above ground storage tank
air quality
asbestos/lead-based paint
baseline environmental assessment
brownfield redevelopment
building/infrastructure restoration
caisson/piles
coatings
concrete
construction materials services
corrosion
dewatering
drilling
due care analysis
earth retention system
environmental compliance
environmental site assessment
facility asset management
failure analyses
forensic engineering
foundation engineering
geodynamic/vibration
geophysical survey
geosynthetic
greyfield redevelopment
ground modification
hydrogeologic evaluation
industrial hygiene
indoor air quality/mold
instrumentation
masonry/stone
metals
nondestructive testing
pavement evaluation/design
property condition assessment
regulatory compliance
remediation
risk assessment
roof system management
sealants/waterproofing
settlement analysis
slope stability
storm water management
structural steel/welding
underground storage tank

GEOTECHNICAL EVALUATION REPORT

ARGO DAM
HEADRACE EMBANKMENT
ANN ARBOR, MICHIGAN

SME Project No. PG60424
December 16, 2009

Soil and Materials Engineers, Inc.

Soil and Materials Engineers, Inc.
The Kramer Building
43980 Plymouth Oaks Blvd.
Plymouth, MI 48170-2584
tel (734) 454-9900
fax (734) 454-0629
www.sme-usa.com

December 16, 2009

Mr. Glen Wiczorek, PE
Stantec Michigan
3959 Research Park Drive
Ann Arbor, Michigan 48108

RE: Geotechnical Evaluation Report
Argo Dam Headrace Embankment
Ann Arbor, Michigan
SME Project No. PG60424

Dear Mr. Wiczorek:

We have completed our geotechnical evaluation to review potential seepage conditions and slope stability at the earthen headrace embankment of the existing Argo Dam located in Ann Arbor, Michigan. This report presents the information from the borings and observation wells, our analyses of the existing and potential seepage and stability, and our recommendations for seepage controls (e.g., the need for the existing drainage system) along the existing earthen headrace embankment.

We appreciate the opportunity to be of service. After review of this report by representatives from Stantec Michigan and the City of Ann Arbor, we recommend SME meet with representatives from Stantec Michigan and the City of Ann Arbor to discuss our recommendations and to jointly outline the course of action related to the headrace embankment. In the interim, if you have questions or require additional information, please contact me.

Very truly yours,

SOIL AND MATERIALS ENGINEERS, INC.

Joel W. Rinkel

Joel W. Rinkel, PE
Senior Project Engineer

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Plymouth
Bay City
Grand Rapids
Kalamazoo
Lansing
Shelby Township
Toledo
Traverse City

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SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. Under current operating conditions, there appears to be no emergency or imminent threat that the earthen headrace embankment will suffer a catastrophic failure. At this time, we do not believe there is an immediate need to dewater the headrace or cease using the headrace. Consequently, SME recommends that Ann Arbor conduct regular inspections (at a minimum, quarterly and during/after significant storm events) to evaluate the effectiveness of the drainage system and be prepared to take responsive actions (e.g. dewatering the headrace) if evidence of insufficient drainage, piping or other possible failure modes are noted. These conclusions and recommendations are based on the following:

    (a) Based on the borings performed during this evaluation, the earthen headrace embankment consists predominantly of fine to coarse sand fill containing cobbles, gravel and silt. The foundation soils beneath the earthen headrace embankment consist of interbedded strata of silty sands, sands and gravels with cobbles or boulders, and occasional organic silt strata. Based on our experience near the dam site, natural clays and clayey glacial till likely exist beneath the stratified foundation soils encountered during this evaluation.

    (b) The water level data collected during this study demonstrate that the existing drainage system is functioning. Previous dam safety inspection reports (completed in 1992, 2001 and 2004) support this finding since these reports indicate water seepage was observed emanating from the toe drains. However, the 2004 Dam Safety Inspection Report states water seepage was also evident emanating from the embankment around and above at least one of the toe drains. SME has not performed analyses to determine the degree of effectiveness of the existing drainage system.

    (c) Based on the limit equilibrium analysis performed during this study, the factors of safety against global stability were determined for three cross-sections in the headrace embankment in its current condition, which were found to be 1.4, 1.5 and 1.9, respectively. At section A (which exhibited the safety factor of 1.4), the value falls slightly below the recommended factor of safety of 1.5 for long-term loading conditions identified by the U. S. Army Corps of Engineers (USACE) Engineering Manual EM 1110-2-1902. The factors of safety at the other two cross-sections were at or above the USACE recommended 1.5 factor of safety.

2. Effective seepage controls are important to demonstrate an appropriate factor of safety. The current drainage control system appears to be operating. SME has not evaluated the degree of effectiveness of the current drainage system. Therefore, SME recommends that Ann Arbor take steps to evaluate the drainage system and be prepared to take steps to improve the system's effectiveness if it is found to be deficient. These conclusions and recommendations are based on the following:

    (a) As noted above, the water level data collected during this study demonstrate that the existing drainage system is functioning. However, the degree of effectiveness of that system has not been determined to date.

(b) Based on our analyses, seepage controls are required to demonstrate an adequate factor of safety against global stability (under both normal operating conditions and design flood conditions) and to mitigate the potential for piping at the toe of the downstream slope of the existing earthen tailrace embankment. The current drainage system serves as the seepage controls. If the drainage system is allowed to deteriorate beyond the condition at the time this report was prepared, the factors of safety for the headrace embankment could decrease further below accepted values, and immediate corrective action could be required.

3. Piping is a potentially dangerous situation in an earthen embankment. However, to date, no evidence of piping has been observed. These conclusions and recommendations are based on the following:

   (a) If the toe drains fails, increased water seepage could result in piping. Piping has not been reported in the 1992, 2001 or 2004 Dam Safety Inspection Reports for Argo Dam reviewed by SME. Based on information provided to SME, there is no evidence of an imminent piping concern.

   (b) In the short term, SME recommends that Ann Arbor continue regular visual monitoring of seepage (at a minimum, quarterly and during/after significant storm events) to identify any visible evidence of potential piping. If indicators of piping are observed, corrective action, such as shutting off water flow into the headrace, could become necessary.

   (c) The results of the quarterly observations could be used to refine the current study results, and in combination with further field exploration, should be used to conduct a piping study for the headrace embankment.

4. SME recommends that the inspection program be performed by a qualified dam safety inspector (a registered PE with familiarity with dam safety requirements). In general, the program must be tailored to visually assess conditions that could alter the results of this evaluation. Regular groundwater level readings should also be taken from the recently installed piezometers. The additional information obtained from further observations/groundwater levels must be reviewed so that the evaluation can be refined accordingly and the data collected will be sufficient to identify conditions that could require further action. Additional field exploration may also be necessary.

The Conclusions, Recommendations and Summary of Findings, presented above were developed based on the limited data collected during this evaluation and could be refined based on the results of further and more extensive field exploration and laboratory testing. The summary presented above includes selected elements of SME's findings and recommendations and is provided solely for purposes of overview. It does not present crucial details needed for the proper application of our findings and recommendations. It should, therefore, not be considered apart from the entire text of this report and appendices, with all of the qualifications and considerations mentioned therein, which are best evaluated with the active participation of SME.

REPORT PREPARED BY:

Jason M. Cumbers, PE
Project Engineer

REPORT REVIEWED BY:

Michael J. Thelen, PE
Senior Consultant

1. INTRODUCTION

This report presents the results of the geotechnical evaluation performed by Soil and Materials Engineers, Inc. (SME) to evaluate the existing conditions of the Argo Dam headrace embankment located along the Huron River in Ann Arbor, Michigan. This evaluation was conducted in general accordance with the scope of services outlined in our Proposal, dated October 5, 2009. Mr. Glen Wiczorek, PE with Stantec Michigan authorized this evaluation.

References to right and left made in this report are based on the observer looking downstream at the dam spillway location.

1.1 General Description of Dam

Argo Dam is located north of Depot Street, south of Longshore Drive, and between Broadway Street and Main Street, on the Huron River in the City of Ann Arbor, Washtenaw County, Michigan. Stantec Michigan provided SME historic drawings of the dam, including a drawing titled "Argo Power Plant – Headrace Layout and Sections" dated April 9, 1913 (5302) that depicts typical cross sections of the existing earthen headrace embankment with the existing drainage system. A copy of the Headrace Layout and Sections drawing is included in Appendix A for information. SME also briefly reviewed the Michigan Department of Environmental Quality (MDEQ) Dam Safety Unit's file for the subject dam.

Argo Dam was constructed around 1920 and consists of a concrete spillway, left and right earthen embankments and an earthen headrace embankment. The headrace embankment, which is approximately 1,500-feet long, is the embankment being evaluated. Argo Dam is classified by the MDEQ Dam Safety Unit as a high hazard potential dam.

As shown on the drawing titled "Argo Power Plant – Headrace Layout and Sections" dated April 9, 1913, the subject embankment section has a 10-foot crest width, a downstream slope inclination of 2H:1V, and a crest elevation near 777 feet. A drainage system consisting of a 4-inch-diameter main drain connected to a series of 4-inch-diameter lateral drain tiles (perpendicular to the subject embankment alignment) was installed during the initial construction. The lateral drain tiles were reportedly installed at a spacing of 25 feet on-center. The lateral extent of these drains along the embankment is unknown, but is expected to extend throughout the entire alignment of the subject embankment.

1.2 Background Data

The 2004 Dam Safety Inspection Report (dated October 27, 2004) for Argo Dam, prepared by the MDEQ, states that in regards to the lateral drains "Seepage water was discharging around and above these drains, indicating that the toe drain system is failing, and thus weakening the embankment." The referenced report recommends the immediate repair or replacement of the toe drain system. The MDEQ Dam Safety Unit file for the subject dam includes an executed permit (Permit No. 05-81-0086-P) to complete repairs to the dam, including repair of the toe drains, but the file did not include the plans and specifications referenced in the permit (entitled "Water Utilities Department City of Ann Arbor, Michigan Plans for Argo Dam Improvements"). Additional information on the condition, use and performance of the dam is available in documents contained in the MDEQ Dam Safety Unit file or the Owner file.

The scope of this evaluation included the evaluation of the potential for through seepage at the headrace embankment (i.e., seepage migrating from the headrace impoundment through the embankment) and the need of the existing drainage system within the subject embankment. Our scope of services did not include a review of the performance of the existing drainage system. We are not aware of whether a study has been performed to identify the proper function or performance of the existing drainage system.

2. EVALUATION PROCEDURES

2.1 Field Exploration

2.1.1 Borings

SME completed eight borings (B1, B2, and B4 through B9) at the site between September 17 and 28, 2009. One planned boring (B3) was eliminated during our site visit with Stantec Michigan and the City of Ann Arbor on September 15, 2009. The approximate locations of the borings are depicted on the Argo Dam Piezometers drawing provided by Stantec Michigan and included in Appendix A. SME determined the number, locations, and depths of the borings. SME staked the locations of the borings in the field using a measuring wheel and referencing existing site features. SME estimated the ground surface elevations at the boring locations to the nearest 1-foot based on the existing topographic information provided on the Argo Dam Piezometers drawing (dated September 30, 2009) prepared by Stantec Michigan.

Borings B1, B4, and B7 were performed along the crest of the subject embankment and extended to depths of about 16 to 20 feet below the surface. Dynamic cone penetrometer (DCP) testing was performed at each of these boring locations to estimate the strength or relative density of the subject embankment soils. The depths of the DCP tests were dependent on subsurface conditions and were limited to 12 feet. These borings were performed with our ATV Geoprobe® rig which collects continuous samples using acetate-lined piston samplers. The liners were sealed in the field and returned to our laboratory for further testing.

Borings B2 and B6 were performed at approximately mid-slope on the downstream side of subject embankment. Borings B5, B8, and B9 were performed near the downstream toe of the subject embankment. These borings were performed using hand augers and extended to depths of 0.5 to 4 feet below the surface. The relatively shallow depth of these borings was due to encountering obstructions (likely cobbles or boulders). Auger samples were collected from the hand augers and sealed in plastic bags or glass jars and returned to our laboratory for further testing. DCP tests were also performed at each of these hand auger boring locations.

Groundwater level measurements were recorded during and immediately after completion of each boring.

2.1.2 Observation Wells

SME installed standpipe piezometers (observations wells) at each boring location. Five of the piezometers were constructed of 1- or 2-inch diameter (I.D.) PVC 10-slot well screens (with conical tips) attached to 1- or 2-inch-diameter (I.D.) PVC riser pipe. The remaining three piezometers were constructed of a 1¼-inch-diameter stainless steel well screen, with galvanized steel riser pipe. Drivable tips were connected to these stainless steel well screens. Prior to driving the wells, a 1-inch diameter steel rod was driven into the ground to create a pilot hole. The rod and well driving was accomplished using a hand-operated post driver. Overall, the piezometers extend about 5 to 11 feet below the existing ground surface. The PVC piezometers were backfilled with a sand filter pack around the screen sections and then sealed with bentonite chips. The piezometers extend approximately 30-inches above grade. A protective metal casing with a locking cover was installed over each piezometer. PVC protective covers were also installed over the driven wells, prior to installing the metal casings. The metal casings were embedded in concrete to about 1.5 to 2 feet below grade. Water levels within the piezometers were read by Stantec Michigan on September 30, 2009.

2.2 Laboratory Testing

The general laboratory testing program consisted of performing visual soil classification on recovered samples along with particle size distribution tests on select samples. The Laboratory Testing Procedures in Appendix C provides general descriptions of the laboratory tests performed.

Upon completion of the laboratory testing, boring and observation well logs were prepared and include information on materials encountered, penetration resistances, well installation information, groundwater level readings, pertinent field observations made during the field exploration, and the results of certain laboratory tests. The boring logs and the observation well logs are included in Appendix B. The soil descriptions included on the boring logs were developed from both visual classification and the results of laboratory tests, where applicable. The approximate existing ground surface elevations at the boring locations are also provided on the boring logs.

Soil samples retained over a long time, even sealed in jars, are subject to moisture loss and are no longer representative of the conditions initially encountered in the field. Therefore, soil samples are normally retained in our laboratory for 60 days and then disposed, unless instructed otherwise.

2.3 Site Survey

On September 29 and 30, 2009, Stantec Michigan performed an elevation survey of select cross sections on the headrace embankment. The drawing titled "Argo Dam Piezometers" included in Appendix A of this report contains the survey information provided to SME.

The survey was performed to obtain the elevation of the top of casing at each of the eight observation wells, as well as surface water elevations in the headrace and the Huron River along the subject embankment, water levels within the observation wells, and ground surface topography for each of three cross sections along the embankment.

3. SUBSURFACE CONDITIONS

3.1 Headrace Embankment Soil Conditions

The embankment borings (B1, B2, and B4 through B9) indicate the existing earthen embankment was constructed of granular soils. The foundation soils consist of interbedded strata of natural silty sands, sands and gravels with cobbles or boulders, and occasional organic silt strata. A generalized summary of the soils encountered in the embankment borings during this evaluation is given below, beginning at the existing ground surface and proceeding downward:

Stratum 1: Topsoil. Six to 18 inches of topsoil were encountered at the ground surface at the boring locations.

Stratum 2: Earthen Embankment Soils (Sand with Gravel Fill). The existing earthen embankment appears to have been constructed of fine to coarse sand fill containing cobbles, gravel, and silt. DCP test resistances within the embankment soils ranged from 3 blows for 6 inches of penetration to 50 blows for 1 inch of penetration, indicating a loose to very dense condition.

Stratum 3: Foundation Soils (Natural Sands). The foundation soils appear to consist of interbedded strata of natural silty sands, sands and gravels with cobbles or boulders, and occasional organic silt strata. DCP test resistances within the natural foundation soils ranged from 1 blow for 6 inches of penetration to 50 blows for 1 inch of penetration, indicating a very loose to very dense condition.

There were no existing boring logs for the subject embankment (either from the original construction or from previous studies) available for our review, although our experience in the area indicates the embankment foundation soils encountered during this evaluation are likely underlain by a natural clays and clayey glacial till.

The soil profile described above and included on the boring logs in Appendix B of this report are generalized descriptions of the conditions encountered. The stratification depths shown on the logs and described above are intended to indicate a zone of transition from one soil type to another. They are not intended to show exact depths of change from one soil type to another. Soil conditions may be different in areas other than at the boring locations. Please refer to the logs for the soil conditions at the specific soil boring locations. The soil descriptions are based on visual classification of the soils encountered.

3.2 Headrace Embankment Groundwater Conditions

Groundwater was encountered during drilling at borings B1, B4, and B7, performed along the crest of the subject embankment, at depths ranging from about 11 to 15 feet below the existing ground surface (or at about elevations 762 and 766 feet). Groundwater was encountered during drilling at borings B2 and B6, performed near the toe of the subject embankment, at depths of about 2.5 and 1 feet below the existing ground surface, respectively (or at about elevations 765.5 to 762 feet, respectively). Groundwater was not observed within the explored depths of the remaining borings (with explored extents to about elevations 762 to 765 feet).

As indicated previously, piezometers (observation wells) were installed at each of the boring locations. Groundwater measurements obtained by Stantec Michigan in the observation wells and provided to SME are contained in Table No. 1 below. The groundwater levels provided by Stantec Michigan from the observation wells were recorded during the site survey discussed in Section 2.3. During the site survey, the surface water level in the headrace was measured at 773.5 feet and the surface water downstream of the headrace embankment in the Huron River ranged between about elevations 760 to 761 feet.

TABLE 1: OBSERVATION WELL GROUNDWATER AND SURFACE WATER ELEVATIONS

Section	Location	Date 9/30/09
Section A	Headrace	773.5
	B1	769.9
	B2	766.4
	Huron River	761.0
Section B	Headrace	773.5
	B4	761.3
	B5	763.8
	B6	762.3
	Huron River	760.0
Section C	Headrace	773.5
	B7	762.3
	B8	761.9
	B9	760.0
	Huron River	760.0

The groundwater levels indicated by the borings and/or observation wells and presented in this report represent conditions at the time the readings were taken. The elevations and volumes of groundwater should be expected to fluctuate throughout the year, based on variations in precipitation, evaporation, run-off, the water level in the Huron River, the water level in the headrace, and other factors (e.g., the efficiency of the existing drainage system within the subject embankment). Additional groundwater level measurements in the observation wells could be collected to further study fluctuations in the groundwater level within the existing headrace embankment.

4. ANALYSIS AND RESULTS

4.1 Review of Seepage Conditions

All earthen dam embankments are subject to some seepage passing under or through the embankment. The location of the phreatic surface within earthen dam embankments is an important consideration in the quantitative evaluation of the stability of embankments. The phreatic surface within an earthen embankment can be estimated by constructing a flow net while considering the soil conditions within (embankment soils) and below the embankment (foundation soils) and the typical head water and tail water elevations. Accurate determination of the phreatic surface is very complex for highly stratified or heterogeneous soils. The estimated phreatic surface can then be verified if needed by the installation of a series of piezometers or observations wells.

The 1992 Dam Safety Inspection Report reviewed by SME stated the only evidence of seepage is through the clay pipes (part of the drainage system) buried within the headrace dike, but visibility was restricted by undergrowth. The 2001 Dam Safety Inspection Report reviewed by SME stated seepage is evident at the toe of the headrace embankment, and is primarily emerging from the clay toe drains (part of the drainage system). The 2004 Dam Safety Inspection Report reviewed by SME stated seepage water was discharging around and above the clay toe drains.

The subject embankment soils consist predominately of fine to coarse sand fill containing cobbles, gravel, and silt. The density of the embankment soils increased with increasing depth, but otherwise the embankment soils are considered fairly homogenous (i.e., composed of generally the same material). For the purposes of this evaluation, the embankment was generally assumed to consist of homogenous and isotropic (i.e., engineering properties are the same in all directions) soils with good drainage characteristics.

The subject embankment foundation soils consist of interbedded strata of permeable natural silty sands, sands and gravels with cobbles or boulders, and occasional less permeable organic silt strata within the explored depths of the borings. Based on our experience near the subject dam site, relatively impermeable clays and clayey glacial till likely exist below about elevation 750 feet. For the purposes of this evaluation, the embankment foundation soils were generally assumed to consist of heterogeneous (i.e., differing materials at different sections) and isotropic soils with poor drainage characteristics. The potential presence of relatively impermeable clays and clayey glacial till below about elevation 750 feet was not considered in our evaluation since we do not have deep borings at this site.

Typically, the phreatic surface within a homogenous earthen embankment with good drainage characteristics and no seepage controls originates at the head water surface along the upstream embankment face and then decreases in head (elevation) through the embankment and exits along the downstream slope face above the embankment toe. Observations during our field exploration indicate seepage is present near the toe of the embankment in the vicinity of Section B and standing water was observed near the toe of the embankment in the vicinity of Section A.

On September 29, 2009, Stantec Michigan surveyed the headrace (head) water elevation at 773.5 feet and the water surface elevation of the Huron River at 760 to 761 feet along the subject embankment. The observation well readings provided by Stantec Michigan indicate the phreatic surface within the subject embankment, at least at Sections B and C, is depressed below typical theoretical values, suggesting the drainage system is functioning at some level of efficiency.

SME used a two-dimensional (2D) limit equilibrium slope stability computer program (SLIDE 5.0 by Rocscience) to evaluate the probable phreatic surface within the subject embankment for a steady-state seepage condition and various boundary conditions. The following loading conditions (cases) were evaluated for the subject embankment geometry at Sections A, B, and C provided by Stantec Michigan:

Case I: Normal operating conditions with headrace water surface elevation of 773.5 feet, tail water (Huron River) surface elevations of 760 or 761 feet and the piezometer readings used as boundary conditions to determine the phreatic surface within the embankment;

Case II: Normal operating conditions with a headrace water surface elevation of 773.5 feet, tail water surface elevations of 760 or 761 feet used as a boundary condition to determine the phreatic surface within the embankment (i.e., assuming a failed drainage system); and

Case III: Design flood conditions with headrace water and tail water elevations of 774.5 feet and 769.0 feet, respectively (provided by Stantec Michigan), used as boundary conditions to determine the phreatic surface within the embankment (i.e., assuming a failed drainage system).

The graphical output of the analyses which depict the probable phreatic surfaces are included in Appendix D of this report. Refer to Section 4.2 for further discussion of the input parameters used and the results of the ~~seepage~~- seepage analysis.

