.12	624.92	628.44	9/17/2015	Sand	2" PVC, 10 slot	10	24 - 34	31.67	37.48
JHC MW-15005	---	517781.42	12633905.01	624.37	627.30	9/18/2015	Sand	2" PVC, 10 slot	10	27 - 37	33.26	40.10
Bottom Ash Pond Unit 3N/3S Downgradient MW												
JHC MW-15012	---	519214.84	12633675.28	632.59	635.66	9/28/2015	Sand	2" PVC, 10 slot	10	28 - 38	28.70	40.96
JHC MW-15013	---	519207.19	12634025.15	632.40	635.25	9/25/2015	Sand	2" PVC, 10 slot	10	28 - 38	25.94	41.15
JHC MW-15014	---	519419.85	12634254.12	635.13	638.18	9/25/2015	Sand	2" PVC, 10 slot	10	39 - 49	29.81	52.00
JHC MW-15015	---	519715.11	12634186.63	632.46	635.20	9/28/2015	Sand	2" PVC, 10 slot	10	28 - 38	28.57	41.28
JHC MW-15016	---	519956.79	12634198.52	631.81	634.64	9/28/2015	Sand	2" PVC, 10 slot	10	28 - 38	30.33	41.06
Background MW												
JHC MW-15023	---	521927.21	12638205.16	617.01	619.98	10/1/2015	Sand	2" PVC, 10 slot	10	14 - 24	18.91	27.68
JHC MW-15024	---	522366.01	12637322.68	613.79	616.62	10/1/2015	Sand	2" PVC, 10 slot	10	7 - 17	14.12	19.93
JHC MW-15025	---	522702.98	12636668.15	614.14	617.17	10/1/2015	Sand	2" PVC, 10 slot	10	7 - 17	13.50	19.94
JHC MW-15026	---	522495.09	12635971.82	615.09	618.04	10/2/2015	Sand	2" PVC, 10 slot	10	8 - 18	15.34	21.02
JHC MW-15027	---	522394.86	12635097.51	614.77	617.30	10/2/2015	Sand	2" PVC, 10 slot	10	10 - 20	15.85	22.99
JHC MW-15028	---	521646.20	12634105.34	611.02	613.80	10/2/2015	Sand	2" PVC, 10 slot	10	8 - 18	14.38	20.82
JHC MW-15029	---	520503.52	12633774.30	608.08	610.95	10/5/2015	Sand	2" PVC, 10 slot	10	8 - 18	10.03	20.96
JHC MW-15030	---	519760.83	12633044.37	604.05	607.17	10/5/2015	Sand	2" PVC, 10 slot	10	4 - 14	7.99	16.93

Notes:
ft = feet
bgs = below ground surface
TOC = top of casing
NR = Not recorded
NA = Not applicable

FIGURES



[illegible]

APPENDIX A

Low Stress (Low Flow) Purging and Sampling of Groundwater
Monitoring Wells SOP (Procedure CHEM-2.7.06)



**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

Written or Revised by Katharyn L Schlueter Date 08/07/09
Level I or Above

Technical Review by Gordon L Cattell Date 08/07/09
Level II or Above (not author)

Technical Approval by Emil Blaj Date 08/07/09
Level III

This electronically produced document has been reviewed and approved by the above-named individuals. The original document bearing the approval signatures is maintained on file by Consumers Energy, Laboratory Services.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

1.0 SCOPE

- 1.1 This procedure is a general method for collecting low stress/low flow ground water samples from monitoring wells. Upon approval by the responsible party, this procedure may be used as a substitute for macro-purging techniques where 3 to 5 well volumes have traditionally been purged prior to sampling. The low stress/low flow method is the preferred technique for ground water monitoring wells located at the former Manufactured Gas Plant (MGP) sites of Consumers Energy.
- 1.2 The presented technique applies to monitoring wells that have an inner casing with a nominal diameter of at least 1.0 inch, and maximum-screened lengths of ten feet per interval.
- 1.3 The technique is appropriate for collection of ground water samples that will be analyzed for: volatile and semi-volatile organics including pesticides and polychlorinated biphenyls (PCBs), total and dissolved metals, and various other analytes such as sulfates, cyanides, and nitrates/nitrites.
- 1.4 The technique is also appropriate when the following conditions are desired: lower turbidity in the sample containers, significantly less purge water for disposal, and higher analyte repeatability.

