APPENDIX A

ENGINEERING APPENDIX FOR FEASIBILITY REPORT

for

LITTLE MANISTEE SEA LAMPREY TRAP AND SSP BARRIER

MANISTEE COUNTY, MICHIGAN

Prepared by the

U.S. ARMY CORPS OF ENGINEERS
DETROIT DISTRICT

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1. General Information

1.1 Introduction: The purpose of this report is to present alternatives for construction of a new sea lamprey barrier and trap structure at the existing USFWS Little Manistee River Spawning Station in Manistee County, MI. This report will be an appendix to the Feasibility Report being prepared by Planning Division.

1.2 Background: The Little Manistee River was selected by the United States Fish and Wildlife Service (USFWS) for construction of a new Sea Lamprey SSP Barrier and Trap. The purpose of the barrier and trap is to prevent the upstream migration of sea lamprey during spawning season. Currently, there is an existing fish weir at the site that provides lamprey passage prevention through the use of stoplogs. In addition, the river is treated with lampricides. Although testing indicates the lampricides are not detrimental to the ecosystem as a whole, there are some native species which are adversely affected by the chemical treatment. A permanent lamprey barrier and trap would significantly reduce, and possibly eliminate, the need for the costly lampricide treatment. In addition, a permanent trap structure has been proven to be more efficient and effective than temporary trapping methods.

1.3 Location: The proposed trap location is at the site of the current USFWS Little Manistee River Spawning Station in Manistee County, MI (See Figure 1). The barrier is currently owned and maintained by the USFWS.

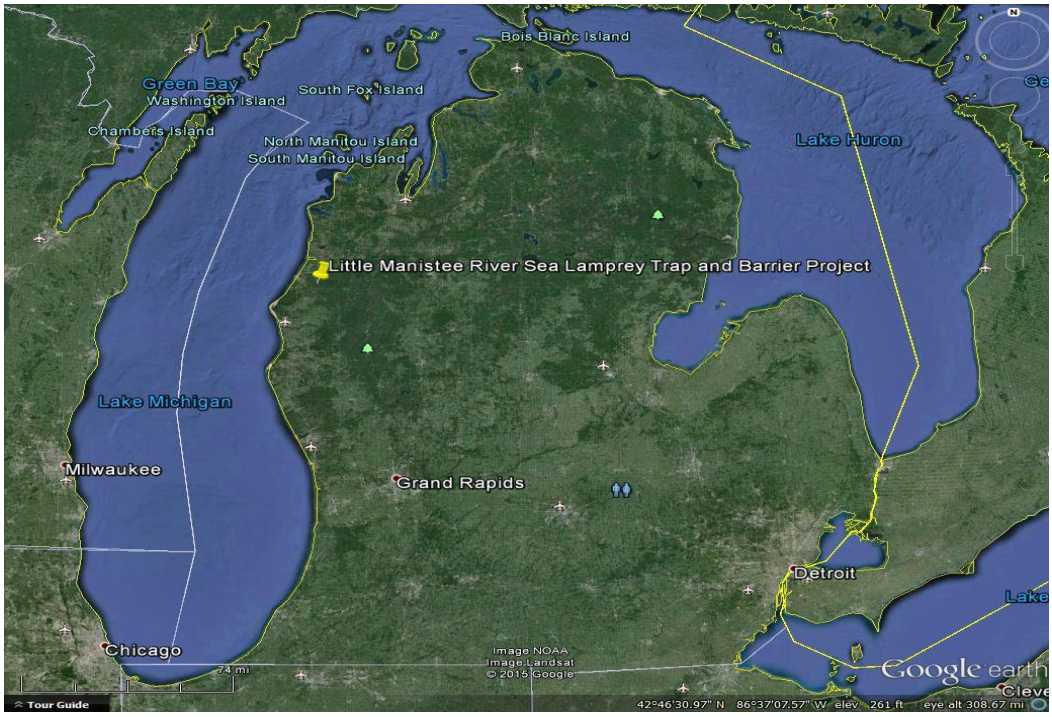


Figure 1: Location Map

1.4 Existing Site Conditions: As-Built survey data of the Little Manistee Little Manistee River Spawning Station was provided to USACE by the USFWS. In addition, a

survey was conducted in summer 2014 at the proposed project site. Both the as-built drawings and the summer 2014 survey will act as the base for project design.

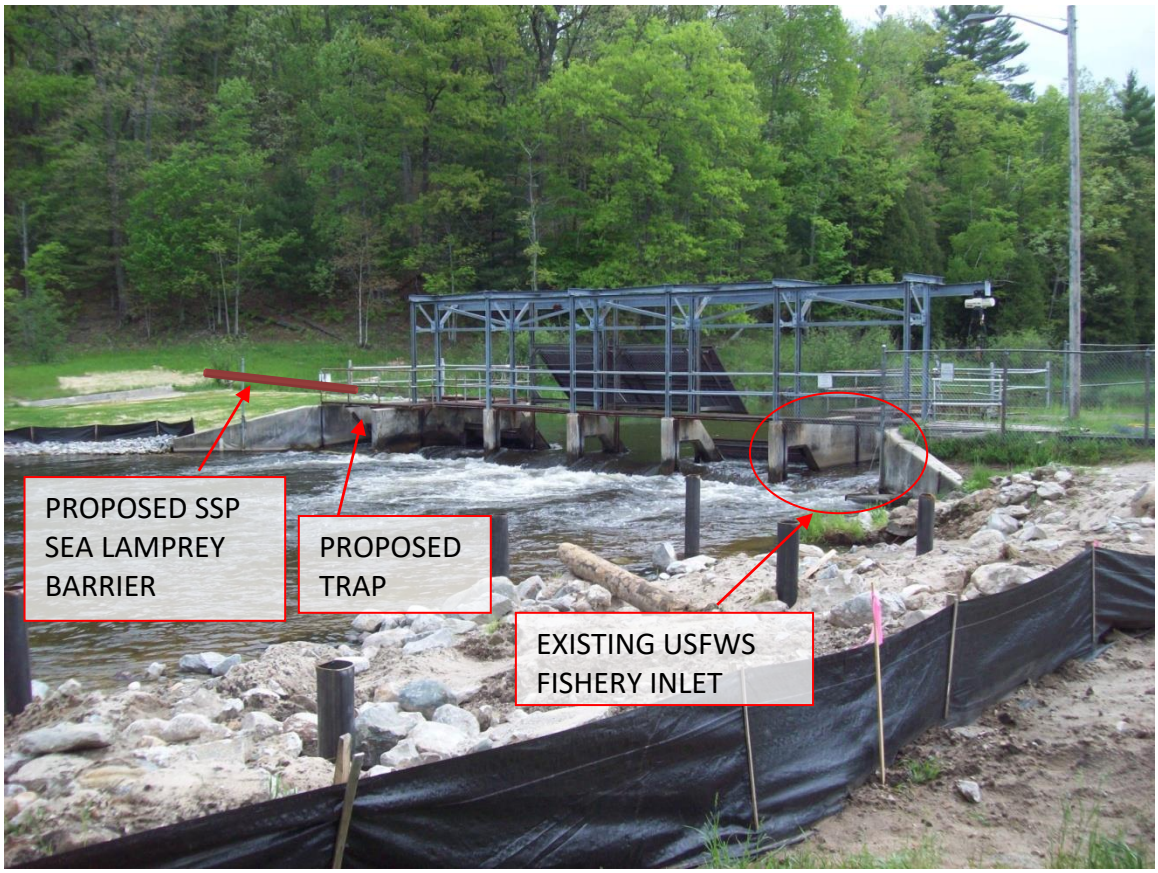


Figure 2: Existing Conditions

2. General Requirements

2.1 Lamprey Traps: Per USFWS one lamprey trap is required for Alternatives 2 and 3. The trap will be approximately 4-feet square and 5 feet tall. The trap is constructed with aluminum mesh, plates and angles. All requirements pertaining to the lamprey trap were provided by USFWS. A typical photo of an existing lamprey trap has been provided in Figure 3. Detailed design of the trap will be completed during the next phase of the project. For the purpose of estimating costs, the detailed design of a similar trap developed for the Au Sable River Sea Lamprey Trap facility will be used. The trap will be located within one bay of the existing USFWS Little Manistee River Spawning Station Fish Weir.

Figure 3: Lamprey Trap

2.2 Lift System: A lift system is required to raise the trap insert from their installed location. Per the USFWS each trap insert will hold up to 500 pounds of lamprey. In addition, USFWS has indicated that the use of a manual, mechanical hoist is preferred. The lift system for the alternative will consist of a jib crane secured to a pile support. The required rating capacity of the crane will be 1000 lbs to account for the potential for additional loading.

2.3 Lamprey Barrier: To prevent lamprey passage at the location of the dam, the existing weir and required spillway extension needs to act as a sea lamprey barrier. Per USFWS, in order to prevent lamprey passage, a minimum of 18" vertical, hydraulic drop is required. Various combinations of hydraulic events were evaluated to establish crest elevations that will meet the drop requirement. After reviewing the data, the USFWS determined that for design, the existing fish weir shall prevent lamprey passage at the 10 year storm event and the spillway extension shall prevent lamprey passage at the 25 year storm event. In addition, the barrier will need to establish a vertical surface and lip at the crest. Finally, USFWS requires a minimum of 2 feet of adjustment, using stoplogs, to the crest of the required spillway extension. The barrier at the existing, or required, fish weir shall be established using stoplogs, thus providing complete adjustability. In order to adjust the stoplogs on the spillway extension, a new service bridge will be required.

2.4 Fish Guidance Weir: The primary function of the existing facility is fish egg collection. Due to the layout of the facility, there is concern that fish traveling upstream may stack up at the required spillway extension. In order to prevent fish from reaching the spillway extension and to guide fish to the weir inlet, a fish guidance weir is required. The fish guidance weir shall be installed at the confluence of the channel

downstream of the spillway extension and the existing river. The weir shall be constructed using grating and allow for debris removal as required. In order to operate the weir, a new service bridge will be required.

2.5 Real Estate: All real estate requirements including work and storage areas, channel improvement, and site access easements were coordinated with Real Estate Branch (RE) and are shown in Attachment A. For further discussion and real estate quantities see the Real Estate Appendix of the Feasibility report.

3. Alternatives

3.1 Alternative 1 - No Action: For this alternative, no action will be taken and the USFWS will continue with their current temporary trapping and lampricide treatment procedures.

3.2 Alternative 2 – Demolition of the Existing MDNR Weir Structure and Construction of a Permanent Lamprey Barrier and Trap at the Weir Location: This alternative consists of demolishing and disposing of the existing MDNR weir structure. The portion of the MNDR egg collection facility such as the holding tanks and raceways, the concrete spillway, the MDNR building where the salmon eggs are taken, and facility pump station would be integrated with the new barrier structure. The new barrier will consist of replacing the existing structure in kind and installing a new adjustable steel sheet pile barrier/spillway adjacent to the concrete structure. The new structure would be constructed to block and trap lamprey during the 25 year (4%) flood event. Stoplog sections would be incorporated on the barrier to allow FWS and MDNR personnel to manipulate outflows and to increase the effectiveness of downstream fish passage and lamprey trapping at the barrier. A walkway would be constructed over the barrier and outfitted with davit lifts to allow FWS lamprey control or MDNR egg collection personnel access to traps and to remove and replace stop logs in the adjustable structure. In addition, downstream a fish guidance weir will be installed to ensure fish approach the fish collection facility.

Sketches of this alternative can be found in Attachment A to this appendix.

3.3 Alternative 3 – Modify the Existing Weir Structure:

Alternative 3 includes the following work components:

1) Install one removable trap within one bay of existing weir.
2) Raise walkway over existing weir above 100 year flood elevation to provide flood clearance and prevent fish jumping over the weir to impact the walkway girders. In addition, existing walkway replacement/reconfiguration may be required to meet current safety regulations.
3) Construct an overflow spillway by driving steel sheet piling (SSP) to create a weir across the entire width of the river (not occupied by existing weir). The spillway will allow crest adjustment through the placement of stoplogs along the entire top of the new weir portion.

4) Excavating the existing earthen and concrete spillway to existing riverbed grade. (Initial estimate of quantity removed is approximately 1200 CY)
5) Install channels on top of the new SSP spillway to secure aluminum stoplogs. The stoplogs will create the required barrier differential to stop lamprey passage at the new spillway.
6) Place scour stone at the upstream and downstream toe of the new SSP weir.
7) Place riprap along the upstream bank of the new spillway weir for erosion control.
8) Install fish blockage weir at confluence of spillway discharge and existing river to direct fish to collection area.
9) Replace existing canoe/kayak portage. The portage will be constructed using SSP revetments and a stone embankment. It will allow access upstream of the dam, between the existing fish weir and required spillway, and extend downstream of the dam.
10) All excavated materials will be placed upland, leveled and seeded.
11) Pedestrian/Worker access bridges will be installed at both the new spillway weir and fish blockage weir for operational purposes. The bridges will be built above the 100 year flood elevation and supported on steel or concrete piers and abutments.

The barrier elevations for alternative 3 will block lamprey up to the 10 year event at the existing spill and up to the 25 year event at the spillway extension.

Sketches of this alternative can be found in Attachment A to this appendix.

4. Design

4.1 General: All design calculations can be found in Attachment B.

4.2 Survey Data: As Built survey data of the USFWS Little Manistee River Spawning Station was provided to USACE by USFWS. In addition, a survey was conducted in summer 2014 at the proposed project site. Both the as-built drawings and the summer 2014 survey will act as the base for project design.

4.3 Geotechnical Data: The generalized subsurface conditions for the proposed Sea Lamprey Traps are based on historical borings conducted in the vicinity of the proposed trap for the adjacent USFWS Little Manistee River Spawning Station. Boring Location 1 provided the nearest and most representative view of the likely subsurface conditions. The maximum depth that the soil borings extended to was 56.0 feet in accordance with ASTM D 1586 procedures. The general soil profile consists of sand to a depth of at least 56 feet, with the upper 35.5 feet of the sand being loose with pockets of peat with the “N” value is 7 or less, and below being sand in a compact state, with an “N” value of 9 to 27.

4.4 Hydraulic Data: The Hydraulics and Hydrology office estimated the flows and water elevations for various intervals. The results are shown in the table included as Attachment D.

4.5 Alternative 3

4.5.1 Loading: Loading on the service bridges will consist of dead loads, live loads, wind loads, and seismic loads. Loads were identified based on the AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges.

For the SSP weir, in addition to hydraulic loading on the structure, ice loading was considered. Based on discussions with Hydraulic Engineering Branch (HEB), the water surface elevations during times of ice will be very close to the 1-year event elevation. It was the opinion of the design engineer however that because the project is located in a cold region it would be reasonable to design for horizontal ice load. The typical LRE ice load of 5 kip per foot was applied to the top of the barrier. The downstream water elevation was taken as equivalent to the 1-year downstream water elevation.

4.5.2 Service Bridges: The service bridges are to be designed in accordance with the AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges using the software program STAAD Pro v8i. A572 Grade 50 steel was assumed for the design. Because the platform supports will be considered fracture critical members (2 girder layout) additional material toughness criteria will be required. All walkway steel will be galvanized for reduced maintenance and increased corrosion resistance. Due to the similarity of the service bridge layout, spans, and structural requirements, for the feasibility study, the design computations for a similar project at Kaukauna Dam located near Green Bay, Wisconsin will be used. Calculations tailored specifically for the project site will be completed in the next project phase.

4.5.3 Walkway Support: Piles will be used to support the service bridges. The piles will be galvanized steel and terminate at a pier cap. Final pier calculations will be completed during the next project phase. For this phase, pile size and depth were assumed utilizing engineering judgement, based on experience with other, similar projects.

The recommended design soil properties for the design of the foundation systems is presented below.

Table 1 Recommended design soil properties

Depth (ft)	Soil Description	N	Relative Density AASHTO 1988	Unit Weight, γ' (pcf)	Angle of Internal Friction, ϕ (degrees)

0 0.5	Top Soil	-	-	90	-
2.5	Sand (SP)	-	-	110	30
4	Peat	6	-	80	35
6.5	Sand (SP)	18	Medium Dense	110	35
23	Sand (SP)	4-7	Loose	95	30
30	Sand (SP)	11	Medium Dense	115	35
35	Peat	4	-	80	-
43	Sand (SP)	9	Loose	110	32
56.5	Sand (SP)	19-27	Medium Dense	125	35

Notes:

1. Due to potential scour effects, some thickness of the soil strata immediately below the channel bottom should omitted from any analysis.

4. Omit soils to 4 feet depth from any P-4 lateral analysis.

The recommended design requirements for the pile foundation are as follows:

1. Specify a minimum embedment depth of the piles based on the provided axial and lateral shear capacity as well as the potential for up to two (2) foot of scour along the river bottom at the pile locations.

4.5.4 Hoist: Per the USFWS, a lift system should be designed to lift 500 pounds of lamprey plus the trap insert from the riverbed to the platform complex. In order to accomplish this, a manual hoist will be specified with a capacity of 1000 lbs to account for any unforeseen applied loadings. A Hoist system will also be installed at the walkway over the spillway extension to allow for installation and removal of stoplogs on top of the weir.

4.5.5 Lamprey Trap: The Lamprey trap as shown in Figure 3 will be designed per USFWS recommendations. The traps are to be 4’x4’ and will be 5’ high allowing trapping of a significant portion of the water column. For the feasibility level design, no design calculations for the traps were completed. The trap materials were estimated based on previous USFWS designs. Design calculations will be completed at the beginning of the next project phase. For the purpose of estimating costs, the detailed design of a similar trap developed for the Au Sable River Sea Lamprey Trap facility will be used.

4.5.6 SSP Weir: The SSP was designed in accordance with EM 1110-2-2504, “Design of Sheet Pile Walls”. Table 2 indicates the required section moduli and required SSP sections.

Table 2 Required section modulus and required SSP sections.

	Yield Stress, F_y (ksi)	Top of Barrier 601.4 (NAVD 88)	Required SSP Section
A572, Gr 50	50	18.1 in^3	PZ-22

For the purpose of estimating, A572, Grade 50 SSP will be assumed.

5. Construction: It was assumed that primary access to the project site would be from the area adjacent to the existing USFWS Little Manistee River Spawning Station, on the south side of the Little Manistee River. Access to the area will be accomplished through the use of the existing road.

6. Operation and Maintenance: Operation and maintenance for this project is expected to be minor over the estimated life. Maintenance of the project would include periodic inspections of all steel components, monitoring of the SSP for rotation or excess corrosion, and inspections of all stone placed to ensure no excessive displacement occurs. No major material corrosion or damage is expected over the expected 50 year design life of the project. Operation of the project may include the removal of accumulated debris at the spillway, fish guidance weir, and/or lamprey trap. Overall operation and maintenance would be performed by USFWS personnel.

7. Environmental: All environmental requirements are available in the required Environmental Assessment. However, due to the presence of the Eastern Massasauga Rattlesnake, an endangered species, within the project area, the following special requirements are required:

1) Install silt fence extending at least 18" above grade on both sides of the work and storage area (nearshore) and the far bank above the riverbank work line

2) Once the silt fence is installed as a snake barrier, walk the sites daily looking for snakes and remove any trapped snakes within the work areas for a 10 day period.

3) If any snakes are found make a record of those present.

4) Continue inspections of the work areas at least on a weekly basis.

5) If any soil erosion control blankets are used on the slopes, use snake friendly erosion control matting for slope stabilization.

8. Cost Estimate: A copy of the construction cost estimate can be found in the cost appendix to the Feasibility Report.

ATTACHMENT A

PROJECT DRAWINGS

US Army Corps of Engineers®
Detroit District

MANISTEE COUNTY, MANISTEE, MICHIGAN
SEA LAMPREY BARRIER & TRAP
DEPT. OF NATURAL RESOURCES WIER
LITTLE MANISTEE RIVER

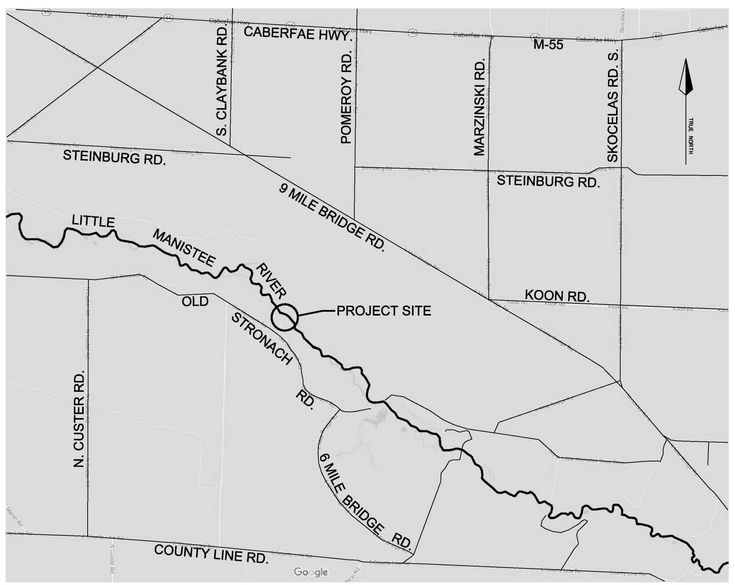
DRIVING DIRECTIONS TO THE WEIR
FROM NORTH OF MANISTEE:

TRAVEL SOUTH ON US-31 TO M-55 INTERSECTION, TURN EAST ONTO M-55 AND FOLLOW TO STRONACH ROAD (ABOUT 3.5 MILES TO LARGE SIGN), TURN SOUTH ONTO STRONACH ROAD AND FOLLOW TO THE BEND IN THE ROAD (SIGN FOR OLD STRONACH ROAD AND WEIR), TURN EAST ONTO OLD STRONACH ROAD AND FOLLOW DOWN THE HILL AND OVER THE LITTLE MANISTEE RIVER (NEW TIMBER BRIDGE) AND PAST SEVERAL HOUSES TO THE "T" TURN EAST (EAST IS OLD STRONACH, WEST IS CARTY RD) AND FOLLOW PAST WHERE THE ROAD CHANGES FROM ASPHALT TO GRAVEL, GO ABOUT 1.5 MILES TO THE DRIVE ON THE LEFT ACROSS FROM THE FEDERAL CAMPGROUND, FOLLOW THIS DOWN THE HILL TO THE PARKING LOT IN FRONT OF THE FACILITY.

FROM SOUTH OF MANISTEE:
TRAVEL NORTH ON US-31 TO STRONACH ROAD (BP GAS STATION ON THE SOUTH END OF TOWN), TURN EAST ON STRONACH ROAD AND FOLLOW TO THE BASE OF THE HILL (ACROSS FROM PCA PLANT), TURN SOUTH AND FOLLOW AROUND THE SOUTH END OF MANISTEE LAKE (THIS IS STILL STRONACH ROAD), AT THE PLAYGROUND TURN EAST ONTO OLD STRONACH ROAD AND FOLLOW UP THE HILL TO THE BEND IN THE ROAD TURN EAST ONTO OLD STRONACH ROAD AND FOLLOW DOWN THE HILL AND OVER THE LITTLE MANISTEE RIVER (NEW TIMBER BRIDGE) AND PAST SEVERAL HOUSES TO THE "T" TURN EAST (EAST IS OLD STRONACH, WEST IS CARTY RD) AND FOLLOW PAST WHERE THE ROAD CHANGES FROM ASPHALT TO GRAVEL, GO ABOUT 1.5 MILES TO THE DRIVE ON THE LEFT ACROSS FROM THE FEDERAL CAMPGROUND, FOLLOW THIS DOWN THE HILL TO THE PARKING LOT IN FRONT OF THE FACILITY.