4.2 Review of Embankment Global Stability

As part of our scope of services, we evaluated the global stability (limit equilibrium) of the headrace embankment using slope stability software and the available soil and groundwater data developed from the borings and observation wells. First, we developed design 2D cross sections through the subject embankment using the survey data provided by Stantec Michigan. We then superimposed soil and groundwater subsurface boundaries on the cross section using data developed from the borings, the observation wells, and the head and tail water information provided by Stantec Michigan. We then estimated soil index properties (drained strength parameters, unit weights, and permeability for each subsurface soil boundary based on the boring information (e.g., DCP resistances), laboratory test data, our experience with similar soils, and published correlations.

SLIDE 5.0 was used to first develop theoretical phreatic surfaces through the subject embankment and then to evaluate trial circular failure surfaces under the various loading conditions to assess a global factor of safety using Spencer's method. As referenced in USACE EM 1110-2-1902 dated 31 Oct 2003, near surface failure surfaces (i.e., surface sloughing) are considered a maintenance problem and therefore were not considered in this evaluation. The soil parameters input into the computer program are summarized in Table 2 below.

TABLE 2 - SOIL PROPERTIES USED FOR SEEPAGE AND SLOPE STABILITY ANALYSES

Soil Type	Moist Unit Weight (pcf)	Drained Cohesion, c' (psf)	Drained Friction Angle, ϕ' (degrees)	Hydraulic Conductivity, k (ft/s)
Upper Embankment Sand Fill	120	0	34	$7.5x10^{-4}$
Lower Embankment Sand Fill	125	0	36	$6.0x10^{-4}$
Foundation Soil - Gravelly Sand (Section A)	125	0	35	$1.0x10^{-5}$
Foundation Soil -Silty Sand (Section B)	120	0	34	$1.0x10^{-7}$
Foundation Soil - Gravelly Sand (Section C	125	0	35	$1.0x10^{-5}$

Three loading conditions (cases), as described in Section 4.1, were analyzed for Sections A, B and C developed as part of this evaluation. The graphical output of the analyses that depict the probable phreatic surfaces and the slope circle failure surface with the minimum factor of safety against global stability are included in Appendix D of this report. The resulting factors of safety for each case and at each section analyzed are summarized in Table 3 below.

TABLE 3 – RESULTING FACTORS OF SAFETY FOR SLOPE STABILITY ANALYSES

	Current Conditions	Future Conditions	
Section	Case I – Normal Headrace Pool with Drainage System Functioning to Current Level of Efficiency	Case II – Normal Headrace Pool with Failed Drainage System	Case III – Design Headrace Pool with Failed Drainage System
A	1.4	1.2	1.1
B	1.5	1.1	1.2
C	1.9	1.4	1.5

Case I resulted in a minimum factor of safety against global stability of 1.4 at Section A, which is considered below the minimum satisfactory value under long-term conditions (normal operating and maximum storage pool conditions) for dams as referenced in Table 3-1 of the USACE EM 1110-2-1902 dated 31 Oct 2003. Case I also resulted in a probable phreatic surfaces below those determined for Case II, indicating the existing drainage system is functioning. The results for the phreatic surfaces indicate the existing drainage system at Section A is functioning less efficiently than the existing drainage system at Sections B and C.

Case II resulted in a probable phreatic surface above the surface suggested by the piezometer readings (Case I) and indicated that without seepage controls (i.e., without a functioning existing drainage system), seepage should be expected to emanate along the downstream slope of the earthen headrace embankment at or below about elevation 767 to 769 feet. Case II also resulted in a minimum factor of safety against global stability of 1.1, which is well below the recommended value of 1.5.

Case III resulted in a minimum factor of safety against global stability of 1.1, which is well below the recommended value of 1.5.

4.3 Piping Considerations

Seepage through earthen structures (such as the subject embankment) could cause, if the seepage (escape) gradient reaches the critical gradient, the movement or transport of soil particles, which is known as piping. This critical gradient approaches unity (1) for sands. Piping could also occur through the joints in the clay drain tiles, or through failed sections of clay drain tiles, used to construct the drainage system within the headrace embankment.

Visible indicators of piping can include the presence soil particles or sediments within seepage water, soil accumulation near the toe of earth slopes, sinkholes along the slope crest or downstream slope face, etc. These visible indicators of piping may not manifest until a significant piping problem arises. Visible indictors of piping were not reported in the 1992, 2001, or 2004 Dam Safety Inspection Reports for Argo Dam reviewed by SME. In fact, the 2001 and 2004 Dam Safety Inspection Reports stated that observed seepage (resulting primarily from the clay toe drains) did not appear to be transporting soil with the water, but did recommend observing the seepage quarterly with notations on evidence of sedimentation associated with the seepage. Based on information provided to us, there is a no evidence of an imminent piping concern.

Determination of piping potential within an earthen structure requires detailed knowledge of the soils and seepage conditions. Since indicators of piping have not been reported to us, we judge a detailed study of piping potential is not warranted until better knowledge of the soils and seepage conditions is known. Quarterly monitoring of the seepage, including documentation of evidence of sedimentation associated with this seepage, should continue. A piping study including additional borings should be performed if detailed quarterly monitoring information shows evidence of piping. Immediate corrective action (e.g., shutting off flow to the headrace) will be required if sedimentation associated with this seepage is observed.

5. CONCLUSIONS

USACE EM 1110-2-1902 dated 31 Oct 2003 recommends a minimum factor of safety of about 1.5 for limit equilibrium (global stability) of earthen dams under long-term (normal operating and maximum storage pool conditions) loading conditions. A lower minimum factor of safety of about 1.3 might be acceptable during extreme events where the consequences of embankment failure are considered low. Based on the factors of safety calculated from our analyses, two sections of the headrace embankment have an acceptable factor of safety; one section, in its current condition, falls short.

Under current operating conditions, there appears to be no emergency or imminent threat that the earthen headrace embankment will suffer a catastrophic failure. At this time, we do not believe there is an immediate need to dewater the headrace or cease using the headrace. Consequently, SME recommends that Ann Arbor conduct regular inspections (at a minimum, quarterly and during/after significant storm events) to evaluate the effectiveness of the drainage system and be prepared to take responsive actions (e.g. dewatering the headrace) if evidence of insufficient drainage, piping or other possible failure modes are noted. These conclusions and recommendations are based on the following:

Based on the borings performed during this evaluation, the earthen headrace embankment consists predominantly of fine to coarse sand fill containing cobbles, gravel and silt. The foundation soils beneath the earthen headrace embankment consist of interbedded strata of silty sands, sands and gravels with cobbles or boulders, and occasional organic silt strata. Based on our experience near the dam site, natural clays and clayey glacial till likely exist beneath the stratified foundation soils encountered during this evaluation.

(a) The water level data collected during this study demonstrate that the existing drainage system is functioning. Previous dam safety inspection reports (completed in 1992, 2001 and 2004) support this finding since these reports indicate water seepage was observed emanating from the toe drains. However, the 2004 Dam Safety Inspection Report states water seepage was also evident emanating from the embankment around and above at least one of the toe drains. SME has not performed analyses to determine the degree of effectiveness of the existing drainage system.

(b) Based on the limit equilibrium analysis performed during this study, the factors of safety against global stability were determined for three cross-sections in the headrace embankment in its current condition, which were found to be 1.4, 1.5 and 1.9, respectively. At section A (which exhibited the safety factor of 1.4), the value falls slightly below the recommended factor of safety of 1.5 for long-term loading conditions identified by the U. S. Army Corps of Engineers (USACE) Engineering Manual EM 1110-2-1902. The factors of safety at the other two cross-sections were at or above the USACE recommended 1.5 factor of safety.

Effective seepage controls are important to demonstrate an appropriate factor of safety. The current drainage control system appears to be operating. SME has not evaluated the degree of effectiveness of the current drainage system. Therefore, SME recommends that Ann Arbor take steps to evaluate the drainage system and be prepared to take steps to improve the system's effectiveness if it is found to be deficient. These conclusions and recommendations are based on the following:

(a) As noted above, the water level data collected during this study demonstrate that the existing drainage system is functioning. However, the degree of effectiveness of that system has not been determined to date.

(b) Based on our analyses, seepage controls are required to demonstrate an adequate factor of safety against global stability (under both normal operating conditions and design flood conditions) and to mitigate the potential for piping at the toe of the downstream slope of the existing earthen tailrace embankment. The current drainage system serves as the seepage controls. If the drainage system is allowed to deteriorate beyond the condition at the time this report was prepared, the factors of safety for the headrace embankment could decrease further below accepted values, and immediate corrective action could be required.

Piping is a potentially dangerous situation in an earthen embankment. However, to date, no evidence of piping has been observed. These conclusions and recommendations are based on the following:

(a) If the toe drains fails, increased water seepage could result in piping. Piping has not been reported in the 1992, 2001 or 2004 Dam Safety Inspection Reports for Argo Dam reviewed by SME. Based on information provided to SME, there is no evidence of an imminent piping concern.

(b) In the short term, SME recommends that Ann Arbor continue regular visual monitoring of seepage (at a minimum, quarterly and during/after significant storm events) to identify any visible evidence of potential piping. If indicators of piping are observed, corrective action, such as shutting off water flow into the headrace, could become necessary

(c) The results of the quarterly observations could be used to refine the current study results, and in combination with further field exploration, should be used to conduct a piping study for the headrace embankment.

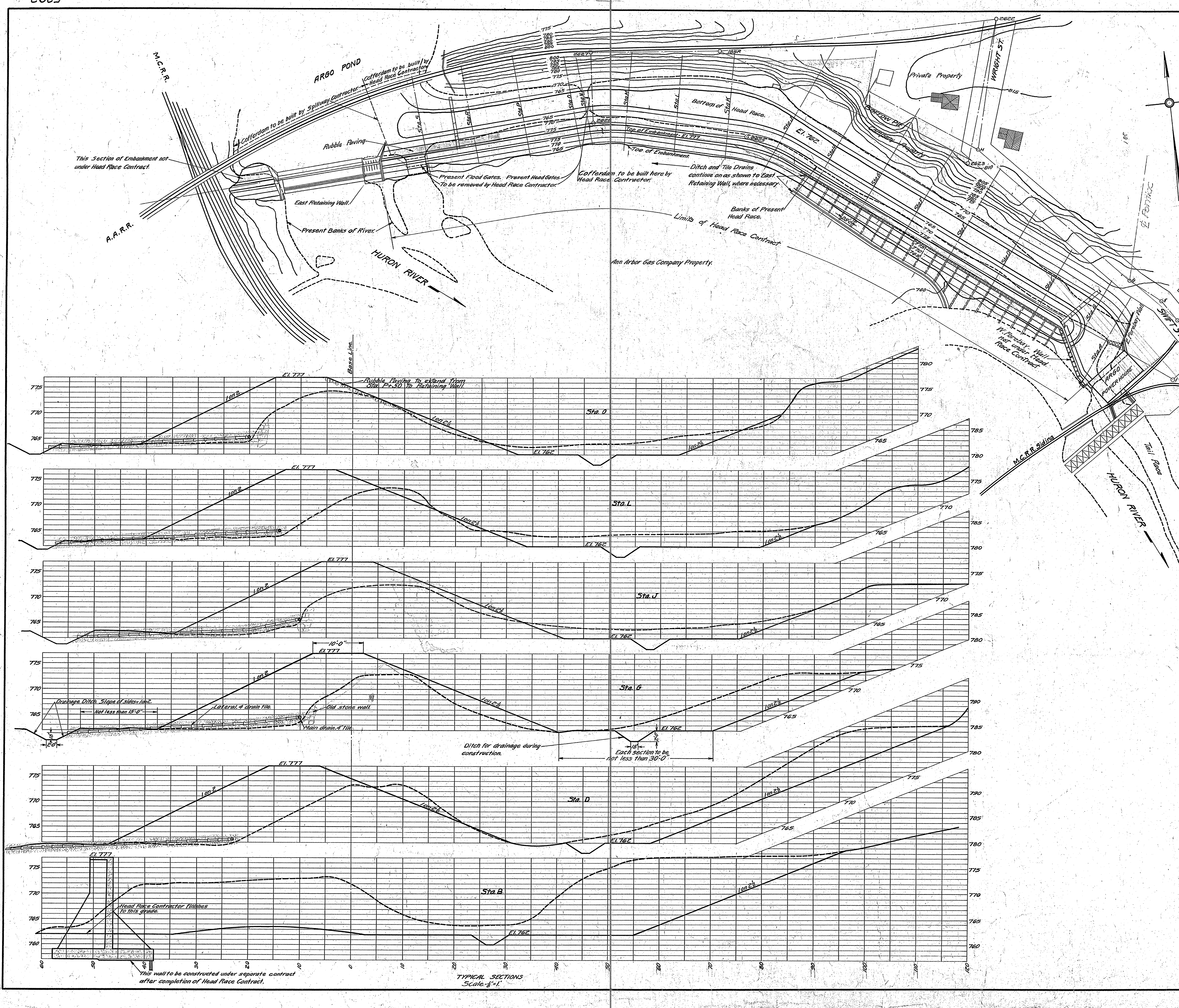
SME recommends that the inspection program be performed by a qualified dam safety inspector (a registered PE with familiarity with dam safety requirements). In general, the program must be tailored to visually assess conditions that could alter the results of this evaluation. Regular groundwater level readings should also be taken from the recently installed piezometers. The additional information obtained from further observations/groundwater levels must be reviewed so that the evaluation can be refined accordingly and the data collected will be sufficient to identify conditions that could require further action. Additional field exploration may also be necessary.

The above conclusions are based on the results of our analysis using the limited data collected during this evaluation and could be refined based on the results of further and more extensive field exploration and laboratory testing.

APPENDIX A

DRAWING NO. 1: HEADRACE LAYOUT AND SECTIONS (5302)

DRAWING. NO. 2: ARGO DAM PIEZOMETERS- STANTEC MICHIGAN



EASTERN MICHIGAN EDISON COMPANY

ARGO POWER PLANT

HEAD RACE
LAYOUT AND SECTIONS

GARDNER S. WILLIAMS, CONSULTING ENGINEER.
ANN ARBOR, MICHIGAN.
1913-4-9
Scale-1"=80'

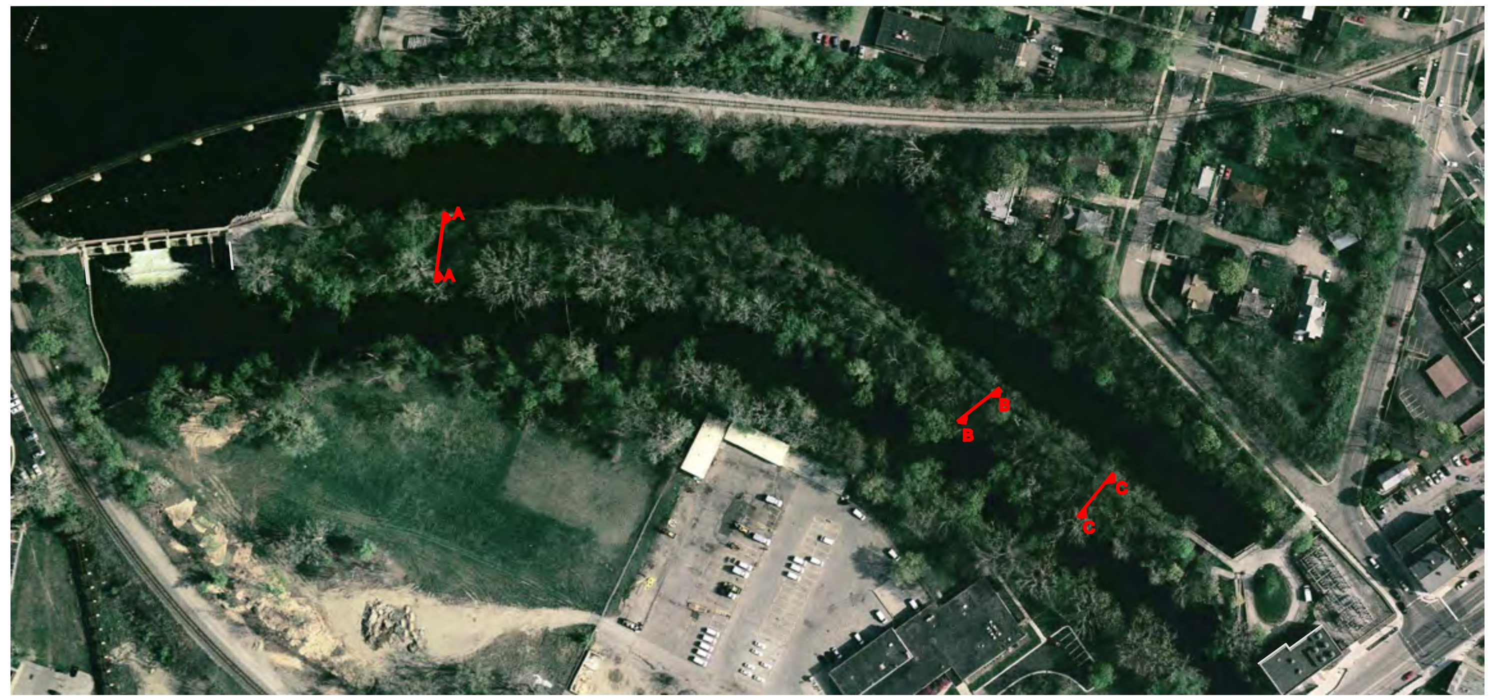
5302

corrected profile line at ground ...

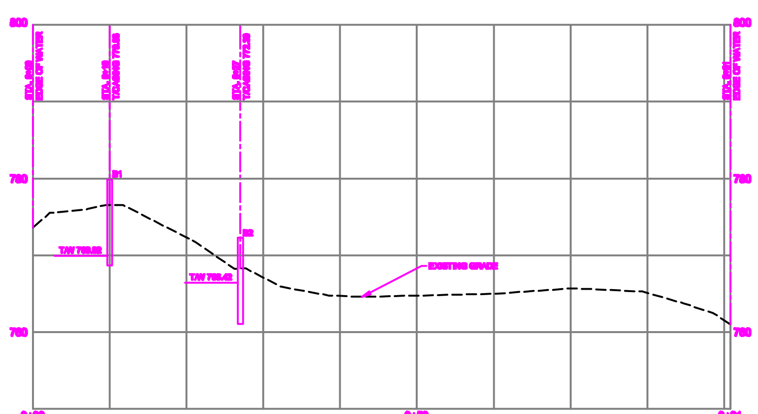
R.B.D.

NOTE:

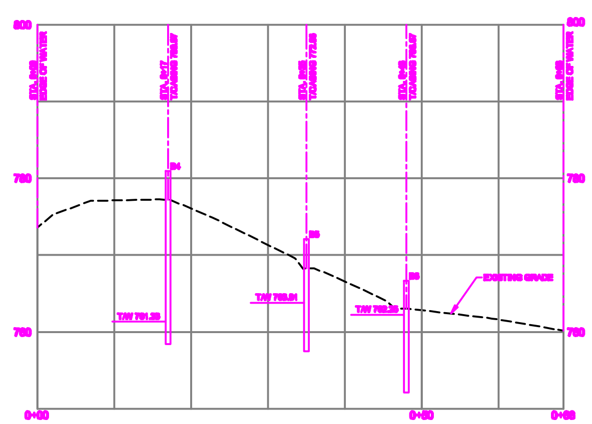
THE LOCATIONS AND ELEVATIONS OF EXISTING UNDERGROUND UTILITIES AS SHOWN ON THIS DRAWING ARE ONLY APPROXIMATE. NO GUARANTEE IS EITHER EXPRESSED OR IMPLIED AS TO THE COMPLETENESS OR ACCURACY THEREOF. THE CONTRACTOR SHALL BE RESPONSIBLE FOR CONTACTING MISS DIG PRIOR TO CONSTRUCTION.



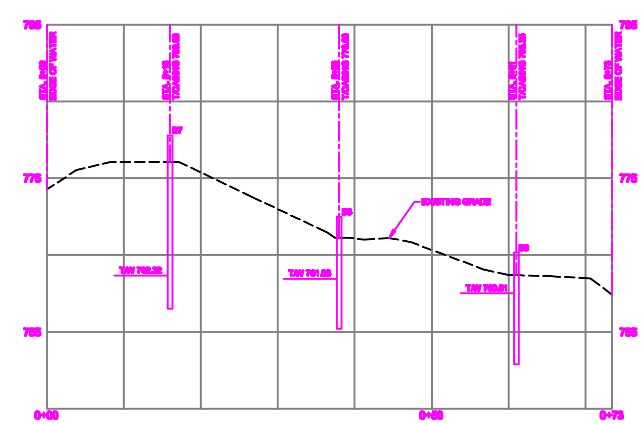
PLAN VIEW



CROSS-SECTION A-A



CROSS-SECTION B-B



CROSS-SECTION C-C

Stantec

Stantec Consulting Michigan Inc.
3959 Research Park Drive
Ann Arbor MI U.S.A.
48108-2216
Tel. 734.761.1010
Fax. 734.761.1200
www.stantec.com

Consultants

Legend

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name: CROSS-SECTIONS-2004.DWG	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

CITY OF ANN ARBOR

ARGO DAM PIEZOMETERS

Ann Arbor, Michigan

Title

Project No.	Scale	
2075090900	AS NOTED	
Drawing No.	Sheet	Revision
	1 of 1	0

APPENDIX B

GENERAL NOTES

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

BORING LOGS (B1, B2 AND B4 THROUGH B9)

OBSERVATION WELL LOGS (B1, B2 AND B4 THROUGH B9)

PARTICLE SIZE DISTRIBUTION REPORTS (FIGURE 1 THROUGH 4)

soil and materials engineers, inc.

GEOTECHNICAL NOTES

Drilling and Sampling Symbols

SS	–	Split-Spoon 1-3/8" I.D., 2" O.D. except where noted	NR	–	No Recovery
LS	–	Liner Sample	RC	–	Rock Core with diamond bit. NQ size, except where noted
AS	–	Power Auger Sample	RB	–	Rock Bit
2ST	–	Shelby Tube – 2" O.D.	VS	–	Vane Shear
3ST	–	Shelby Tube – 3" O.D.	PM	–	Pressuremeter
PS	–	Piston Sample – 3" diameter	WOH	–	Weight of Hammer
WS	–	Wash Sample			
HA	–	Hand Auger Sample	SP	–	Soil Probe
BS	–	Bag or Bottle Sample	PID	–	Photo Ionization Device
CS	–	Continuous Sample	FID	–	Flame Ionization Device

Standard Penetration 'N' – Blows per foot of a 140-pound hammer falling 30 inches on a 2-inch O.D. split spoon, except where noted.