2.0 APPLICABLE DOCUMENTS AND REFERENCES

- 2.1 CHEM-1.1.02, Chemistry Department Procedure Requirements.
- 2.2 Ground Water Issue, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures, Puls and Barcelona, USEPA, Office of Research and Development, Office of Solid Waste and Emergency Response, EPA/540/S-95/504, April 1996.
- 2.3 Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Ground Water Samples From Monitoring Wells, USEPA Region 1, SOP No GW 0001, Revision 2, July 30, 1996.
- 2.4 Technical Guidance on Low-Flow Purging and Sampling and Passive Sampling, D M and G L Nielson, The Nielson Environmental Field School, NEFS-TG001-99, December 1999.
- 2.5 Manufacturer Operation Manual, as appropriate.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

- 2.6 Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations, D6452-99, American Society for Testing and Materials.
- 2.7 MDEQ RRD Operational Memorandum 2, Attachment 5, Sampling and Analysis, October 2004, Revision.
- 2.8 Field worksheets (Attachments A-D).

3.0 DEFINITIONS

- 3.1 COC – Chain of Custody
- 3.2 NAPL – Non-aqueous Phase Liquids
- 3.3 LNAPL – Light Non-aqueous Phase Liquids
- 3.4 DNAPL – Dense Non-aqueous Phase Liquids
- 3.5 DTW – Depth-to-Groundwater

4.0 SUMMARY OF METHOD

- 4.1 Once depth-to-water is measured; a suitable pumping device is lowered to the target depth, generally mid-screen. Ground water is purged from the well casing at a slow rate, typically 100-500 mL/minute. While drawdown is measured and minimized, the purged water is diverted to a flow cell that contains several probes for indicating stabilization parameters, such as pH, conductivity, etc. Once the parameters have stabilized within pre-determined limits, the purged water stream is diverted from the flow cell to sample containers for collection of proper test parameters.

5.0 PREREQUISITES

5.1 MEASURING AND TEST EQUIPMENT

- 5.1.1 Flow-cell, hand-held monitor, and sonde, containing in-line probes calibrated for at least dissolved oxygen and oxidation-reduction potential (ORP). If necessary, pH and conductivity may be monitored with external monitors, although in-line probes are recommended. Turbidity or other probes/monitors may be added as site-specific requirements dictate.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

- 5.1.2 Adjustable rate groundwater pumping devices including: Peristaltic pump with pump head and electrical power source; bladder pump(s) with controller and a source of compressed air; gear pump (Keck or “bullet”), with controller and electrical power source. Gear and bladder pumps should be constructed of stainless steel or PTFE.
- 5.1.3 Tubing of the appropriate size, length, and material.
- 5.1.4 Interface probe for determining the presence or absence of NAPLs.
- 5.1.5 Water level measuring device with a minimum 0.01-foot accuracy.
- 5.1.6 Flow measurement supplies such as a rotometer or graduated cylinder with a stopwatch.
- 5.1.7 Portable PID meter, calibrated the same day as use.
- 5.1.8 Decontamination supplies, including deionized water, brushes, buckets, and commercially available 2-propanol soaked wipes.
- 5.1.9 Sample bottles with appropriate preservatives.
- 5.1.10 Field hazardous materials kit, including eyewash, sampling gloves, goggles, earplugs, etc.
- 5.1.11 Purge water collection device, such as a sturdy plastic bucket.
- 5.2 REAGENTS
 - 5.2.1 Assorted standards as needed to fully calibrate the above system.
- 5.3 CALIBRATION REQUIREMENTS
 - 5.3.1 All meters, probes, etc must be calibrated according to manufacturer’s instructions. Periodic checks are recommended during or at the end of the day to ensure the calibration curves. Written documentation is required for all calibrations and periodic checks.
 - 5.3.1.1 In general, daily recalibration will be required. In some cases where a periodic check indicates the calibration curves are still valid, no daily calibration may be necessary.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