FROM EAST OF MANISTEE:
TRAVEL WEST ON M-55 TO STRONACH ROAD (LARGE SIGN), TURN SOUTH ONTO STRONACH ROAD AND FOLLOW TO THE BEND IN THE ROAD (SIGN FOR OLD STRONACH ROAD AND WEIR), TURN EAST ONTO OLD STRONACH ROAD AND FOLLOW DOWN THE HILL AND OVER THE LITTLE MANISTEE RIVER (NEW TIMBER BRIDGE) AND PAST SEVERAL HOUSES TO THE "T" TURN EAST (EAST IS OLD STRONACH, WEST IS CARTY RD) AND FOLLOW PAST WHERE THE ROAD CHANGES FROM ASPHALT TO GRAVEL, GO ABOUT 1.5 MILES TO THE DRIVE ON THE LEFT ACROSS FROM THE FEDERAL CAMPGROUND, FOLLOW THIS DOWN THE HILL TO THE PARKING LOT IN FRONT OF THE FACILITY.

REFERENCED http://www.michigan.gov/dnr/0,4570,7-153-10364_52259_19092-51534--,00.html#directions



LOCATION MAP
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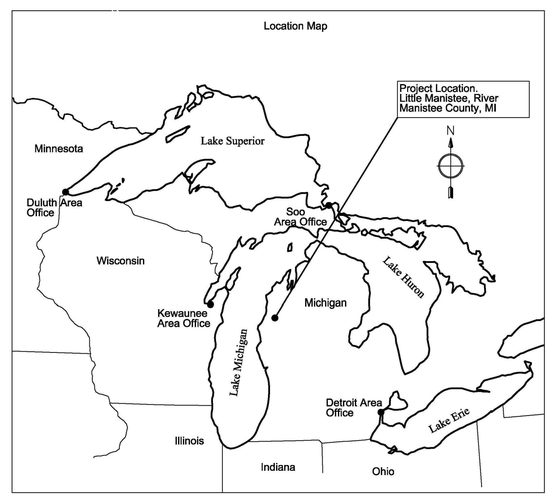

PROJECT MAP

Sheet ID	Sheet Title
	Title & General Plans
G-001	General Plan, Location Map, Vicinity Map and Drawings Index
V-101	Existing Conditions Plan
C-101	Required Overall Site Plan
C-102	Required Site Work and Grading
C-301	Required Cross Sections
C-501	Required Details
RR101	Real Estate Plan

SOLICITATION NO.: XXXXXX-XX-X-XXXX
CONTRACT NO.: XXXXXX-XX-X-XXXX
ISSUE DATE: MMMMMMMMM YYYY
VOLUME X

NICHOLAS J. ZAGER P.E., CHIEF GEOTECH & STRUCTURES BRANCH

WILLIAM D. MERTE P.E., CHIEF COST & GENERAL ENGINEERING BRANCH

PHILLIP C. ROSS P.E., CHIEF ENGINEERING & CONSTRUCTION OFFICE

MARIE T. STRUM P.E., CHIEF ENGINEERING & TECHNICAL SERVICES

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MARK	DESCRIPTION	DATE
1	FEASIBILITY STUDY	13APR2017

DESIGNED BY: B. GERKEN
DRAWN BY: B.MELBY/B.KORZETZ
CHECKED BY:
SUBMITTED BY: PHILLIP ROSS
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ISSUE DATE: 11 APRIL 2017
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U.S. ARMY CORPS OF ENGINEERS
DETROIT DISTRICT

MANISTEE COUNTY, MANISTEE, MICHIGAN
LITTLE MANISTEE RIVER
SEA LAMPREY BARRIER & TRAP

COVER SHEET

SHEET ID
GI001

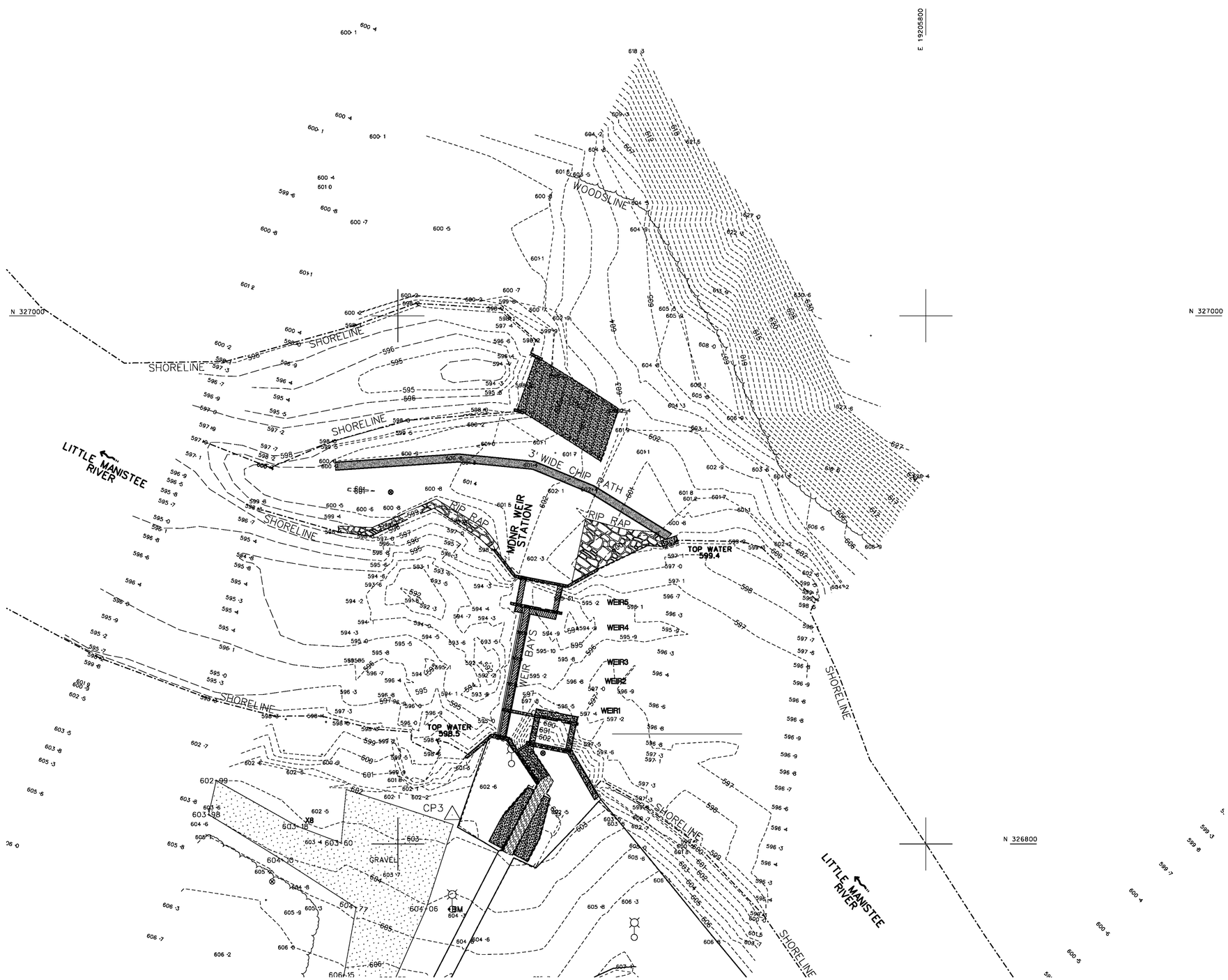
FEASIBILITY STUDY

NOTES:
THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF THE SURVEYS MADE ON THE DATES INDICATED AND
CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME.

GRID COORDINATES:
GRIDS SHOWN ARE BASED ON THE U.S. STATE PLANE COORDINATE SYSTEM. STATE OF MICHIGAN, CENTRAL ZONE (2112), 1983 NORTH
AMERICAN DATUM. (NAD83), U.S. SURVEY FEET.

VERTICAL DATUM:
ALL ELEVATIONS SHOWN ARE BASED ON THE
NORTH AMERICAN VERTICAL DATUM OF 1988. (NAVD88)

SURVEY INFORMATION:
SURVEY BY GOURDIE-FRASER
DATE OF SURVEY 06/03/2014 - 06/13/2014



OVERALL PLAN VIEW
EXISTING CONDITIONS

SCALE: 1"=20'

AT CENTER OF SHEET
-1°16'14.29530"
GRID NORTH
TRUE NORTH

LEGEND:

- LIGHT POLE
- 586·6 GROUND SHOT
- 587·32 HARD SURFACE SHOT
- CAMERA LOCATION & PHOTO NUMBER
- 100D CROSS SECTION NUMBER
- CONCRETE SURFACE
- GRAVEL SURFACE
- RIP RAP
- CAT WALK
- CHAIN LINK FENCE

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1	FEASIBILITY STUDY	13APR2017

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SUBMITTED BY: PHILLIP ROSS
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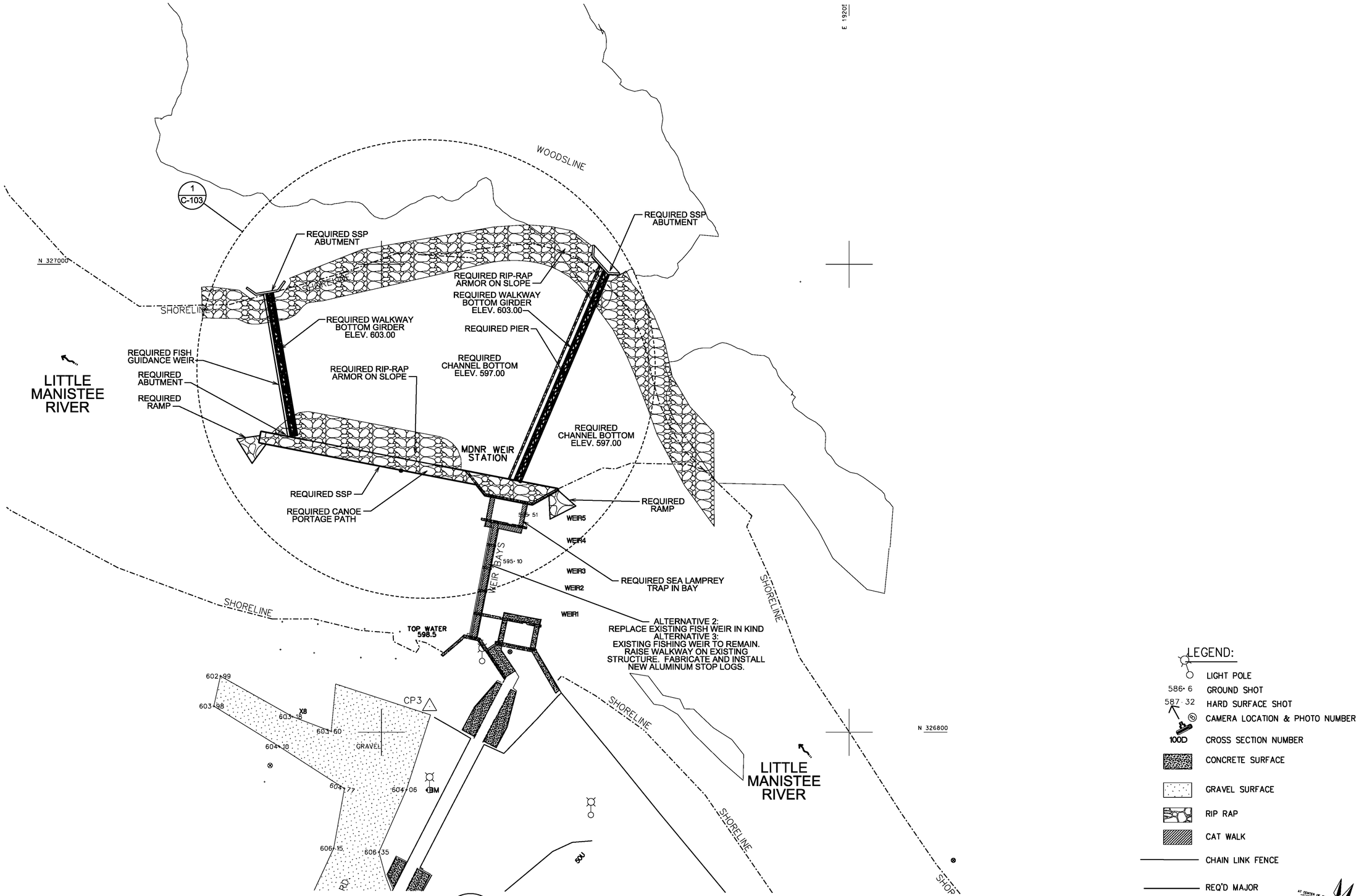
U.S. ARMY CORPS OF ENGINEERS
DETROIT DISTRICT

MANISTEE COUNTY, MANISTEE, MICHIGAN
LITTLE MANISTEE RIVER
SEA LAMPREY BARRIER & TRAP

EXISTING CONDITIONS PLAN

SHEET ID
V-101

FEASIBILITY STUDY



1 / C-101 REQ'D OVERALL PLAN VIEW ALTERNATE 2 AND 3

SCALE: 1"=10'

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1	FEASIBILITY STUDY	13APR2017

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SUBMITTED BY: PHILLIP ROSS
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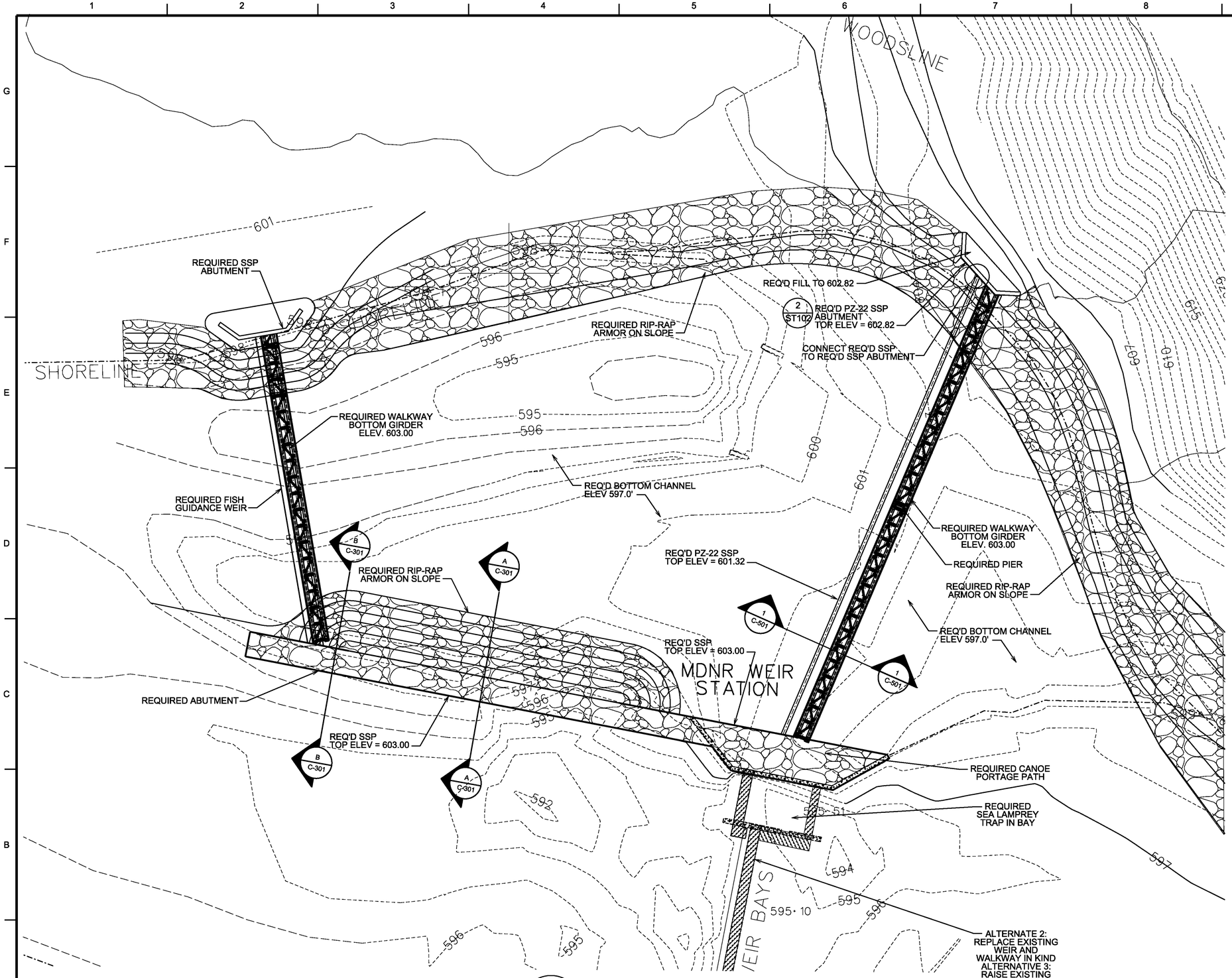
U.S. ARMY CORPS OF ENGINEERS
DETROIT DISTRICT

MANISTEE COUNTY, MANISTEE, MICHIGAN
LITTLE MANISTEE RIVER
SEA LAMPREY BARRIER & TRAP

REQUIRED OVERALL SITE PLAN

SHEET ID
C-101

FEASIBILITY STUDY



1 / C-101 REQ'D SITE PLAN VIEW ALTERNATE 2 AND 3

SCALE: 1"=10'

LEGEND:

- LIGHT POLE
- 586·6 GROUND SHOT
- 587·32 HARD SURFACE SHOT
- CAMERA LOCATION & PHOTO NUMBER
- 100D CROSS SECTION NUMBER
- CONCRETE SURFACE
- GRAVEL SURFACE
- RIP RAP
- CAT WALK
- CHAIN LINK FENCE
- REQ'D MAJOR
- REQ'D MINOR
- EXISTING MINOR
- EXISTING MAJOR

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MARK	DESCRIPTION	DATE
1	FEASIBILITY STUDY	13APR2017

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SUBMITTED BY: PHILLIP ROSS
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FILE: AEC_G-001.dgn

U.S. ARMY CORPS OF ENGINEERS DETROIT DISTRICT

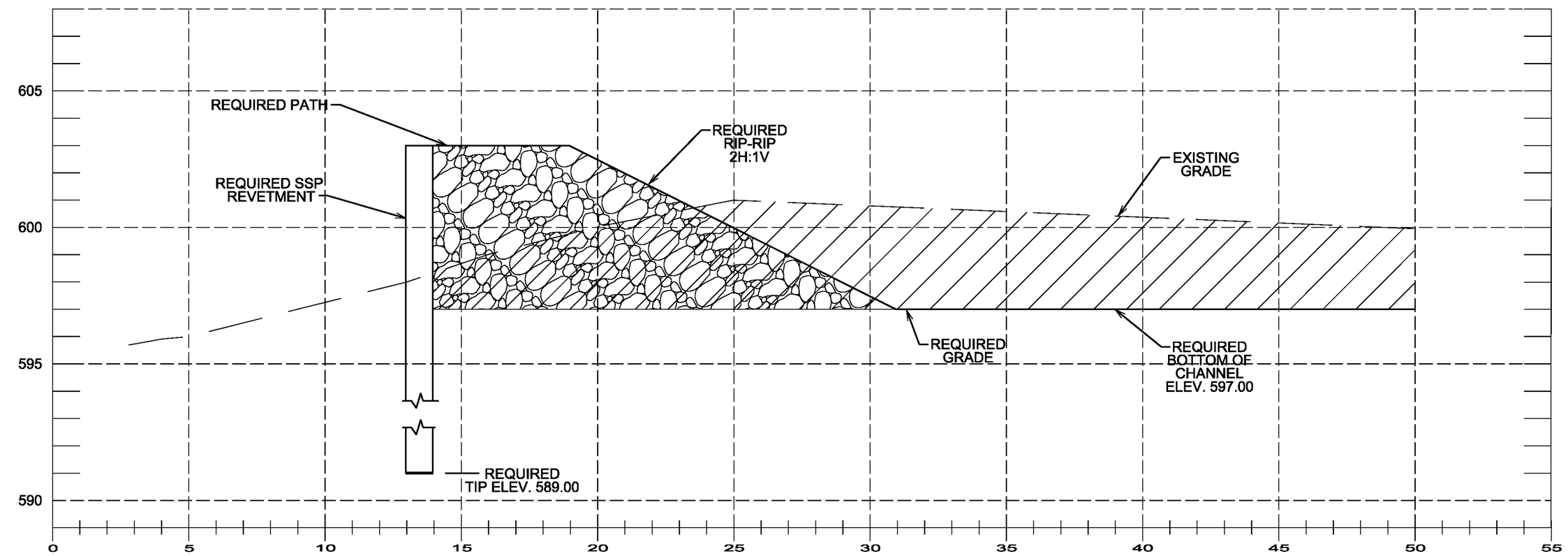
Value Engineering

MANISTEE COUNTY, MANISTEE, MICHIGAN
LITTLE MANISTEE RIVER
SEA LAMPREY BARRIER & TRAP

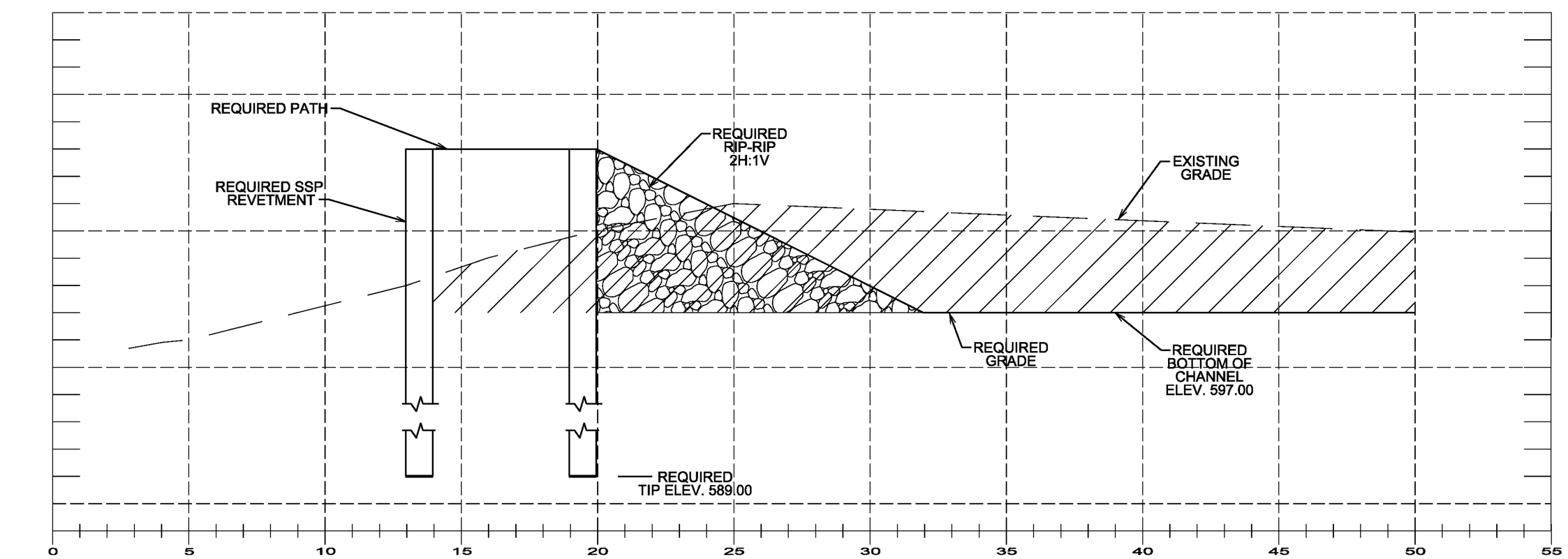
REQUIRED SITE WORK AND GRADING

SHEET ID
C-103

FEASIBILITY STUDY



A / C-301 SECTION



B / C-301 SECTION

LEGEND

REQUIRED CUT

REQUIRED RIP-RAP

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE
1	FEASIBILITY STUDY	13APR2017