Particle Sizes

Boulders	-	Greater than 12 inches (305 mm)
Cobbles	-	3 inches (76.2 mm) to 12 inches (305 mm)
Gravel-Coarse	-	3/4 inches (19.05 mm) to 3 inches (76.2mm)
Fine	-	No. 4 (4.75 mm) to 3/4 inches (19.05 mm)
Sand- Coarse	-	No. 10 (2.00 mm) to No. 4 (4.75 mm)
Medium	-	No. 40 (0.425 mm) to No. 10 (2.00 mm)
Fine	-	No. 200 (0.074 mm) to No. 40 (0.425 mm)
Silt	-	0.005 mm to 0.074 mm
Clay	-	Less than (0.005 mm)

Depositional Features

Parting	-	as much as 1/16 inch (1.6 mm) thick
Seam	-	1/16 inch (1.6 mm) to 1/2 inch (12.7 mm) thick
Layer	-	1/2 inch (12.7 mm) to 12 (305 mm) inches thick
Stratum	-	greater than 12 inches (305 mm) thick
Pocket	-	small, erratic deposit of limited lateral extent
Lens	-	lenticular deposit
Varved	-	alternating seams or layers of silt and/or clay and sometimes fine sand
Occasional	-	one or less per foot (305 mm) of thickness
Frequent	-	more than one per foot (305 mm) of thickness
Interbedded	-	applied to strata of soil or beds of rock lying between or alternating with other strata of a different nature

Groundwater levels indicated on the boring log are the levels measured in the boring at the times indicated. The accurate determination of groundwater levels may not be possible with short term observations, especially in low permeability soils. The groundwater levels shown may fluctuate throughout the year with variation in precipitation, evaporation and runoff.

Classification

Cohesionless Soils (Blows per foot or 0.3 m)

Very Loose	:	0 to 4
Loose	:	5 to 9
Medium Dense	:	10 to 29
Dense	:	30 to 49
Very Dense	:	50 to 80
Extremely Dense	:	Over 80

Cohesive Soils

Consistency		Shear Strength
Very Soft	:	0.25 kips/ft^2 (12.0 kPa) or less
Soft	:	0.25 to 0.49 kips/ft^2 (12.0 to 23.8 kPa)
Medium	:	0.50 to 0.99 kips/ft^2 (23.9 to 47.7 kPa)
Stiff	:	1.00 to 1.99 kips/ft^2 (47.8 to 95.6 kPa)
Very Stiff	:	2.00 to 3.99 kips/ft^2 (95.7 to 191.3 kPa)
Hard	:	4.00 kips/ft^2 (191.4 kPa) or greater

Soil Constituents

Trace	:	Less than 5%
Trace to Some	:	5% to 12%
Some	:	12% to 25%
Use Descriptor (i.e., Silty, Clayey, etc.)	:	25% to 50%

Soil description

If clay content sufficiently dominates soil properties, then clay becomes the primary noun with the other major soil constituent as modifier: i.e. silty clay. Other minor soil constituents may be added according to estimates of soil constituents present, i.e., silty clay, trace to some sand, trace gravel.

UNIFIED SOIL CLASSIFICATION SYSTEM

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

Major divisions		Symbol	Description
COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels; sandy gravels, little or no fines
		GP	Poorly-graded gravels; sandy gravels, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, some sand or sandy gravels, some silt
		GC	Clayey gravels, some sand or sandy gravels, some silt
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands or sands, some silt
		SC	Clayey sands or sands, some clay
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic sandy silts or clayey silts with slight plasticity
		CL	Inorganic clays of low plasticity, sandy clays, silty clays
		OL	Organic silts and organic clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts of high plasticity
		CH	Inorganic clays of high plasticity
		OH	Organic silts and organic clays of high plasticity
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

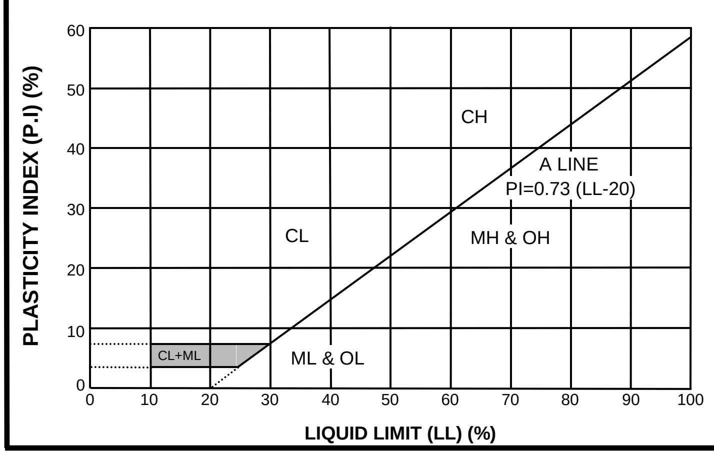
LABORATORY CLASSIFICATION CRITERIA

Symbol	Criteria	
GW	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
GC	Atterberg limits above "A" line with P.I. greater than 7	
SW	$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
SP	Not meeting all gradation requirements for SW	
SM	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
SC	Atterberg limits above "A" line with P.I. greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent……………………………………………GW, GP, SW, SP
More than 12 percent………………………………………..GM, GC, SM, SC
5 to 12 percent…………………….Borderline cases requiring dual symbols

PLASTICITY CHART



soil and materials engineers, inc.

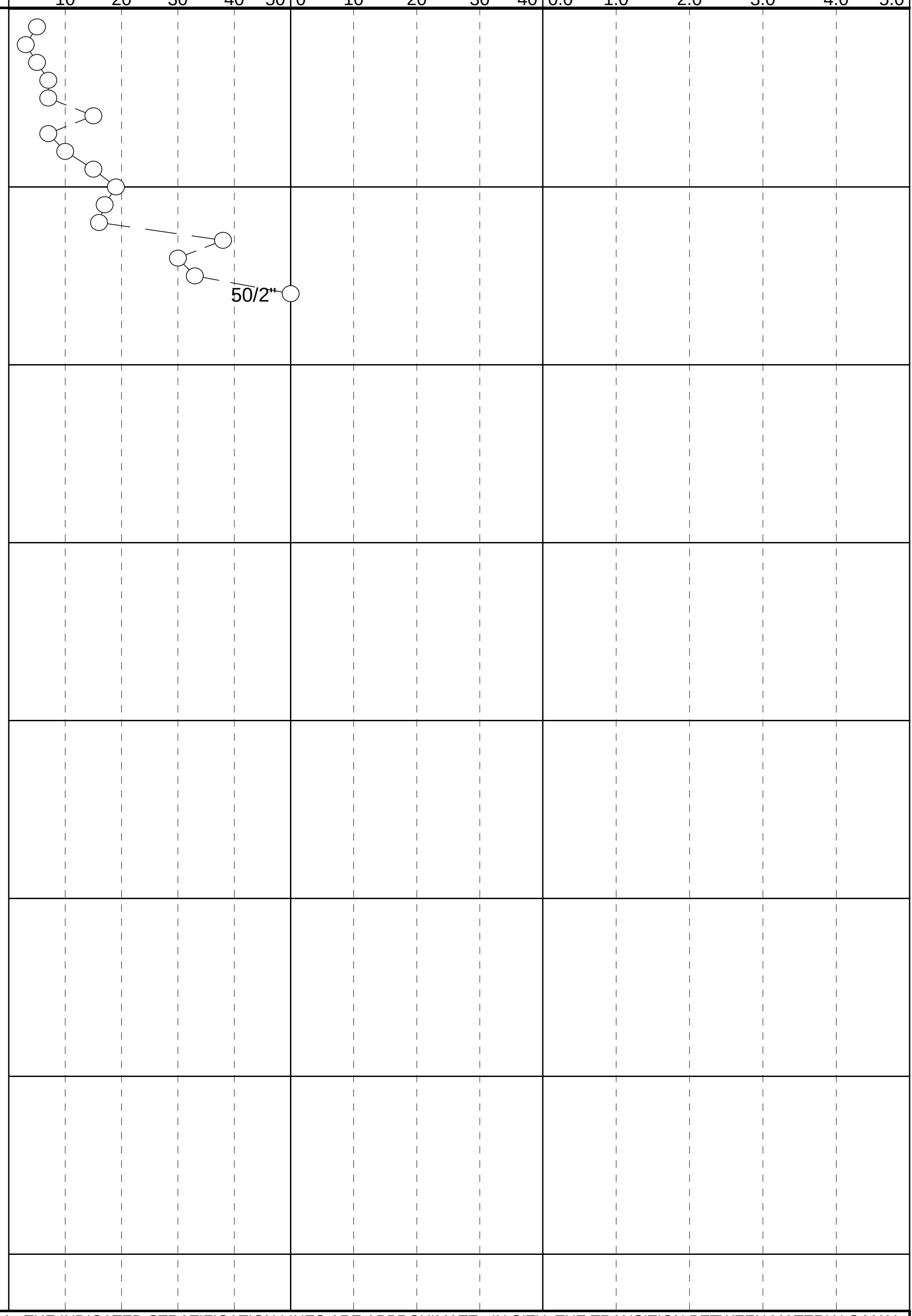
PROJECT NAME: ARGO DAM — **A/E:** STANTEC MICHIGAN

PROJECT LOCATION: ANN ARBOR, MICHIGAN — **BY:** SB/CGN — **DATE:** 9/17/09 — **BORING B1**

CLIENT: STANTEC MICHIGAN — **PROJECT NUMBER:** PG60424 — **SHEET:** 1

GROUND SURFACE ELEVATION= 777

DEPTH (FEET)	PROFILE DESCRIPTION	SAMPLE TYPE/NUMBER INTERVAL	BLOWS PER SIX INCHES
0	Fine to Medium Sand- Trace to Some Gravel & Silt- Trace Root Fibers- Dark Brown- Moist- Very Loose (SP-SM/Topsoil)	LS1	5, 3, 5, 7
	Fine to Coarse Sand- Some Gravel- Trace to Some Silt- Brown- Moist- Very Loose to Dense (SP-SM/Fill)	LS2, LS3, LS4	7, 15, 7, 10, 15, 19, 17, 16, 38, 30, 33, 50/2"
	Gravelly Fine to Coarse Sand- Trace to Some Silt- Brown- Wet (SP-SM)	LS5	
	Organic Silt- Trace to Some Sand- Trace Shell Fragments- Dark Gray- Wet (OL)	LS6, LS7	
	Fine to Coarse Sand- Some Silt- Trace to Some Gravel- Trace Shell Fragments- Dark Gray- Wet (SM)	LS8	
20	Fine to Coarse Sand- Some Gravel- Trace to Some Silt- Gray & Brown- Wet (SP-SM)		
	END OF BORING AT 20 FEET		



LEGEND
- HAND PENETROMETER TEST
- TORVANE SHEAR TEST
- UNCONFINED COMPRESSION TEST
- VANE SHEAR TEST
- REMOLDED VANE SHEAR
- TRIAXIAL TEST

WATER LEVEL OBSERVATIONS
- GROUNDWATER ENCOUNTERED DURING AUGERING
- GROUNDWATER ENCOUNTERED UPON COMPLETION OF AUGERING

Notes: 1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.

FIELD ENG.: CGN — **AUGER METHOD:** DIRECT PUSH — **WATER LEVEL DURING AUGERING:** 11 — **WATER LEVEL** — **HOURS AFTER COMPLETION:**

EQUIPMENT: Geoprobe — **BACKFILL METHOD:** SOIL CUTTINGS — **WATER LEVEL UPON COMPLETION:** 11 — **CAVE OF AUGERHOLE AT**

soil and materials engineers, inc.

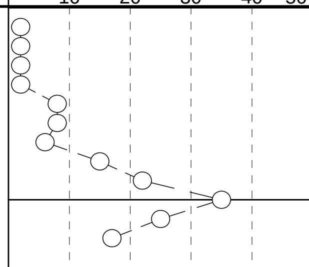
PROJECT NAME: ARGO DAM
A/E: STANTEC MICHIGAN

PROJECT LOCATION: ANN ARBOR, MICHIGAN
BY: CGN **DATE:** 9/17/09 **BORING** B2

CLIENT: STANTEC MICHIGAN
PROJECT NUMBER: PG60424 **SHEET:** 1

DEPTH (FEET)	SYMBOLIC PROFILE	PROFILE DESCRIPTION GROUND SURFACE ELEVATION= 768	SAMPLE TYPE/NUMBER INTERVAL	BLOWS PER SIX INCHES
0		Engineer reported Sandy Topsoil- Black- Moist	HA1	2 2
		Fine to Medium Sand- Trace to Some Silt- Trace Gravel- Frequent Cobbles & Topsoil Seams- Dark Brown- Moist to Wet- Very Loose to Loose (SP-SM)	HA2	2 2 8 8
		Sandy Clay- Some Silt- Trace Gravel- Dark Brown & Black (CL)	HA3	6 15 22
5		DCP READINGS		35 25 17
		END OF BORING AT 4 FEET, DCP READINGS RECORDED TO 6 FEET.		

DYNAMIC CONE PENETROMETER (DCP) -- ○



NATURAL DRY DENSITY -- ■ (pcf) 90 100 110

MOISTURE, % -- ◆

ATTERBERG ⊢⊣ LIMITS 0 10 20 30 40

LEGEND
- ▽ **HAND PENETROMETER TEST**
- ⊠ **TORVANE SHEAR TEST**
- ○ **UNCONFINED COMPRESSION TEST**
- ▣ **VANE SHEAR TEST**
- × **REMOLDED VANE SHEAR**
- ⊕ **TRIAXIAL TEST**

SHEAR STRENGTH (KSF) 0.0 1.0 2.0 3.0 4.0 5.0

WATER LEVEL OBSERVATIONS
- GROUNDWATER ENCOUNTERED DURING AUGERING
- GROUNDWATER ENCOUNTERED UPON COMPLETION OF AUGERING

Notes: 1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. NO STRENGTH TESTS WERE PERFORMED ON SAMPLE HA3 DUE TO SAMPLE DISTURBANCE.

FIELD ENG.: CGN **AUGER METHOD:** HAND AUGER **WATER LEVEL DURING AUGERING:** 2.5 **WATER LEVEL** **HOURS AFTER COMPLETION:**

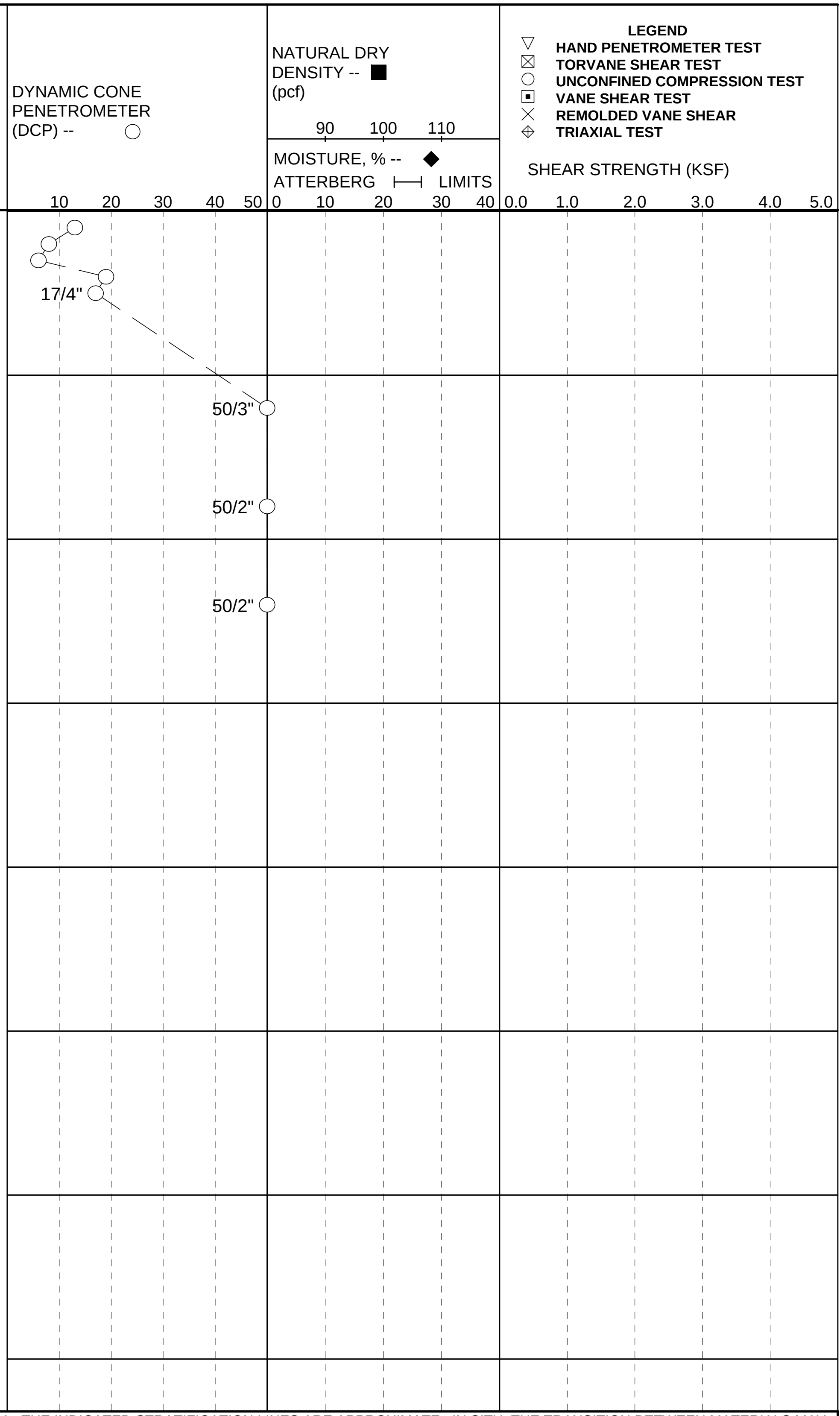
EQUIPMENT: Hand Auger **BACKFILL METHOD:** SOIL CUTTINGS **WATER LEVEL UPON COMPLETION:** 2.5 **CAVE OF AUGERHOLE AT**

soil and materials engineers, inc.

PROJECT NAME: ARGO DAM
A/E: STANTEC MICHIGAN
PROJECT LOCATION: ANN ARBOR, MICHIGAN
BY: SB/CGN **DATE:** 9/17/09 **BORING** B4
CLIENT: STANTEC MICHIGAN
PROJECT NUMBER: PG60424 **SHEET:** 1

GROUND SURFACE ELEVATION= 777

DEPTH (FEET)	PROFILE DESCRIPTION	SAMPLE TYPE/NUMBER INTERVAL	BLOWS PER SIX INCHES
0	Fine to Medium Sand- Trace to Some Silt- Trace Gravel & Root Fibers- Dark Brown- Moist- Loose (SP-SM/Topsoil)	LS1	13, 8, 6, 19, 17/4"
5	Fine to Coarse Sand- Some Gravel- Trace to Some Silt- Brown- Moist- Loose to Very Dense (SP-SM/Fill)	LS2, LS3, LS4	50/3", 50/2"
10	Fine to Coarse Sand- Some Silt- Trace to Some Gravel- Dark Brown- Moist- Very Dense (SM/Fill)	LS5	50/2"
15	Fine to Coarse Sand- Some Silt & Gravel- Trace Shell Fragments- Occasional Organic Silt Seams- Gray- Wet (SM/Fill)	LS6	
	Silty Fine to Coarse Sand- Some Gravel- Brown & Gray- Wet (SM) (Cobbles or Boulders encountered at 19.5 feet)	LS7, LS8	
20	END OF BORING AT 20 FEET		



WATER LEVEL OBSERVATIONS
- GROUNDWATER ENCOUNTERED DURING AUGERING
- GROUNDWATER ENCOUNTERED UPON COMPLETION OF AUGERING

Notes: 1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.

FIELD ENG.: CGN **AUGER METHOD:** DIRECT PUSH **WATER LEVEL DURING AUGERING:** 15 **WATER LEVEL** **HOURS AFTER COMPLETION:**
EQUIPMENT: Geoprobe **BACKFILL METHOD:** SOIL CUTTINGS **WATER LEVEL UPON COMPLETION:** 15 **CAVE OF AUGERHOLE AT**

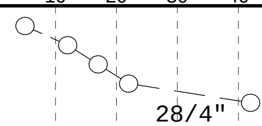
soil and materials engineers, inc.

PROJECT NAME: ARGO DAM | **A/E:** STANTEC MICHIGAN

PROJECT LOCATION: ANN ARBOR, MICHIGAN | **BY:** CGN | **DATE:** 9/17/09 | **BORING** B5

CLIENT: STANTEC MICHIGAN | **PROJECT NUMBER:** PG60424 | **SHEET:** 1

DEPTH (FEET)	SYMBOLIC PROFILE	PROFILE DESCRIPTION GROUND SURFACE ELEVATION= 768	SAMPLE TYPE/NUMBER INTERVAL	BLOWS PER SIX INCHES	DYNAMIC CONE PENETROMETER (DCP) -- ○ 10 20 30 40 50	NATURAL DRY DENSITY -- ■ (pcf) 90 100 110 MOISTURE, % -- ◆ ATTERBERG ⊢⊣ LIMITS 0 10 20 30 40	SHEAR STRENGTH (KSF) 0.0 1.0 2.0 3.0 4.0 5.0
0		Engineer reported Sandy Topsoil- Black- Moist		5 12 17 22 28/4"			
		Engineer reported Fine to Coarse Sand- Trace to Some Silt- Frequent Cobbles or Boulders- Trace Gravel- Brown- Moist- Loose to Medium Dense (SP-SM/Fill)					
		END OF BORING AT 3 FEET					
5							
10							
15							
20							
25							
30							
35							



LEGEND
- ▽ HAND PENETROMETER TEST
- ⊠ TORVANE SHEAR TEST
- ○ UNCONFINED COMPRESSION TEST
- ▣ VANE SHEAR TEST
- × REMOLDED VANE SHEAR
- ⊕ TRIAXIAL TEST

WATER LEVEL OBSERVATIONS
- GROUNDWATER ENCOUNTERED DURING AUGERING
- GROUNDWATER ENCOUNTERED UPON COMPLETION OF AUGERING

Notes:
1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. GROUNDWATER WAS NOT ENCOUNTERED.
3. ENGINEER ENCOUNTERED REFUSAL DURING AUGERING, OFFSET & RE-AUGERED TWO MORE TIMES & MET REFUSAL, LIKELY DUE TO COBBLES OR BOULDERS.