5.4 QUALITY CONTROL DOCUMENTS AND RECORDS

- 5.4.1 Historical documentation, including well construction data (eg, screen depth), well location map, and field data from a previous sampling event.
- 5.4.2 Material Safety Data Sheets (MSDSs) for all reagents taken to the job site.
- 5.4.3 A field log book or field worksheet must be kept at each sampling event (see Attachments A-D). The following should be documented:
 - 5.4.3.1 Field instrumentation calibration data.
 - 5.4.3.2 Monitoring well identification number and physical condition.
 - 5.4.3.3 Monitoring well data such as casing material, casing diameter, and screen length.
 - 5.4.3.4 Monitoring well depth and DTW, measurement technique, date and time of measurement.
 - 5.4.3.5 Presence and thickness of NAPLs and detection method.
 - 5.4.3.6 Sample tubing material, diameter, length, placement, and pump type.
 - 5.4.3.7 Pumping rate, water level, water quality indicator values, date and time of measurements.
 - 5.4.3.8 Identification of any unacceptable water quality indicator values.
 - 5.4.3.9 Time and date of sample collection.
 - 5.4.3.10 Sample ID and control number.
 - 5.4.3.11 Field observations.
 - 5.4.3.12 Sampler's name or initials.
- 5.4.4 The COC must contain the analytical parameters requested, sample time and date, sampler's name or initials, site location, sample ID, control number, preservatives added, and filtration status.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

5.4.5 The sample labels must contain the sample ID, control number, sample time and date, sampler's initials, preservative, filtration status, and analytical parameter requested.

5.4.6 Field worksheets (Attachments A-D).

5.4.6.1 Monitoring Well Sampling Worksheet (Attachment A)

5.4.6.2 Monitoring Well Depth-To-Water Measurements Worksheet (Attachment B)

5.4.6.3 Flowcell/Sonde Calibration and Periodic Checks Worksheets (Attachment C)

5.4.6.4 Field Screening of Monitoring Wells Via PID (Attachment D)

5.5 PERSONNEL REQUIREMENTS

5.5.1 All tests and data reporting shall be performed by certified persons of Level I or above, in the appropriate discipline. (The project report shall be issued and reviewed by a certified person of Level II or above, in the appropriate discipline. The project report, if so indicated on the work request [or form similar in intent], may require approval from a certified person of Level III, in the appropriate discipline.)

5.6 ENVIRONMENTAL CONDITIONS

See Section 6.0.

6.0 PRECAUTIONS

6.1 The site-specific Health and Safety Plan is used to identify any physical or chemical precautions and actions to be taken to prevent injury. A pre-job briefing shall be conducted prior to initiating sampling.

6.2 Observe normal safety practices as specified in the latest online revision of the Environmental and Laboratory Services Accident Prevention Manual and the Consumers Energy Chemical Hygiene Plan in Lotus Notes.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

7.0 LIMITATIONS AND ACTIONS

- 7.1 This technique is generally not suitable for very low-yield wells (<50 mL/minute with continued drawdown).
- 7.2 Even with pre-planning, a number of problems may be encountered which will challenge the sampler. These include: insufficient yield, failure of one or more key indicator parameters to stabilize, cascading, and equipment failure. Each of these problems will be addressed on a case-by-case basis and their impact can be minimized by consulting the references in Section 2.
- 7.3 This method does not address the collection of light or dense non-aqueous phase liquids (LNAPLs and DNAPLs). Collection of these sample types is both atypical and non-standardized and must therefore be addressed on an as-needed basis.

8.0 ACCEPTANCE CRITERIA

Refer to Section 9.3.9.3 in this procedure.

9.0 PROCEDURE

- 9.1 Orient the equipment and yourself upwind of the monitoring wells if possible.
- 9.2 DETERMINATION OF DEPTH-TO-GROUNDWATER (DTW)
 - 9.2.1 Start at either the well known, or believed to have, the least contaminated groundwater and proceed systematically to the well known, or believed to have, the highest level of contamination.
 - 9.2.2 Check the well casing protector, lock, locking cap, and well casing for obvious damage or evidence of tampering. Record any abnormal observations.
 - 9.2.3 The sampler may desire to minimize contamination from the ground and provide a clean area for laying down equipment. This can be accomplished by cutting a section from a sheet of plastic and fitting it around the well casing protector.
 - 9.2.4 Remove the well cap. At some sites, it may be necessary to remove all well caps first, then proceed to 9.2.5. This will be determined prior to any field events.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