DESIGNED BY: B. GERKEN
DRAWN BY: B.MELBY/B.KORZETZ
CHECKED BY:
SUBMITTED BY: PHILLIP ROSS
SIZE: ANSI D
ISSUE DATE: 11 APRIL 2017
SOLICITATION NO.: W911XK-XX-X-XXXX
CONTRACT NO.: W911XK-XX-X-XXXX
%UOPTION 1%
%UOPX1%
AEC_G-001.dgn

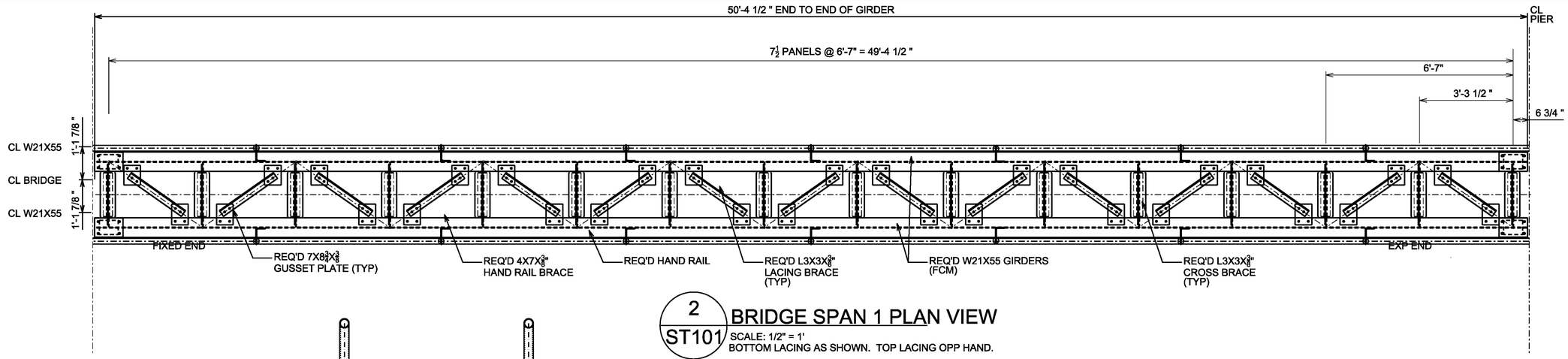
U.S. ARMY CORPS OF ENGINEERS
DETROIT DISTRICT

MANISTEE COUNTY, MANISTEE, MICHIGAN
LITTLE MANISTEE RIVER
SEA LAMPREY BARRIER & TRAP

REQUIRED CROSS SECTIONS

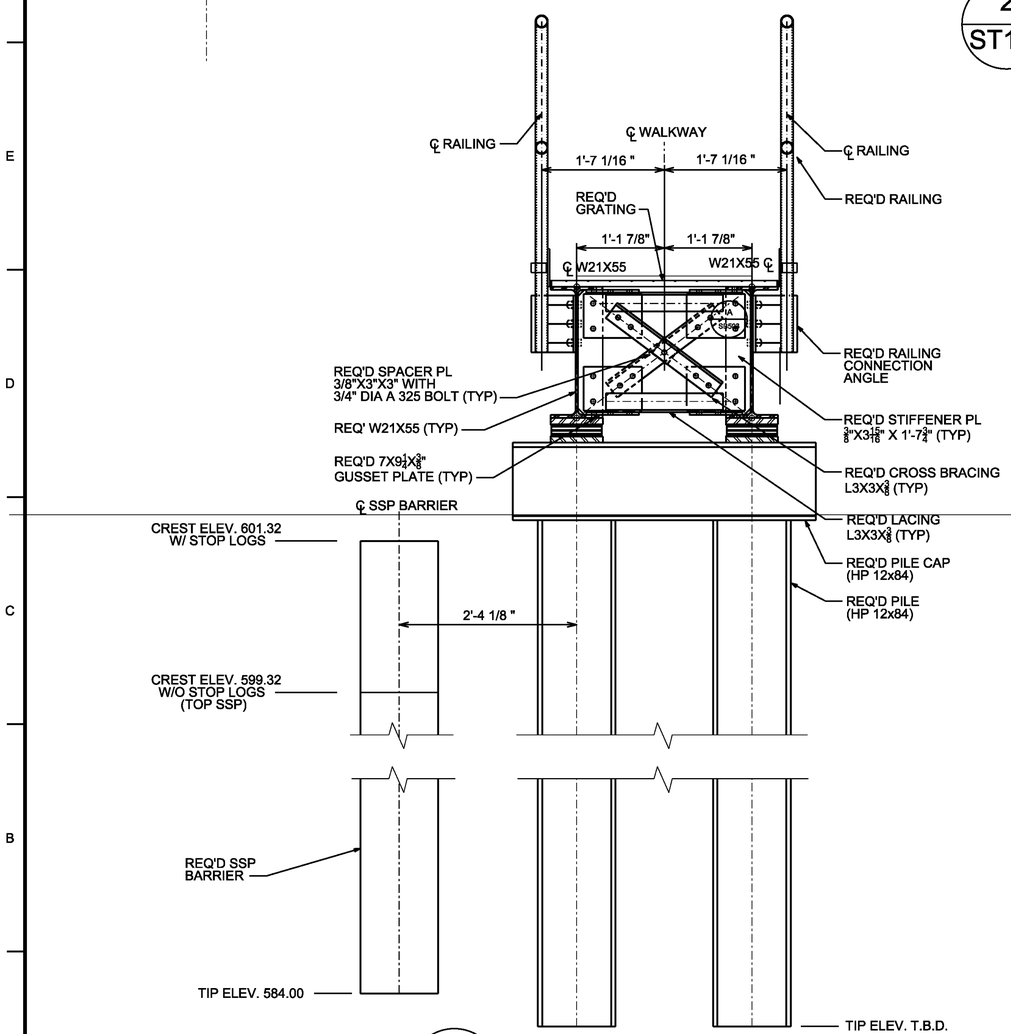
SHEET ID
C-301

FEASIBILITY STUDY



2 / ST101 BRIDGE SPAN 1 PLAN VIEW

SCALE: 1/2" = 1'
BOTTOM LACING AS SHOWN. TOP LACING OPP HAND.



1 / ST101 SECTION ALTERNATIVE 3

SCALE: ¼"=1'

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE
1	FEASIBILITY STUDY	13APR2017

ISSUE DATE: 11 APRIL 2017
SOLICITATION NO.: W911XK-XX-X-XXXX
CONTRACT NO.: W911XK-XX-X-XXXX
%UOPTION 1%
%UOPX1%

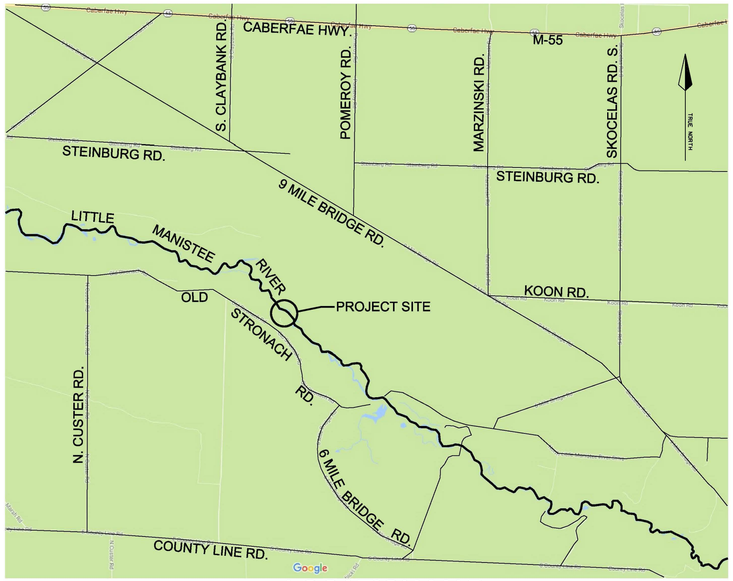
DESIGNED BY: B. GERKEN
DRAWN BY: B.MELBY/B.KORZETZ
CHECKED BY:
SUBMITTED BY: PHILLIP ROSS
SIZE: ANSI D
AEC_G-001.dgn

U.S. ARMY CORPS OF ENGINEERS
DETROIT DISTRICT

MANISTEE COUNTY, MANISTEE, MICHIGAN
LITTLE MANISTEE RIVER
SEA LAMPREY BARRIER & TRAP

REQUIRED DETAILS

SHEET ID
C-501



LOCATION MAP

SCALE: 1"=3000'

REAL ESTATE PLAN

SCALE: 1"=50'

NOTES:
THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF THE SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME.

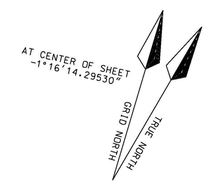
GRID COORDINATES:
GRIDS SHOWN ARE BASED ON THE U.S. STATE PLANE COORDINATE SYSTEM. STATE OF MICHIGAN, CENTRAL ZONE (2112), 1983 NORTH AMERICAN DATUM. (NAD83), U.S. SURVEY FEET.

VERTICAL DATUM:
ALL ELEVATIONS SHOWN ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM OF 1988. (NAVD88)

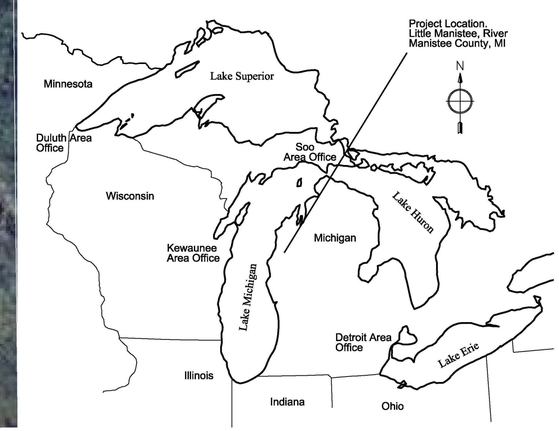
SURVEY INFORMATION:
SURVEY BY GOURDIE-FRASER
DATE OF SURVEY 06/03/2014 - 06/13/2014

LEGEND

- FEE (0.57 AC.)
- TEMPORARY WORK AREA EASEMENT (1.61 AC.)
- ROAD EASEMENT (0.77 AC.)
- MDNR PROPERTY BOUNDARY



Location Map



PROJECT MAP

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE
1	FEASIBILITY STUDY	13APR2017

DESIGNED BY: B. GERKEN
DRAWN BY: B.MELBY/B.KORZETZ
CHECKED BY:
SUBMITTED BY: PHILLIP ROSS
SIZE: ANSI D
ISSUE DATE: 11 APRIL 2017
SOLICITATION NO.: W911XK-XX-X-XXXX
CONTRACT NO.: W911XK-XX-X-XXXX
%UOPTION 1%
%UOPX1%
AEC_G-001.dgn

U.S. ARMY CORPS OF ENGINEERS
DETROIT DISTRICT

Visual Engineering

MANISTEE COUNTY, MANISTEE, MICHIGAN
LITTLE MANISTEE RIVER
SEA LAMPREY BARRIER & TRAP

REAL ESTATE PLAN

SHEET ID
RR101

FEASIBILITY STUDY

ATTACHMENT B

DESIGN COMPUTATIONS

US Army Corps of Engineers Detroit District	PROJECT TITLE: **Little Manistee**	COMPUTED BY: **J.Carr**	DATE: **7/5/2017**
	COMPUTATION TITLE: **SSP Revetment CWALSHT Summary**	CHECKED BY: **B. Gerken**	DATE: **7/5/017**

UPDATED: 6/14/2017: Revised Tie Rod Elevation.

This is for a 100 ft ssp spillway at the Little Manistee Fish Weir site. The top elevation will be 601.32 in order to be above the 25 year flood event.

Summary of Results for SSP

Load Case	Embed Depth	Tie Rod Pull (plf)	Max Deflection (in)	Max Moment (k-ft)
Water @ +0 LWD and 2700 psf stone storage load surcharge (FSP = 1.5)	12.77	0		
Water @ +0 LWD and 2700 psf stone storage load surcharge (FSP = 1.0)			0.29	5.19

Member Size Results	
SSP Shape	PZ-22 (S_{min} 18.1 in^3) ASTM A572 Gr. 50
SSP Tip Elevation	Elevation = -17.32 LWD

Note: This design procedure follows the guidelines set forth by EM 1110-2-2504, 1994, starting on pg. 6-1

allowable bending stress = $f_b = 0.5 f_y$

minimum section modulus = $S_{min} = \frac{M_{max}}{f_b}$

Maximum Moment, M_{max} =	5.19	k-ft	
Assumed Yield Strength, F_y =	50	ksi	
Alowable Bending Stress, f_b =	25	ksi	
Minimum Section Modulus, S_{min} =	2.5	in^3	
Assumed SSP Section =	PZ-22		
Section Modulus of Section, S =	18.1	in^3	**OK**
Moment of Inertia I =	84.38	in^4	

Per calculations from Dave Force (LRC) only minor bending stress will be transferred to the SSP.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:45:57

```
****************
*  INPUT DATA  *
****************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:45:57

```
****************
*  INPUT DATA  *
****************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:03

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*************************
*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
*************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

574.3	300.8	3061.8	208.2	-2559.9	3045.4	201.1	2952.8
573.3	300.8	3245.5	220.7	-2731.3	3216.5	213.4	3136.4
573.0	300.8	2764.9	211.3	-2258.8	2777.3	205.3	2687.8
572.3	300.8	2250.1	220.3	-1734.3	2286.7	215.1	2206.2
571.3	300.8	3159.2	275.4	-2591.3	3089.7	267.2	3064.3
570.3	300.8	3303.9	288.0	-2723.4	3221.8	279.7	3209.0
569.3	300.8	3448.6	300.6	-2855.5	3353.9	292.3	3353.7
568.3	300.8	3593.3	313.1	-2987.6	3486.0	304.9	3498.4
567.3	300.8	3738.0	325.7	-3119.7	3618.2	317.5	3643.1
566.3	300.8	3882.7	338.3	-3251.9	3750.3	330.1	3787.8

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

```
WALL BOTTOM ELEV. (FT)      :      584.23
      PENETRATION (FT)      :       12.77

MAX. BEND. MOMENT (LB-FT)   :  5.1927E+03
      AT ELEVATION (FT)     :      590.07

MAX. SCALED DEFL. (LB-IN^3):  7.4213E+08
      AT ELEVATION (FT)     :      601.32
```

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

```
****************************
* COMPLETE OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--RESULTS

BENDING SCALED NET

ELEVATION (FT)	MOMENT (LB-FT)	SHEAR (LB)	DEFLECTION (LB-IN^3)	PRESSURE (PSF)
601.32	0.0000E+00	0.	7.4213E+08	0.00
600.32	1.0400E+01	31.	6.7060E+08	62.40
599.32	8.3200E+01	125.	5.9909E+08	124.80
598.32	2.8080E+02	281.	5.2774E+08	187.20
597.32	6.6560E+02	499.	4.5690E+08	249.60
597.00	8.3846E+02	582.	4.3444E+08	269.57
596.50	1.1591E+03	692.	3.9966E+08	169.88
596.32	1.2863E+03	720.	3.8726E+08	145.20
596.00	1.5238E+03	762.	3.6538E+08	112.22
595.32	2.0634E+03	819.	3.1985E+08	57.23
594.62	2.6500E+03	839.	2.7443E+08	0.00
594.32	2.8978E+03	836.	2.5602E+08	-24.01
593.32	3.7081E+03	771.	1.9719E+08	-105.34
592.32	4.4131E+03	625.	1.4476E+08	-186.70
591.32	4.9314E+03	398.	9.9922E+07	-268.06
590.32	5.1816E+03	89.	6.3569E+07	-349.42
589.32	5.0824E+03	-301.	3.6119E+07	-430.78
588.32	4.5524E+03	-772.	1.7390E+07	-512.15
587.46	3.6914E+03	-1242.	7.5820E+06	-581.98
587.32	3.5107E+03	-1319.	6.4539E+06	-497.67
586.32	2.0429E+03	-1517.	1.5171E+06	100.12
585.32	6.7532E+02	-1118.	1.2482E+05	697.91
584.32	5.6146E+00	-121.	6.8485E+00	1295.70
584.23	0.0000E+00	0.	0.0000E+00	1350.59

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<----------SOIL PRESSURES---------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
601.32	0.	0.	0.	0.	0.
600.32	62.	0.	0.	0.	0.
599.32	125.	0.	0.	0.	0.
598.32	187.	0.	0.	0.	0.
597.32	250.	0.	0.	0.	0.
597.00	270.	0.	0.	0.	0.
596.50	301.	137.	13.	6.	63.
596.32	301.	164.	17.	8.	80.
596.00	301.	200.	20.	11.	113.
595.32	301.	261.	27.	18.	174.
594.62	301.	325.	33.	25.	238.
594.32	301.	352.	36.	27.	265.
593.32	301.	443.	46.	37.	356.
592.32	301.	534.	55.	46.	447.
591.32	301.	624.	64.	55.	537.
590.32	301.	715.	74.	65.	628.
589.32	301.	806.	83.	74.	719.
588.32	301.	897.	93.	84.	810.
587.46	301.	974.	101.	92.	888.
587.32	301.	987.	102.	93.	900.
586.32	301.	1078.	111.	102.	991.
585.32	301.	1169.	121.	112.	1082.
584.32	301.	1259.	130.	121.	1173.
584.23	301.	1350.	140.	131.	1263.
582.32	301.	1441.	149.	140.	1354.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 13:45:38

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****************
*  INPUT DATA  *
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 13:46:01

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*************************
*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
*************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:03

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*************************
*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
*************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:03

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*************************
*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
*************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

574.3	300.8	3061.8	208.2	-2559.9	3045.4	201.1	2952.8
573.3	300.8	3245.5	220.7	-2731.3	3216.5	213.4	3136.4
573.0	300.8	2764.9	211.3	-2258.8	2777.3	205.3	2687.8
572.3	300.8	2250.1	220.3	-1734.3	2286.7	215.1	2206.2
571.3	300.8	3159.2	275.4	-2591.3	3089.7	267.2	3064.3
570.3	300.8	3303.9	288.0	-2723.4	3221.8	279.7	3209.0
569.3	300.8	3448.6	300.6	-2855.5	3353.9	292.3	3353.7
568.3	300.8	3593.3	313.1	-2987.6	3486.0	304.9	3498.4
567.3	300.8	3738.0	325.7	-3119.7	3618.2	317.5	3643.1
566.3	300.8	3882.7	338.3	-3251.9	3750.3	330.1	3787.8

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

```
WALL BOTTOM ELEV. (FT)      :      584.23
      PENETRATION (FT)      :       12.77

MAX. BEND. MOMENT (LB-FT)   :  5.1927E+03
      AT ELEVATION (FT)     :      590.07

MAX. SCALED DEFL. (LB-IN^3):  7.4213E+08
      AT ELEVATION (FT)     :      601.32
```

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
* COMPLETE OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--RESULTS

BENDING SCALED NET

ELEVATION (FT)	MOMENT (LB-FT)	SHEAR (LB)	DEFLECTION (LB-IN^3)	PRESSURE (PSF)
601.32	0.0000E+00	0.	7.4213E+08	0.00
600.32	1.0400E+01	31.	6.7060E+08	62.40
599.32	8.3200E+01	125.	5.9909E+08	124.80
598.32	2.8080E+02	281.	5.2774E+08	187.20
597.32	6.6560E+02	499.	4.5690E+08	249.60
597.00	8.3846E+02	582.	4.3444E+08	269.57
596.50	1.1591E+03	692.	3.9966E+08	169.88
596.32	1.2863E+03	720.	3.8726E+08	145.20
596.00	1.5238E+03	762.	3.6538E+08	112.22
595.32	2.0634E+03	819.	3.1985E+08	57.23
594.62	2.6500E+03	839.	2.7443E+08	0.00
594.32	2.8978E+03	836.	2.5602E+08	-24.01
593.32	3.7081E+03	771.	1.9719E+08	-105.34
592.32	4.4131E+03	625.	1.4476E+08	-186.70
591.32	4.9314E+03	398.	9.9922E+07	-268.06
590.32	5.1816E+03	89.	6.3569E+07	-349.42
589.32	5.0824E+03	-301.	3.6119E+07	-430.78
588.32	4.5524E+03	-772.	1.7390E+07	-512.15
587.46	3.6914E+03	-1242.	7.5820E+06	-581.98
587.32	3.5107E+03	-1319.	6.4539E+06	-497.67
586.32	2.0429E+03	-1517.	1.5171E+06	100.12
585.32	6.7532E+02	-1118.	1.2482E+05	697.91
584.32	5.6146E+00	-121.	6.8485E+00	1295.70
584.23	0.0000E+00	0.	0.0000E+00	1350.59

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<----------SOIL PRESSURES---------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
601.32	0.	0.	0.	0.	0.
600.32	62.	0.	0.	0.	0.
599.32	125.	0.	0.	0.	0.
598.32	187.	0.	0.	0.	0.
597.32	250.	0.	0.	0.	0.
597.00	270.	0.	0.	0.	0.
596.50	301.	137.	13.	6.	63.
596.32	301.	164.	17.	8.	80.
596.00	301.	200.	20.	11.	113.
595.32	301.	261.	27.	18.	174.
594.62	301.	325.	33.	25.	238.
594.32	301.	352.	36.	27.	265.
593.32	301.	443.	46.	37.	356.
592.32	301.	534.	55.	46.	447.
591.32	301.	624.	64.	55.	537.
590.32	301.	715.	74.	65.	628.
589.32	301.	806.	83.	74.	719.
588.32	301.	897.	93.	84.	810.
587.46	301.	974.	101.	92.	888.
587.32	301.	987.	102.	93.	900.
586.32	301.	1078.	111.	102.	991.
585.32	301.	1169.	121.	112.	1082.
584.32	301.	1259.	130.	121.	1173.
584.23	301.	1350.	140.	131.	1263.
582.32	301.	1441.	149.	140.	1354.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 13:45:38

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****************
*  INPUT DATA  *
****************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 13:46:01

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*************************
*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
*************************
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:45:57

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****************
*  INPUT DATA  *
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:45:57

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****************
*  INPUT DATA  *
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```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:03

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*************************
*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

574.3	300.8	3061.8	208.2	-2559.9	3045.4	201.1	2952.8
573.3	300.8	3245.5	220.7	-2731.3	3216.5	213.4	3136.4
573.0	300.8	2764.9	211.3	-2258.8	2777.3	205.3	2687.8
572.3	300.8	2250.1	220.3	-1734.3	2286.7	215.1	2206.2
571.3	300.8	3159.2	275.4	-2591.3	3089.7	267.2	3064.3
570.3	300.8	3303.9	288.0	-2723.4	3221.8	279.7	3209.0
569.3	300.8	3448.6	300.6	-2855.5	3353.9	292.3	3353.7
568.3	300.8	3593.3	313.1	-2987.6	3486.0	304.9	3498.4
567.3	300.8	3738.0	325.7	-3119.7	3618.2	317.5	3643.1
566.3	300.8	3882.7	338.3	-3251.9	3750.3	330.1	3787.8

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
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```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