FIELD ENG.: CGN | **AUGER METHOD:** HAND AUGER | **WATER LEVEL DURING AUGERING:** None | **WATER LEVEL** | **HOURS AFTER COMPLETION:**

EQUIPMENT: Hand Auger | **BACKFILL METHOD:** SOIL CUTTINGS | **WATER LEVEL UPON COMPLETION:** None | **CAVE OF AUGERHOLE AT**

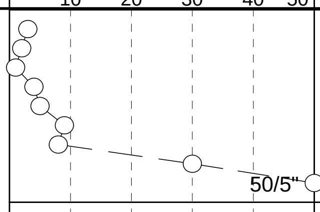
soil and materials engineers, inc.

PROJECT NAME: ARGO DAM
A/E: STANTEC MICHIGAN
PROJECT LOCATION: ANN ARBOR, MICHIGAN
BY: CGN **DATE:** 9/17/09 **BORING** B6
CLIENT: STANTEC MICHIGAN
PROJECT NUMBER: PG60424 **SHEET:** 1

GROUND SURFACE ELEVATION= 763

DEPTH (FEET)	PROFILE DESCRIPTION	SAMPLE TYPE/NUMBER INTERVAL	BLOWS PER SIX INCHES
0	Silty Fine to Medium Sand- Trace to Some Clay- Trace Gravel, Roots & Organics- Black- Moist (SM/ Topsoil)	HA1	3, 2, 1
	Gravelly Fine to Coarse Sand- Some Silt- Trace Gravel & Roots- Occasional Cobbles or Boulders- Gray- Wet- Very Loose to Medium Dense (SM)	HA2, HA3, HA4	4, 5, 9, 8, 30, 50/5"
5	DCP READINGS		
	END OF BORING AT 3.5 FEET, DCP READINGS RECORDED TO 4.5 FEET.		

DYNAMIC CONE PENETROMETER (DCP) -- ○ (10, 20, 30, 40, 50)



NATURAL DRY DENSITY -- ■ (pcf) 90 100 110
MOISTURE, % -- ◆
ATTERBERG LIMITS (0, 10, 20, 30, 40)

LEGEND
- ▽ HAND PENETROMETER TEST
- ⊠ TORVANE SHEAR TEST
- ○ UNCONFINED COMPRESSION TEST
- ▣ VANE SHEAR TEST
- × REMOLDED VANE SHEAR
- ⊕ TRIAXIAL TEST

SHEAR STRENGTH (KSF) 0.0 1.0 2.0 3.0 4.0 5.0

WATER LEVEL OBSERVATIONS
- GROUNDWATER ENCOUNTERED DURING AUGERING
- GROUNDWATER ENCOUNTERED UPON COMPLETION OF AUGERING

Notes:
1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. ENGINEER ENCOUNTERED REFUSAL DURING AUGERING LIKELY DUE TO COBBLES OR BOULDERS.

FIELD ENG.: CGN **AUGER METHOD:** HAND AUGER **WATER LEVEL DURING AUGERING:** 1 **WATER LEVEL** **HOURS AFTER COMPLETION:**
EQUIPMENT: Hand Auger **BACKFILL METHOD:** SOIL CUTTINGS **WATER LEVEL UPON COMPLETION:** 1 **CAVE OF AUGERHOLE AT**

soil and materials engineers, inc.

PROJECT NAME: ARGO DAM
PROJECT LOCATION: ANN ARBOR, MICHIGAN
CLIENT: STANTEC MICHIGAN

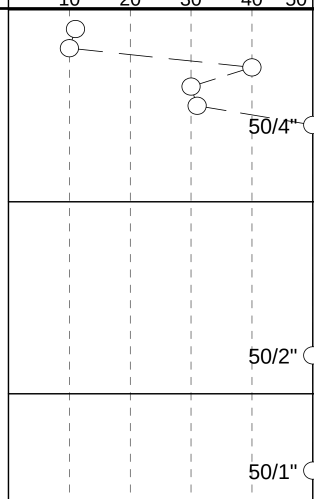
A/E: STANTEC MICHIGAN
BY: SB/CGN **DATE:** 9/17/09
PROJECT NUMBER: PG60424

BORING B7
SHEET: 1

GROUND SURFACE ELEVATION= 777

DEPTH (FEET)	PROFILE DESCRIPTION	SAMPLE TYPE/NUMBER INTERVAL	BLOWS PER SIX INCHES
0	Fine to Medium Sand- Some Silt- Trace to Some Gravel- Trace Root Fibers- Dark Brown & Black- Moist- Loose (SP-SM/Topsoil)	LS1	11 10 40 30
	Fine to Coarse Sand- Trace to Some Gravel & Silt- Occasional Gravel & Silty Sand Seams- Brown- Moist to Wet- Dense to Very Dense (SP-SM/Fill)	LS2	31 50/4"
		LS3	50/2"
		LS4	50/1"
15	Gravelly Fine to Coarse Sand- Trace to Some Silt- Brown & White- Wet (SP-SM)	LS5	
	Organic Silt- Trace Sand, Gravel, Roots & Shell Fragments- Dark Brown (OL)	LS6	
20	END OF BORING AT 20 FEET		

DYNAMIC CONE PENETROMETER (DCP) -- ○



NATURAL DRY DENSITY -- ■ (pcf) 90 100 110

MOISTURE, % -- ◆
ATTERBERG ⊢⊣ LIMITS
0 10 20 30 40

LEGEND
▽ HAND PENETROMETER TEST
⊠ TORVANE SHEAR TEST
○ UNCONFINED COMPRESSION TEST
▣ VANE SHEAR TEST
× REMOLDED VANE SHEAR
⊕ TRIAXIAL TEST

SHEAR STRENGTH (KSF)
0.0 1.0 2.0 3.0 4.0 5.0

WATER LEVEL OBSERVATIONS
- GROUNDWATER ENCOUNTERED DURING AUGERING
- GROUNDWATER ENCOUNTERED UPON COMPLETION OF AUGERING

Notes:
1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. GRADATION ON LS5 CONDUCTED ON A LAYER OF GRAVEL WITHIN THE SAND STRATA.

FIELD ENG.: CGN **AUGER METHOD:** DIRECT PUSH **WATER LEVEL DURING AUGERING:** 15 **WATER LEVEL** **HOURS AFTER COMPLETION:**

EQUIPMENT: Geoprobe **BACKFILL METHOD:** SOIL CUTTINGS **WATER LEVEL UPON COMPLETION:** 15 **CAVE OF AUGERHOLE AT**

soil and materials engineers, inc.

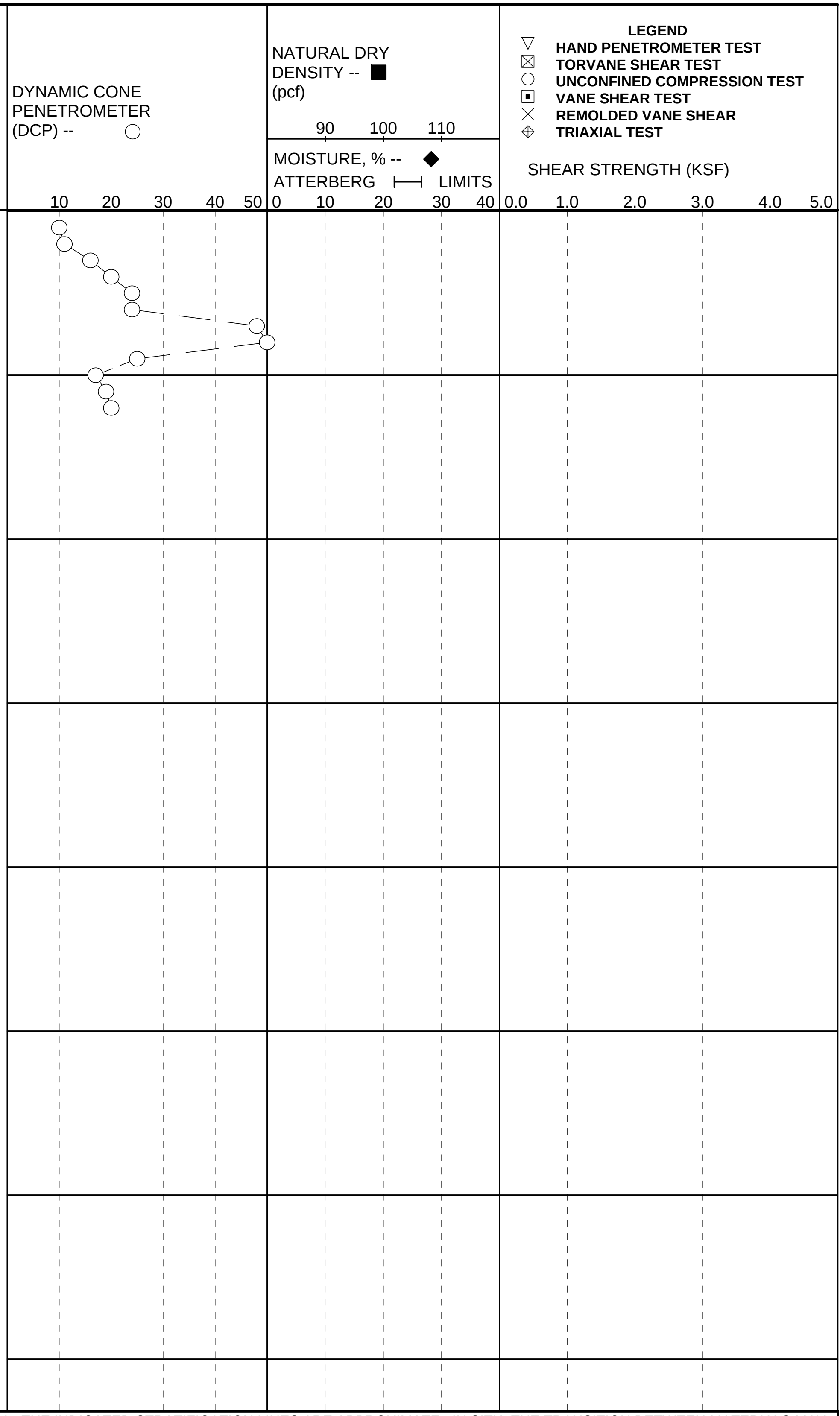
PROJECT NAME: ARGO DAM
PROJECT LOCATION: ANN ARBOR, MICHIGAN
CLIENT: STANTEC MICHIGAN

A/E: STANTEC MICHIGAN
BY: CGN **DATE:** 9/17/09
PROJECT NUMBER: PG60424

BORING B8
SHEET: 1

GROUND SURFACE ELEVATION= 768

DEPTH (FEET)	PROFILE DESCRIPTION	SAMPLE TYPE/NUMBER INTERVAL	BLOWS PER SIX INCHES
0	Fine to Medium Sand- Some Silt- Trace to Some Gravel- Trace Organics- Frequent Cobbles & Roots- Black- Moist- Loose to Medium Dense (SM/Topsoil/Fill)	HA1	10
			11
		HA2	16
			20
			24
	Fine to Medium Sand- Trace to Some Silt- Trace Gravel- Frequent Cobbles or Boulders- Brown- Moist- Medium Dense to Dense (SP-SM/ Fill)		24
		HA3	48
			50
5			25
			17
			19
	DCP READINGS		20
	END OF BORING AT 4 FEET, DCP READINGS RECORDED TO 6 FEET.		
10			
15			
20			
25			
30			
35			



WATER LEVEL OBSERVATIONS
- GROUNDWATER ENCOUNTERED DURING AUGERING
- GROUNDWATER ENCOUNTERED UPON COMPLETION OF AUGERING

Notes:
1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. GROUNDWATER WAS NOT ENCOUNTERED.
3. ENGINEER ENCOUNTERED REFUSAL DURING AUGERING, OFFSET & RE-AUGERED TWO MORE TIMES & MET REFUSAL, LIKELY DUE TO COBBLES OR BOULDERS.

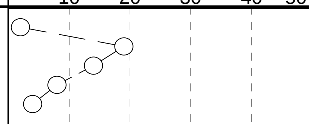
FIELD ENG.: CGN **AUGER METHOD:** HAND AUGER **WATER LEVEL DURING AUGERING:** None **WATER LEVEL** **HOURS AFTER COMPLETION:**
EQUIPMENT: Hand Auger **BACKFILL METHOD:** SOIL CUTTINGS **WATER LEVEL UPON COMPLETION:** None **CAVE OF AUGERHOLE AT**

soil and materials engineers, inc.

PROJECT NAME: ARGO DAM
A/E: STANTEC MICHIGAN
PROJECT LOCATION: ANN ARBOR, MICHIGAN
BY: CGN **DATE:** 9/17/09 **BORING** B9
CLIENT: STANTEC MICHIGAN
PROJECT NUMBER: PG60424 **SHEET:** 1

DEPTH (FEET)	SYMBOLIC PROFILE	PROFILE DESCRIPTION GROUND SURFACE ELEVATION= 762	SAMPLE TYPE/NUMBER INTERVAL	BLOWS PER SIX INCHES
0		Engineer reported Sandy Topsoil- Black- Frequent Cobbles- Black- Moist (SM/Topsoil/Fill)		2 19 14 8 4
		DCP READINGS		
		END OF BORING AT .5 FEET, DCP READINGS RECORDED TO 2.5 FEET.		

DYNAMIC CONE PENETROMETER (DCP) -- ○ (scale 10, 20, 30, 40, 50)



NATURAL DRY DENSITY -- ■ (pcf) 90 100 110
MOISTURE, % -- ◆
ATTERBERG ⊢⊣ LIMITS 0 10 20 30 40

LEGEND
- ▽ **HAND PENETROMETER TEST**
- ☒ **TORVANE SHEAR TEST**
- ○ **UNCONFINED COMPRESSION TEST**
- ▣ **VANE SHEAR TEST**
- × **REMOLDED VANE SHEAR**
- ⊕ **TRIAXIAL TEST**

SHEAR STRENGTH (KSF) 0.0 1.0 2.0 3.0 4.0 5.0

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35

WATER LEVEL OBSERVATIONS
- GROUNDWATER ENCOUNTERED DURING AUGERING
- GROUNDWATER ENCOUNTERED UPON COMPLETION OF AUGERING

Notes:
1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. GROUNDWATER WAS NOT ENCOUNTERED.
3. ENGINEER ENCOUNTERED REFUSAL DURING AUGERING, OFFSET & RE-AUGERED SEVEN MORE TIMES & MET REFUSAL, LIKELY DUE TO COBBLES OR BOULDERS.

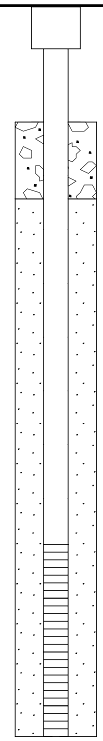
FIELD ENG.: CGN **AUGER METHOD:** HAND AUGER **WATER LEVEL DURING AUGERING:** None **WATER LEVEL** **HOURS AFTER COMPLETION:**
EQUIPMENT: Hand Auger **BACKFILL METHOD:** SOIL CUTTINGS **WATER LEVEL UPON COMPLETION:** None **CAVE OF AUGERHOLE AT**

soil and materials engineers, inc.

Observation Well
B1

OBSERVATION WELL LOG
SME PROJECT No. PG60424

PROJECT NAME: ARGO DAM
PROJECT LOCATION: ANN ARBOR, MICHIGAN **BY:** SB/CGN **DATE:** 9/17/09
CLIENT: STANTEC MICHIGAN

ELEVATION (Ft.)	WELL DIAGRAM	DEPTH (Ft.)	PROFILE DESCRIPTION — GROUND SURFACE ELEVATION IN FEET MSL= 777	WELL CONSTRUCTION DETAILS
780		0	**Fine to Medium Sand- Trace to Some Gravel & Silt- Trace Root Fibers- Dark Brown- Moist- Very Loose (SP-SM/Topsoil)**	**Top of Casing Elevation:** 779.88
775		5	**Fine to Coarse Sand- Some Gravel- Trace to Some Silt- Brown- Moist- Very Loose to Dense (SP-SM/Fill)**	**Well Screen Tip Elevation:** 761
770		10		**Borehole Diameter:** 2.25 inches
765		15	**Gravelly Fine to Coarse Sand- Trace to Some Silt- Brown- Wet (SP-SM)**	**Filter Pack Type:** Natural Sand
760			**Organic Silt- Trace to Some Sand- Trace Shell Fragments- Dark Gray- Wet (OL)**	**Well Casing** **Diameter:** 1 inch **Length:** 14 feet **Type:** PVC
			Fine to Coarse Sand- Some Silt- Trace to Some Gravel- Trace Shell Fragments- Dark Gray- Wet (SM)	**Joint Type:**
			Fine to Coarse Sand- Some Gravel- Trace to Some Silt- Gray & Brown- Wet (SP-SM)	**Well Screen** **Diameter:** 1 inch **Length:** 5 feet **Type:** PVC **Mesh:** **Screen Plug (Y/N):** Y
755		20	**END OF BORING AT 20 FEET**	**Protective Casing** **Total Length:** **Length Above Ground:** 3.5 feet **Diameter:** **Type:** Metal
750		25		**Well Cap** **Type:** 3/4-inch Locking Well Cap
745		30		**Northing:** **Easting:**

WELL TYPE: OBSERVATION
DRILLER: CGN
RIG NUMBER OR CONTRACTOR: GEOPROBE
DRILLING METHODS: DIRECT PUSH
GROUNDWATER DURING DRILLING
GROUNDWATER AFTER DRILLING

WATER LEVEL DATA

DATE	DEPTH (Feet)	ELEVATION (Feet)
9/30/09	9.96	767.04

Notes:
1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. OBSERVATION WELL INSTALLED IN BORING B1.

soil and materials engineers, inc.

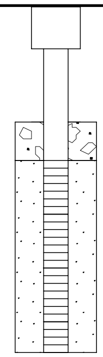
Observation Well

B2

OBSERVATION WELL LOG

SME PROJECT No. PG60424

PROJECT NAME: ARGO DAM
PROJECT LOCATION: ANN ARBOR, MICHIGAN **BY:** CGN **DATE:** 9/17/09
CLIENT: STANTEC MICHIGAN

ELEVATION (Ft.)	WELL DIAGRAM	DEPTH (Ft.)	PROFILE	PROFILE DESCRIPTION GROUND SURFACE ELEVATION IN FEET MSL= 768	WELL CONSTRUCTION DETAILS
770					**Top of Casing Elevation:** 772.30
		0		**Engineer reported Sandy Topsoil- Black- Moist**	**Well Screen Tip Elevation:** 762
				Fine to Medium Sand- Trace to Some Silt- Trace Gravel- Frequent Cobbles & Topsoil Seams- Dark Brown- Moist to Wet- Very Loose to Loose (SP-SM)	
765					**Borehole Diameter:** 3.25 inches
				Sandy Clay- Some Silt- Trace Gravel- Dark Brown & Black (CL)	**Filter Pack Type:** 2NS Sand
		5		**END OF BORING AT 4 FEET, OBSERVATION WELL INSTALLED TO A DEPTH OF 6 FEET.**	
760					**Well Casing** **Diameter:** 2 inches **Length:** 4 feet **Type:** PVC
		10			**Joint Type:**
755					**Well Screen** **Diameter:** 2 inches **Length:** 5 feet **Type:** PVC **Mesh:** **Screen Plug (Y/N):** Y
		15			
750					**Protective Casing** **Total Length:** **Length Above Ground:** 3.5 feet **Diameter:** **Type:** Metal
		20			
745					**Well Cap** **Type:** 3/4-inch Locking Well Cap
		25			**Northing:** **Easting:**
740					
		30			
735					

WELL TYPE: OBSERVATION
DRILLER: CGN
RIG NUMBER OR CONTRACTOR: HAND AUGER

DRILLING METHODS: HAND AUGER
GROUNDWATER DURING DRILLING
GROUNDWATER AFTER DRILLING

WATER LEVEL DATA

DATE	DEPTH (Feet)	ELEVATION (Feet)
9/30/09	5.88	762.12

Notes:
1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. OBSERVATION WELL INSTALLED IN BORING B2.

soil and materials engineers, inc.

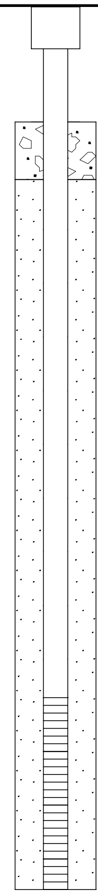
Observation Well
B4

OBSERVATION WELL LOG

SME PROJECT No. PG60424

PROJECT NAME: ARGO DAM
PROJECT LOCATION: ANN ARBOR, MICHIGAN **BY:** SB/CGN **DATE:** 9/17/09
CLIENT: STANTEC MICHIGAN

WELL DIAGRAM



ELEVATION (Ft.)	DEPTH (Ft.)	PROFILE DESCRIPTION (GROUND SURFACE ELEVATION IN FEET MSL= 777)
777	0	**Fine to Medium Sand- Trace to Some Silt- Trace Gravel & Root Fibers- Dark Brown- Moist- Loose (SP-SM/Topsoil)**
		Fine to Coarse Sand- Some Gravel- Trace to Some Silt- Brown- Moist- Loose to Very Dense (SP-SM/Fill)
		Fine to Coarse Sand- Some Silt- Trace to Some Gravel- Dark Brown- Moist- Very Dense (SM/Fill)
		Fine to Coarse Sand- Some Silt & Gravel- Trace Shell Fragments- Occasional Organic Silt Seams- Gray- Wet (SM/Fill)
		Silty Fine to Coarse Sand- Some Gravel- Brown & Gray- Wet (SM) (Cobbles or Boulders encountered at 19.5 feet)
757	20	**END OF BORING AT 20 FEET**

Elevation scale: 780, 775, 770, 765, 760, 755, 750, 745
Depth scale: 0, 5, 10, 15, 20, 25, 30

WELL CONSTRUCTION DETAILS

Top of Casing
Elevation: 780.97

Well Screen Tip
Elevation: 757

Borehole Diameter: 2.25 inches

Filter Pack Type:
Natural Sand

Well Casing
Diameter: 1 inch
Length: 18 feet
Type: PVC
Joint Type:

Well Screen
Diameter: 1 inch
Length: 5 feet
Type: PVC
Mesh:
Screen Plug (Y/N): Y

Protective Casing
Total Length:
Length Above Ground: 3.5 feet
Diameter:
Type: Metal

Well Cap
Type: 3/4-inch Locking Well Cap

Northing:
Easting:

WELL TYPE: OBSERVATION
DRILLER: CGN
RIG NUMBER OR CONTRACTOR: GEOPROBE

DRILLING METHODS: DIRECT PUSH
GROUNDWATER DURING DRILLING
GROUNDWATER AFTER DRILLING

WATER LEVEL DATA

DATE	DEPTH (Feet)	ELEVATION (Feet)
9/30/09	19.64	757.36

Notes:
1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. OBSERVATION WELL INSTALLED IN BORING B4.

soil and materials engineers, inc.