- 9.2.5 If the site has not been characterized yet, or there is insufficient history, it will be useful to determine the concentration of organic vapors in the heads case. Using a portable, calibrated, PID meter measure and record the organic vapor concentration as follows: (1) At the highest risk breathing zone elevation, defined here as the point located at roughly 6" above the center of the top of the well casing. (2) At 0-6" within the well casing.
- 9.2.6 If the well casing does not have a reference point, make one. The reference point is typically a V-cut or an indelible mark in the well casing.
- 9.2.7 Measure and record the DTW to 0.01 feet. Duplicate the reading. Hold the tape against the reference point when making the reading. Care should be taken to minimize disturbance of the water column.
- 9.2.8 Measure and record the thickness and depth of any NAPLs.
- 9.2.9 If desired or required by the site plan, measure the depth of the well. Care should be taken to minimize disturbance of the water column and any sediment that has accumulated.
- 9.2.10 Decontaminate the electronic tape and interface meter. Wipe dry using a clean Kaydry-type material. Rinse with DI water and wipe dry again. If organic contamination is suspected, the sampler must decontaminate accordingly before proceeding. One option is to use commercially prepared decontamination wipes that are saturated with 2-propanol.
- 9.2.11 If the monitoring well will be sampled the same day and will remain in visual range and/or without a reasonable risk of tampering, loosely recap the well and leave the well casing protector unlocked. Otherwise, secure the well as if not returning.
- 9.2.12 If a sheet of plastic has been fitted around the well casing protector, leave it in place if the well will be sampled the same day.
- 9.2.13 Continue with the determination of DTW on the rest of the monitoring wells. Continue with purging and sampling when appropriate (ie, large distance between wells).

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

9.3 PURGING

- 9.3.1 If not already determined at the laboratory or by prior sampling events, determine the type of pump to be used (operation of each pump type will not be covered here).
- 9.3.2 For ease of use and portability, a peristaltic pump may generally be used for any well where DTW plus casing height above grade does not exceed 15 feet.
- 9.3.3 Keck (gear or “bullet”) and bladder pumps can be used in any instance where there is sufficient water in the casing to completely submerge the pump and intake screen at all times.
- 9.3.4 Use well installation and historical data to determine the length of tubing needed to place the pump intake or tubing at the desired sample depth, generally mid-screen. Attach the tubing to the pump and prepare to lower the tubing or tubing/pump down the well. To keep from introducing contamination into the monitoring well, never allow the tubing or tubing/pump to touch bare ground.
- 9.3.5 Install the tubing or pump/tubing. Slowly lower the pump, tubing, and any safety cable and electrical lines into the monitoring well. Final placement is generally at mid-screen. Typically, the intake must be kept at least 2 feet above the bottom of the well to prevent disturbance and resuspension of any sediment or NAPL present in the bottom of the well. Once the desired depth is reached, clamp or otherwise secure the tubing to prevent the pump/tubing from dropping any lower. Record the depth to which the pump was lowered.
- 9.3.6 Before starting the pump, wait a few minutes and measure the water level again. Record this level. This short waiting period allows for reduced turbidity and reequilibrium of the water level. Leave the electronic tape in the well for later use.
- 9.3.7 Attach the in-line flow cell. Start the pump and collect roughly 100 mL/minute. Start with a faster or slower pumping rate if historical data suggests to do so.
- 9.3.8 Collect all water for proper disposal.
- 9.3.9 Monitor and record the water quality parameters and water level every 3-5 minutes.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

- 9.3.9.1 Ideally, a steady flow rate should be maintained that results in a stabilized water level. Pumping rates should be reduced or increased to ensure stabilization of the water level in the well. Avoid entrainment of air in the tubing.
- 9.3.9.2 Record the time of the readings and the pump rate.
- 9.3.9.3 The well is considered stabilized and ready for sample collection when the indicator parameters have stabilized for three consecutive readings as follows:
- ± 0.1 pH units
 - $\pm 3\%$ conductivity units (specific conductance)
 - ± 10 mV for redox potential (Eh/ORP)
 - $\pm 10\%$ for DO and turbidity
 - Temperature – For information only. Record only.

Dissolved oxygen and turbidity usually require the longest time to achieve stabilization. (Above criteria may not apply to very clean wells.)