```
WALL BOTTOM ELEV. (FT)      :      584.23
      PENETRATION (FT)      :       12.77

MAX. BEND. MOMENT (LB-FT)   :  5.1927E+03
      AT ELEVATION (FT)     :      590.07

MAX. SCALED DEFL. (LB-IN^3):  7.4213E+08
      AT ELEVATION (FT)     :      601.32
```

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
* COMPLETE OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
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```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--RESULTS

BENDING SCALED NET

ELEVATION (FT)	MOMENT (LB-FT)	SHEAR (LB)	DEFLECTION (LB-IN^3)	PRESSURE (PSF)
601.32	0.0000E+00	0.	7.4213E+08	0.00
600.32	1.0400E+01	31.	6.7060E+08	62.40
599.32	8.3200E+01	125.	5.9909E+08	124.80
598.32	2.8080E+02	281.	5.2774E+08	187.20
597.32	6.6560E+02	499.	4.5690E+08	249.60
597.00	8.3846E+02	582.	4.3444E+08	269.57
596.50	1.1591E+03	692.	3.9966E+08	169.88
596.32	1.2863E+03	720.	3.8726E+08	145.20
596.00	1.5238E+03	762.	3.6538E+08	112.22
595.32	2.0634E+03	819.	3.1985E+08	57.23
594.62	2.6500E+03	839.	2.7443E+08	0.00
594.32	2.8978E+03	836.	2.5602E+08	-24.01
593.32	3.7081E+03	771.	1.9719E+08	-105.34
592.32	4.4131E+03	625.	1.4476E+08	-186.70
591.32	4.9314E+03	398.	9.9922E+07	-268.06
590.32	5.1816E+03	89.	6.3569E+07	-349.42
589.32	5.0824E+03	-301.	3.6119E+07	-430.78
588.32	4.5524E+03	-772.	1.7390E+07	-512.15
587.46	3.6914E+03	-1242.	7.5820E+06	-581.98
587.32	3.5107E+03	-1319.	6.4539E+06	-497.67
586.32	2.0429E+03	-1517.	1.5171E+06	100.12
585.32	6.7532E+02	-1118.	1.2482E+05	697.91
584.32	5.6146E+00	-121.	6.8485E+00	1295.70
584.23	0.0000E+00	0.	0.0000E+00	1350.59

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<----------SOIL PRESSURES---------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
601.32	0.	0.	0.	0.	0.
600.32	62.	0.	0.	0.	0.
599.32	125.	0.	0.	0.	0.
598.32	187.	0.	0.	0.	0.
597.32	250.	0.	0.	0.	0.
597.00	270.	0.	0.	0.	0.
596.50	301.	137.	13.	6.	63.
596.32	301.	164.	17.	8.	80.
596.00	301.	200.	20.	11.	113.
595.32	301.	261.	27.	18.	174.
594.62	301.	325.	33.	25.	238.
594.32	301.	352.	36.	27.	265.
593.32	301.	443.	46.	37.	356.
592.32	301.	534.	55.	46.	447.
591.32	301.	624.	64.	55.	537.
590.32	301.	715.	74.	65.	628.
589.32	301.	806.	83.	74.	719.
588.32	301.	897.	93.	84.	810.
587.46	301.	974.	101.	92.	888.
587.32	301.	987.	102.	93.	900.
586.32	301.	1078.	111.	102.	991.
585.32	301.	1169.	121.	112.	1082.
584.32	301.	1259.	130.	121.	1173.
584.23	301.	1350.	140.	131.	1263.
582.32	301.	1441.	149.	140.	1354.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 13:45:38

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****************
*  INPUT DATA  *
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:45:57

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****************
*  INPUT DATA  *
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:45:57

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****************
*  INPUT DATA  *
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```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:03

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*************************
*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

574.3	300.8	3061.8	208.2	-2559.9	3045.4	201.1	2952.8
573.3	300.8	3245.5	220.7	-2731.3	3216.5	213.4	3136.4
573.0	300.8	2764.9	211.3	-2258.8	2777.3	205.3	2687.8
572.3	300.8	2250.1	220.3	-1734.3	2286.7	215.1	2206.2
571.3	300.8	3159.2	275.4	-2591.3	3089.7	267.2	3064.3
570.3	300.8	3303.9	288.0	-2723.4	3221.8	279.7	3209.0
569.3	300.8	3448.6	300.6	-2855.5	3353.9	292.3	3353.7
568.3	300.8	3593.3	313.1	-2987.6	3486.0	304.9	3498.4
567.3	300.8	3738.0	325.7	-3119.7	3618.2	317.5	3643.1
566.3	300.8	3882.7	338.3	-3251.9	3750.3	330.1	3787.8

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
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```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

```
WALL BOTTOM ELEV. (FT)      :      584.23
      PENETRATION (FT)      :       12.77

MAX. BEND. MOMENT (LB-FT)   :  5.1927E+03
      AT ELEVATION (FT)     :      590.07

MAX. SCALED DEFL. (LB-IN^3):  7.4213E+08
      AT ELEVATION (FT)     :      601.32
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NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
* COMPLETE OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--RESULTS

BENDING SCALED NET

ELEVATION (FT)	MOMENT (LB-FT)	SHEAR (LB)	DEFLECTION (LB-IN^3)	PRESSURE (PSF)
601.32	0.0000E+00	0.	7.4213E+08	0.00
600.32	1.0400E+01	31.	6.7060E+08	62.40
599.32	8.3200E+01	125.	5.9909E+08	124.80
598.32	2.8080E+02	281.	5.2774E+08	187.20
597.32	6.6560E+02	499.	4.5690E+08	249.60
597.00	8.3846E+02	582.	4.3444E+08	269.57
596.50	1.1591E+03	692.	3.9966E+08	169.88
596.32	1.2863E+03	720.	3.8726E+08	145.20
596.00	1.5238E+03	762.	3.6538E+08	112.22
595.32	2.0634E+03	819.	3.1985E+08	57.23
594.62	2.6500E+03	839.	2.7443E+08	0.00
594.32	2.8978E+03	836.	2.5602E+08	-24.01
593.32	3.7081E+03	771.	1.9719E+08	-105.34
592.32	4.4131E+03	625.	1.4476E+08	-186.70
591.32	4.9314E+03	398.	9.9922E+07	-268.06
590.32	5.1816E+03	89.	6.3569E+07	-349.42
589.32	5.0824E+03	-301.	3.6119E+07	-430.78
588.32	4.5524E+03	-772.	1.7390E+07	-512.15
587.46	3.6914E+03	-1242.	7.5820E+06	-581.98
587.32	3.5107E+03	-1319.	6.4539E+06	-497.67
586.32	2.0429E+03	-1517.	1.5171E+06	100.12
585.32	6.7532E+02	-1118.	1.2482E+05	697.91
584.32	5.6146E+00	-121.	6.8485E+00	1295.70
584.23	0.0000E+00	0.	0.0000E+00	1350.59

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<----------SOIL PRESSURES---------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
601.32	0.	0.	0.	0.	0.
600.32	62.	0.	0.	0.	0.
599.32	125.	0.	0.	0.	0.
598.32	187.	0.	0.	0.	0.
597.32	250.	0.	0.	0.	0.
597.00	270.	0.	0.	0.	0.
596.50	301.	137.	13.	6.	63.
596.32	301.	164.	17.	8.	80.
596.00	301.	200.	20.	11.	113.
595.32	301.	261.	27.	18.	174.
594.62	301.	325.	33.	25.	238.
594.32	301.	352.	36.	27.	265.
593.32	301.	443.	46.	37.	356.
592.32	301.	534.	55.	46.	447.
591.32	301.	624.	64.	55.	537.
590.32	301.	715.	74.	65.	628.
589.32	301.	806.	83.	74.	719.
588.32	301.	897.	93.	84.	810.
587.46	301.	974.	101.	92.	888.
587.32	301.	987.	102.	93.	900.
586.32	301.	1078.	111.	102.	991.
585.32	301.	1169.	121.	112.	1082.
584.32	301.	1259.	130.	121.	1173.
584.23	301.	1350.	140.	131.	1263.
582.32	301.	1441.	149.	140.	1354.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 13:45:38

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****************
*  INPUT DATA  *
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 13:46:01

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*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:03

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*************************
*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
*************************
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:03

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*************************
*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
*************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

574.3	300.8	3061.8	208.2	-2559.9	3045.4	201.1	2952.8
573.3	300.8	3245.5	220.7	-2731.3	3216.5	213.4	3136.4
573.0	300.8	2764.9	211.3	-2258.8	2777.3	205.3	2687.8
572.3	300.8	2250.1	220.3	-1734.3	2286.7	215.1	2206.2
571.3	300.8	3159.2	275.4	-2591.3	3089.7	267.2	3064.3
570.3	300.8	3303.9	288.0	-2723.4	3221.8	279.7	3209.0
569.3	300.8	3448.6	300.6	-2855.5	3353.9	292.3	3353.7
568.3	300.8	3593.3	313.1	-2987.6	3486.0	304.9	3498.4
567.3	300.8	3738.0	325.7	-3119.7	3618.2	317.5	3643.1
566.3	300.8	3882.7	338.3	-3251.9	3750.3	330.1	3787.8

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

```
WALL BOTTOM ELEV. (FT)      :      584.23
      PENETRATION (FT)      :       12.77

MAX. BEND. MOMENT (LB-FT)   :  5.1927E+03
      AT ELEVATION (FT)     :      590.07

MAX. SCALED DEFL. (LB-IN^3):  7.4213E+08
      AT ELEVATION (FT)     :      601.32
```

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
* COMPLETE OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--RESULTS

BENDING SCALED NET

ELEVATION (FT)	MOMENT (LB-FT)	SHEAR (LB)	DEFLECTION (LB-IN^3)	PRESSURE (PSF)
601.32	0.0000E+00	0.	7.4213E+08	0.00
600.32	1.0400E+01	31.	6.7060E+08	62.40
599.32	8.3200E+01	125.	5.9909E+08	124.80
598.32	2.8080E+02	281.	5.2774E+08	187.20
597.32	6.6560E+02	499.	4.5690E+08	249.60
597.00	8.3846E+02	582.	4.3444E+08	269.57
596.50	1.1591E+03	692.	3.9966E+08	169.88
596.32	1.2863E+03	720.	3.8726E+08	145.20
596.00	1.5238E+03	762.	3.6538E+08	112.22
595.32	2.0634E+03	819.	3.1985E+08	57.23
594.62	2.6500E+03	839.	2.7443E+08	0.00
594.32	2.8978E+03	836.	2.5602E+08	-24.01
593.32	3.7081E+03	771.	1.9719E+08	-105.34
592.32	4.4131E+03	625.	1.4476E+08	-186.70
591.32	4.9314E+03	398.	9.9922E+07	-268.06
590.32	5.1816E+03	89.	6.3569E+07	-349.42
589.32	5.0824E+03	-301.	3.6119E+07	-430.78
588.32	4.5524E+03	-772.	1.7390E+07	-512.15
587.46	3.6914E+03	-1242.	7.5820E+06	-581.98
587.32	3.5107E+03	-1319.	6.4539E+06	-497.67
586.32	2.0429E+03	-1517.	1.5171E+06	100.12
585.32	6.7532E+02	-1118.	1.2482E+05	697.91
584.32	5.6146E+00	-121.	6.8485E+00	1295.70
584.23	0.0000E+00	0.	0.0000E+00	1350.59

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<----------SOIL PRESSURES---------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
601.32	0.	0.	0.	0.	0.
600.32	62.	0.	0.	0.	0.
599.32	125.	0.	0.	0.	0.
598.32	187.	0.	0.	0.	0.
597.32	250.	0.	0.	0.	0.
597.00	270.	0.	0.	0.	0.
596.50	301.	137.	13.	6.	63.
596.32	301.	164.	17.	8.	80.
596.00	301.	200.	20.	11.	113.
595.32	301.	261.	27.	18.	174.
594.62	301.	325.	33.	25.	238.
594.32	301.	352.	36.	27.	265.
593.32	301.	443.	46.	37.	356.
592.32	301.	534.	55.	46.	447.
591.32	301.	624.	64.	55.	537.
590.32	301.	715.	74.	65.	628.
589.32	301.	806.	83.	74.	719.
588.32	301.	897.	93.	84.	810.
587.46	301.	974.	101.	92.	888.
587.32	301.	987.	102.	93.	900.
586.32	301.	1078.	111.	102.	991.
585.32	301.	1169.	121.	112.	1082.
584.32	301.	1259.	130.	121.	1173.
584.23	301.	1350.	140.	131.	1263.
582.32	301.	1441.	149.	140.	1354.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 13:45:38

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****************
*  INPUT DATA  *
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 13:46:01

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*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
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I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:45:57

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****************
*  INPUT DATA  *
****************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:03

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*************************
*   SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
*************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
601.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.3	62.4	0.0	0.0	62.4	62.4	0.0	0.0
599.3	124.8	0.0	0.0	124.8	124.8	0.0	0.0
598.3	187.2	0.0	0.0	187.2	187.2	0.0	0.0
597.3	249.6	0.0	0.0	249.6	249.6	0.0	0.0
597.0	269.6	0.0	0.0	269.6	269.6	0.0	0.0
596.5	300.8	137.0	13.4	169.9	350.2	6.1	62.8
596.3	300.8	163.9	17.0	145.2	364.2	8.3	80.4
596.0	300.8	200.0	20.4	112.2	393.0	11.5	112.7
595.3	300.8	261.4	26.9	57.2	448.3	17.9	174.4
594.6	300.8	325.3	33.5	0.0	505.6	24.5	238.3
594.3	300.8	352.1	36.3	-24.0	529.6	27.3	265.1
593.3	300.8	442.8	45.7	-105.3	611.0	36.7	355.9
592.3	300.8	533.5	55.1	-186.7	692.4	46.1	446.7
591.3	300.8	624.3	64.5	-268.1	773.7	55.5	537.4
590.3	300.8	715.1	73.9	-349.4	855.1	64.9	628.2
589.3	300.8	805.8	83.3	-430.8	936.5	74.3	719.0
588.3	300.8	896.6	92.7	-512.1	1017.8	83.7	809.7
587.3	300.8	987.3	102.1	-593.4	1099.1	93.1	900.4
586.3	300.8	1078.0	111.5	-674.7	1180.4	102.5	991.1
585.3	300.8	1168.7	120.8	-756.1	1261.8	111.9	1081.9
584.3	300.8	1259.4	130.2	-837.4	1343.1	121.3	1172.6
583.3	300.8	1350.2	139.6	-918.8	1424.5	130.6	1263.3
582.3	300.8	1440.9	149.0	-1000.1	1505.8	140.0	1354.1
581.3	300.8	1531.7	158.4	-1081.5	1587.2	149.4	1444.8
580.3	300.8	1622.4	167.8	-1162.8	1668.5	158.8	1535.6
580.0	300.8	2057.9	180.5	-1587.0	2057.2	170.1	1937.0
579.3	300.8	2663.1	183.0	-2190.1	2621.8	172.2	2504.0
578.3	300.8	2329.0	158.0	-1877.4	2363.0	150.9	2220.3
577.3	300.8	2511.8	170.2	-2048.0	2533.6	163.1	2403.0
576.3	300.8	2695.0	182.4	-2218.9	2704.4	175.3	2586.1
575.3	300.8	2878.3	195.2	-2389.4	2875.0	188.1	2769.3

574.3	300.8	3061.8	208.2	-2559.9	3045.4	201.1	2952.8
573.3	300.8	3245.5	220.7	-2731.3	3216.5	213.4	3136.4
573.0	300.8	2764.9	211.3	-2258.8	2777.3	205.3	2687.8
572.3	300.8	2250.1	220.3	-1734.3	2286.7	215.1	2206.2
571.3	300.8	3159.2	275.4	-2591.3	3089.7	267.2	3064.3
570.3	300.8	3303.9	288.0	-2723.4	3221.8	279.7	3209.0
569.3	300.8	3448.6	300.6	-2855.5	3353.9	292.3	3353.7
568.3	300.8	3593.3	313.1	-2987.6	3486.0	304.9	3498.4
567.3	300.8	3738.0	325.7	-3119.7	3618.2	317.5	3643.1
566.3	300.8	3882.7	338.3	-3251.9	3750.3	330.1	3787.8

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

```
WALL BOTTOM ELEV. (FT)      :      584.23
      PENETRATION (FT)      :       12.77

MAX. BEND. MOMENT (LB-FT)   :  5.1927E+03
      AT ELEVATION (FT)     :      590.07

MAX. SCALED DEFL. (LB-IN^3):  7.4213E+08
      AT ELEVATION (FT)     :      601.32
```

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 14:46:04

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****************************
* COMPLETE OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--RESULTS

BENDING SCALED NET

ELEVATION (FT)	MOMENT (LB-FT)	SHEAR (LB)	DEFLECTION (LB-IN^3)	PRESSURE (PSF)
601.32	0.0000E+00	0.	7.4213E+08	0.00
600.32	1.0400E+01	31.	6.7060E+08	62.40
599.32	8.3200E+01	125.	5.9909E+08	124.80
598.32	2.8080E+02	281.	5.2774E+08	187.20
597.32	6.6560E+02	499.	4.5690E+08	249.60
597.00	8.3846E+02	582.	4.3444E+08	269.57
596.50	1.1591E+03	692.	3.9966E+08	169.88
596.32	1.2863E+03	720.	3.8726E+08	145.20
596.00	1.5238E+03	762.	3.6538E+08	112.22
595.32	2.0634E+03	819.	3.1985E+08	57.23
594.62	2.6500E+03	839.	2.7443E+08	0.00
594.32	2.8978E+03	836.	2.5602E+08	-24.01
593.32	3.7081E+03	771.	1.9719E+08	-105.34
592.32	4.4131E+03	625.	1.4476E+08	-186.70
591.32	4.9314E+03	398.	9.9922E+07	-268.06
590.32	5.1816E+03	89.	6.3569E+07	-349.42
589.32	5.0824E+03	-301.	3.6119E+07	-430.78
588.32	4.5524E+03	-772.	1.7390E+07	-512.15
587.46	3.6914E+03	-1242.	7.5820E+06	-581.98
587.32	3.5107E+03	-1319.	6.4539E+06	-497.67
586.32	2.0429E+03	-1517.	1.5171E+06	100.12
585.32	6.7532E+02	-1118.	1.2482E+05	697.91
584.32	5.6146E+00	-121.	6.8485E+00	1295.70
584.23	0.0000E+00	0.	0.0000E+00	1350.59

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<----------SOIL PRESSURES---------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
601.32	0.	0.	0.	0.	0.
600.32	62.	0.	0.	0.	0.
599.32	125.	0.	0.	0.	0.
598.32	187.	0.	0.	0.	0.
597.32	250.	0.	0.	0.	0.
597.00	270.	0.	0.	0.	0.
596.50	301.	137.	13.	6.	63.
596.32	301.	164.	17.	8.	80.
596.00	301.	200.	20.	11.	113.
595.32	301.	261.	27.	18.	174.
594.62	301.	325.	33.	25.	238.
594.32	301.	352.	36.	27.	265.
593.32	301.	443.	46.	37.	356.
592.32	301.	534.	55.	46.	447.
591.32	301.	624.	64.	55.	537.
590.32	301.	715.	74.	65.	628.
589.32	301.	806.	83.	74.	719.
588.32	301.	897.	93.	84.	810.
587.46	301.	974.	101.	92.	888.
587.32	301.	987.	102.	93.	900.
586.32	301.	1078.	111.	102.	991.
585.32	301.	1169.	121.	112.	1082.
584.32	301.	1259.	130.	121.	1173.
584.23	301.	1350.	140.	131.	1263.
582.32	301.	1441.	149.	140.	1354.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 15-APRIL-2015 TIME: 13:45:38