Observation Well

B5

OBSERVATION WELL LOG
SME PROJECT No. PG60424

PROJECT NAME: ARGO DAM
PROJECT LOCATION: ANN ARBOR, MICHIGAN **BY:** CGN **DATE:** 9/17/09
CLIENT: STANTEC MICHIGAN

ELEVATION (Ft.)	DEPTH (Ft.)	PROFILE DESCRIPTION — GROUND SURFACE ELEVATION IN FEET MSL= 768
770		
	0	**Engineer reported Sandy Topsoil- Black- Moist**
		Engineer reported Fine to Coarse Sand- Trace to Some Silt- Frequent Cobbles or Boulders- Trace Gravel- Brown- Moist- Loose to Medium Dense (SP-SM/Fill)
765	5	**END OF BORING AT 3 FEET, OBSERVATION WELL INSTALLED TO A DEPTH OF 9.5 FEET.**
760	10	
755	15	
750	20	
745	25	
740	30	
735		

WELL DIAGRAM

WELL CONSTRUCTION DETAILS

Top of Casing
Elevation: 772.06

Well Screen Tip
Elevation: 758.5

Borehole Diameter: Driven

Filter Pack Type: None

Well Casing
Diameter: 1.25 inch
Length: 9 feet
Type: Galvanized Steel

Joint Type:

Well Screen
Diameter: 1.25 inches
Length: 3 feet
Type: Stainless Steel
Mesh:
Screen Plug (Y/N): Y

Protective Casing
Total Length:
Length Above Ground: 3.5 feet
Diameter:
Type: Metal

Well Cap
Type: 3/4-inch Locking Well Cap

Northing:
Easting:

WELL TYPE: OBSERVATION
DRILLER: CGN
RIG NUMBER OR CONTRACTOR: HAND AUGER
DRILLING METHODS: HAND AUGER
GROUNDWATER DURING DRILLING ▼
GROUNDWATER AFTER DRILLING ▽

WATER LEVEL DATA

DATE	DEPTH (Feet)	ELEVATION (Feet)
9/30/09	8.25	759.75

Notes:
1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. OBSERVATION WELL INSTALLED NEAR BORING B5.
3. ENGINEER ENCOUNTERED REFUSAL DURING AUGERING, OFFSET & RE-AUGERED TWO MORE TIMES & MET REFUSAL, LIKELY DUE TO COBBLES OR BOULDERS.
4. A 2 INCH DIAMETER 5 FOOT LONG PVC CASING WAS DRIVEN ABOUT 1.5 FEET BELOW THE EXISTING GROUND SURFACE TO PROTECT THE 1.25 INCH GALVANIZED RISER PIPE. THE 1.25 INCH GALVANIZED RISER PIPE HAD A STICK-UP OF ABOUT 2.5 FEET FROM THE EXISTING GROUND SURFACE.

soil and materials engineers, inc.

Observation Well

B6

OBSERVATION WELL LOG

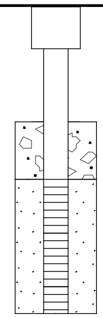
SME PROJECT No. PG60424

PROJECT NAME: ARGO DAM

PROJECT LOCATION: ANN ARBOR, MICHIGAN

BY: CGN **DATE:** 9/17/09

CLIENT: STANTEC MICHIGAN

ELEVATION (Ft.)	WELL DIAGRAM	DEPTH (Ft.)	PROFILE	PROFILE DESCRIPTION GROUND SURFACE ELEVATION IN FEET MSL= 763
765				
		0		**Silty Fine to Medium Sand- Trace to Some Clay- Trace Gravel, Roots & Organics- Black- Moist (SM/Topsoil)**
760				**Gravelly Fine to Coarse Sand- Some Silt- Trace Gravel & Roots- Occasional Cobbles or Boulders- Gray- Wet- Very Loose to Medium Dense (SM)**
				END OF BORING AT 3.5 FEET, OBSERVATION WELL INSTALLED TO A DEPTH OF 5 FEET.
		5		
755				
		10		
750				
		15		
745				
		20		
740				
		25		
735				
		30		
730				

WELL CONSTRUCTION DETAILS

Top of Casing
Elevation: 766.67

Well Screen Tip
Elevation: 758

Borehole Diameter: 3.25 inches

Filter Pack Type: 2NS Sand

Well Casing
Diameter: 2 inches
Length: 3 feet
Type: PVC

Joint Type:

Well Screen
Diameter: 2 inches
Length: 3.5 feet
Type: PVC
Mesh:
Screen Plug (Y/N): Y

Protective Casing
Total Length:
Length Above Ground: 3.5 feet
Diameter:
Type: Metal

Well Cap
Type: 3/4-inch Locking Well Cap

Northing:
Easting:

WELL TYPE: OBSERVATION
DRILLER: CGN
RIG NUMBER OR CONTRACTOR: HAND AUGER

DRILLING METHODS: HAND AUGER
GROUNDWATER DURING DRILLING ▼
GROUNDWATER AFTER DRILLING ▽

WATER LEVEL DATA

DATE	DEPTH (Feet)	ELEVATION (Feet)
9/30/09	4.42	758.58

Notes:

1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. OBSERVATION WELL INSTALLED IN BORING B6.
3. ENGINEER ENCOUNTERED REFUSAL DURING AUGERING LIKELY DUE TO COBBLES OR BOULDERS.

soil and materials engineers, inc.

Observation Well

B7

OBSERVATION WELL LOG

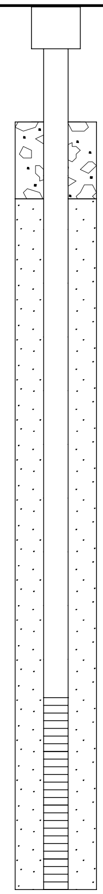
SME PROJECT No. PG60424

PROJECT NAME: ARGO DAM

PROJECT LOCATION: ANN ARBOR, MICHIGAN

BY: SB/CGN **DATE:** 9/17/09

CLIENT: STANTEC MICHIGAN

ELEVATION (Ft.)	WELL DIAGRAM	DEPTH (Ft.)	PROFILE	PROFILE DESCRIPTION GROUND SURFACE ELEVATION IN FEET MSL= 777	WELL CONSTRUCTION DETAILS
780					**Top of Casing** **Elevation:** 780.60
		0		**Fine to Medium Sand- Some Silt- Trace to Some Gravel- Trace Root Fibers- Dark Brown & Black- Moist- Loose (SP-SM/Topsoil)**	**Well Screen Tip** **Elevation:** 757
775					**Borehole Diameter:** 2.25 inches **Filter Pack Type:** Natural Sand
		5			
770				**Fine to Coarse Sand- Trace to Some Gravel & Silt- Occasional Gravel & Silty Sand Seams- Brown- Moist to Wet- Dense to Very Dense (SP-SM/Fill)**	**Well Casing** **Diameter:** 1 inch **Length:** 18 feet **Type:** PVC **Joint Type:**
		10			
765					**Well Screen** **Diameter:** 1 inch **Length:** 5 feet **Type:** PVC **Mesh:** **Screen Plug (Y/N):** Y
		15			
760				**Gravelly Fine to Coarse Sand- Trace to Some Silt- Brown & White- Wet (SP-SM)**	**Protective Casing** **Total Length:** **Length Above Ground:** 3.5 feet **Diameter:** **Type:** Metal
				Organic Silt- Trace Sand, Gravel, Roots & Shell Fragments- Dark Brown (OL)	
		20		**END OF BORING AT 20 FEET**	**Well Cap** **Type:** 3/4-inch Locking Well Cap
755					**Northing:** **Easting:**
		25			
750					
		30			
745					

WELL TYPE: OBSERVATION
DRILLER: CGN
RIG NUMBER OR CONTRACTOR: GEOPROBE

DRILLING METHODS: DIRECT PUSH
GROUNDWATER DURING DRILLING ▽
GROUNDWATER AFTER DRILLING ▽

WATER LEVEL DATA

DATE	DEPTH (Feet)	ELEVATION (Feet)
9/30/09	18.28	758.72

Notes:

1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. OBSERVATION WELL INSTALLED IN BORING B7.
3. GRADATION ON LS5 CONDUCTED ON A LAYER OF GRAVEL WITHIN THE SAND STRATA.

soil and materials engineers, inc.

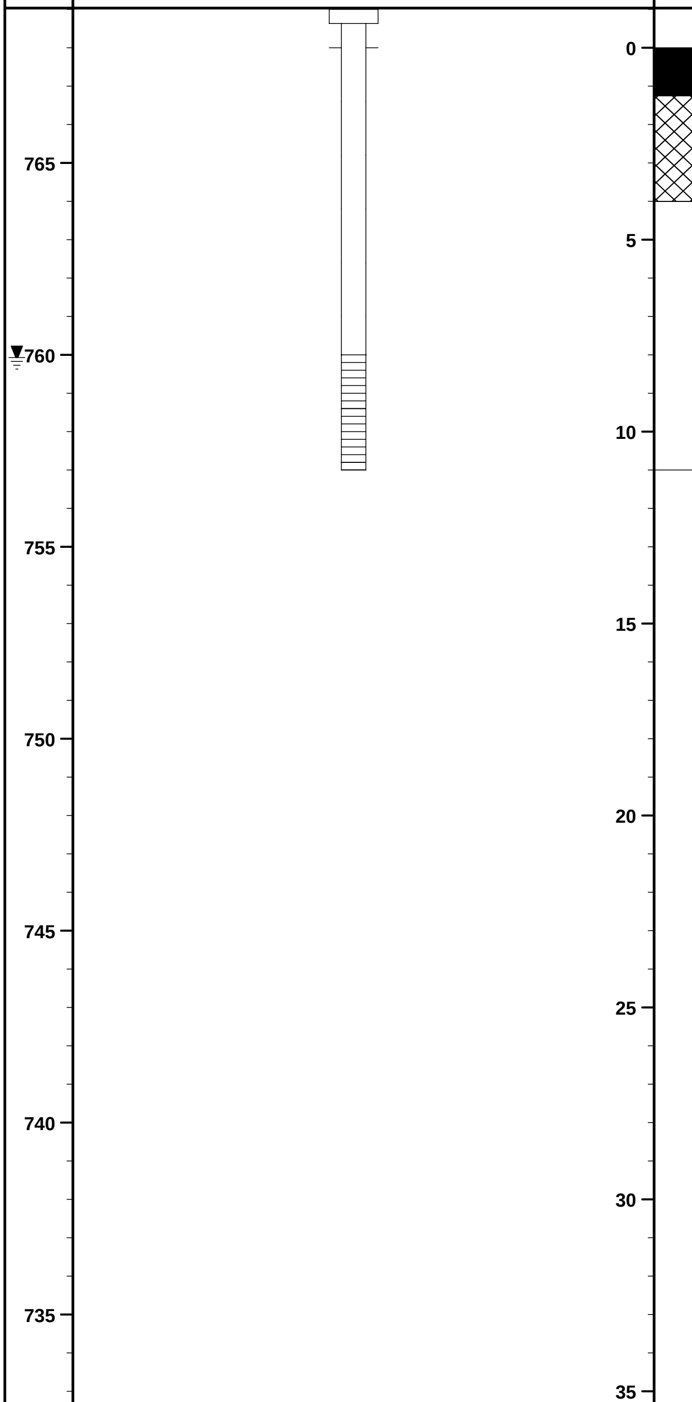
Observation Well
B8

OBSERVATION WELL LOG

SME PROJECT No. PG60424

PROJECT NAME: ARGO DAM
PROJECT LOCATION: ANN ARBOR, MICHIGAN **BY:** CGN **DATE:** 9/17/09
CLIENT: STANTEC MICHIGAN

ELEVATION (Ft.) | WELL DIAGRAM | DEPTH (Ft.) | PROFILE



PROFILE DESCRIPTION

GROUND SURFACE ELEVATION IN FEET MSL= 768

Fine to Medium Sand- Some Silt- Trace to Some Gravel- Trace Organics- Frequent Cobbles & Roots- Black- Moist- Loose to Medium Dense (SM/Topsoil/Fill)

Fine to Medium Sand- Trace to Some Silt- Trace Gravel- Frequent Cobbles or Boulders- Brown- Moist- Medium Dense to Dense (SP-SM/Fill)

END OF BORING AT 4 FEET, OBSERVATION WELL INSTALLED TO A DEPTH OF 11 FEET.

WELL CONSTRUCTION DETAILS

Top of Casing
Elevation: 770.0

Well Screen Tip
Elevation: 757

Borehole Diameter: Driven

Filter Pack Type: None

Well Casing
Diameter: 1.25 inches
Length: 9 feet
Type: Galvanized Steel

Joint Type:

Well Screen
Diameter: 1.25 inches
Length: 3 feet
Type: Stainless Steel
Mesh:
Screen Plug (Y/N): Y

Protective Casing
Total Length:
Length Above Ground: 3.5 feet
Diameter:
Type: Metal

Well Cap
Type: 3/4-inch Locking Well Cap

Northing:
Easting:

WELL TYPE: OBSERVATION
DRILLER: CGN
RIG NUMBER OR CONTRACTOR: HAND AUGER
DRILLING METHODS: HAND AUGER
GROUNDWATER DURING DRILLING ▼
GROUNDWATER AFTER DRILLING ▽

WATER LEVEL DATA

DATE	DEPTH (Feet)	ELEVATION (Feet)
9/30/09	8.07	759.93

Notes:

1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. OBSERVATION WELL INSTALLED NEAR BORING B8.
3. ENGINEER ENCOUNTERED REFUSAL DURING AUGERING, OFFSET & RE-AUGERED TWO MORE TIMES & MET REFUSAL, LIKELY DUE TO COBBLES OR BOULDERS.
4. A 2 INCH DIAMETER 5 FOOT LONG PVC CASING WAS DRIVEN ABOUT 1.5 FEET BELOW THE EXISTING GROUND SURFACE TO PROTECT THE 1.25 INCH GALVANIZED RISER PIPE. THE 1.25 INCH GALVANIZED RISER PIPE HAD A STICK-UP OF ABOUT 2.5 FEET FROM THE EXISTING GROUND SURFACE.

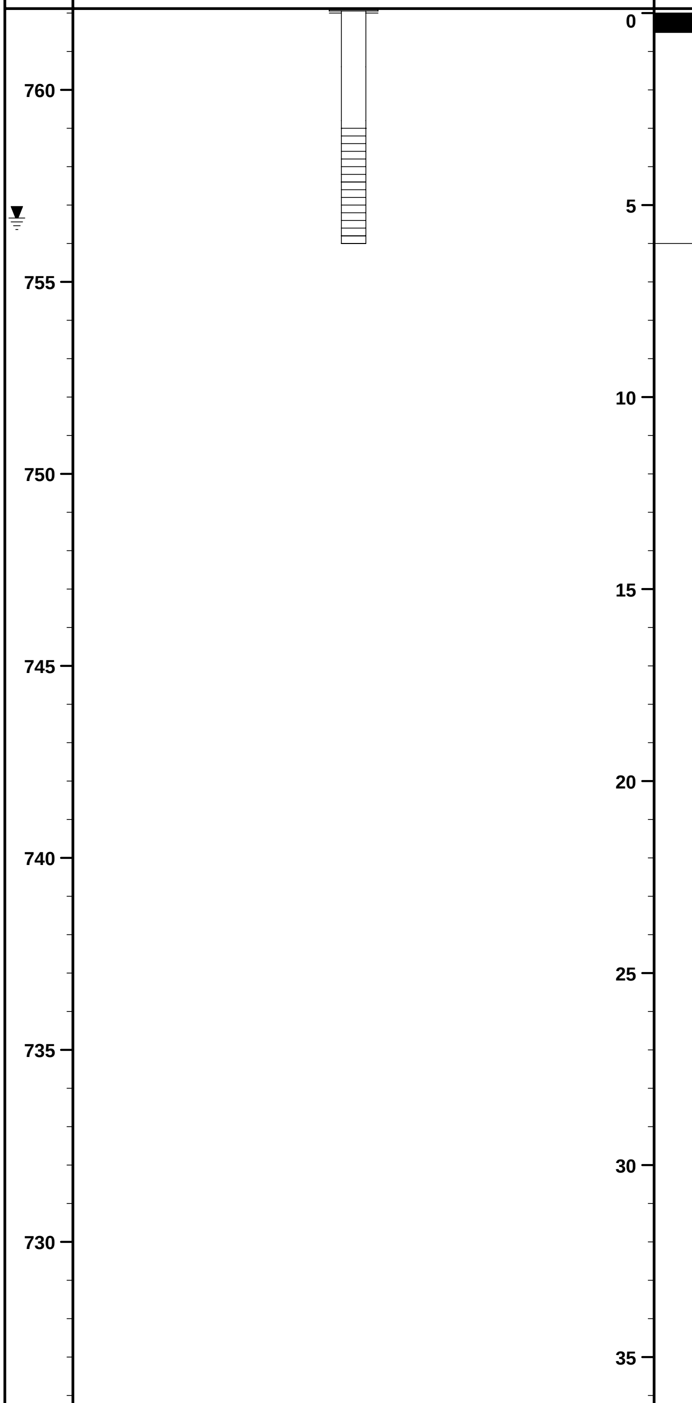
soil and materials engineers, inc.

Observation Well B9

OBSERVATION WELL LOG

SME PROJECT No. PG60424

PROJECT NAME: ARGO DAM
PROJECT LOCATION: ANN ARBOR, MICHIGAN **BY:** CGN **DATE:** 9/17/09
CLIENT: STANTEC MICHIGAN



PROFILE DESCRIPTION

GROUND SURFACE ELEVATION IN FEET MSL= 762

Engineer reported Sandy Topsoil- Black- Frequent Cobbles- Black- Moist (SM/Topsoil/Fill)

END OF BORING AT .5 FEET, OBSERVATION WELL INSTALLED TO A DEPTH OF 6 FEET.

WELL CONSTRUCTION DETAILS

Top of Casing
Elevation: 765.35

Well Screen Tip
Elevation: 756

Borehole Diameter: Driven

Filter Pack Type: None

Well Casing
Diameter: 1.25 inches
Length: 3 feet
Type: Galvanized Steel

Joint Type:

Well Screen
Diameter: 1.25 inches
Length: 3 feet
Type: Stainless Steel
Mesh:
Screen Plug (Y/N): Y

Protective Casing
Total Length:
Length Above Ground: 3.5 feet
Diameter:
Type: Metal

Well Cap
Type: 3/4-inch Locking Well Cap

Northing:
Easting:

WELL TYPE: OBSERVATION
DRILLER: CGN
RIG NUMBER OR CONTRACTOR: HAND AUGER

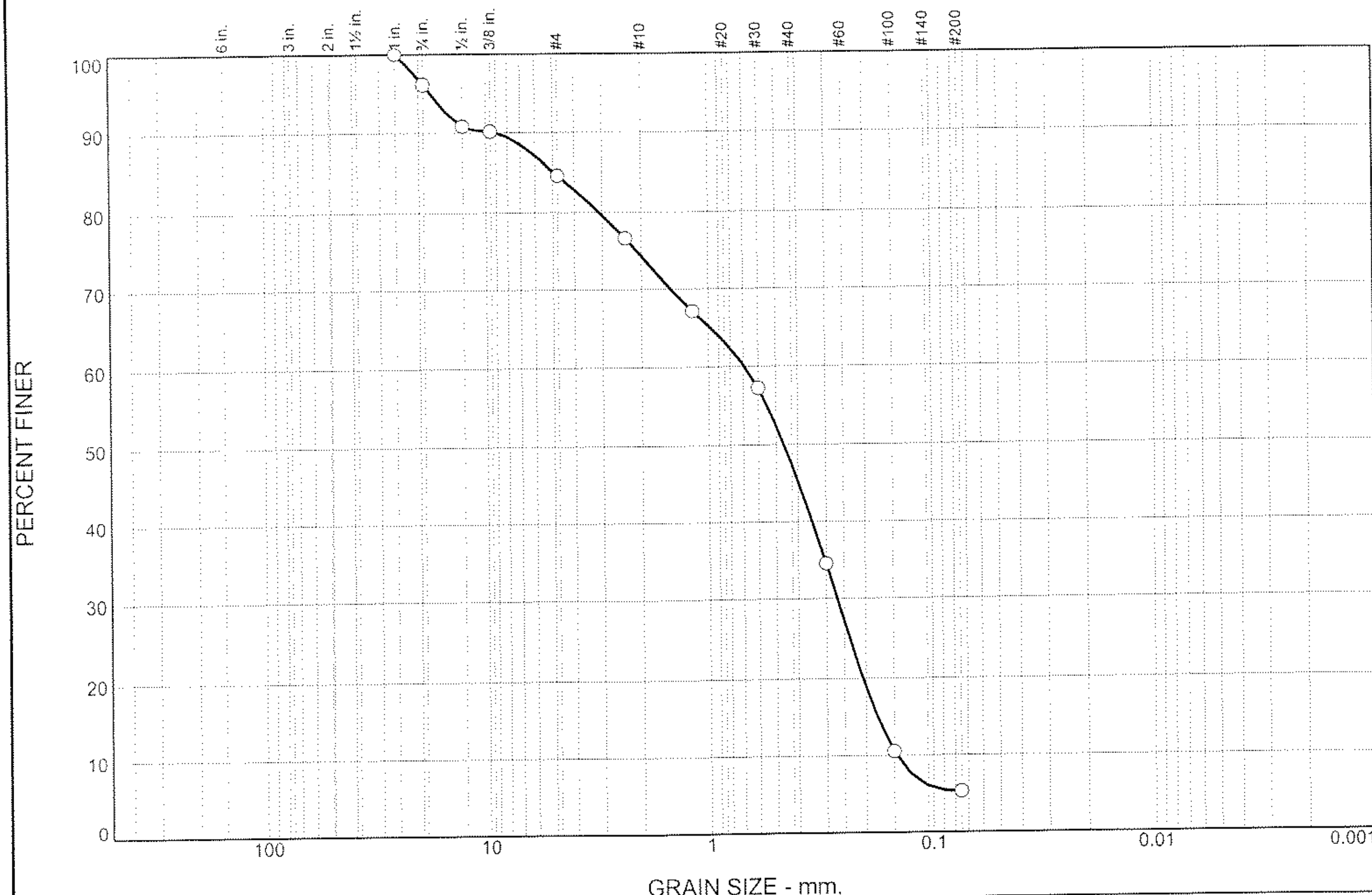
DRILLING METHODS: HAND AUGER
GROUNDWATER DURING DRILLING
GROUNDWATER AFTER DRILLING

WATER LEVEL DATA

DATE	DEPTH (Feet)	ELEVATION (Feet)
9/30/09	5.34	756.66

Notes:
1. THE INDICATED STRATIFICATION LINES ARE APPROXIMATE. IN SITU, THE TRANSITION BETWEEN MATERIALS MAY BE GRADUAL.
2. OBSERVATION WELL INSTALLED NEAR BORING B9.
3. ENGINEER ENCOUNTERED REFUSAL DURING AUGERING, OFFSET & RE-AUGERED SEVEN MORE TIMES & MET REFUSAL, LIKELY DUE TO COBBLES OR BOULDERS.
4. A 2 INCH DIAMETER 5 FOOT LONG PVC CASING WAS DRIVEN ABOUT 1.5 FEET BELOW THE EXISTING GROUND SURFACE TO PROTECT THE 1.25 INCH GALVANIZED RISER PIPE. THE 1.25 INCH GALVANIZED RISER PIPE HAD A STICK-UP OF ABOUT 0.08 FEET FROM THE EXISTING GROUND SURFACE.