9.4 SAMPLE COLLECTION

- 9.4.1 The pump must not be removed from the well between purging and sample collection. It is recommended that the pump not be turned off between purging and sample collection. Continue to collect excess groundwater for proper disposal.
- 9.4.2 Disconnect or bypass the flow cell.
- 9.4.3 Collect samples at the same flow rate as the purging rate. Minimize potential contamination from dust, rain, etc by shielding the open bottles as needed.
- 9.4.4 Samples will be collected directly into the sample containers. Minimize aeration by allowing the water to flow down the side of the container rather than splashing against the bottom of the bottle. Avoid placing the sample tubing below the liquid level of the sample being collected. Label the containers and chill immediately.
- 9.4.5 VOC samples must be collected first except as noted below for Low Level Mercury. Check for air bubbles in the container before proceeding to collecting the next parameter. Carbonaceous waters will naturally produce bubbles in the containers, which cannot, and should not, be removed.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

NOTE: A sample for low level mercury should be the first sample collected when multiple analyte containers will be filled. Low level mercury sample bottles should be pre-cleaned and individually stored in Ziploc®-style plastic bags. Use clean nitrile gloves for each sample collection point, immediately prior to handling any bagged sample bottles.

When collecting a sample from a monitoring well:

- Remove the sample bottle from the plastic bag and remove the cap.
- The bottle should be thoroughly rinsed with the sample stream, holding the sample tubing very close to, not within, the open bottle (approximately 1/8"). Never place the sample tubing within the bottle.
- Fill to approximately 1/4" below the bottle threads, affix a label, cap the bottle, and return it to the plastic bag.
- Place the bagged bottle in a cooler designated only for low level mercury.

9.4.6 Semi-volatile samples must be collected next, followed by any other parameters that do not require filtration.

9.4.7 Samples that require only filtration with no additional preparation steps should be collected using in-line filters. Filtered samples are typically collected last. One exception is collection for available cyanide, which must be collected last due to the potential for cross-contamination from the lead carbonate reagent.

9.4.8 Once all samples from the monitoring well are collected, remove the tubing or pump/tubing. Record the stop time, if required. In addition, the total volume purged can be calculated and recorded.

9.4.9 Cap and secure the monitoring well.

9.4.10 In general, the purged water is poured on to the ground next to the monitoring well. Whether to collect in a drum or to use another strategy will be determined prior to starting any field activities.

9.4.11 Continue with sampling all of the other monitoring wells.

9.5 FIELD QUALITY CONTROL (QC) SAMPLES

9.5.1 Field QC samples must be collected to determine if sample collection and handling procedures have adversely affected the quality of the ground water samples. All QC samples are treated the same as samples with regard to volume, bottle type, preservatives, and any pretreatment.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

9.5.2 TYPES OF QC SAMPLES

- 9.5.2.1 Trip Blank – For VOCs only. Consists of DI water in a VOC vial (contains preservative) and is prepared at the lab prior to the field event. The vial is left capped and chilled while sampling. Used to determine if sample holding and transport has introduced contamination into the samples.
- 9.5.2.2 Field Blank – Consists of DI water in an appropriate bottle with the appropriate preservative. Obtained from the lab prior to the sampling event and can prepare for a variety of analytes. The bottle is uncapped while sampling to indicate contamination that may have occurred during the operation.
- 9.5.2.3 Equipment Blank – DI water is exposed to the sample path at any time decontamination needs to be verified. Collect for any suspect parameter and treat it exactly the same as if collecting a sample.
- 9.5.2.4 Sample Duplicate – One monitoring well per 20 will be selected for collection of a duplicate sample. This is simply an additional set of the sample collected in exactly the same manner as the original sample. The sample type is used to determine precision.
- 9.5.2.5 Matrix Spike and Matrix Spike Duplicate – One monitoring well per 20 will be selected. These are additional sets of samples collected in exactly the same manner as the sample is collected. This sample type is used to determine accuracy but can also indicate matrix bias.