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****************
*  INPUT DATA  *
****************
```

I.--HEADING
'LITTLE MANISTEE SLB SSP BARRIER

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

III.--WALL DATA
ELEVATION AT TOP OF WALL = 601.32 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	597.00
5.00	597.00
10.00	597.00
15.00	597.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = 1.00
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = 1.50

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
110.00	110.00	35.00	0.00	18.90	0.00	596.50	0.00	DEF	DEF
95.00	95.00	30.00	0.00	16.20	0.00	580.00	0.00	DEF	DEF
115.00	115.00	35.00	0.00	18.90	0.00	573.00	0.00	DEF	DEF
110.00	110.00	32.00	0.00	17.28	0.00	560.00	0.00	DEF	DEF
125.00	125.00	35.00	0.00	18.90	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 601.32 (FT)
LEFTSIDE ELEVATION = 596.50 (FT)

US Army Corps of Engineers® Detroit District	PROJECT TITLE: FY14 Kaukauna Spillway Walkway and Pier Replacement	COMPUTED BY: Heather Calappi		DATE: 3/31/2014
	COMPUTATION TITLE: Walkway Design	CHECKED BY: BG	DATE: 4/7/2014	

Note: These calculations are for the leftmost Kaukauna bridge span which is approx 49'-7 1/2" face of pier to face of abutment at d/s edge of d/s girder. When the model was prepared this dimension was estimated at 51'3". Additionally, it was assumed the walkway girders would be spaced at 3'-6". The actual spacing is 27.75". The model will not be updated as results will be slightly conservative.

References

1. LRFD Guide Specification for the Design of Pedestrian Bridges, December 2009
2. AASHTO LRFD 2012
3. AASHTO Standard Specification for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, Fifth Edition 2009
4. Hilti Adhesive Anchoring Systems
5. ACI 318-11, Structural Concrete Building Code

Determine Design Loadings

Note: Loadings will be placed into STAAD to determine design bending moments and shears.

Dead Load

Beam Self Weight	See STAAD Analysis		
Steel Bracing	See STAAD Analysis		
Galvanized Steel Grating	15	lb/ft	Assumed
Handrailing & Toe Plate	25	lb/ft	Assumed

Live Load

Live Load Pressure=	90	psf	(Ref 1)
Bridge Width, w=	3.5	feet	(To Outer Edge Of Girder)
Load Applied At Girder=	157.5	lb/ft	

Wind Loading

Lateral Wind Loading - Transverse Direction

$$P_z = 0.00256 K_z G V^2 I_R C_d$$

(AASHTO Signs Arcticles 3.8 and 3.9)

Design Wind Speed, V=	90	mph	
K_z=	1		(H=0, Ref 3 C3.8.4 conservative to use 1.0)
G=	1.14		(Ref 3, 3.8.5)
I_r=	1.15		(Ref 1 Section 3.4)
C_d=	1.7		(Flat Shape)
Design Wind Pressure, P_z=	46.21	psf	

Area Impacted by Wind:

Toe Plate Area =	3420	in^2
Girder Area =	11970	in^2
Handrail Area Impacted by Wind =	2952	in^2
TOTAL	127.4	ft^2
Lateral Wind Loading =	0.124	k/ft

*** Assumed Transverse Lateral Wind Load is acting on the centroid of the girder in the Staad Model.

Vertical Wind Loading

$$Vertical\ Wind\ Loading = (0.02ksf) w_{deck}$$

(Ref 2 Section 3.8.2)

Upward Wind Force =	0.02	ksf
Width of deck, w_{deck} =	3.50	ft
Vertical Wind Load @ windward quarterpoint of deck =	0.07	k/ft

The load on the deck is to be distributed to the girders. Assuming a simply supported beam, 75% of the load is distributed to the windward girder and 25% of the load to the leeward girder.

Vertical Wind Load on Windward Girder =	0.053	k/ft
Vertical Wind Load on Opposite Girder =	0.018	k/ft

US Army Corps of Engineers Detroit District	PROJECT TITLE: FY14 Kaukauna Spillway Walkway and Pier Replacement	COMPUTED BY: Heather Calappi		DATE: 3/31/2014
	COMPUTATION TITLE: Walkway Design	CHECKED BY: BG	DATE: 4/7/2014	

Seismic Load

Seismic Load Determination

Peak Ground Accerlation Coeff, PGA =	1.5	%	Fig 3.10.2.1-1
Long-period spectral acceleration coeff, S_1 =	2	% g	Fig 3.10.2.1-3
Short-period spectral acceleration coeff, S_s =	4	% g	Fig 3.10.2.1-2

Assume Site Class A

Determine Seismic Zone

$$S_{D1} = F_v S_1$$ Eq 3.10.4.2-6

Site Factor, F_v =	0.8	Table 3.10.3.2-3
Accerlation Coeff, S_{D1} =	0.016	
Seismic Zone =	1	Table 3.10.6-1

Per 4.7.41 because the bridge is in seismic zone 1, seismic analysis is not required. However, Section 3.10.9 requires a minimum design connection force for all seismic zones.

Determine Minimum Design Connection Force

$$A_S = F_{pga} PGA$$ Eq 3.10.4.2-2

Site Factor, F_{pga} =	0.8	Table 3.10.3.2-1
Accerlation Coeff, A_s =	0.012	

Therefore, horizontal design connection force in retrained directions shall not be less than .25 times vertical reaction due to tributary permanent load and tributary live loads assumed to exist during an earthquake. It is assumed no live load will exist during an earthquake. Ref: Section 3.10.9.2
NOTE: CHECKER NOTED THAT WITH As<0.05 COULD HAVE USED .15*DL REACTION BUT SINCE THIS IS NOT CONTROLLING LOAD MODEL AND CALCS WILL NOT BE REVISED.

Determine Dead Load

Dead Load Reaction	3	kips	(STAAD Analysis)
Total Horizontal Force Per Support	0.8	kips	

Ice Accretion/Snow Loading

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Snowfall (in.)	11.8	8.9	8.5	1.7	0.1	T	T	T	T	0.4	3.5	8.1	43.0

Reference: http://lwf.ncdc.noaa.gov/oa/climate/online/ccd/snowfall.html

According to Reference 2 Section 3.9.6, snowloads are typically negligible in areas of the United States that are below 2,000 ft elevation and east of longitude 105°W. Kaukauna, WI is approximately at 710 ft elevation and well east of longitude 105°W. Therefore, given the average snowfall accumulations and the previous statement, ice accretion and snow loading will have minimal implications on the project. Loading due to ice accretion and snow loading will still be included for safe engineering practices.

ASCE 7 Figure 7-1 recommends a ground snow load of 40 psf be used in Kaukauna, WI.

Ground Snow Load, p_g =	40	psf	(ASCE 7 Figure 7-1)
Width of deck, w_{deck} =	3.50	ft	
Ice Accretion/Snow Load on Girder =	70	lb/ft	

Thermal Loading

Per Reference 2 3.12.2, use Procedure A to determine the design thermal movement associated with a uniform temperature change.

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The number of freezing days (average temperature less than 32 deg F) is more than 14. Therefore, Kaukauna, WI is considered a Cold Climate region and the Temperature Ranges for Steel will be -30° to 120°F (Reference 2 Table3.12.2.1-1.

$$\Delta_T = \alpha\, L\, (T_{MaxDesign} - T_{MinDesign})$$ (Reference 2 3.12.2.3-1)

$T_{MinDesign}$=	-30	°F	
$T_{MaxDesign}$=	120	°F	
Coefficient of Thermal Expansion, α=	0.0000065	in/in/°F	(AISC Table 17-11)
Expansion Length of Girder, L=	570	in	
Design Thermal Movement Range, Δ_T=	0.55575	in	

Load Cases

Strength 1:	1.25DL+1.75LL	DL=	Dead Load
Strength 3:	1.25DL+1.4W	LL=	Live Load
Extreme 1:	1.25DL+0.5LL+1.0E	S=	Snow Load
Extreme 2:	1.0DL+0.5LL+1.0S	W=	Wind Load
Service 1:	1.0DL+1.0LL+.3W	E =	Seismic Load
Service 2:	1.0DL+1.3LL		
Fatigue 1:	1.0LL+1.0W		

STAAD RESULTS

Primary Girder

A STAAD Model Was Developed - Refer To *Kaukauna Walkway.std*

V_{MAX}:	16.371	KIPS	Vertical Shearing Load
Load Cond:	Strength 1 (Beam 10 and 11)		
M_Z:	141.5569167	K-FT	Strong Axis Bending
Load Cond:	Strength 1 (Beam 15)		
M_Y:	8.476416667	K-FT	Weak Axis Bending
Load Cond:	Strength 3 (Beam 11)		

Top and Bottom Lacing (Along Length of Span)

P_{MAX}:	**7.12**	KIPS	
Location	Beam no. = 16		Axial Loading
Load Cond:	Strength 3		

Vertical Cross Bracing

P_{MAX}:	**11.44**	KIPS	
Location	Beam no. = 36		Axial Loading
Load Cond:	Strength 3		

Design Primary Girder

Design Beam Section:	W21x55	

Beam Properties

Total Span, L=	47.5	ft
Flange Width, b_f=	8.22	in
Flange Thickness, t_f=	0.522	in
Beam Depth, d=	20.8	in
Web/flange radius, k_{det} =	1.1875	in
Web Depth for Shear, D=	18.43	in
Web Thickness, t_w=	0.375	in
Section Modulus, S_x=	110	in^3
Section Modulus, S_y=	11.8	in^4

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Moment of Inertia (x-axis), I_x= 1140 in^4

Plastic Section Modulus, Z_x= 126 in^3

$$L_p = 1.0 r_t \sqrt{\frac{E}{F_y}}$$ (Ref 2 Eqn 6.10.8.2.3-4)

r_t = effective radius of gyration for lateral torsional buckling (in.)

$$= \frac{b_{fc}}{\sqrt{12\left(1+\frac{1}{3}\frac{D_c t_w}{b_{fc} t_{fc}}\right)}}$$ (6.10.8.2.3-9)

r_t= 2.109196182 in

Steel Yield Strength, F_y = 50 ksi

Modulus of Elasticity, E= 29000 ksi

Lower Unbraced Limit, L_p= 4.23 ft

$$L_r = \pi r_t \sqrt{\frac{E}{F_{yr}}}$$ (Reference 2 6.10.8.2.3-5)

r_t= 2.11 in

Compression Flange Yield Stress incl Residual Stress Effects, F_{yr}= 35 ksi (Ref 2, Sect 6.10.8.2.2 = .7Fy)

Upper Unbraced Length Limit, L_r= 15.89 ft

Unbraced Length, L_b= 9.50 ft

h/tw= 54.07466667

Check Cross Section Proportion Limits (REF 2 Section 6.10.2)

Web Proportion Limits

$$\frac{D}{t_w} \le 150$$ (Ref 2 Eqn 6.10.2.1.1-1)
(No Longitudinal Web Stiffeners)

D/t_w= 49.13333333 OK

Flange Proportion Limits

$$\frac{b_f}{2t_f} \le 12.0$$ (Ref 2 Eqn 6.10.2.2-1)

$\lambda_f = b_f/2t_f$= 7.873563218 OK

$$b_f \ge \frac{D}{6}$$ (Ref 2 Eqn 6.10.2.2-2)

b_f= 8.22 in

D/6= 3.070833333 in OK

$$t_f \ge 1.1 t_w$$ (Ref 2 Eqn 6.10.2.2-3)

t_f= 0.522

$1.1t_w$= 0.4125 OK

$$0.1 \le \frac{I_{yc}}{I_{yt}} \le 10$$ (Ref 2 Eqn 6.10.2.2-4)

I_{yc}= 1140 in^4

I_{yt}= 1140 in^4

I_{yc}/I_{yt}= 1 OK

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Size W-Shape Beam

Yield Stress, F_y= 50 ksi

$$F_y = \frac{M_u}{\phi S_{req}}$$

Maximum Bending Moment, M_u= 141.6 ft-kips

ϕ= 1.00 (Ref 2 Section 6.5.4.2)

Required Section Modulus, S_{req}= 33.97 in^3

Calculate Applied Bending Stresses

Strong Axis Bending

Maximum Bending Moment, M_u= 141.56 ft-kips

Beam Strong Axis Section Modulus, S_x= 110.00 in^3

Steel Yield Strength, F_y = 50.00 ksi

Applied Bending Stress, F_b= 15.44 ksi

Weak Axis Bending

Maximum Bending Moment, M_u= 8.48 ft-kips

Beam Weak Axis Section Modulus, S_y= 11.8 in^3

Steel Yield Strength, F_y = 50 ksi

Applied Bending Stress, F_b= 8.62 ksi

Checks

Check if shape is compact

Shape must satisfy both of the following criteria

1) $$\frac{b_f}{2t_f} \le 0.38\sqrt{\frac{E}{F_y}}$$ (Ref 2 Section 6.10.8.2.2)

Flange Width, b_f= 8.22 in

Flange Thickness, t_f= 0.522 in

Steel Yield Strength, Fy = 50 ksi

Modulus of Elasticity, E= 29000 ksi

$b_f/2t_f$= 7.87

0.38√(E/Fy) 9.152

bf/tf < 0.38(E/Fy)^0.5 Therefore Shape Meets Compact Criteria

2) $$\frac{h}{t_w} \le 5.7\sqrt{\frac{E}{F_y}}$$ (Ref 2 Section 6.10.1.10.2)

Steel Yield Strength, Fy = 50 ksi

Modulus of Elasticity, E= 29000 ksi

h/t_w= 54.07

$5.7*E/\sqrt{F_y}$= 137.27

Shape Meets Non Compact Criteria

Both Criteria are satisfied, therefore shape is compact, R_b=1

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Check Lateral Torsional Buckling

- If $L_b \le L_p$, then:

$$F_{nc} = R_b R_h F_{yc} \qquad (6.10.8.2.3\text{-}1)$$

- If $L_p < L_b \le L_r$, then:

$$F_{nc} = C_b\left[1-\left(1-\frac{F_{yr}}{R_h F_{yc}}\right)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] R_b R_h F_{yc} \le R_b R_h F_{yc} \qquad (6.10.8.2.3\text{-}2)$$

- If $L_b > L_r$, then:

$$F_{nc} = F_{cr} \le R_b R_h F_{yc} \qquad (6.10.8.2.3\text{-}3)$$

L_b = unbraced length (in.)

L_p = limiting unbraced length to achieve the nominal flexural resistance of $R_b R_h F_{yc}$ under uniform bending (in.)

$$= 1.0 r_t \sqrt{\frac{E}{F_{yc}}} \qquad (6.10.8.2.3\text{-}4)$$

L_r = limiting unbraced length to achieve the onset of nominal yielding in either flange under uniform bending with consideration of compression-flange residual stress effects (in.)

$$= \pi r_t \sqrt{\frac{E}{F_{yr}}} \qquad (6.10.8.2.3\text{-}5)$$

Unbraced Length, L_b=	9.50	ft	
Lower Unbraced Limit, L_p=	4.23	ft	
Upper Unbraced Limit, L_r=	15.89	ft	
	$L_p<L_b<=L_r$		
Moment Gradient Modifier, C_b=	1	Conservative	
Compression Flange Yield Stress incl Residual Stress Effects, F_{yr}=	35	ksi	
Hybrid Factor, R_h=	1		(Ref 2 Section 6.10.1.10.1)
Web Load Shedding Factor, R_b=	1		(Ref 2 Section 6.10.1.10.2)
Compression Flange Yield Strength, F_{yc}=	50	ksi	
Lateral Torsional Buckling Resistance, F_{nc}=	43.23	ksi	
Lateral Torsional Buckling Resistance, $M_n=F_{nc}S_x$=	396.231	kip-ft	

Check Deflection

Deflections as determined from the STAAD Model

Service Load 1 Deflection, δ_{max}=	1.1260	in	(Ref 1, Section 5)
L/360=	1.5833	in	

Deflection Less than L/360, OK

Maximum DL Deflection, δ_{max}=	0.495	in

Determine Camber

Per Ref 2, camber is only required to offset DL deflection. Past ATR reviews have recommended camber for deflection due to DL + .5LL. Therefore, 1" camber will be required.

Check Vibration

The fundamental frequency in a vertical mode without consideration of live load should be greater than 3.0 Hz to avoid the first harmonic.

$$f = 0.18\sqrt{\frac{g}{\Delta_{DL}}} \qquad \text{(Reference 1 6.1)}$$

Acceleration Due to Gravity, g =	32.2	ft/s^2	
Maximum Vertical Deflection due to Service Load 1, Δ_{SL1} =	0.093833333	ft	Ref 1, 6.1
Fundamental Frequency in Vertical Direction, f =	3.334	Hz	

Meets Vibration Criterion

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The fundamental frequency in a lateral mode without consideration of live load should be greater than 1.3 Hz to avoid the first harmonic.

Acceleration Due to Gravity, g =	32.2	ft/s^2	
Maximum Lateral Deflection due to Service Load 1, Δ_{SL1} =	0.010583333	ft	Ref 1, 6.1
Fundamental Frequency in Lateral Direction, f =	9.929	Hz	

Meets Vibration Criterion

Check Shear

$$V_n = V_{cr} = CV_p \qquad (6.10.9.2\text{-}1)$$

in which:

$$V_p = 0.58 F_{yw} D t_w \qquad (6.10.9.2\text{-}2)$$

where:

C = ratio of the shear-buckling resistance to the shear yield strength determined by Eqs. 6.10.9.3.2-4, 6.10.9.3.2-5 or 6.10.9.3.2-6 as applicable, with the shear-buckling coefficient, k, taken equal to 5.0

V_{cr} = shear-buckling resistance (kip)

V_n = nominal shear resistance (kip)

V_p = plastic shear force (kip)

F_{yw}=	50	ksi
D=	18.43	in
t_w=	0.375	in

- If $\frac{D}{t_w} \le 1.12\sqrt{\frac{Ek}{F_{yw}}}$, then:

$$C = 1.0 \qquad (6.10.9.3.2\text{-}4)$$

- If $1.12\sqrt{\frac{Ek}{F_{yw}}} < \frac{D}{t_w} \le 1.40\sqrt{\frac{Ek}{F_{yw}}}$, then:

$$C = \frac{1.12}{\frac{D}{t_w}}\sqrt{\frac{Ek}{F_{yw}}} \qquad (6.10.9.3.2\text{-}5)$$

- If $\frac{D}{t_w} > 1.40\sqrt{\frac{Ek}{F_{yw}}}$, then:

$$C = \frac{1.57}{\left(\frac{D}{t_w}\right)^2}\left(\frac{Ek}{F_{yw}}\right) \qquad (6.10.9.3.2\text{-}6)$$

D/t_w=	49.13333333		
$1.12\sqrt{(Ek/F_{yw})}$=	60.31	(6.10.9.3.2-4 Applies, k=5)	(Assuming No Stiffeners)
C=	1		
Nominal Shear Capacity of Girder, V_n=	200.37	kips	
Φ=	1.00		
Factored Shear Capacity, ΦV_n=	200.37	kips	

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Check Torsional Shear Stress

At 4.25 k-ft torsional stress was considered negligible.

Check Web Yielding

Depth of beam, d=	20.8	in
Maximum load applied to beam web, R_u=	16.371	kips
Distance of Load from End of Member, l=	0	ft

USE D6.5.2-3

- For interior-pier reactions and for concentrated loads applied at a distance from the end of the member that is greater than *d*:

$$R_n = (5k + N) F_{yw} t_w \qquad \text{(D6.5.2-2)}$$

- Otherwise:

$$R_n = (2.5k + N) F_{yw} t_w \qquad \text{(D6.5.2-3)}$$

where:

ϕ_b = resistance factor for bearing specified in Article 6.5.4.2

d = depth of the steel section (in.)

k = distance from the outer face of the flange resisting the concentrated load or bearing reaction to the web toe of the fillet (in.)

N = length of bearing (in.). N shall be greater than or equal to k at end bearing locations.

k=	0.842	in
N=	7	in
F_y=	50	ksi
t_w=	0.375	in
Φ=	1	
Web Capacity, ΦRn=	170.71875	kips
Maximum load applied to beam web, R_u=	16.371	kips

Web Has Sufficient Capacity, OK

Check Web Crippling

- For interior-pier reactions and for concentrated loads applied at a distance from the end of the member that is greater than or equal to *d*/2:

$$R_n = 0.8 t_w^2 \left[1 + 3\left(\frac{N}{d}\right)\left(\frac{t_w}{t_f}\right)^{1.5}\right]\sqrt{\frac{E F_{yw} t_f}{t_w}} \qquad \text{(D6.5.3-2)}$$

- Otherwise:
  - If $N/d \le 0.2$, then:

$$R_n = 0.4 t_w^2 \left[1 + 3\left(\frac{N}{d}\right)\left(\frac{t_w}{t_f}\right)^{1.5}\right]\sqrt{\frac{E F_{yw} t_f}{t_w}} \qquad \text{(D6.5.3-3)}$$

  - If $N/d > 0.2$, then:

$$R_n = 0.4 t_w^2 \left[1 + \left(\frac{4N}{d} - 0.2\right)\left(\frac{t_w}{t_f}\right)^{1.5}\right]\sqrt{\frac{E F_{yw} t_f}{t_w}} \qquad \text{(D6.5.3-4)}$$

Depth of beam, d=	20.8	in
Maximum load applied to beam web, R_u=	16.371	kips
Distance of Load from End of Member, l=	0	ft

USE D6.5.3-3 or 3-4

N=	7	in

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F_y=	50	ksi
t_w=	0.375	in
t_f=	0.522	in
Modulus of Elasiticity, E=	29000	ksi
N/d=	0.336538462	
Φ=	0.8	
Web Capacity, ΦRn=	108.5486649	kips
Maximum load applied to beam web, R_u=	16.371	kips
	Web Has Sufficient Capacity, OK	

Check Net Section Fracture

6.10.1.8—Net Section Fracture

When checking flexural members at the strength limit state or for constructibility, the following additional requirement shall be satisfied at all cross-sections containing holes in the tension flange:

$$f_t \le 0.84\left(\frac{A_n}{A_g}\right)F_u \le F_{yt} \qquad (6.10.1.8\text{-}1)$$

where:

A_n = net area of the tension flange determined as specified in Article 6.8.3 (in.^{2})

A_g = gross area of the tension flange (in.^{2})

f_t = stress on the gross area of the tension flange due to the factored loads calculated without consideration of flange lateral bending (ksi)

F_u = specified minimum tensile strength of the tension flange determined as specified in Table 6.4.1-1 (ksi)

Diameter of Holes in Flange,D=d+1/16=	0.8125	in	
Number of holes in Flange, n=	2		
Flange Width, b_f=	8.22	in	
Flange Thickness, t_f=	0.522	in	
F_u=	65	ksi	A709
Net Area, $A_n=(b_f-nD)t_f$=	3.44259	in^2	
Gross Area, $A_g=b_ft_f$=	4.29084	in^2	
Yield Stress, F_y=	50	ksi	
$0.84(A_n/A_g)F_u$=	43.81	ksi	
Bending Stress, f_t=	15.44	ksi	
	Flange Has Sufficient Capacity, OK		

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Check Web Bend Buckling Resistance

6.10.1.9—Web Bend-Buckling Resistance

6.10.1.9.1—Webs without Longitudinal Stiffeners

The nominal bend-buckling resistance shall be taken as:

$$F_{crw} = \frac{0.9Ek}{\left(\frac{D}{t_w}\right)^2} \qquad (6.10.1.9.1\text{-}1)$$

but not to exceed the smaller of R_hF_{yc} and $F_{yw}/0.7$.

in which:

k = bend-buckling coefficient

$$= \frac{9}{(D_c/D)^2} \qquad (6.10.1.9.1\text{-}2)$$

where:

D_c = depth of the web in compression in the elastic range (in.). For composite sections, D_c shall be determined as specified in Article D6.3.1.

R_h = hybrid factor specified in Article 6.10.1.10.1

When both edges of the web are in compression, k shall be taken as 7.2.

Modulus of Elasiticity, E=	29000	ksi
Bend-Buckling Coefficient, k=	36	
Web Depth, D=	18.43	in
Web Thickness, t_w=	0.375	in
Hybrid Factor, R_h=	1	
F_y=	50	ksi
R_hF_y=	50	ksi
$F_y/0.7$=	71.429	ksi
Calculated F_{crw}=	389.22	ksi
Applied F_{crw}=	50.00	ksi
Web Bend-Buckling Resistance, $M_n=F_{crw}S_x$=	458.33	kip-ft
Φ=	1	
Web Bend-Buckling Capacity, $ΦM_n=ΦF_{crw}S_x$=	458.3333333	kip-ft
Maximum Bending Moment, M_u=	141.6	kip-ft
	Web Has Sufficient Capacity, OK	

Check Combined Bending Stresses