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	3.8	11.5	10.3	27.0	42.1	5.3	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			4.8956	0.6901	0.4608	0.2683	0.1779	0.1462	0.71	4.72

Material Description	USCS	AASHTO
○ Fine to Coarse Sand, Some Gravel, Trace to Some Silt	SP-SM	

Project No. PG60424 **Client:** Stantec Michigan

Project: Argo Dam Toe Drain Evaluation

Ann Arbor, MI

○

Remarks:

○ Boring: B1

Sample: LS3

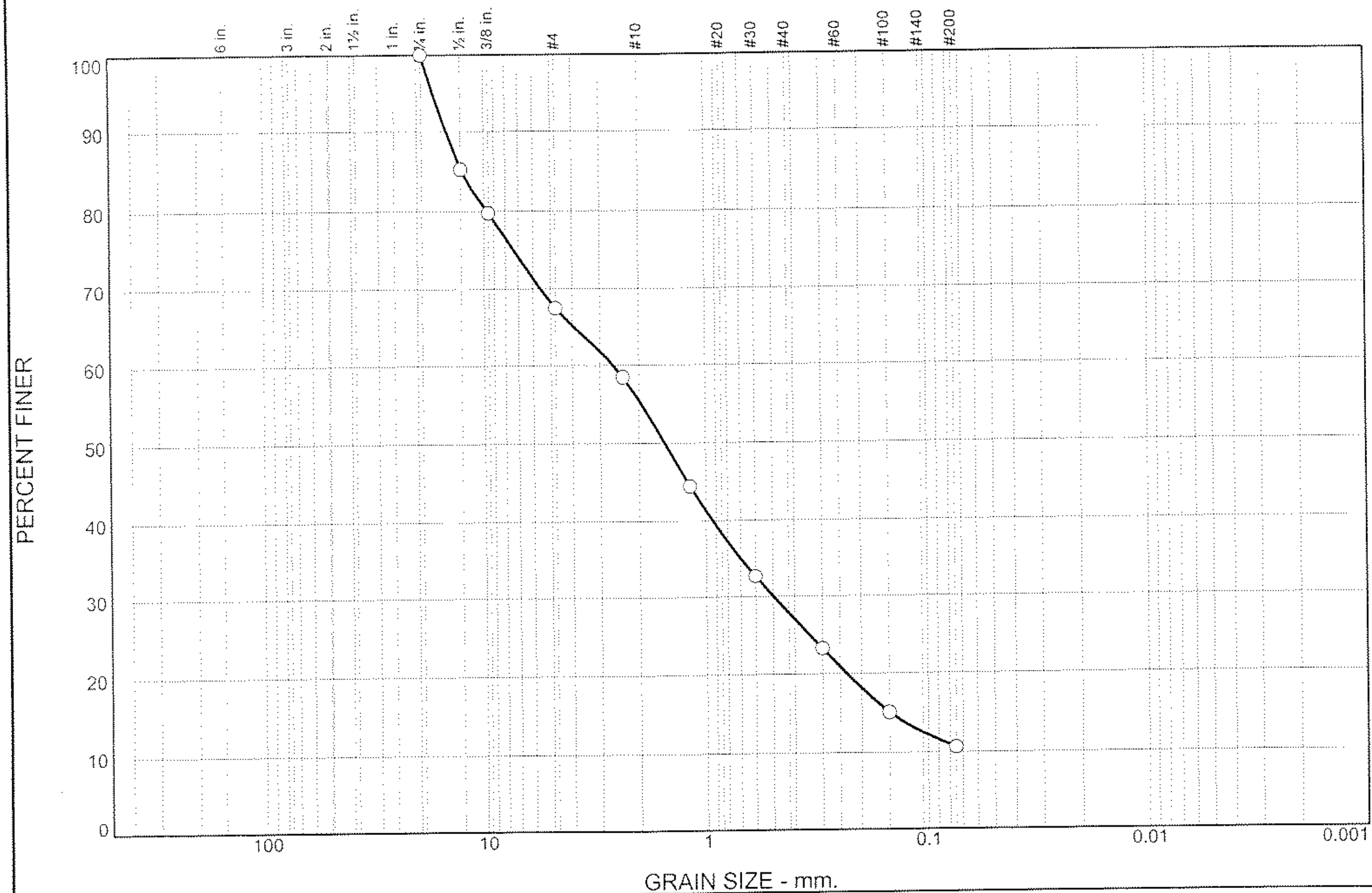
Soil and Materials Engineers, Inc.

Plymouth, MI

Figure 1

Tested By: Kanti Patel **Checked By:** Jason Cumbers

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	32.5	11.9	27.8	17.1	10.7	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			12.5578	2.6083	1.5304	0.4981	0.1476			

Material Description	USCS	AASHTO
○ Gravelly Fine to Coarse Sand, Trace to Some Silt	SP-SM	

Project No. PG60424 **Client:** Stantec Michigan
Project: Argo Dam Toe Drain Evaluation
Ann Arbor, MI
○

Remarks:
○ Botring: B1
Sample: LS5

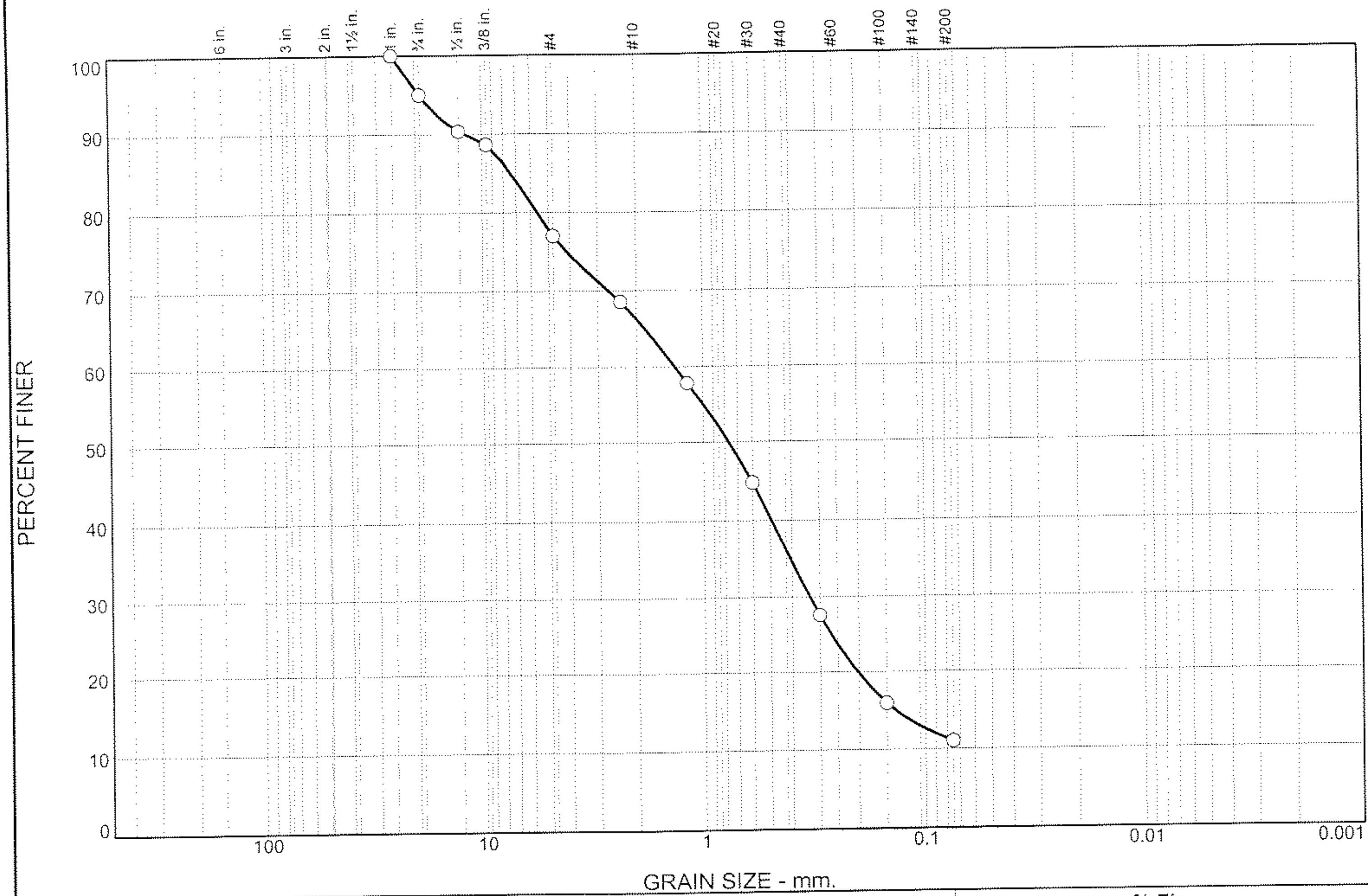
Soil and Materials Engineers, Inc.

Plymouth, MI

Figure 2

Tested By: Kanti Patel **Checked By:** Jason Cumbers

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	5.0	18.0	10.7	30.1	25.2	11.0	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			7.3256	1.3428	0.7681	0.3325	0.1379			

Material Description	USCS	AASHTO
○ Fine to Coarse Sand, Some Gravel, Trace to Some Silt	SP-SM	

Project No. PG60424 **Client:** Stantec Michigan

Project: Argo Dam Toe Drain Evaluation

Ann Arbor, MI

○

Remarks:

○ Boring: B4

Sample: LS3

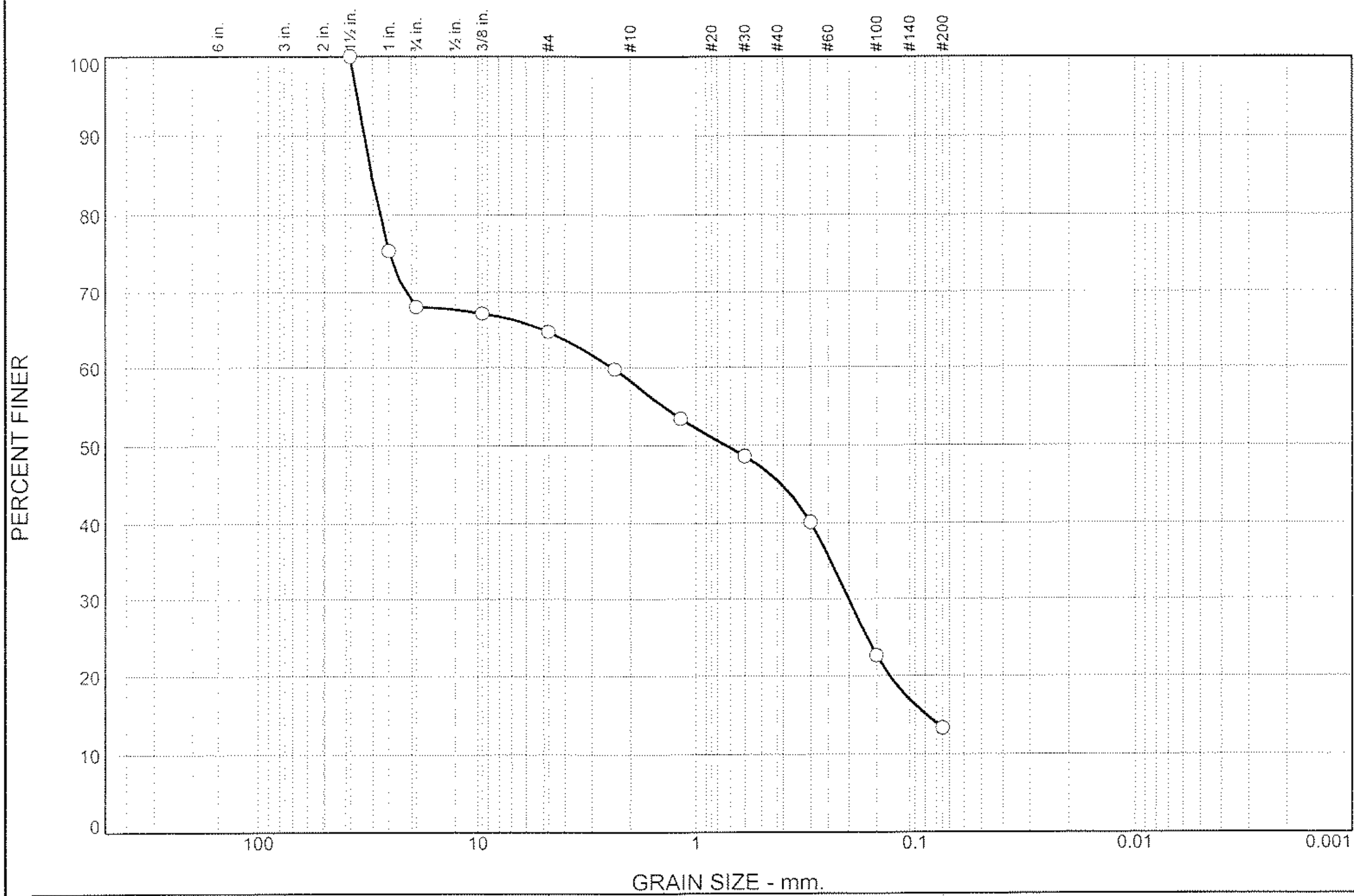
Soil and Materials Engineers, Inc.

Plymouth, MI

Figure 3

Tested By: Kanti Patel **Checked By:** Jason Cumbers

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	31.9	3.3	6.6	12.6	32.2	13.4	

╳	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			30.4683	2.4362	0.7300	0.2015	0.0890			

Material Description	USCS	AASHTO
○ Gravelly Fine to Coarse Sand, Some Silt	SM	

Project No. PG60424 **Client:** Stantec Michigan
Project: Argo Dam Toe Drain Evaluation
Ann Arbor, MI
○

Remarks:
○ Boring: B6
Samples: HA3 & HA4

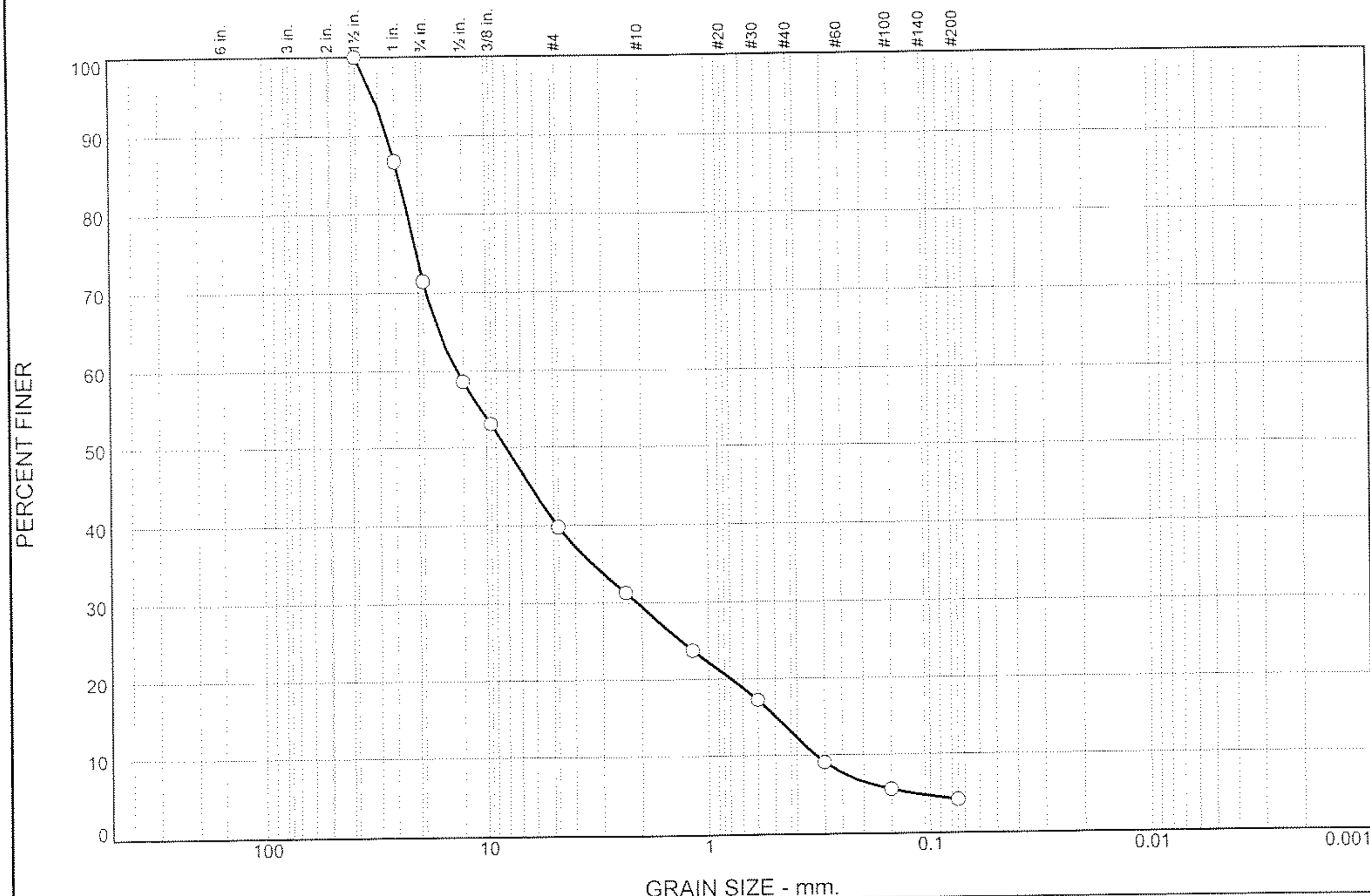
Soil and Materials Engineers, Inc.

Plymouth, MI

Figure 4

Tested By: Kanti Patel **Checked By:** Jason Cumbers

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	28.6	31.6	10.3	16.5	8.9	4.1	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			24.4731	13.5487	8.1467	2.0968	0.4993	0.3298	0.98	41.08

Material Description	USCS	AASHTO
○ Sandy Fine to Coarse Gravel, Trace Silt	GP	

Project No. PG60424 **Client:** Stantec Michigan
Project: Argo Dam Toe Drain Evaluation
Ann Arbor, MI
○

Remarks:
○ Boring: B7
Sample: LS5

Soil and Materials Engineers, Inc.

Plymouth, MI

Figure 5

Tested By: Kanti Patel **Checked By:** Jason Cumbers

APPENDIX C

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL ENGINEERING REPORT

GENERAL COMMENTS

LABORATORY TESTING PROCEDURES

Important Information About Your

Geotechnical Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

The following information is provided to help you manage your risks.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared *solely* for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply the report for any purpose or project except the one originally contemplated.

Read the Full Report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. *Do not rely on a geotechnical engineering report* whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. *Always* contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are *Not* Final

Do not overrely on the construction recommendations included in your report. *Those recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.*

A Geotechnical Engineering Report Is Subject to Misinterpretation

Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

Give Contractors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure contractors have sufficient time* to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations" many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform a *geoenvironmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. *Do not rely on an environmental report prepared for someone else.*

Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, a number of mold prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; ***none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.***

Rely, on Your ASFE-Member Geotechncial Engineer for Additional Assistance

Membership in ASFE/The Best People on Earth exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you ASFE-member geotechnical engineer for more information.

ASFE
The Best People on Earth

8811 Colesville Road/Suite G106, Silver Spring, MD 20910
Telephone: 301/565-2733 Facsimile: 301/589-2017
e-mail: info@asfe.org www.asfe.org

IIGER06045.0M

GENERAL COMMENTS

Basis of Geotechnical Report

This report has been prepared in accordance with generally accepted geotechnical engineering practices to assist in the design and/or evaluation of this project. If the project plans, design criteria, and other project information referenced in this report and utilized by SME to prepare our recommendations are changed, the conclusions and recommendations contained in this report are not considered valid unless the changes are reviewed, and the conclusions and recommendations of this report are modified or approved in writing by our office.