9.6 DECONTAMINATION

9.6.1 **General Considerations**

- 9.6.1.1 All nondedicated sampling equipment that is to be reused must be decontaminated prior to its reuse.
- 9.6.1.2 All disposable tubing will be properly discarded and new tubing used in its place. No tubing will be reused.
- 9.6.1.3 All equipment washings/rinsates must be collected for proper disposal.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

- 9.6.1.4 The flow cell may be cleaned using the procedure in Section 9.6.2.1 or a manufacturer recommended procedure. Special attention must be paid to care of the probes on the sonde portion of the unit.
- 9.6.1.5 To avoid cross-contamination, pumps that are contaminated with NAPLs will be isolated and decontaminated at the laboratory.
- 9.6.2 **Between Well and End-of-Day Decontamination Process**
- 9.6.2.1 Flow Cell
- A. In the case of the flow cell when new tubing will be used, a double rinse at half volume using deionized water is typically adequate. Continue with sampling. If the sample location is historically not contaminated, this step may be omitted.
 - B. If NAPLs, odors, or colors are present and cannot be flushed out, assess if the probes are fouled by spot-checking the calibration curves. If the probes are not fouled, no further action is necessary since the flow cell does not contact the sample. Continue with sampling.
 - C. If the probes are fouled, contact the MGP sample coordinator at the laboratory for guidance.
 - D. At the end of the day, the in-line flow cell should be free of sediment and NAPLs. Fill the cell with tap water, insert the sonde, and store.
- 9.6.3 **Pumps**
- 9.6.3.1 Peristaltic pumps need to only have the pump head tubing and sample tubing replaced.
- 9.6.3.2 If the equipment, such as the peristaltic pump case, is contaminated with organic material, wipe down with commercially available wipes presaturated with 2-propanol. If the organic material does not dislodge, stop now, isolate for decontamination at the lab, and use different equipment for the next monitoring well.
- 9.6.4 **Specific Bladder and Keck (gear or bullet) Pump Decontamination Measures**

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

- 9.6.4.1 Pump pre-rinse – Operate the pump in a deep basin containing 1-5 gallons of deionized water and continue through several cycles.
- 9.6.4.2 Pump wash – Operate the pump in a deep basin containing 1-5 gallons of nonphosphate detergent solution, such as Alconox. Operate through several cycles.
- 9.6.4.3 Pump rinse – Operate the pump in a deep basin containing 1-5 gallons of DI water. Continue for several cycles.
- 9.6.4.4 Disassemble pump, if required, and continue with 9.6.4.5. If not required, go to 9.6.4.7.
- 9.6.4.5 Pre-rinse, wash, and rinse as above, scrubbing as needed at the wash stage.
- 9.6.4.6 Reassemble the pump.
- 9.6.4.7 Store the pump so as to keep it clean until needed.

10.0 CALCULATIONS

None

11.0 DATA REPORTING

Refer to Section 5.4 in this procedure. At a minimum the COC shall be stored in the project folder.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

**Consumers Energy Company
Chemistry Section – Laboratory Services Department
Monitoring Well Sampling Worksheet**

Sample

MW_ID		Today's Date		Control Number	
Location					
MW Reference Name			GPS Grid Reference		
Top-of-Casing Elevation (ft)		Depth-to-Screen Bottom (ft)		Depth-to-MidScreen (ft)	
Screen Length (ft)		Casing ID (in)		Typical Purge Volume	
				Protective Casing Mount	
Comments					

Field Measurements

Depth-to-Water (ft)				HC Layer Detected				PID Reading (ppm)			
Time	pH	Temp	Sp Cond	DO	DO	ORP	Pump Rate Indicate	Water Level	Turbidity		
Hr : Min	Units	°C	µS/cm	ppm	% Sat	mV	mL/min gal/min	Draftdown (ft)	NTU		
3-5 Min	± 0.1	na	± 3%	± 10%	± 10%	± 10%	See Notes	<0.33	± 10%		
Completed By >>			Total Pump Time >>			Total Purge Volume >>					
Acceptance criteria are low-flow general acceptance. Pump rate should be <500 mL/min for low-flow and <1 gal/min for high-volume.											