At the strength limit state, the following requirement shall be satisfied:

$$f_{bu} + \frac{1}{3} f_\ell \le \phi_f F_{nc} \qquad (6.10.8.1.1\text{-}1)$$

where:

ϕ_f = resistance factor for flexure specified in Article 6.5.4.2

f_{bu} = flange stress calculated without consideration of flange lateral bending determined as specified in Article 6.10.1.6 (ksi)

f_ℓ = flange lateral bending stress determined as specified in Article 6.10.1.6 (ksi)

F_{nc} = nominal flexural resistance of the flange

determined as specified in Article 6.10.8.2 (ksi)

Note: For simplicity use max bending and max lateral bending stress even though they do not occur during same load combination.

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Flange Bending Stress, f_{bu}=	15.44	ksi	
Flange Lateral Bending Stress, f_l=	8.62	ksi	
Φ=	1		(6.5.4.2)
Flange Capacity, F_{nc}=	43.23	ksi	(Flange is Compact)
f_{bu}+1/3f_l=	18.31593431	ksi	

Flange Has Sufficient Capacity, OK

Check:

$$f_{bu} + f_{\ell} \leq \phi_f R_h F_{yc}, \qquad (6.10.3.2.1\text{-}1)$$

Flange Capacity, F_{yc}=	50	ksi
f_{bu}+f_l=	24.06	ksi
Hybrid Factor, R_h=	1.00	
Φ=	1	(6.5.4.2)
$\Phi R_h F_{yc}$=	50	ksi

Flange Has Sufficient Capacity, OK

Girder Design Summary

Failure Mode	Capacity	Required	Check
Flexure (Section Modulus)	**110.00**	**33.97**	**OK**
Lateral Torsional Buckling (Bending Moment ft-kips)	**396.231**	**141.56**	**OK**
Shear (Kips)	**200.37**	**16.371**	**OK**
Weak Axis Flexure (Bending Moment ft-kips)	**49.17**	**8.48**	**OK**

Beam Size: W21x55
Beam Material: FCM A572 Gr 50 with A709 Charpy requirements

Design Top and Bottom Lacing

Design Beam Section: L3x3x3/8

Compression Members

Check Limiting Slenderness Ratio for Bracing Member

Effective Length Factor, K =	1		(Ref 2 Section 4.6.2.5)
Unbraced Length, L	6.4167	ft	
Governing Radius of Gyration, r_s	0.581	in	Z-Axis Governs

$$\frac{KL}{r_s} \leq 140 \qquad \text{(Ref 2 Section 6.9.3)}$$

KL/r_s= 132.5 **OK**

$KL/r_s \leq 140$ Therefore, shape meets limiting slenderness requirement

Check for Slender Elements

Check leg

Width of Plate, b =	3	in	Width of Outstanding Leg (Ref 2 Section 6.9.4.2.1-1)
Plate Thickness, t =	0.375	in	
Plate Buckling Coefficient, k =	0.45		(Ref 2 Section 6.9.4.2.1-1)
Modulus of Elasticity, E =	29000	ksi	
Yield Strength, F_y =	36	ksi	

$$\frac{b}{t} \le k\sqrt{\frac{E}{F_y}}$$ (Ref 2 Section 6.9.4.2.1-1)

b/t =	8.0	
$k\sqrt{(E/F_y)}$	12.8	
	Leg of angle is non-slender	

Determine Axial Compression

For non-slender, noncomposite, equal leg angle members in compression only flexural buckling must be checked.

Flexural Buckling

Gross cross-sectional area, A_g = 2.11 in^2

$$P_e = \frac{\pi^2 E}{\left(\frac{KL}{r_s}\right)^2} A_g$$ (Reference 2 6.9.4.1.2-1)

Elastic Critical Buckling Resistance, P_e = 34.4 kips

For compression member cross-sections that consists entirely of non-slender elements take Q=1.0 (Reference 2 6.9.4.2.1)

Equivalent Nominal Yield Resistance, $P_o = QF_yA_g$ =	75.96	kips
P_e/P_o =	0.45	

Since Pe/Po > 0.44 use equation 6.9.4.1.1-1 from reference 2.

$$P_n = \left[0.658^{\left(\frac{P_o}{P_e}\right)}\right] P_o$$ (Reference 2 6.9.4.1.1-1)

P_n =	30.13	kips	
Available Strength, $P_r = \Phi_c P_n$	27.1	kips	(Φc = 0.9 for steel members subjected to axial compression)
Ultimate Load, P_{MAX} =	7.12	kips	
PMAX < Pr		**OK**	

Tension Members

$$P_r = \phi_y P_{ny} = \phi_y F_y A_g \quad (6.8.2.1\text{-}1)$$

$$P_r = \phi_u P_{nu} = \phi_u F_u A_n R_p U \quad (6.8.2.1\text{-}2)$$

Resistance Factor for Yielding of Tension Members, Φ_y =	0.95		(Ref 2 6.5.4.2)
Resistance Factor for Fracture of Tension Members, Φ_u =	0.8		(Ref 2 6.5.4.2)
Tensile Strength, F_u =	58	ksi	
Reduction Factor for Holes, R_p =	1		Assumed holes are drilled full size.
Reduction Factor for Shear Lag, U =	0.6		Case 8 (Ref 2 6.8.2.2-1)
Required $A_g = P_{max}/(\Phi_y F_y)$ =	0.21	in^2	
Required $A_n = P_{max}/(\Phi_u F_u R_p U)$ =	0.26	in^2	

A_g =	2.11	in^2	**OK**
$A_n = A_g - A_{HOLES}$ (Assuming 3/4" Bolts)	1.78	in^2	**OK**

Check slenderness ratio requirement for bracing member

$$\frac{L_b}{r_s} \leq 240$$ (Ref 2 6.8.4)

L/r_s =	132.53	Non-slender

Top and Bottom Lacing Design Summary

Size: L3x3x3/8

Member Material: A36 Steel

Design Vertical Cross Bracing

Design Beam Section: L3x3x3/8

Compression Members

Check Limiting Slenderness Ratio for Bracing Member

Lacing was inserted into the Structural Model. Therefore, it must be considered a primary member in calculations.

Effective Length Factor, K =	1		(Ref 2 Section 4.6.2.5)
Unbraced Length, L	2.9167	ft	
Governing Radius of Gyration, r_s	0.581	in	Z-Axis Governs

$$\frac{KL}{r_s} \leq 140$$ (Ref 2 Section 6.9.3)

KL/r_s=	60.2	**OK**

$KL/r_s \leq 140$ Therefore, shape meets limiting slenderness requirement

Check for Slender Elements

Check leg

Width of Plate, b =	3	in	Width of Outstanding Leg (Ref 2 Section 6.9.4.2.1-1)
Plate Thickness, t =	0.375	in	
Plate Buckling Coefficient, k =	0.45		(Ref 2 Section 6.9.4.2.1-1)
Modulus of Elasticity, E =	29000	ksi	
Yield Strength, F_y =	36	ksi	

$$\frac{b}{t} \leq k\sqrt{\frac{E}{F_y}}$$ (Ref 2 Section 6.9.4.2.1-1)

b/t =	8.0
$k\sqrt{(E/F_y)}$	12.8

Leg of angle is non-slender

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Determine Axial Compression

For non-slender, noncomposite, equal leg angle members in compression only flexural buckling must be checked.

Flexural Buckling

Gross cross-sectional area, A_g = 2.11 in^2

Reference 2 6.9.4.4 states that the effective slenderness ratio should be used when single angles are used as compression members in cross-frames.

r_x = 0.91 in

L/r_x= 38.46 **OK**

If $\frac{\ell}{r_x} \leq 80$, then:

$$\left(\frac{K\ell}{r}\right)_{eff} = 72 + 0.75\frac{\ell}{r_x}$$ (Reference 2 6.9.4.4-1)

$(KL/r)_{eff}$= 100.85

$$P_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)_{eff}^2} A_g$$ (Reference 2 6.9.4.1.2-1)

Elastic Critical Buckling Resistance, P_e = 59.4 kips

For compression member cross-sections that consists entirely of non-slender elements take Q=1.0 (Reference 2 6.9.4.2.1)

Equivalent Nominal Yield Resistance, $P_o = QF_yA_g$ = 75.96 kips

P_e/P_o = 0.78 **OK**

Since Pe/Po > 0.44 use equation 6.9.4.1.1-1 from reference 2.

$$P_n = \left[0.658^{\frac{P_o}{P_e}}\right]P_0$$ (Reference 2 6.9.4.1.1-1)

P_n = 44.47 kips

Available Strength, $P_r = \Phi_c P_n$ 40.0 kips (Φc = 0.9 for steel members subjected to axial compression)

Ultimate Load, P_{MAX} = 11.44 kips

PMAX < Pr **OK**

Tension Members

$$P_r = \phi_y P_{ny} = \phi_y F_y A_g \quad (6.8.2.1\text{-}1)$$

$$P_r = \phi_u P_{nu} = \phi_u F_u A_n R_p U \quad (6.8.2.1\text{-}2)$$

Resistance Factor for Yielding of Tension Members, Φ_y = 0.95 (Ref 2 6.5.4.2)

Resistance Factor for Fracture of Tension Members, Φ_u = 0.8 (Ref 2 6.5.4.2)

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Tensile Strength, F_u =	58	ksi	
Reduction Factor for Holes, R_p =	1		Assumed holes are drilled full size.
Reduction Factor for Shear Lag, U =	0.6		Case 8 (Ref 2 6.8.2.2-1)
Required $A_g = P_{max}/(\Phi_y F_y)$ =	0.33	in^2	
Required $A_n = P_{max}/(\Phi_u F_u R_p U)$ =	0.41	in^2	
A_g =	2.11	in^2	**OK**
$A_n = A_g - A_{HOLES}$ (Assuming 3/4" Bolts)	1.78	in^2	**OK**

Check slenderness ratio requirement for bracing member

$$\frac{L_b}{r_s} \leq 240$$ (Ref 2 6.8.4)

L/r_s = 60.24 Non-slender

Vertical Cross Bracing Design Summary

Size: L3x3x3/8

Member Material: A36 Steel

CONNECTION DESIGN

Required Minimum Bolt Spacing =	2.25	in	(Reference 2 6.13.2.6.1)
Minimum Edge Distance for Sheared Edge =	1.25	in	(Reference 2 Table 6.13.2.6.6-1)
Minumum Edge Distance for Rolled/Gas Cut Edge =	1	in	(Reference 2 Table 6.13.2.6.6-1)
Maximum Edge Distance =	3	in	(Reference 2 6.13.2.6.6)

The cross braces will be attached to a gusset plate that is bolted to a stiffener plate. The stiffener plate is welded to the web and flanges of the primary girder. The cross braces are in direct tension or compression, therefore the bolt will be subject to a direct shear loading. All bolted connections will be considered slip critical.

Design Cross Bracing to Gusset Plate Connection

Maximum Tensile/Compressive Force In Cross Brace, V=	11.44	kips
Bolt Diameter, d=	0.75	in
Thickness of Thinnest Member in Connection, t_{plate} =	0.375	in
Bolt Edge Distance, L_e=	1.5	in
Hole Diameter=d+1/16=h=	0.8125	in
Bolt Area, A_b=	0.4418	in^2

1) Bolt Shear (A325 Bolt with threads in Shear Plane)

$$R_n = 0.38\, F_{ub}\, A_b\, N_s$$ (Reference 2 6.13.2.7-2)

Bolt Shear Strength, F_{ub} =	120	ksi	(Reference 2 6.4.3.1)
Bolt Area, A_b =	0.4418	in^2	
Number of Shear Planes, N_s =	1		
φ_s =	0.8		(Ref 2 Section 6.5.4.2)
Shear Strength Per Bolt, ϕR_n=	16.12	kips/bolt	

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Number of Bolts, n=	2	
Connection Capacity, $R_r = \phi R_n$=	32.23	kips

2)Bolt Bearing

The bearing stresses in the Plate to Angle connection will be governed by the thinnest steel portion. Gussett Plate and Crossbracing Angle are both 3/8" thick.

Angle Thickness, t=	0.375	in	
Angle F_u=	58	ksi	(A36 Steel)

Use Equation 6.13.2.9-1 since bolts are spaced at greater than 2.0d for both clear distance between holes and end distance.

$$R_n = 2.4\,dtF_u$$ (Reference 2 6.13.2.9-1)

Material Thickness, t=	0.375	in
F_u=	58	ksi
Bolt Diameter, d=	0.75	in
φ=	0.8	(Ref 2 Section 6.5.4.2)
$2.4dtF_u$=	39.15	kips
Bolt Capacity, ϕR_n=	31.320	kips
Connection Capacity For Bearing, R_r =	62.640	kips

3)Slip-critical Strength

$$R_n = k_h k_s N_s P_t$$ (Reference 2 6.13.2.8-1)

Hole Size Factor for Standard Hole, k_h =	1.000		(Reference 2 6.13.2.8-2)
Class C Surface Condition Factor, k_s =	0.330		(Reference 2 6.13.2.8-3)
Number of Shear Planes, N_s =	1.000		
Minimum Required Bolt Tension, P_t =	28.000	kips	(Reference 2 6.13.2.8-1)
Nominal Slip Resistance, R_n =	9.240	kips	
Factored Resistance, Rr =	18.480	kips	

4) Block Shear Rupture

Block shear on the gusset plate will not be checked because the shear area is significantly greater than the angle.

Block Shear on Angle

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$$R_r = \varphi_{bs} R_p \left(0.58 F_u A_{vn} + U_{bs} F_u A_{tn}\right) \le \varphi_{bs} R_p \left(0.58 F_y A_{vg} + U_{bs} F_u A_{tn}\right)$$ (Reference 2 6.13.4-1)

φ_{bs}=	0.8		(Ref 2 Section 6.5.4.2)
Angle Ultimate Stress, F_u=	58	ksi	
Angle Yield Stress, F_y=	36	ksi	
U_{bs}=	1	(Uniform Stress)	
Angle Thickness, t=	0.375	in	
Edge Distance, L_e=	1.5	in	
Bolt Spacing, s=	3	in	
Hole Diameter, h=	0.8125	in	
Net Shear Area=(s+L_e-1.5(h))t=A_{vn}=	1.23046875	in^2	

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Gross Shear Area=$(s+L_e)t=A_{vg}$=	1.6875	in^2
Net Tension Area=$(L_e-0.5h)t=A_{tn}$=	0.41015625	in^2
$0.58F_uA_{vn}+U_{bs}F_uA_{tn}$=	65.18	kips
$0.58F_yA_{vg}+U_{bs}F_uA_{tn}$=	59.02	kips
Governing Strength=	59.02	kips
Block Shear Capacity, ϕR_n=	47.22	kips

5) Yield On Gross Section

Yield of Angle

$$P_r = \phi_y P_{ny} = \phi_y F_y A_g$$ (Reference 2 6.8.2.1-1)

Resistance Factor for Yielding of Tension Members, Φ_y =	0.95		(Reference 2 6.5.4.2)
Specified Minimum Yield Strength, F_y =	36.00	ksi	
Gross Cross-sectional Area of the Member, A_g =	2.11	in^2	
Factored Tensile Resistance, P_r =	72.16	kips	

Yield of Gusset Plate

Conservatively assumed that yielding occurs at bolt nearest plate edge.

Resistance Factor for Yielding of Tension Members, Φ_y =	0.95		(Reference 2 6.5.4.2)
Specified Minimum Yield Strength, F_y =	36.00	ksi	
Gross Cross-sectional Area of the Member, A_g =	2.19	in^2	
Factored Tensile Resistance, P_r =	74.84	kips	

6) Fracture On Net Section

Fracture of Angle

$$P_r = \phi_u P_{nu} = \phi_u F_u A_n R_p U$$ (Reference 2 6.8.2.1-1)

Resistance Factor for Yielding of Tension Members, Φ_u =	0.80		(Reference 2 6.5.4.2)
Tensile Strength, F_u =	58.00	ksi	
Net Area of the Member, A_n =	1.81	in^2	
Reduction Factor for Holes, R_p=	1.00		(Reference 2 6.8.2.1)
Reduction Factor to Account for Shear Lag, U=	0.60		(Reference 2 6.8.2.2-1)
Factored Tensile Resistance, P_r =	50.26	kips	

Fracture of Gusset Plate

Resistance Factor for Yielding of Tension Members, Φ_u =	0.80		(Reference 2 6.5.4.2)
Tensile Strength, F_u =	58.00	ksi	
Net Area of the Member, A_n =	1.88	in^2	
Reduction Factor for Holes, R_p=	1.00		(Reference 2 6.8.2.1)
Reduction Factor to Account for Shear Lag, U=	1.00		(Reference 2 6.8.2.2-1)
Factored Tensile Resistance, P_r =	87.40	kips	

Connection Summary

Bolt Shear Strength=	32.23	kips
Bolt Bearing Strength=	62.640	kips
Slip-critical Strength=	18.480	kips
Block Shear on Angle=	47.219	kips

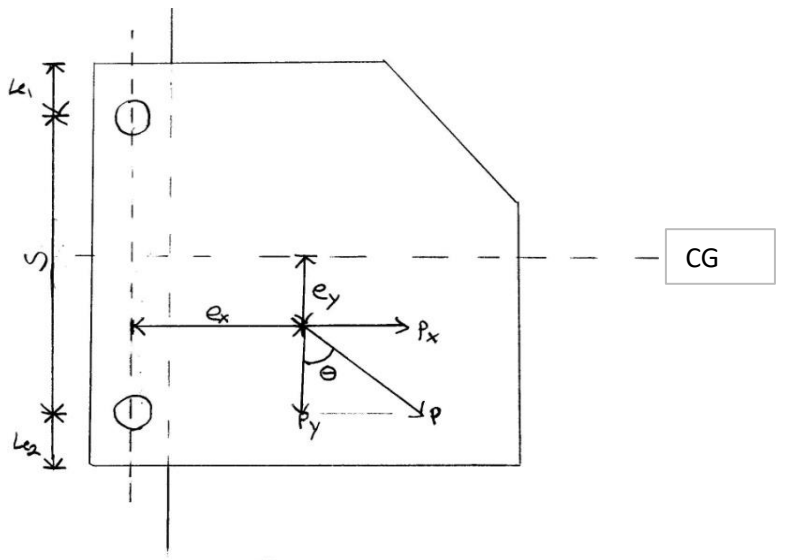
Yield on Angle=	72.162	kips
Fracture on Angle=	50.260	kips
Yield on Plate=	74.842	kips
Fracture on Plate=	87.402	kips
Connection Capacity=	18.48	kips
Capacity Required=	11.44	kips

Connection has sufficient capacity, OK

The horizontal lacing will be attached to a gusset plate that is bolted to the flanges of the primary girder. The horizontal lacing is in direct tension or compression, therefore the bolt will be subject to a direct shear loading. All bolted connections will be considered slip critical.

Design Cross Bracing Gusset Plate to Stiffener Connection

The cross bracing gusset plate will be connected to the stiffener using two bolts. The connection will account for the eccentric loading applied to the bolts.



Gussed -Stiffener Connection

Bolt Edge Distance, L_{e1}=	1.5	in
Bolt Edge Distance, L_{e2}=	2.75	in
Bolt Spacing, s=	4	in
Load Eccentricity in X Direction, e_x=	3.4752	in
Load Eccentricity in Y Direction, e_y=	-0.1008	in (Negative due to location above shown)
Number of Bolts, n=	2	
Applied Loading, P=	11.44	kips
Loading Angle, θ=	53.14	degrees
Loading Angle, θ=	0.93	radians
Direct Shear Component, P_x=	9.15	kips
Direct Shear Component Per Bolt, p_{cx}=	4.58	kips
Direct Shear Component, P_y=	6.86	kips
Direct Shear Component Per Bolt, p_{cy}=	3.43	kips

No guidance in AASHTO was found for shear only eccentric bolted connections, therefore, the Elastic Analyis method outlined in AISC 13th ed. is being applied to determine the required design force for the bolts. The bolt capacity checks will apply AASHTO requirements.

$M=P_x(e_y)+P_y(e_x)=$ 22.920 kip-in

$$\sum\left(x^2+y^2\right)=2(0.5s)^2=$$ 8 in^2

The top bolt is critical (Coordinates=(0,s))

$$p_{mx}=\frac{My}{\sum\left(x^2+y^2\right)}=$$ 5.730 kips

$$\sum p_x=$$ 10.305 kips

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$$\sum p_y = \quad 3.43 \text{ kips}$$

$$p = \sqrt{\left(\sum p_x\right)^2 + \left(\sum p_y\right)^2} = \quad 10.861 \text{ kips}$$

Maximum Bolt Shear Force, p= 10.86 kips

Bolt Diameter, d= 0.75 in

Thickness of Thinnest Member in Connection, t_{plate} = 0.375 in

Bolt Edge Distance, L_e= 1.5 in

Hole Diameter=d+1/16=h= 0.8125 in

Bolt Area, A_b= 0.4418 in^2

1) Bolt Shear (A325 Bolt with threads in Shear Plane)

$$R_n = 0.38\, F_{ub}\, A_b\, N_s$$ (Reference 2 6.13.2.7-2)

Bolt Shear Strength, F_{ub} = 120 ksi (Reference 2 6.4.3.1)

Bolt Area, A_b = 0.4418 in^2

Number of Shear Planes, N_s = 1

φ_s = 0.8 (Ref 2 Section 6.5.4.2)

Shear Strength Per Bolt, ϕR_n= 16.12 kips/bolt

Number of Bolts, n= 1 (Critical Bolt Only Considered)

Connection Capacity, $R_r = \phi R_n$= 16.12 kips

Maximum Bolt Shear Force, p= 10.86 kips

Bolt Has Sufficient Capacity, OK

2)Bolt Bearing

The bearing stresses in the Plate to Angle connection will be governed by the thinnest steel portion. Plate and Lacing Angle are both 3/8" thick.

Angle Thickness, t= 0.375 in

Angle F_u= 58 ksi (A36 Steel)

Use Equation 6.13.2.9-1 since bolts are spaced at greater than 2.0d for both clear distance between holes and end distance.

$$R_n = 2.4\, dtF_u$$ (Reference 2 6.13.2.9-1)

Material Thickness, t= 0.375 in

F_u= 58 ksi

Bolt Diameter, d= 0.75 in

φ= 0.8 (Ref 2 Section 6.5.4.2)

$2.4dtF_u$= 39.15 kips

Bolt Capacity, ϕR_n= 31.320 kips

Connection Capacity For Bearing, R_r = 31.320 kips

Maximum Bolt Shear Force, p= 10.86 kips

Bolt Has Sufficient Capacity, OK

3)Slip-critical Strength

$$R_n = k_h k_s N_s P_t$$ (Reference 2 6.13.2.8-1)

Hole Size Factor for Standard Hole, k_h = 1.000 (Reference 2 6.13.2.8-2)

Class C Surface Condition Factor, k_s = 0.330 (Reference 2 6.13.2.8-3)

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Number of Shear Planes, N_s =	1.000		
Minimum Required Bolt Tension, P_t =	28.000	kips	(Reference 2 6.13.2.8-1)
Nominal Slip Resistance, R_n =	9.240	kips/bolt	
Factored Resistance, Rr =	18.480	kips	
Applied Loading, P=	11.44	kips	

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4) Block Shear Rupture

Block Shear on Gusset

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$$R_r = \varphi_{bs} R_p \left(0.58 F_u A_{vn} + U_{bs} F_u A_{tn}\right) \le \varphi_{bs} R_p \left(0.58 F_y A_{vg} + U_{bs} F_u A_{tn}\right)$$ (Reference 2 6.13.4-1)

φ_{bs}=	0.8	(Ref 2 Section 6.5.4.2)
Angle Ultimate Stress, F_u=	58	ksi
Angle Yield Stress, F_y=	36	ksi
U_{bs}=	1	(Uniform Stress)
Angle Thickness, t=	0.375	in
Edge Distance, L_e=	1.5	in
Bolt Spacing, s=	3	in
Hole Diameter, h=	0.8125	in
Net Shear Area=(s+L_e-1.5(h))t=A_{vn}=	1.23046875	in^2
Gross Shear Area=(s+L_e)t=A_{vg}=	1.6875	in^2
Net Tension Area=(L_e-0.5h)t=A_{tn}=	0.41015625	in^2
$0.58F_uA_{vn}+U_{bs}F_uA_{tn}$=	65.18	kips
$0.58F_yA_{vg}+U_{bs}F_uA_{tn}$=	59.02	kips
Governing Strength=	59.02	kips
Block Shear Capacity, ϕR_n=	47.22	kips

The following checks for shear yield and shear rupture are for unstiffened webs and are typical checks for AISC connection design. The similar procedure was applied using AASHTO factors.

5) Shear Yield

$$\phi R_n = \phi 0.58 F_y A_g$$ Ref 2 6.10.9.2-2

φ=	1	(Ref 2 Section 6.5.4.2)
Plate Yield Stress, F_y=	36	ksi
Plate Length, l=	7.25	in
Plate Thickness, t=	0.375	in
Plate Gross Area, A_g=lt=	2.71875	in^2
Plate F_yA_g=	97.875	kips
Shear Yield Capacity, ϕR_n=	56.7675	kips

6) Shear Rupture

$$\phi R_n = \phi 0.58 F_u A_{nv}$$ Ref 2 6.10.9.2-2 Adapted for Rupture

φ=	0.8	(Ref 2 Section 6.5.4.2)
Plate Ultimate Stress, F_u=	58	ksi
Plate Length, l=	7.25	in
Plate Thickness, t=	0.375	in
Plate Gross Area, A_g=lt=	2.71875	in^2
Number of Bolt Holes in Shear Plane=n=	1.5	
Hole Diameter, h=	0.8125	in
Hole Area=A_h=	0.3047	in^2
Plate Net Shear Area, A_{nv}=(s+L_e)*t-1.5A_h=	1.230	in^2
Plate, F_uA_{nv}=	71.3671875	kips
Shear Rupture Capacity, ϕR_n=	33.114	kips

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Connection Summary

Bolt Shear Strength=	16.12	kips
Bolt Bearing Strength=	31.320	kips
Bolt Capacity=	16.116	kips
Capacity Required=	10.86	kips

Critical Bolt has sufficient capacity, OK

Slip-critical Strength=	18.480	kips
Block Shear on Plate=	47.219	kips
Shear Yield of Plate=	56.768	kips
Shear Rupture of Plate=	33.114	kips
Connection Capacity=	18.48	kips
Capacity Required=	11.44	kips

Connection has sufficient capacity, OK

Design Stiffener Plate to Girder Connection

Design plate welds utilizes elastic method.

Per Reference 2 6.13.3.4, the minimum and maximum fillet weld size for a 3/8" thick member is 1/4" and 5/16", respectively.

Per Reference 2 6.13.3.5, the minimum effective length of a fillet weld is 1.5".