The discussions and recommendations submitted in this report are based on the available project information, described in this report, and the geotechnical data obtained from the field exploration at the locations indicated in the report. Variations in the soil and groundwater conditions commonly occur between or away from sampling locations. The nature and extent of the variations may not become evident until the time of construction. If significant variations are observed during construction, SME should be contacted to reevaluate the recommendations of this report. SME should be retained to continue our services through construction to observe and evaluate the actual subsurface conditions relative to the recommendations made in this report.

In the process of obtaining and testing samples and preparing this report, procedures are followed that represent reasonable and accepted practice in the field of soil and foundation engineering. Specifically, field logs are prepared during the field exploration that describe field occurrences, sampling locations, and other information. Samples obtained in the field are frequently subjected to additional testing and reclassification in the laboratory and differences may exist between the field logs and the report logs. The engineer preparing the report reviews the field logs, laboratory classifications, and test data and then prepares the report logs. Our recommendations are based on the contents of the report logs and the information contained therein.

Review of Design Details, Plans, and Specifications

SME should be retained to review the design details, project plans, and specifications to verify those documents are consistent with the recommendations contained in this report.

Review of Report Information With Project Team

Implementation of our recommendations may affect the design, construction, and performance of the proposed improvements, along with the potential inherent risks involved with the proposed construction. The client and key members of the design team, including SME, should discuss the issues covered in this report so that the issues are understood and applied in a manner consistent with the owner's budget, tolerance of risk, and expectations for performance and maintenance.

Field Verification of Geotechnical Conditions

SME should be retained to verify the recommendations of this report are properly implemented during construction. This may avoid misinterpretation of our recommendations by other parties and will allow us to review and modify our recommendations if variations in the site subsurface conditions are encountered.

Project Information for Contractor

This report and any future addenda or other reports regarding this site should be made available to prospective contractors prior to submitting their proposals for their information only and to supply them with facts relative to the subsurface evaluation and laboratory test results. If the selected contractor encounters subsurface conditions during construction, which differ from those presented in this report, the contractor should promptly describe the nature and extent of the differing conditions in writing and SME should be notified so that we can verify those conditions. The construction contract should include provisions for dealing with differing conditions and contingency funds should be reserved for potential problems during earthwork and foundation construction. We would be pleased to assist you in developing the contract provisions based on our experience.

The contractor should be prepared to handle environmental conditions encountered at this site, which may affect the excavation, removal, or disposal of soil; dewatering of excavations; and health and safety of workers. Any Environmental Assessment reports prepared for this site should be made available for review by bidders and the successful contractor.

Third Party Reliance/Reuse of This Report

This report has been prepared solely for the use of our Client for the project specifically described in this report. This report cannot be relied upon by other parties not involved in the project, unless specifically allowed by SME in writing. SME also is not responsible for the interpretation by other parties of the geotechnical data and the recommendations provided herein.

LABORATORY TESTING PROCEDURES

Visual Engineering Classification

Visual classification was performed on recovered samples. The appended General Notes and Unified Soil Classification System (USCS) sheets include a brief summary of the general method used visually classify the soil and assign an appropriate USCS group symbol. The estimated group symbol, according to the USCS, is shown in parentheses following the textural description of the various strata on the boring logs appended to this report. The soil descriptions developed from visual classifications are sometimes modified to reflect the results of laboratory testing.

Moisture Content

Moisture content tests were performed by weighing samples from the field at their in-situ moisture condition. These samples were then dried at a constant temperature (approximately 110° C) overnight in an oven. After drying, the samples were weighed to determine the dry weight of the sample and the weight of the water that was expelled during drying. The moisture content of the specimen is expressed as a percent and is the weight of the water compared to the dry weight of the specimen.

Hand Penetrometer Tests

In the hand penetrometer test, the unconfined compressive strength of a cohesive soil sample is estimated by measuring the resistance of the sample to the penetration of a small calibrated, spring-loaded cylinder. The maximum capacity of the penetrometer is 4.5 tons per square-foot (tsf). Theoretically, the undrained shear strength of the cohesive sample is one-half the unconfined compressive strength. The undrained shear strength (based on the hand penetrometer test) presented on the boring logs is reported in units of kips per square-foot (ksf).

Torvane Shear Tests

In the Torvane test, the shear strength of a low strength, cohesive soil sample is estimated by measuring the resistance of the sample to a torque applied through vanes inserted into the sample. The undrained shear strength of the samples is measured from the maximum torque required to shear the sample and is reported in units of kips per square-foot (ksf).

Loss-on-Ignition (Organic Content) Tests

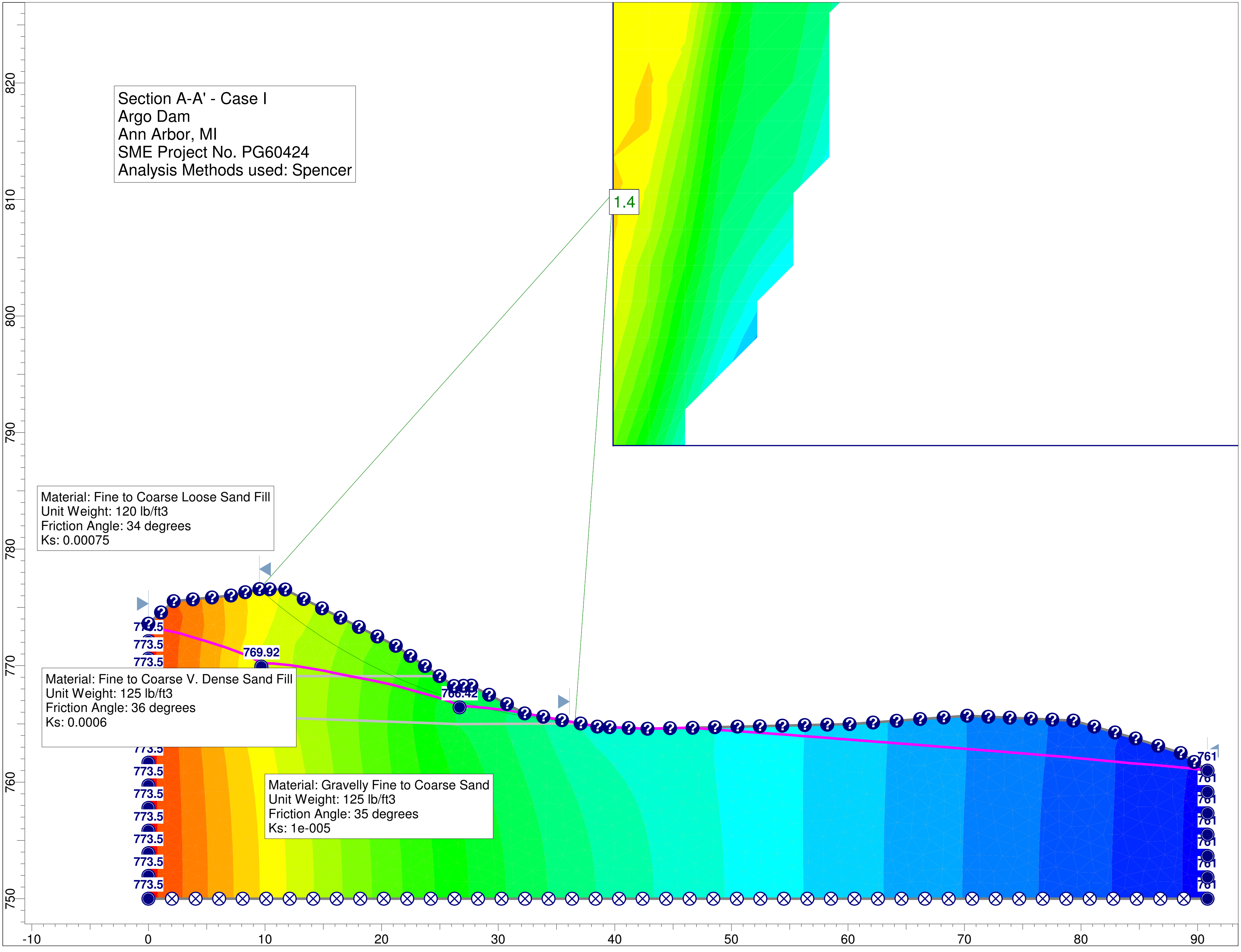
Loss-on-ignition (LOI) tests are conducted by first weighing the sample and then heating the sample to dry the moisture from the sample (in the same manner as determining the moisture content of the soil). The sample is then re-weighed to determine the dry weight and then heated for 4 hours in a muffle furnace at a high temperature (approximately 440° C). After cooling, the sample is re-weighed to calculate the amount of ash remaining, which in turn is used to determine the amount of organic matter burned from the original dry sample. The organic matter content of the specimen is expressed as a percent compared to the dry weight of the sample.

Atterberg Limits Tests

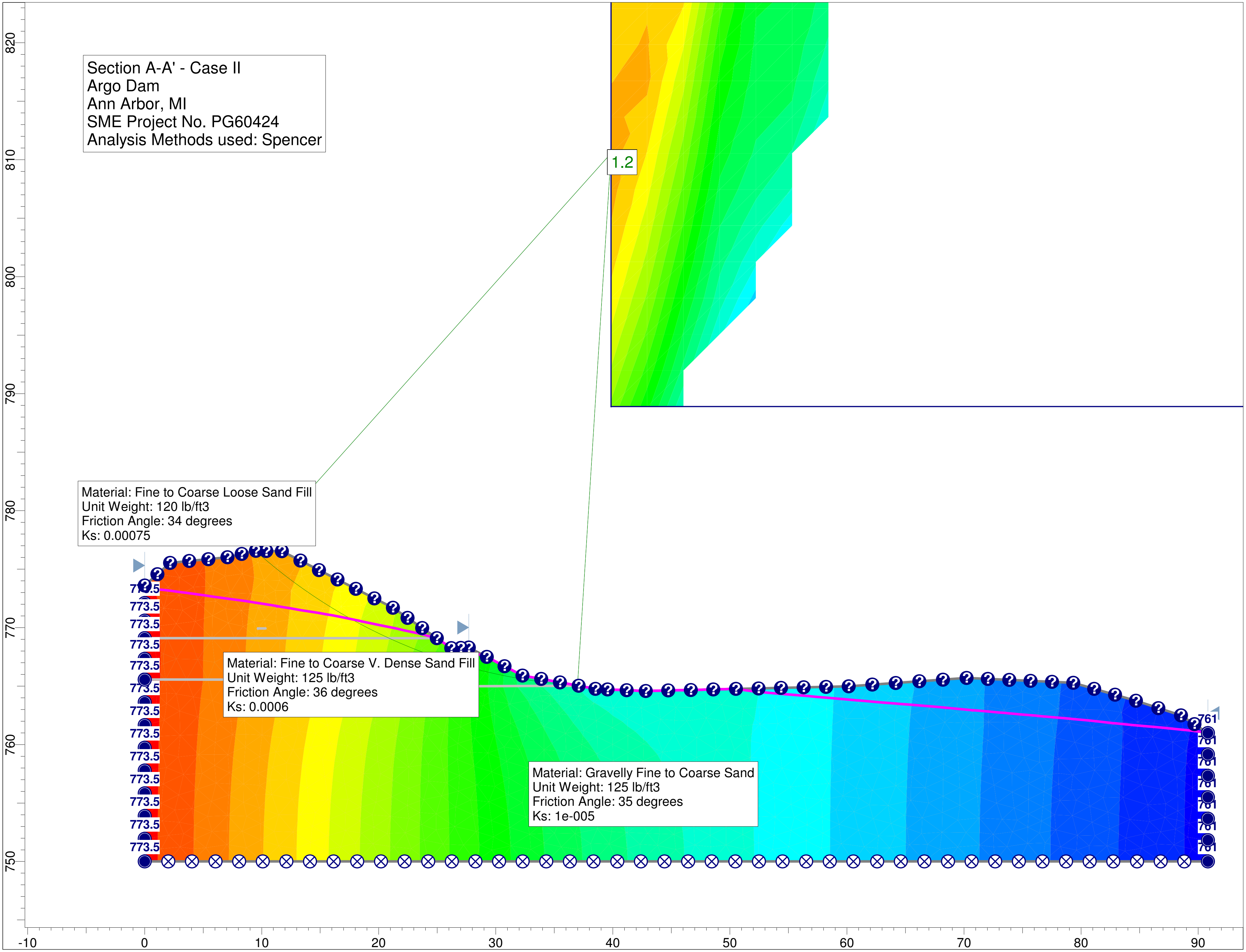
Atterberg limits tests consist of two components. The plastic limit of a cohesive sample is determined by rolling the sample into a thread and the plastic limit is the moisture content where a 1/8-inch thread begins to crumble. The liquid limit is determined by placing a ½-inch thick soil pat into the liquid limits cup and using a grooving tool to divide the soil pat in half. The cup is then tapped on the base of the liquid limits device using a crank handle. The number of drops of the cup to close the gap formed by the grooving tool ½ inch is recorded along with the corresponding moisture content of the sample. This procedure is repeated several times at different moisture contents and a graph of moisture content and the corresponding number of blows is plotted. The liquid limit is the moisture content at a nominal 25 drops of the cup. From this test, the plasticity index can be determined by subtracting the plastic limit from the liquid limit.

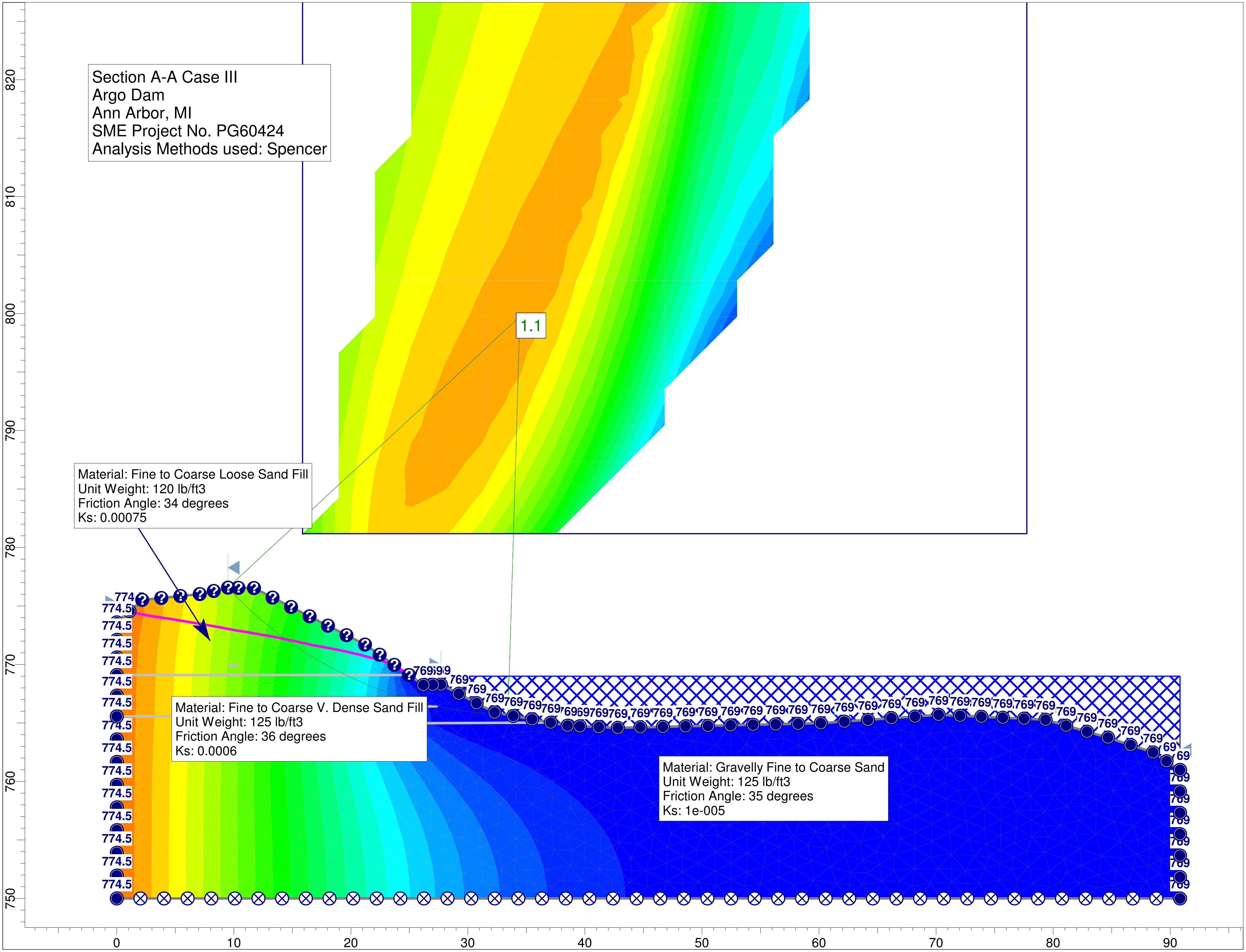
APPENDIX D

SEEPAGE AND SLOPE STABILITY RESULTS AND INPUT

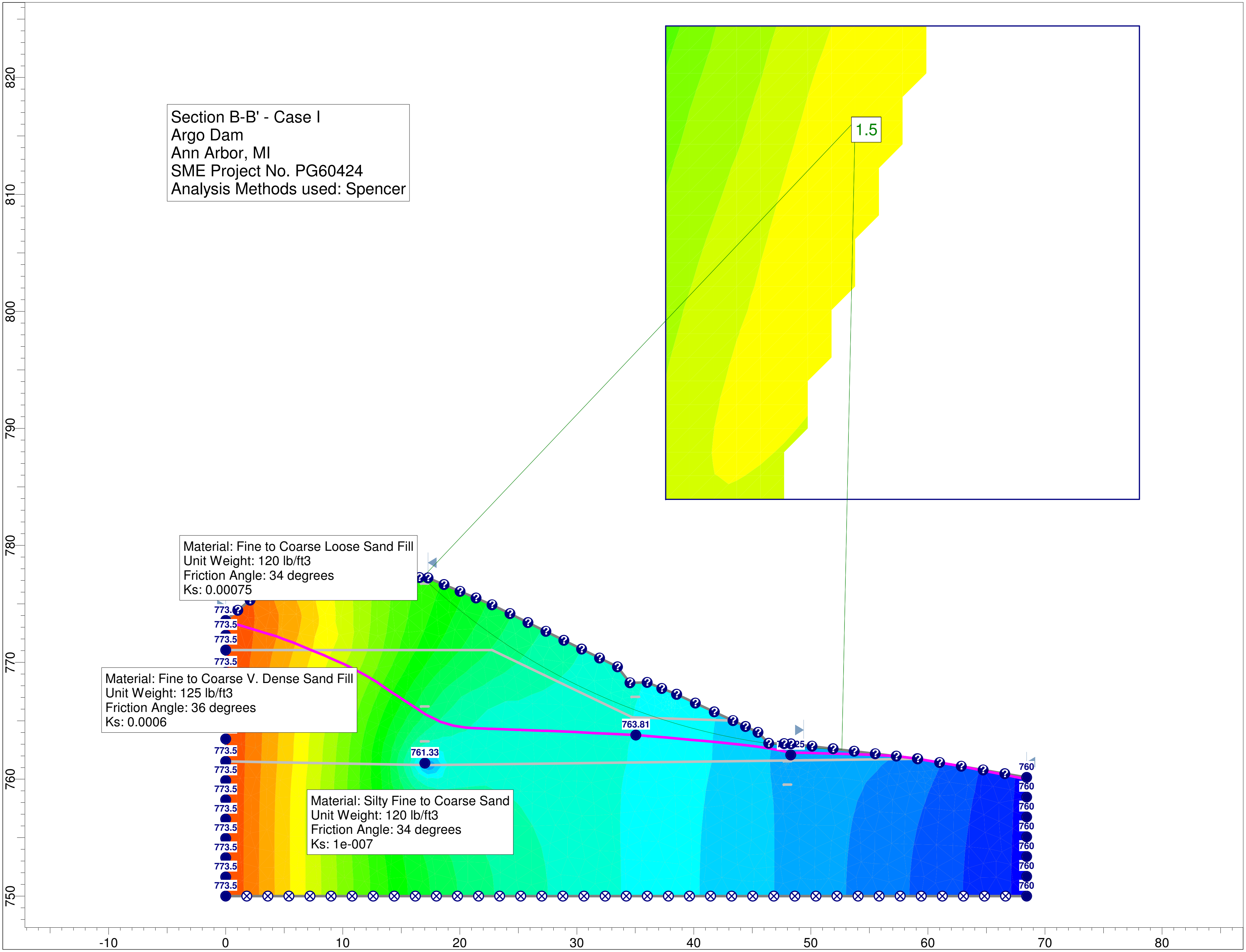


Section A-A' - Case I
Argo Dam
Ann Arbor, MI
SME Project No. PG60424
Analysis Methods used: Spencer
1.4
Material: Fine to Coarse Loose Sand Fill
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 0.00075
Material: Fine to Coarse V. Dense Sand Fill
Unit Weight: 125 lb/ft3
Friction Angle: 36 degrees
Ks: 0.0006
Material: Gravelly Fine to Coarse Sand
Unit Weight: 125 lb/ft3
Friction Angle: 35 degrees
Ks: 1e-005
769.92
766.42
773.5
761
820
810
800
790
780
770
760
750
-10
0
10
20
30
40
50
60
70
80
90