Monitoring Well Depth-to-Water Measurements

Tape ID: Solinst, Model 122, S/N 122001406-1

Sample

[illegible]

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

Project Sonde Check; As-Found Readings & Recalibration

Page 1 of 2

I. *Site or Project Tracking*

Site or Project : _____

Chem. Control # : _____

II. *System Identifiers*

Monitor Brand, Model & S/N:	YSI 650MDS S/N 08C100135
Sonde Brand, Model & S/N:	YSI 6820V2 S/N 08C101426
Flow Cell Brand & Model:	YSI 6160
DO Probe Brand, Model & S/N:	YSI 6150 S/N 08C101539
Turbidity Probe Brand, Model & S/N:	YSI 6136 S/N 08C101363
pH With ORP Brand, Probe Model & Lot:	YSI 6565 Lot Number 08B*26
Conductivity & Temperature Probe Model & S/N:	YSI No additional information

SampleIII. *pH Check*

Standard vs As-found, pH Units	Standard Source	Catalog # & Lot #	Exp. Date
4.00			
7.00			
10.00			

Analyst Initials: _____

Date & Time: _____

As-Found Evaluation

Are the readings within +/- 0.10 of their calibration points? Yes No

If 'No' and you are at the start of a project, then recalibration is **required**.If 'No' and you are **within, or at the end** of project, indicate whether recalibration has been performed. Yes No

Note: If recalibration was performed, the solutions listed above were used.

IV. *ORP Check With Zobell Solution*

Standard vs As-found, mV	Source	Catalog # & Lot #	Exp. Date
231			

Analyst Initials: _____

Date & Time: _____

As-Found Evaluation

Is the reading in the 221-241mV range? Yes No

If 'No' and you are at the start of a project, then recalibration is **required**.If 'No' and you are **within, or at the end** of project, indicate whether recalibration has been performed. Yes No

Note: If recalibration was performed, the solution listed above was used.

V. *DO Check With DI Water; 100% Saturation*

As-Found: _____

Analyst Initials, Date & Time: _____

As-Found Evaluation

Is the reading in the 90-110 % saturation range? Yes No

If 'No' and you are at the start of a project, then recalibration is **required**.If 'No' and you are **within, or at the end** of project, indicate whether recalibration has been performed. Yes No

Note: If recalibration was performed, lab DI water was used.

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

Project Sonde Check; As-Found Readings & Recalibration

Page 2 of 2

Site or Project : _____

Chem. Control # : _____

VI. Conductivity Check

Standard vs As-Found, us	Source	Catalog # & Lot #	Exp. Date
0 (DI Water)	Lab DI System	----	----

Analyst Initials: _____

Date & Time: _____

As-Found Evaluation

Is the reading +/- 3% of the reference point? Yes No

If 'No' and you are at the start of a project, then recalibration is **required**.If 'No' and you are **within, or at the end** of project, indicate whether recalibration has been performed. Yes No

Note: If recalibration was performed, the solutions listed above were used.

Sample**Linearity Check**

Standard vs As-Found, us	Source	Catalog # & Lot #	Exp. Date

Analyst Initials: _____

Date & Time: _____

VII. Turbidity Check

Standard vs As-Found, NTU	Source	Catalog # & Lot #	Exp. Date
0 (DI Water)	Lab DI System	----	----

Analyst Initials: _____

Date & Time: _____

As-Found Evaluation

Is the reading +/- 10% of the reference point? Yes No

If 'No' and you are at the start of a project, then recalibration is **required**.If 'No' and you are **within, or at the end** of project, indicate whether recalibration has been performed. Yes No

Note: If recalibration was performed, the solutions listed above were used.

Linearity Check

Standard vs As-Found, NTU	Source	Catalog # & Lot #	Exp. Date

Analyst Initials: _____

Date & Time: _____

Reviewed By _____ Date _____

**TITLE: LOW STRESS (LOW FLOW) PURGING AND SAMPLING OF GROUND
WATER MONITORING WELLS**

Field Screening of Monitoring Wells Via PID

Project Information

Site: _____

Project No: _____

Date: _____

Sample

Instrument Information

Instrument ID and Serial Number: _____

Calibration (Span) Gas ID, Lot Number Concentration, etc: _____

Zero Gas ID, Lot Number, Concentration, etc: _____

Periodic Calibration Checks

Time	Analyst	Cal Gas Conc, ppm v/v	Display Conc, ppm v/v

Monitoring Well Screening

MW ID	Time	Analyst	Breathing Zone Display Conc	0-6" Within Casing Display Conc
Background Air				NA

APPENDIX B

Chain-of-Custody, Handling, Packing and Shipping SOP (Procedure
CHEM-1.2.04)



TITLE: CHAIN OF CUSTODY REQUIREMENTS (CoC)

1.0 PURPOSE

To provide guidance for uniform preparation of a Chain-of-Custody document.