$$R_r = 0.6\phi_{e2}F_{exx}$$ (Reference 2 6.13.3.2.4b-1)

Weld Shear Strength= $\phi R_n = 0.6\Phi_{e2}F_{eXX}(0.707wL)$

Weld Width for Calculation, w=	0.0625	inches
Weld Length for Calculation, L=	1	inches
Weld Metal Tensile Strength, F_{EXX}=	70	ksi
Resistance Factor for the Weld Metal, Φ_{e2} =	0.8	(Reference 2 6.5.4.2)
Weld Capacity, ΦR_n=	1.4847	kips per sixteenth of an inch of weld

Height of Stiffener, H =	19.75	in
Width of Stiffener, W =	3.9228	in
Length of Horizontal Welds, L_{hw} =	3	in
Length of Vertical Weld, L_{vw} =	15.75	in

$$Weld_Centroid_of_x-axis = 2W\left[\frac{(W-L_{hw})+(\frac{L_{hw}}{2})}{2L_{hw}+L_{vw}}\right]$$

Weld Centroid of the X-axis =	0.67	in

$$Weld_Centroid_of_y-axis = \frac{H}{2}$$

Weld Centroid of the y-axis =	-9.88	in

e_x and e_y are referenced from the weld centroids to the midpoint of the crossbracing bolts.

e_x =	5.730	in
e_y =	5.1008	in
Moment Caused by Eccentricity, M = 2Pe =	171.97	kip-in
Moment of Inertia, I =$(bh^3)/12+Ad^2$ =	910.93	in^4

b = width/thickness of weld being observed
h = height/thickness of weld being observed
A = Area of Weld being observed
d = distance between centroid of weld being observed to weld centroid
Note: The thickness of the welds were assumed to be equal to 1 since we are attempting to determine how many sixteenths of an inch are required.

c =	9.88	in
f_t = Mc/I =	1.86	kips/in
$f_v = P_u/A$ =	0.61	kips/in
$f_r = \sqrt{(f_t^2+f_v^2)}$ =	1.96	kips/in
Required width of weld = $f_r/\Phi R_n$ =	1.4	sixteenths of an inch

The minimum weld size permitted by AASHTO of 1/4" will be used.

Design Lacing to Plate Connection

Angle Size=	L3x3x3/8	
Maximum Tensile/Compressive Force In Cross Brace, V=	7.12	kips
Bolt Diameter, d=	0.75	in
Thickness of Thinnest Member in Connection, t_{plate} =	0.375	in
Bolt Edge Distance,L_e=	1.5	in
Hole Diameter=d+1/16=h=	0.8125	in
Bolt Area, A_b=	0.4418	in^2

1) Bolt Shear (A325 Bolt with threads in Shear Plane)

$$R_n = 0.38\, F_{ub}\, A_b\, N_s$$ (Reference 2 6.13.2.7-2)

Bolt Shear Strength, F_{ub} =	120	ksi	(Reference 2 6.4.3.1)
Bolt Area, A_b =	0.4418	in^2	
Number of Shear Planes, N_s =	1		
φ_s =	0.8		(Ref 2 Section 6.5.4.2)
Shear Strength Per Bolt, ϕR_n=	16.12	kips/bolt	
Number of Bolts, n=	2		
Connection Capacity, $R_r = \phi R_n$=	32.23	kips	

2)Bolt Bearing

The bearing stresses in the Plate to Angle connection will be governed by the thinnest steel portion. Plate and Lacing Angle are both 3/8" thick.

Angle Thickness, t=	0.375	in	
Angle F_u=	58	ksi	(A36 Steel)

Use Equation 6.13.2.9-1 since bolts are spaced at greater than 2.0d for both clear distance between holes and end distance.

$$R_n = 2.4\, dtF_u$$ (Reference 2 6.13.2.9-1)

Material Thickness, t=	0.375	in	
F_u=	58	ksi	
Bolt Diameter, d=	0.75	in	
φ=	0.8		(Ref 2 Section 6.5.4.2)
$2.4dtF_u$=	39.15	kips	
Bolt Capacity, ϕR_n=	31.320	kips	
Connection Capacity For Bearing, R_r =	62.640	kips	

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3)Slip-critical Strength

$$R_n = k_h k_s N_s P_t$$ (Reference 2 6.13.2.8-1)

Hole Size Factor for Standard Hole, k_h =	1.000		(Reference 2 6.13.2.8-2)
Class C Surface Condition Factor, k_s =	0.330		(Reference 2 6.13.2.8-3)
Number of Shear Planes, N_s =	1.000		
Minimum Required Bolt Tension, P_t =	28.000	kips	(Reference 2 6.13.2.8-1)
Nominal Slip Resistance, R_n =	9.240	kips	
Factored Resistance, Rr =	18.480	kips	

4) Block Shear Rupture

Block shear on the gusset plate will not be checked because the shear area is significantly greater than the angle.

Block Shear on Angle

`

$$R_r = \varphi_{bs} R_p \left(0.58 F_u A_{vn} + U_{bs} F_u A_{tn}\right) \le \varphi_{bs} R_p \left(0.58 F_y A_{vg} + U_{bs} F_u A_{tn}\right)$$ (Reference 2 6.13.4-1)

φ_{bs}=	0.8		(Ref 2 Section 6.5.4.2)
Angle Ultimate Stress, F_u=	58	ksi	
Angle Yield Stress, F_y=	36	ksi	
U_{bs}=	1	(Uniform Stress)	
Angle Thickness, t=	0.375	in	
Edge Distance, L_e=	1.5	in	
Bolt Spacing, s=	3	in	
Hole Diameter, h=	0.8125	in	
Net Shear Area=(s+L_e-1.5(h))t=A_{vn}=	1.23046875	in^2	
Gross Shear Area=(s+L_e)t=A_{vg}=	1.6875	in^2	
Net Tension Area=(L_e-0.5h)t=A_{tn}=	0.41015625	in^2	
$0.58F_uA_{vn}+U_{bs}F_uA_{tn}$=	65.18	kips	
$0.58F_yA_{vg}+U_{bs}F_uA_{tn}$=	59.02	kips	
Governing Strength=	59.02	kips	
Block Shear Capacity, ϕR_n=	47.22	kips	

5) Yield On Gross Section

Yield of Angle

$$P_r = \phi_y P_{ny} = \phi_y F_y A_g$$ (Reference 2 6.8.2.1-1)

Resistance Factor for Yielding of Tension Members, Φ_y =	0.95		(Reference 2 6.5.4.2)
Specified Minimum Yield Strength, F_y =	36.00	ksi	
Gross Cross-sectional Area of the Member, A_g =	2.11	in^2	
Factored Tensile Resistance, P_r =	72.16	kips	

Yield of Gusset Plate

Conservatively assumed that yielding occurs at bolt nearest plate edge.

Resistance Factor for Yielding of Tension Members, Φ_y =	0.95		(Reference 2 6.5.4.2)

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Specified Minimum Yield Strength, F_y =	36.00	ksi
Gross Cross-sectional Area of the Member, A_g =	1.35	in^2
Factored Tensile Resistance, P_r =	46.00	kips

6) Fracture On Net Section

Fracture of Angle

$$P_r = \phi_u P_{nu} = \phi_u F_u A_n R_p U$$ (Reference 2 6.8.2.1-1)

Resistance Factor for Yielding of Tension Members, Φ_u =	0.80		(Reference 2 6.5.4.2)
Tensile Strength, F_u =	58.00	ksi	
Net Area of the Member, A_n =	1.81	in^2	
Reduction Factor for Holes, R_p=	1.00		(Reference 2 6.8.2.1)
Reduction Factor to Account for Shear Lag, U=	0.60		(Reference 2 6.8.2.2-1)
Factored Tensile Resistance, P_r =	50.26	kips	

Fracture of Gusset Plate

Resistance Factor for Yielding of Tension Members, Φ_u =	0.80		(Reference 2 6.5.4.2)
Tensile Strength, F_u =	58.00	ksi	
Net Area of the Member, A_n =	1.04	in^2	
Reduction Factor for Holes, R_p=	1.00		(Reference 2 6.8.2.1)
Reduction Factor to Account for Shear Lag, U=	1.00		(Reference 2 6.8.2.2-1)
Factored Tensile Resistance, P_r =	48.27	kips	

7) Check Fatigue

Maximum Force Applied, P_{max}=	6.20	kips	Fatigue 1	Beam 21
Minimum Force Applied, P_{min}=	-6.20	kips	Fatigue 1	Beam 21
Load Range=	12.40	kips		
Net Area of Member, A_n=	1.81	in^2		
Stress Range, Δf=	6.87	ksi		
Nominal Fatigue Resistance, ΔF=	16.00	ksi	(Cat. B Detail)	

Connection Is Not Subject to Fatigue Failure, OK

Connection Summary

Bolt Shear Strength=	32.23	kips
Bolt Bearing Strength=	62.640	kips
Slip-critical Strength=	18.480	kips
Block Shear on Angle=	47.219	kips
Yield on Angle=	72.162	kips
Fracture on Angle=	50.260	kips
Yield on Plate=	46.001	kips
Fracture on Plate=	48.273	kips
Connection Capacity=	18.48	kips
Capacity Required=	7.12	kips

Connection has sufficient capacity, OK

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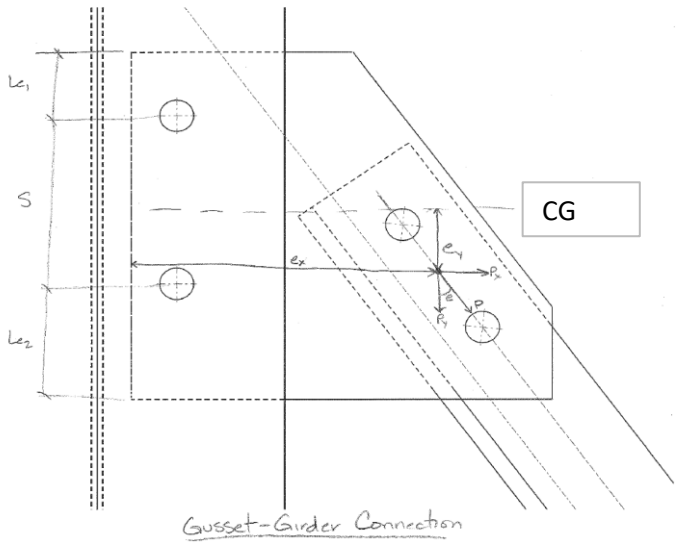
Design Plate to Beam Flange Connection

The lacing gusset plate will be connected to the girder flange using three bolts. The connection will account for the eccentric loading applied to the bolts.



Bolt Edge Distance, L_{e1}=	1.5	in
Bolt Edge Distance, L_{e2}=	1.5	in
Bolt Spacing, s=	4	in
Load Eccentricity in X Direction, e_x=	5.8404	in
Load Eccentricity in Y Direction, e_y=	1.8192	in
Number of Bolts, n=	2	
Applied Loading, P=	7.12	kips
Loading Angle, θ=	35.77	degrees
Loading Angle, θ=	0.62	radians
Direct Shear Component, P_x=	4.16	kips
Direct Shear Component Per Bolt, p_{cx}=	2.08	kips
Direct Shear Component, P_y=	5.77	kips
Direct Shear Component Per Bolt, p_{cy}=	2.89	kips

No guidance in AASHTO was found for shear only eccentric bolted connections, therefore, the Elastic Analyis method outlined in AISC 13th ed. is being applied to determine the required design force for the bolts. The bolt capacity checks will apply AASHTO requirements.

$M=P_x(e_y)+P_y(e_x)=$ 41.282 kip-in

$$\sum\left(x^2+y^2\right)=2s^2=$$ 32 in^2

The top bolt is critical
(Coordinates=(0,s))

$$p_{mx}=\frac{My}{\sum\left(x^2+y^2\right)}=$$ 5.160 kips

$$\sum p_x=$$ 7.240 kips

$$\sum p_y=$$ 2.89 kips

7.794 kips

Maximum Bolt Shear Force, p= 7.79 kips

Bolt Diameter, d=	0.75	in
Thickness of Thinnest Member in Connection, t_{plate} =	0.375	in
Bolt Edge Distance,L_e=	1.5	in
Hole Diameter=d+1/16=h=	0.8125	in
Bolt Area, A_b=	0.4418	in^2

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1) Bolt Shear (A325 Bolt with threads in Shear Plane)

$$R_n = 0.38\, F_{ub}\, A_b\, N_s$$ (Reference 2 6.13.2.7-2)

Bolt Shear Strength, F_{ub} =	120	ksi	(Reference 2 6.4.3.1)
Bolt Area, A_b =	0.4418	in^2	
Number of Shear Planes, N_s =	1		
φ_s =	0.8		(Ref 2 Section 6.5.4.2)
Shear Strength Per Bolt, ϕR_n=	16.12	kips/bolt	
Number of Bolts, n=	1	(Critical Bolt Only Considered)	
Connection Capacity, $R_r = \phi R_n$=	16.12	kips	
Maximum Bolt Shear Force, p=	7.79	kips	
	Bolt Has Sufficient Capacity, OK		

2)Bolt Bearing

The bearing stresses in the Plate to Angle connection will be governed by the thinnest steel portion. Plate and Lacing Angle are both 3/8" thick.

Angle Thickness, t=	0.375	in	
Angle F_u=	58	ksi	(A36 Steel)

Use Equation 6.13.2.9-1 since bolts are spaced at greater than 2.0d for both clear distance between holes and end distance.

$$R_n = 2.4\, dtF_u$$ (Reference 2 6.13.2.9-1)

Material Thickness, t=	0.375	in	
F_u=	58	ksi	
Bolt Diameter, d=	0.75	in	
φ=	0.8	(Ref 2 Section 6.5.4.2)	
$2.4dtF_u$=	39.15	kips	
Bolt Capacity, ϕR_n=	31.320	kips	
Connection Capacity For Bearing, R_r =	31.320	kips	
Maximum Bolt Shear Force, p=	7.79	kips	
	Bolt Has Sufficient Capacity, OK		

3)Slip-critical Strength

$$R_n = k_h k_s N_s P_t$$ (Reference 2 6.13.2.8-1)

Hole Size Factor for Standard Hole, k_h =	1.000		(Reference 2 6.13.2.8-2)
Class C Surface Condition Factor, k_s =	0.330		(Reference 2 6.13.2.8-3)
Number of Shear Planes, N_s =	1.000		
Minimum Required Bolt Tension, P_t =	28.000	kips	(Reference 2 6.13.2.8-1)
Nominal Slip Resistance, R_n =	9.240	kips/bolt	
Factored Resistance, Rr =	18.480	kips	
Applied Loading, P=	7.12	kips	

4) Block Shear Rupture

Block Shear on Gusset

`

$$R_r = \varphi_{bs} R_p \left(0.58 F_u A_{nn} + U_{bs} F_u A_{tn}\right) \le \varphi_{bs} R_p \left(0.58 F_y A_{vg} + U_{bs} F_u A_{tn}\right)$$ (Reference 2 6.13.4-1)

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φ_{bs}=	0.8	(Ref 2 Section 6.5.4.2)
Angle Ultimate Stress, F_u=	58	ksi
Angle Yield Stress, F_y=	36	ksi
U_{bs}=	1	(Uniform Stress)
Angle Thickness, t=	0.375	in
Edge Distance, L_e=	1.5	in
Bolt Spacing, s=	4	in
Hole Diameter, h=	0.8125	in
Net Shear Area=(s+L_e-1.5(h))t=A_{vn}=	1.60546875	in^2
Gross Shear Area=(s+L_e)t=A_{vg}=	2.0625	in^2
Net Tension Area=(L_e-0.5h)t=A_{tn}=	0.41015625	in^2
$0.58F_uA_{vn}+U_{bs}F_uA_{tn}$=	77.80	kips
$0.58F_yA_{vg}+U_{bs}F_uA_{tn}$=	66.85	kips
Governing Strength=	66.85	kips
Block Shear Capacity, ϕR_n=	53.48	kips

5) Shear Yield

$$\phi R_n = \phi 0.58 F_y A_g$$

Ref 2 6.10.9.2-2

φ=	1	(Ref 2 Section 6.5.4.2)
Plate Yield Stress, F_y=	36	ksi
Plate Length, l=	8.25	in
Plate Thickness, t=	0.375	in
Plate Gross Area, A_g=lt=	3.09375	in^2
Plate F_yA_g=	111.375	kips
Shear Yield Capacity, ϕR_n=	64.5975	kips

6) Shear Rupture

$$\phi R_n = \phi 0.58 F_u A_{nv}$$

Ref 2 6.10.9.2-2 Adapted for Rupture

φ=	0.8	(Ref 2 Section 6.5.4.2)
Plate Ultimate Stress, F_u=	58	ksi
Plate Length, l=	8.25	in
Plate Thickness, t=	0.375	in
Plate Gross Area, A_g=lt=	3.09375	in^2
Number of Bolt Holes in Shear Plane=n=	1.5	
Hole Diameter, h=	0.8125	in
Hole Area=A_h=	0.3047	in^2
Plate Net Shear Area, A_{nv}=(1s+L_e)*t-1.5A_h=	1.605	in^2
Plate, F_uA_{nv}=	93.1171875	kips
Shear Rupture Capacity, ϕR_n=	43.206	kips

Connection Summary

Bolt Shear Strength=	16.12	kips
Bolt Bearing Strength=	31.320	kips
Bolt Capacity=	16.116	kips

Critical Bolt has sufficient capacity, OK

Slip-critical Strength=	18.480	kips
Block Shear on Plate=	53.483	kips

Shear Yield of Plate=	64.598	kips
Shear Rupture of Plate=	43.206	kips
Connection Capacity=	18.48	kips
Capacity Required=	7.12	kips

Connection has sufficient capacity, OK

Design Grating

Determine Design Loadings

Check Loading Chart

From ANSI/NAAMM Standard Metal Bar Grating for W-19-4 (1"x1/8") Grating — Size selected to match other dams

Recommended max span =	51	in
Max Uniform Load, U =	206	psf
Max Deflection, =	0.228	in

Check Bearing at Concrete

Bearing at the concrete will be checked at the sluiceway pier/abutment assuming the length of supporting concrete is 1/2 the width of the notch in the pier. This is conservative because the supporting concrete actually extends beyond the notch. It will be assumed that the concrete has a f'c = 3 ksi.

$$P_r = \phi P_n \qquad (5.7.5\text{-}1)$$

in which:

$$P_n = 0.85 f'_c A_1 m \qquad (5.7.5\text{-}2)$$

where:

P_n = nominal bearing resistance (kip)
A_1 = area under bearing device (in.^{2})
m = modification factor
A_2 = a notional area defined herein (in.^{2})

The modification factor may be determined as follows:

- Where the supporting surface is wider on all sides than the loaded area:

$$m = \sqrt{\frac{A_2}{A_1}} \le 2.0 \qquad (5.7.5\text{-}3)$$

ϕ =	0.7		Ref 2 - 5.5.4.2.1
Bearing length =	12	in	
Bearing width =	8.25	in	
Area under bearing device, A_1 =	99	in^2	
Length of supporting concrete =	20.875	in	Conservatively assume 1/2 width of notch
Width of supporting concrete =	18	in	
Area of supporting concrete, A_2 =	375.75	in^2	
m=	1.948192636		
f'c =	3	ksi	assumed
P_r =	344.2748616	kip	
Maximum bearing load, P_u =	18.8	kip	From STAAD Strength 1 load case

Bearing Requirement Met

ATTACHMENT C

SOIL PROFILE

GEOTECHNICAL SUBSURFACE INVESTIGATION
LITTLE MANISTEE SEA LAMPREY TRAP -
AND EAST AU GRES SEA LAMPREY TRAP -
MANISTEE COUNTY AND IOSCO COUNTY, MICHIGAN

FOR

US ARMY CORPS OF ENGINEERS
DETROIT DISTRICT
477 MICHIGAN AVENUE, 7TH FLOOR
DETROIT, MICHIGAN 48226

SUBMITTED

OCTOBER 6, 2015
USACE CONTRACT NO. W912P6-14-D-0003, DELIVERY ORDER NUMBER DC02
TTL PROJECT NO. 10835.05

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1.0 INTRODUCTION

1.1 Authorization and Purpose of Investigation

This study was performed in general accordance with TTL Associates, Inc. (TTL) and USACE negotiated cost fee proposal dated July 22, 2015, and authorized by Mr. Robert Austin of USACE via Contract No. W912P6-14-D-0003 Delivery Order Number DC02, dated July 27, 2015.

This geotechnical subsurface investigation has been performed to determine and characterize the subsurface conditions below the proposed improvements at the two project sites.

This report contains a description of the investigative procedures, as well as the results of the subsurface investigation. Engineering analysis or design recommendations were not included in the scope of services for this project.

The scope of this study did not include an Environmental Site Assessment of the surface or subsurface materials.

1.2 Project Location

The Little Manistee Sea Lamprey Trap is located near Manistee, Manistee County, Michigan. The East Au Gres Sea Lamprey Trap is located near National City, Iosco County, Michigan. The general location of the project sites are identified on the attached Site Location Maps (Plates 1.1 and 1.2).

2.0 INVESTIGATIVE PROCEDURES -

This subsurface investigation included four test borings drilled by TTL on August 10 through 12, 2015. These borings are fully designated as Borings LM-15-01, LM-15-02, AG-15-01, and AG-15-02 in accordance with USACE protocol, but the -15 portion of the nomenclature is generally omitted in the discussions within this report. At the Little Manistee River, Boring LM-01 was located south of the west wingwall and Boring LM-02 was located in the embankment north of the existing weir. At the East Branch Au Gres River, Boring AG-01 was located near the top of the slope east of the existing weir structure, and Boring AG-02 was located within the existing wingwall west of the river. The approximate locations of the borings are shown on the Test Boring Location Plans (Plates 2.1 and 2.2).

2.1 Exploration Survey

The boring locations were established based on northing and easting coordinates indicated on the provided boring location plans furnished by USACE and included with the Request for Proposal (RFP) dated June 26, 2015. The State Plane Michigan South (FIPS 2113) based on North American Datum 1983 (NAD83) horizontal coordinate system was used to establish the northing and easting coordinates. Ground surface elevations at the boring locations were surveyed by TTL referencing the North American Vertical Datum of 1988 (NAVD88). In absence of any available control points, TTL referenced the Michigan Department of Transportation Virtual Reference Station (MDOT VRS) system to survey the boring locations.

The boring locations were identified using a Trimble® GNSS system partnered with a Trimble® hand-held GPS unit and the provided coordinates in real time. While the requested boring location coordinates were provided by the USACE in U.S. Survey Feet, the coordinates were input into the GPS using International Feet by our GPS provider, which consequently resulted in unintended offsets from the requested locations for Borings LM-02 and AG-02. The requested location for Boring LM-01 was located within a gated area inaccessible to our drill rig, and was offset approximately 20 feet south of its proposed location. The requested location for Boring AG-01 was relocated approximately 55 feet northeast due to tree density, canopy overhang, and steep slopes in the vicinity of the requested boring location. These offsets were discussed with and accepted by the Technical POC. The survey data inputs and outputs are attached to this report.

Boring locations and ground surface elevations, as well as boring termination depths and elevations are summarized in Table 1.

Table 1 Summary of Subsurface Exploration

Project: Little Manistee Sea Lamprey Trap and East Au Gres Sea Lamprey Trap
State Plane: Michigan South (FIPS 2113) based on North American Datum 1983 (NAD83)
Drilling Firm: TTL Associates, Inc.

Boring No.	Proposed		As-Drilled		Offset (feet)	Ground Surface Elevation (feet)	Boring Termination	
	Northing	Easting	Northing	Easting			Depth (feet)	Elevation (feet)
LM-15-01	326829.1	19205621.7	326809.719	19205616.957	20	603.3	60	543.3
LM-15-02	326943.5	19205668.0	326942.799	19205629.515	39	601.3	60	541.3
AG-015-01	330762.1	19860342.6	330799.924	19860302.530	55	648.1	75	573.1
AG-015-02	330747.4	19860410.8	330750.530	19860404.810	7	634.7	10	624.7

Boring No.	Dates Drilled	Shelby Tube Sample Interval Depth (feet)	Borehole Status
LM-15-01	August 10 to 11, 2015	-	Backfilled with Cuttings and Bentonite Chips
LM-15-02	August 11, 2015	-	Borehole Sealed with Cement/Bentonite Grout
AG-015-01	August 12, 2015	14 to 16, 26 to 28, and 58 to 60	Backfilled with Cuttings and Bentonite Chips
AG-015-02	August 12, 2015	-	Backfilled with Cuttings

2.2 Subsurface Exploration

The borings were performed in general accordance with geotechnical investigative procedures outlined in ASTM Standards D 1452 and D 5434.