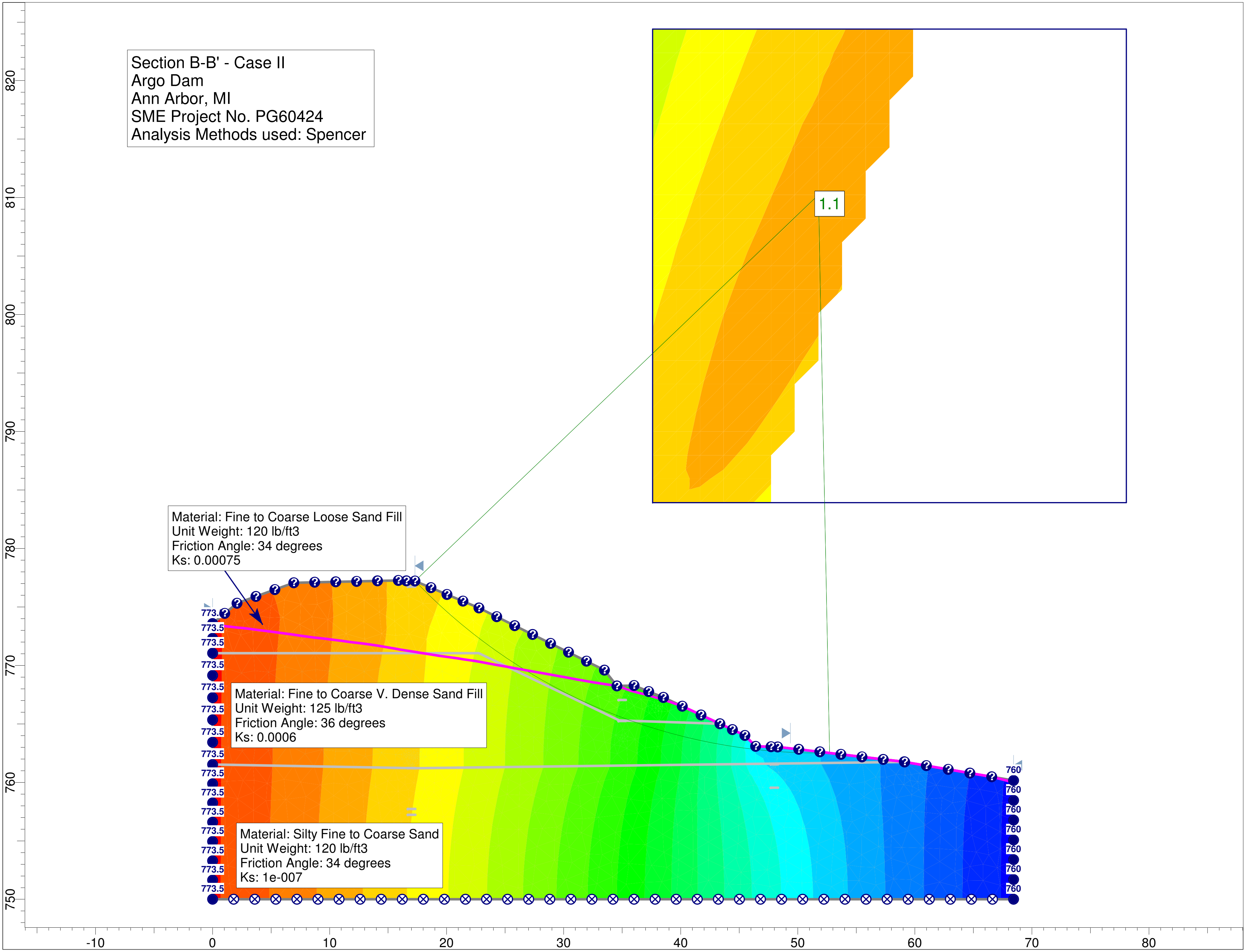

Section A-A' - Case II
Argo Dam
Ann Arbor, MI
SME Project No. PG60424
Analysis Methods used: Spencer
1.2
Material: Fine to Coarse Loose Sand Fill
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 0.00075
Material: Fine to Coarse V. Dense Sand Fill
Unit Weight: 125 lb/ft3
Friction Angle: 36 degrees
Ks: 0.0006
Material: Gravelly Fine to Coarse Sand
Unit Weight: 125 lb/ft3
Friction Angle: 35 degrees
Ks: 1e-005
773.5
761
820
810
800
790
780
770
760
750
-10
0
10
20
30
40
50
60
70
80
90



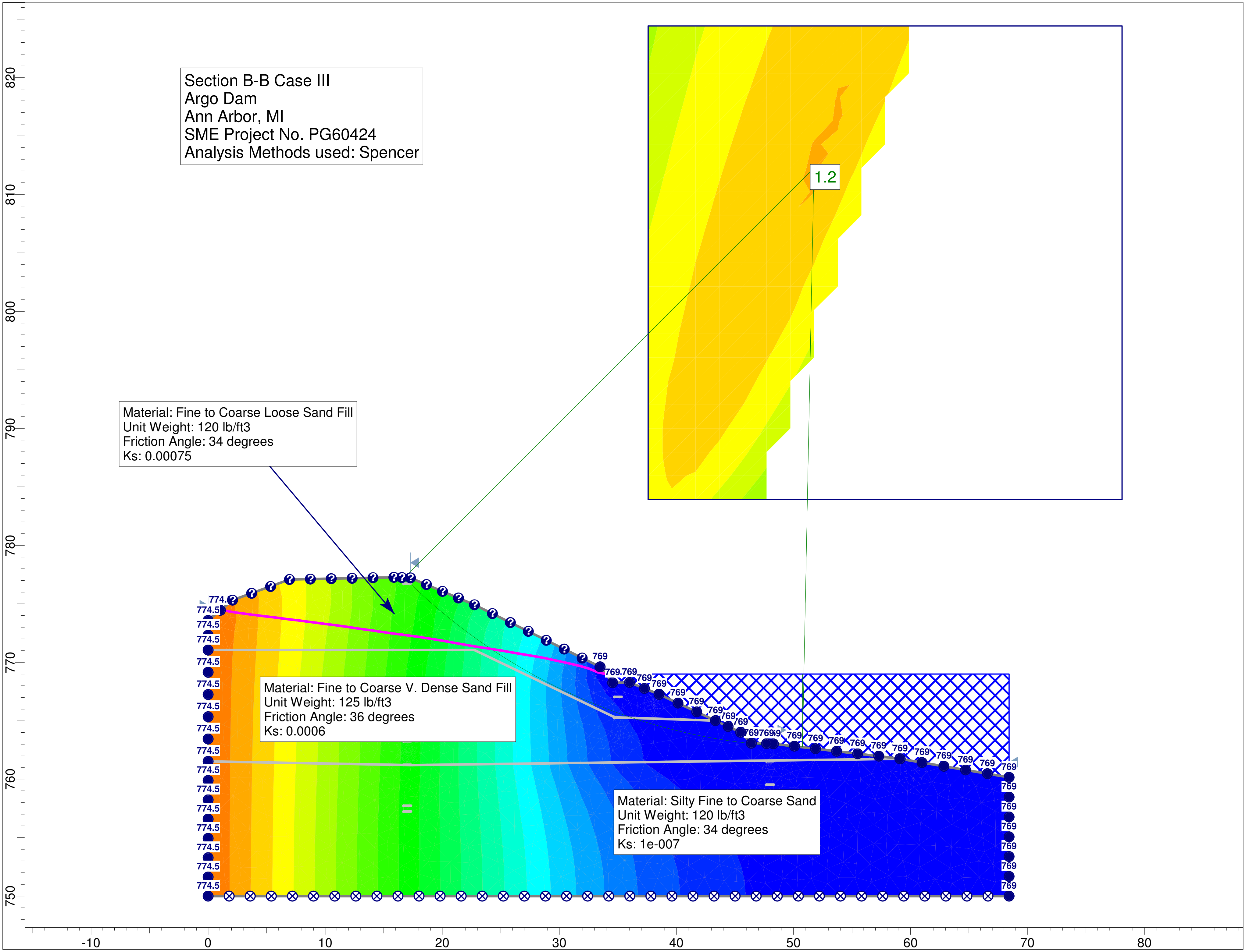
Section A-A Case III
Argo Dam
Ann Arbor, MI
SME Project No. PG60424
Analysis Methods used: Spencer
1.1
Material: Fine to Coarse Loose Sand Fill
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 0.00075
Material: Fine to Coarse V. Dense Sand Fill
Unit Weight: 125 lb/ft3
Friction Angle: 36 degrees
Ks: 0.0006
Material: Gravelly Fine to Coarse Sand
Unit Weight: 125 lb/ft3
Friction Angle: 35 degrees
Ks: 1e-005



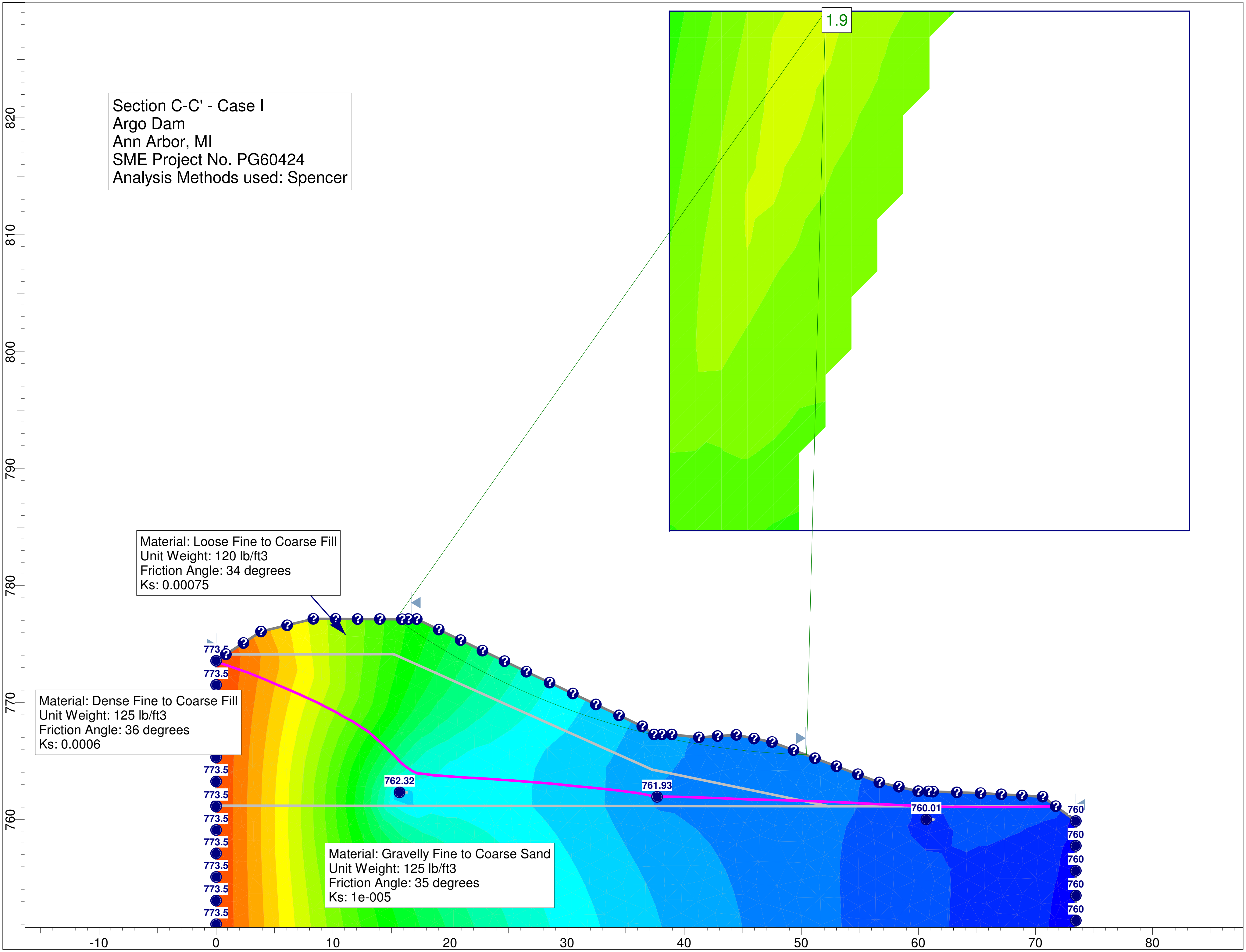
Section B-B' - Case I
Argo Dam
Ann Arbor, MI
SME Project No. PG60424
Analysis Methods used: Spencer
1.5
Material: Fine to Coarse Loose Sand Fill
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 0.00075
Material: Fine to Coarse V. Dense Sand Fill
Unit Weight: 125 lb/ft3
Friction Angle: 36 degrees
Ks: 0.0006
Material: Silty Fine to Coarse Sand
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 1e-007
763.81
761.33
773.5
760



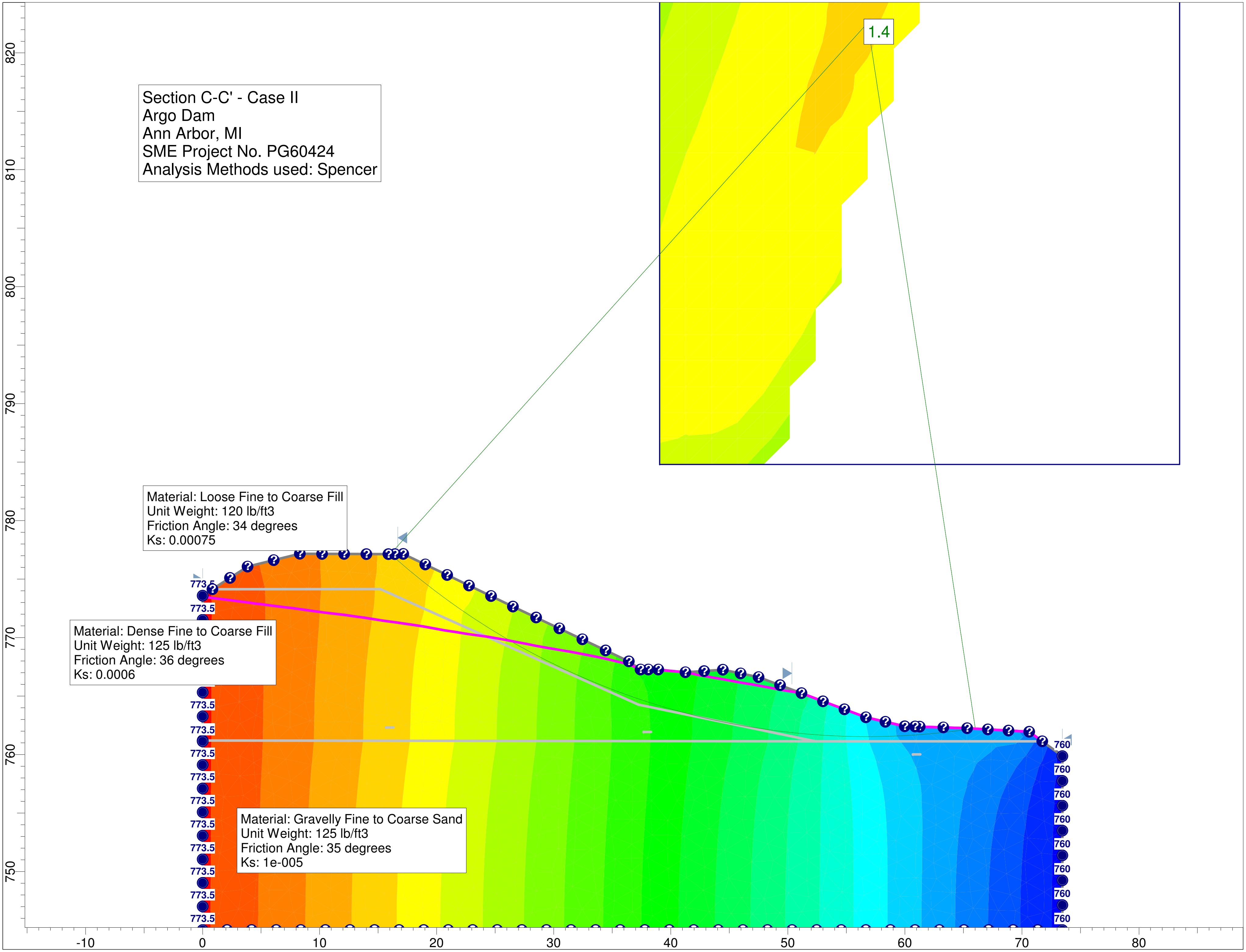
Section B-B' - Case II
Argo Dam
Ann Arbor, MI
SME Project No. PG60424
Analysis Methods used: Spencer
1.1
Material: Fine to Coarse Loose Sand Fill
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 0.00075
Material: Fine to Coarse V. Dense Sand Fill
Unit Weight: 125 lb/ft3
Friction Angle: 36 degrees
Ks: 0.0006
Material: Silty Fine to Coarse Sand
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 1e-007
773.5
760
820
810
800
790
780
770
760
750
-10
0
10
20
30
40
50
60
70
80



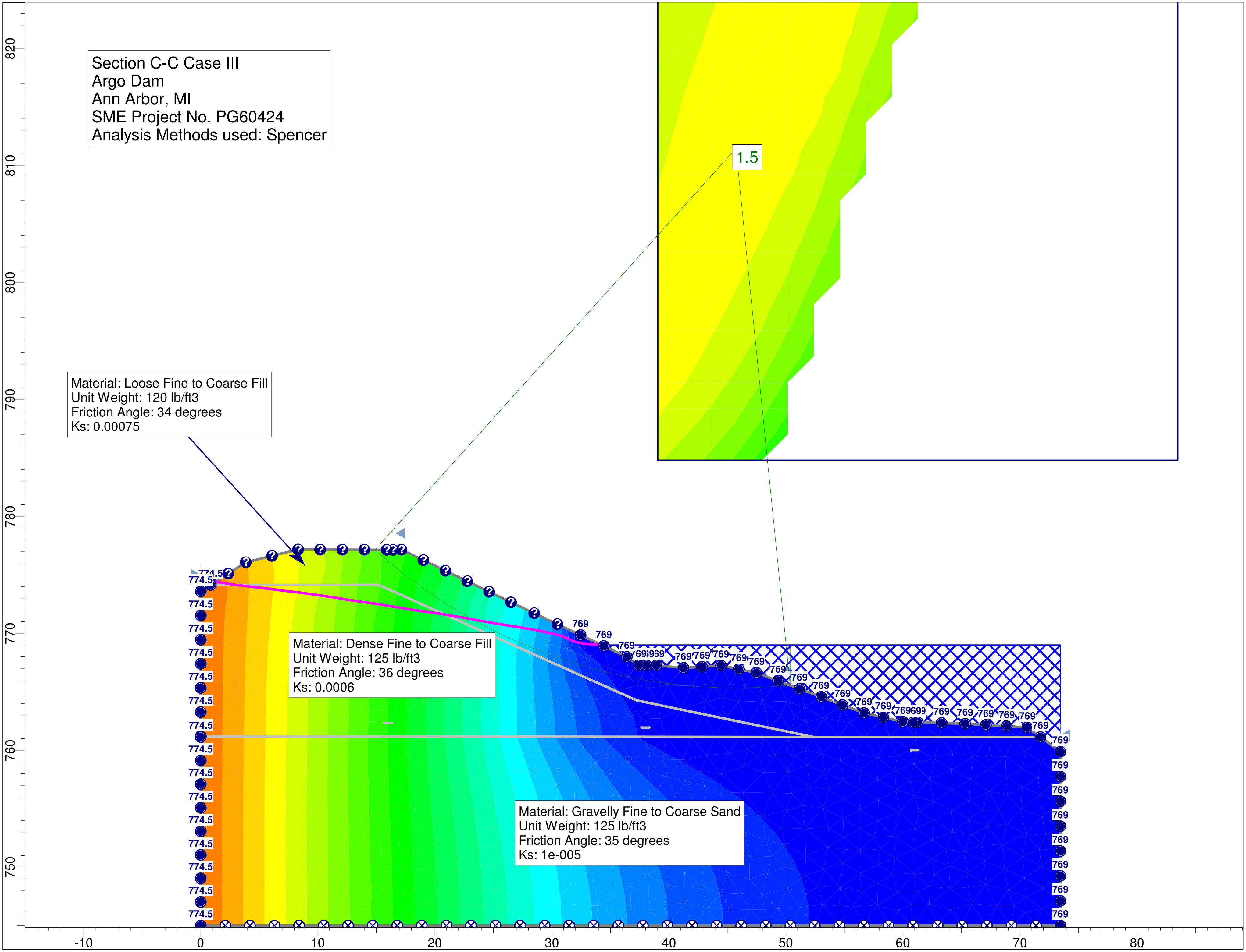
Section B-B Case III
Argo Dam
Ann Arbor, MI
SME Project No. PG60424
Analysis Methods used: Spencer
1.2
Material: Fine to Coarse Loose Sand Fill
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 0.00075
Material: Fine to Coarse V. Dense Sand Fill
Unit Weight: 125 lb/ft3
Friction Angle: 36 degrees
Ks: 0.0006
Material: Silty Fine to Coarse Sand
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 1e-007
774.5
769
750
760
770
780
790
800
810
820
-10
0
10
20
30
40
50
60
70
80



Section C-C' - Case I
Argo Dam
Ann Arbor, MI
SME Project No. PG60424
Analysis Methods used: Spencer
1.9
Material: Loose Fine to Coarse Fill
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 0.00075
Material: Dense Fine to Coarse Fill
Unit Weight: 125 lb/ft3
Friction Angle: 36 degrees
Ks: 0.0006
Material: Gravelly Fine to Coarse Sand
Unit Weight: 125 lb/ft3
Friction Angle: 35 degrees
Ks: 1e-005
762.32
761.93
760.01
773.5
760
820
810
800
790
780
770
760
-10
0
10
20
30
40
50
60
70
80



Section C-C' - Case II
Argo Dam
Ann Arbor, MI
SME Project No. PG60424
Analysis Methods used: Spencer
1.4
Material: Loose Fine to Coarse Fill
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 0.00075
Material: Dense Fine to Coarse Fill
Unit Weight: 125 lb/ft3
Friction Angle: 36 degrees
Ks: 0.0006
Material: Gravelly Fine to Coarse Sand
Unit Weight: 125 lb/ft3
Friction Angle: 35 degrees
Ks: 1e-005
773.5
760
820
810
800
790
780
770
760
750
-10
0
10
20
30
40
50
60
70
80



Section C-C Case III
Argo Dam
Ann Arbor, MI
SME Project No. PG60424
Analysis Methods used: Spencer
1.5
Material: Loose Fine to Coarse Fill
Unit Weight: 120 lb/ft3
Friction Angle: 34 degrees
Ks: 0.00075
Material: Dense Fine to Coarse Fill
Unit Weight: 125 lb/ft3
Friction Angle: 36 degrees
Ks: 0.0006
Material: Gravelly Fine to Coarse Sand
Unit Weight: 125 lb/ft3
Friction Angle: 35 degrees
Ks: 1e-005
774.5
769