2.0 SCOPE

The Chain-of-Custody (CoC) document is required for all samples where the analysis results are used for environmental reporting. It may also be used as requested by the customer for other forms of reporting. This method provides guidance for the use of the CoC document.

3.0 DEFINITIONS

Chain-of-Custody (CoC) – A document that is a management tool used to verify sample identification information, sample inventory and sample possession from the time the sample is collected to the time the sample is received by a laboratory.

4.0 REFERENCE DOCUMENTS

- 4.1 Chapter 1 – SW-846, Test Method for Evaluating Solid Waste, USEPA
- 4.2 ASTM Method D 5283-92, Standard Practice for Generation of Environmental Data Related to Waste Management Activities: Quality Assurance and Quality Control Planning and Implementation
- 4.3 ASTM Method D 4840-95, Standard Guide for Sampling Chain-of-Custody Procedures
- 4.4 Chemistry Department Standard Operating Procedures, as applicable
- 4.5 Laboratory Services Quality Assurance (LSQA) Procedure Manual, as applicable

5.0 PROCEDURE

- 5.1 Prior to sampling, the sample team shall be provided with CoC forms. It shall be the responsibility of the on-site supervisor or designated representative to ensure that CoC requirements, sample collection protocol and proper sample handling protocol are initiated on-site.

TITLE: CHAIN OF CUSTODY REQUIREMENTS (CoC)

- 5.2 A sample is considered under custody if one or more of the following criteria are met:
- The sample is in the sampler's possession.
 - The sample is within the sampler's view after being in possession.
 - The sample was in the sampler's possession and then placed in a secure container to prevent tampering.
 - It is in a designated secure area.
- 5.3 Each CoC shall identify basic site information and include the following:
- The sampling site name, project name or other site/project identification.
 - The initials of the sampling teams.
 - Project Leader or report distribution personnel.
 - If a site sketch or other documents are to be found with the CoC.
 - Necessary remarks as required.
- 5.4 Each sample entry into the CoC shall include the following:
- Date of sample collection.
 - Time of sample collection.
 - Type of sample matrix (soil, water, vapor, product, etc).
 - Sample identification, name or description.
 - Sample depth, if applicable.
 - Number of sample containers.
 - Specific analytical test parameters. In some cases the specific test parameters may not be known at the time of sample collection. However, the samples are collected in accordance with the protocol for a general group of analytes (e.g., dissolved metals, volatile organic compounds) and the specific test analytes are determined after the sampling event. In these cases, the entry for the analytical test parameter is not required.
- 5.5 The original of the CoC record shall accompany the samples and a copy should be maintained by the on-site supervisor.
- 5.6 When transferring the possession of samples, the individuals relinquishing and the individuals receiving the samples should sign, date and note the time on the CoC record.
- 5.7 In cases where the sample leaves the originator's immediate control, such as shipment to the laboratory by a common carrier (e.g., Federal Express or

TITLE: CHAIN OF CUSTODY REQUIREMENTS (CoC)

Consumers Energy's internal mail) a seal should be placed on the shipping container to detect unauthorized entry to the samples. Any shipping containers that arrive at the Laboratory with the seals damaged should be evaluated to ascertain if the contents have been in valid custody.

- 5.8 In the event samples requiring the CoC protocol arrive at the Laboratory without the CoC document, the Laboratory shall complete the CoC document upon sample login and under the supervision of the assigned Laboratory Project Leader or Area Coordinator. The person completing the CoC shall enter the statement "CoC completed by the Laboratory upon receipt of sample(s)" in the remarks section of the CoC and initial the entry.
- 5.9 A sample CoC form is attached (Attachment A).
- 5.10 Other CoC formats and forms may be used as long as the CoC meets the recommendations of this procedure.
- 5.11 The CoC shall be stored in the project folder and retained according to CHEM-1.1.7, Record Retention.

QA Review Katharyn L Schlueter
Chemistry Quality Assurance Coordinator

Date 02/27/08

Administrative Approval Gordon L Cattell
Chemistry Department Supervisor

Date 02/27/08

This electronically produced document has been reviewed and approved by the above-named individuals. The original document bearing the approval signatures is maintained on file by Consumers Energy, Laboratory Services.

TITLE: CHAIN OF CUSTODY FORM (CoC)

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