Borings LM-01, LM-02, and AG-01were drilled with an ATV-mounted CME 550X drilling rig utilizing 3¼-inch inside diameter hollow-stem augers. During auger advancement, soil samples were collected at 2½-foot intervals to a depth of 20 feet below existing grade and at 5-foot intervals thereafter. Split-spoon (SS) samples were obtained by the Standard Penetration Test (SPT) Method (ASTM D 1586), which consists of driving a 2-inch (or 3-inch) outside diameter split-barrel sampler into the soil with an automated hammer consisting of a 140-pound weight falling freely through a distance of 30 inches. The split-spoon samples were obtained using a 2-inch outside diameter sampler. The sampler was driven in three successive 6-inch increments with the number of blows per increment being recorded. The sum of the number of blows required to advance the sampler the second and third 6-inch increments is termed the Standard Penetration Resistance (N-value) and is presented on the Logs of Test Borings attached to this report. The samples were sealed in jars and transported to our laboratory for further classification and testing. Borings LM-01 and LM-02 were terminated at the target completion depth of 60 feet below existing grade. Boring AG-01 was terminated at the target completion depth of 75 feet.

Boring AG-02 was performed using a hand auger. Auger (AU) samples were collected at 2½-foot intervals to boring termination at the target completion depth of 10 feet. The hand auger samples were sealed in jars and transported to our laboratory for further classification and testing.

Heaving sands were encountered at depths of 30 feet, 45 feet, and 50 feet in Boring LM-01, and at depths of 10 feet, 18½ feet, 30 feet, and from 40 to 55 feet in Boring LM-02. To flush out heaving sands from within the auger in order to obtain samples at the requested sample depths and to rebalance the head difference during drilling, water was introduced down the augers. While the water effectively flushed out sands from the auger hole for sampling at most depths, drilling mud was used below a depth of 50 feet in Boring LM-02.

Thin-walled Shelby tube samples, designated ST on the Logs of Test Borings, were obtained at depths of 14 to 16 feet, 26 to 28 feet, and 58 to 59½ feet in Boring AG-01. The Shelby tube samples were obtained by hydraulically advancing a 3-inch diameter, thin-walled sampler approximately 24 inches beyond the hollow-stem auger into relatively undisturbed soil in accordance with ASTM D 1587. The Shelby tubes were then extracted from the subsoils, and the ends were capped and sealed. The samples were transported to our laboratory where they were extruded, classified, and tested. The Shelby tube sample ST-3 encountered resistance to pushing beyond 18 inches and was extruded at a depth of 59½ feet.

Soil conditions encountered in the test borings are presented in the Logs of Test Borings, along with information related to sample data, SPT results, water conditions observed in the borings, and laboratory test data. It should be noted that these logs have been prepared on the basis of laboratory classification and testing as well as field logs of the encountered soils. Experience indicates that the actual subsoil conditions at a site could vary from those generalized on the basis of test borings made at specific locations.

2.3 Laboratory Testing Program

All samples of the subsoils were visually or manually classified in accordance with the Unified Soil Classification System (ASTM D 2487 and D 2488). Moisture content determinations (ASTM D 2216) were performed on each cohesive or silt sample. Complete classifications consisting of Atterberg limits tests (ASTM D 4318) and particle size analyses (ASTM D 422) were performed on samples obtained from Borings AG-01 (ST-1, ST-2, and ST-3) and AG-02 (AU-3). Additionally, an Atterberg limits test (ASTM D 4318) was performed on a sample obtained from Boring AG-02 (AU-1), and particle size analyses (ASTM D 422) were performed on samples obtained from AG-01 (SS-4 and SS-10). Wash sieve analyses (ASTM D 6913) were performed on samples from Borings LM-01 (SS-3 and SS-10b) and LM-01 (SS-1 and SS-9) to determine soil classification. These test results are presented on the Logs of Test Borings, Tabulation of Test Data sheets, and Grain Size Distribution sheets attached to this report.

Unconsolidated-undrained (UU) triaxial compressive strength tests (ASTM D 2850) were performed on two specimens from each of the recovered Shelby tubes, and the results are attached to this report. The UU tests were performed at two confining pressures, one approximately equal to the overburden pressure at the sample depth, and the other at 2 times that pressure. The results of these tests are attached to this report.

Direct Shear Tests (ASTM D 3080) was performed on samples from Boring LM-01 (BS-1 and a composite sample of material from SS-11, SS-12, and SS-13). These tests were performed to evaluate the shear strength of the representative soil. The results of these tests are presented in the attached Shear Stress versus Normal Stress curves.

3.0 PROPOSED CONSTRUCTION -

Based on the provided information, it is our understanding that the United States Army Corps of Engineers Detroit District (USACE) is currently designing permanent improvements to the United States Fish and Wildlife Service (USFWS) Sea Lamprey Traps on the East Au Gres River near National City, Michigan (44º 13.321'N, 83º 41.861'W) and the Little Manistee River near Manistee, Michigan (44º 11.909'N, 86º 11.674'W).

4.0 GENERAL SITE AND SUBSURFACE CONDITIONS -

4.1 Encountered Subsurface Conditions

Based on the results of the field and laboratory tests, the subsurface conditions encountered underlying the topsoil consisted of predominantly granular soils at the Litle Manistee site, and predominantly cohesive soils at the East Au Gres site. These strata have been interpreted based on soil texture, moisture contents, unconfined compressive strengths, undrained shear strength from unconsolidated-undrained (UU) triaxial tests, and SPT N-values recorded in the borings. It should be noted that the demarcations between cohesive soil strata can be transitional with respect to strength and moisture conditions.

Additional descriptions of the stratigraphy encountered in the borings are presented on the attached Logs of Test Borings. Additionally, generalized subsurface diagrams of the borings performed at each project location are attached to this report (Plates 3.1 and 3.2).

4.1.1 Little Manistee

The surface cover encountered at the boring locations consisted of topsoil varying in thickness from 4 to 5 inches.

Granular **fill** materials were encountered underlying the topsoil in Boring LM-02 to a depth of 3½ feet below existing grade (approximate Elev. 598). The granular fill materials consisted of poorly graded sand (SP) with trace silt and gravel. An SPT N-value of 9 blows per foot (bpf), indicating **loose** compactness, was determined for the recovered sample.

Stratum I consisted of medium dense granular soils underlying the topsoil in Boring LM-01 to a depth of 8½ feet (approximate Elev. 595). The Stratum I granular soils consisted of poorly graded sand (SP) with trace silt, gravel, and organics. SPT N-values ranged from 13 to 19 bpf.

Stratum II consisted of **loose** granular soils underlying the granular fill in Boring LM-02 and Stratum I in Boring LM-01 to depths ranging from 34½ to 48½ feet (approximate Elevs. 569 to 553). The Stratum II granular soils consisted of poorly graded sand (SP) with trace silt, and varying amounts of gravel and organics. Where encountered, organics were generally encountered in trace quantities. However, an organic content of 5.8 percent was determined by a Loss-on-Ignition (LOI) test for the uppermost sample from Boring LM-02 (SS-2a).SPT N-values generally ranged from 2 to 4 bpf. It is our experience that low SPT N-values determined for granular soils encountered at or slightly below the groundwater table are not necessarily indicative of the actual compactness of the soils, but may reflect a bias toward apparent looser compaction due to sampling disturbance phenomena coincident with soil saturation due to groundwater.

Within the Stratum II granular soils in Boring LM-01, a zone of loose **peat** (PT) with sand and silt was encountered from 29.9 to 33 feet feet (approximate Elevs. 573 to 570). An organic content of 28.4 percent was determined by an LOI test.

Stratum III consisted of predominantly medium dense to dense granular soils underlying Stratum II to boring termination at 60 feet (approximate Elevs. 643 to 640). The Stratum III granular soils consisted of poorly graded sand (SP) with trace silt and varying amounts of gravel, and organics. SPT N-values generally ranged from 15 to 23 bpf.

4.1.2 East Au Gres

The surface cover encountered at Boring AG-01 consisted of approximately 6 inches of topsoil. Distinct surface cover was not encountered in Boring AG-02, although rip rap fill consisting of cobble to boulder size rocks with sand were encountered at the surface to a depth on the order of 12 inches.

Cohesive **fill** materials were encountered underlying the surface cover to a depth of 4½ feet (approximate Elev. 644) in Boring AG-01, and to boring termination at a depth of 10 feet (approximate Elev. 625) in Boring AG-02. The cohesive fill materials consisted of lean clay (CL) with sand, trace gravel, and organics. Within the cohesive fill materials in Boring AG-01, an SPT N-value of 18 bpf and a moisture content of 15 percent were determined. Within the cohesive fill materials in Boring AG-02, moisture contents ranged from 22 to 32 percent. Woven geogrid was observed within cuttings from Boring AG-02 during hand augering.

Dense granular **fill** materials were encountered underlying the cohesive fill in Boring AG-01 to a depth of 5 feet (approximate Elev. 643). The granular fill materials consisted of crushed stone (GP) with sand and clay.

Stratum I consisted of interbedded granular and cohesive soils encountered underlying the granular fill materials to a depth of 14½ feet (approximate Elev. 635).

The Stratum I cohesive soils consisted of very stiff lean clay (CL) with varying amounts of sand. An SPT N-value of 17 bpf was determined for the recovered sample from this stratum. Unconfined compressive strengths ranged from 5,000 to 7,000 pounds per square foot (psf). Moisture contents for the Stratum I cohesive soils ranged from 22 to 26 percent.

The Stratum I granular soils consisted of medium dense to dense poorly graded sand (SP) with trace silt. An SPT N-value of 34 bpf was determined for the recovered sample from this stratum. Moisture contents for the Stratum I granular soils ranged from 17 to 19 percent.

Stratum II consisted of medium stiff cohesive soils encountered underlying Stratum I to a depth of approximately 23½ feet (approximate Elev. 625). The Stratum II cohesive soils consisted of lean clay (CL) with varying amounts of sand. SPT N-values for these soils ranged from 7 to 8 bpf. Unconfined compressive strengths were on the order of 4,000 psf. Moisture contents ranged from 27 to 33 percent in the upper half of this stratum.

Stratum III consisted of medium stiff cohesive soils encountered underlying Stratum II to a depth of approximately 29½ feet (approximate Elev. 619). The Stratum III cohesive soils consisted of sandy lean clay (CL) with trace gravel. SPT N-values for these soils ranged from 5 to 13 bpf. An unconfined compressive strength of 3,000 psf was determined for the recovered split-spoon sample from this stratum. Moisture contents ranged from 10 to 12 percent.

Stratum IV consisted of very stiff to hard cohesive soils encountered underlying Stratum III to a depth of 59½ feet (approximate Elev. 589). The Stratum IV cohesive soils consisted of sandy lean clay (CL) with trace gravel. SPT N-values for these soils typically ranged from 23 to 34 bpf. Unconfined compressive strengths were estimated range from 6,000 psf to greater than 9,000 psf (maximum obtainable reading using a calibrated hand penetrometer). Moisture contents ranged from 9 to 15 percent.

Stratum V consisted of stiff to very stiff cohesive soils encountered underlying Stratum IV to a depth of 68½ feet (approximate Elev. 580). The Stratum V cohesive soils consisted of sandy lean clay (CL). SPT N-values for these soils ranged from 15 to 23 bpf. Unconfined compressive strengths ranged from 3,000 to 5,000 psf. Moisture contents were on the order of 16 percent.

Stratum VI consisted of medium stiff to stiff cohesive soils encountered underlying Stratum V to boring termination at a depth of 75 feet (approximate Elev. 573). The Stratum VI cohesive soils consisted of lean clay (CL) with trace sand and gravel. SPT N-values for these soils ranged from 8 to 12 bpf. Unconfined compressive strengths ranged from 1,000 to 2,000 psf. Moisture contents ranged from 22 to 37 percent.

4.2 Laboratory Test Results

Results of the index property tests used to classify the soils in accordance with the Unified Soil Classification System (USCS) are summarized in Table 2. The Grain Size Distribution curves for these tests are also attached to this report. It should be noted that silt and clay designations (of the overall percentage of "fines" or particles passing the No. 200 sieve) were based on ASTM demarcation of percent finer than 0.005 mm (for clay). Other classifications systems (e.g., USDA, EPA) define clay demarcation at percent finer than 0.002 mm.

Table 2 Index Property Tests

Boring No. (Sample No.)	Sample Depth Below Water Surface Elevation (feet)	Approximate Sample Elevation (feet)	Interpreted Stratum	Grain Size Distribution				Liquid Limit	Plastic Limit	Plasticity Index	Moisture Content (%)	USCS Class.
				% Gravel	% Sand	% Silt[1]	% Clay[1]					
AG-15-01 (SS-4)	8.5 to 10	640 to 638	I	0	3	19	77	Not Measured			22	CL
AG-15-01 (ST-1)	14 to 16	634 to 632	II	0	2	21	77	48	24	24	26	CL
AG-15-01 (ST-2)	26 to 28	622 to 620	III	3	43	34	20	20	11	9	10	CL
AG-15-01 (SS-10)	33½ to 35	615 to 613	IV	3	41	29	27	Not Measured			12	CL
AG-15-01 (ST-3)	58 to 59½	590 to 589	IV	5	31	33	29	21	12	9	11	CL
AG-15-02 (AU-1)	1 to 2½	634 to 632	CF	Not Measured				32	19	13	22	CL
AG-15-02 (AU-3)	6 to 7½	629 to 627	CF	0	4	28	68	42	19	23	26	CL
LM-15-01 (SS-3)	6 to 7½	597 to 596	I	1	96	3		Non-Plastic				SP
LM-15-01 (SS-10b)	29½ to 30	574 to 572	PT	41	53	6		Non-Plastic				SP/SM
LM-15-02 (SS-1)	1 to 2½	600 to 599	GF	6	91	3		Non-Plastic				SP
LM-15-02 (SS-9)	23½ to 25	578 to 576	II	15	84	1		Non-Plastic				SP

(1) Silt and clay designations (of the overall percentage of "fines" or particles passing the No. 200 sieve) were based on ASTM demarcation of percent finer than 0.005 mm (for clay). Other classifications systems (e.g., USDA, EPA) define clay demarcation at percent finer than 0.002 mm.

(2) Interpreted Strata denoted CF, GF, and PT represent cohesive fill, granular fill, and peat, respectively.

Unconsolidated-undrained (UU) triaxial compressive strength tests (ASTM D 2850) were performed on two specimens from each of the recovered Shelby tubes, and the results are attached to this report. The UU tests were performed at two confining pressures, one approximately equal to the overburden pressure at the sample depth, and the other at 2 times that pressure. The results of these tests, with the corresponding Mohr circle strength envelopes, are attached to this report, and are summarized in Table 3.

Table 3 Unconsolidated-Undrained (UU) Triaxial Compressive Strength Test Results

Boring (Sample)	Sample Depth (feet)	Approximate Sample Elevation (feet)	Interpreted Stratum	Average Undrained Shear Strength, c (psf)	Liquid Limit/ Plasticity Index	Percent Passing No. 200 Sieve (%)	Moisture Content (%)	Average Void Ratio, e_o (%)
AG-15-01 (ST-1)	14 to 16	634 to 632	II	820	48 / 24	98	26	0.79
AG-15-01 (ST-2)	26 to 28	622 to 620	III	2,680	20 / 9	54	10	0.35
AG-15-01 (ST-3)	58 to 59½	590 to 589	IV	4,090	21 / 9	62	11	0.34

Direct Shear Tests (ASTM D 3080) was performed on samples from Boring LM-01 (BS-1, and a composite sample of material from SS-11, SS-12, and SS-13) at confining pressures equal to approximately ½, 1, and 1½ times the overburden pressure at the sample depth. The specimens were compacted to a dry density of 115 pounds per cubic foot. The results of these tests are presented in the attached Shear Stress versus Normal Stress curves, and are summarized in Table 4.

Table 4 Direct Shear Strength Test Results

Boring (Sample)	Sample Depth (feet)	Approximate Sample Elevation (feet)	Interpreted Stratum	Trial	Confining Pressure (tsf)	Normal Stress (psi)	Peak Shear Stress (psi)	Peak Shear Angle, ϕ (degrees)
LM-15-01 (BS-1)	3 to 8	598 to 593	I	1	0.15	2.1	3.3	28.7
				2	0.31	4.3	4.3	
				3	0.63	8.8	6.9	
LM-15-01 (SS-11, SS-12, and SS-13)	33½ to 45	568 to 556	II / III	1	0.61	8.5	6.5	36.6
				2	1.22	16.9	16.3	
				3	2.44	33.9	23.3	

4.3 Groundwater Conditions

4.3.1 Little Manistee

During our exploration, the water level in Little Manistee varied in depth, and was estimated to be approximately 18 inches above the level of the streambed at the construction crossing just downriver from the weir. Based on the provided drawing showing topographic contour lines, we estimate the streambed in that location to be on the order of Elevs. 595 to 594, and the top of the water at the crossing can be estimated on the order of Elevs. 597 to 596.

Groundwater was encountered at a depth of 6 feet (approximate Elev. 597) in Boring LM-01, and at a depth of 4 feet (approximate Elev. 597) in Boring LM-02. Water and/or drilling mud was introduced to flush heaving sands from the auger hole, and the groundwater encountered upon completion of drilling operations was not observed.

4.3.2 East Au Gres

During our exploration, the water level in East Au Gres varied in depth. The water was observed near that of the level sand approximately 5 feet below the top of the wingwall south of Boring AG-02. Based on the provided drawing showing topographic contour lines, we estimate the water level at the time of our investigation to be on the order of Elev. 630.

Groundwater was encountered during drilling at a depth of 7 feet (approximate Elev. 641) and was observed upon completion of drilling at a depth of 15 feet (approximate Elev. 633) in Boring AG-01. Groundwater was not encountered nor observed upon completion of augering in Boring AG-02.

4.3.3 General Groundwater Observations

It should be noted that each test boring was drilled and backfilled within the same day. Therefore, stabilized water levels may not have occurred over this limited time period. Instrumentation was not installed to observe long-term groundwater levels.

Based on the soil characteristics and moisture conditions encountered in the borings, it is our opinion that "normal" groundwater levels at the site will generally be encountered at or slightly above the water levels observed in the rivers (indicated on the provided plans as Elev. 598.5 at Little Manistee and at Elev. 632.8 at East Au Gres). However, it should be noted that groundwater elevations can fluctuate with seasonal and climatic influences. In particular, "perched" water may be encountered in fill materials or granular soils that are underlain by relatively impermeable native cohesive soils. Therefore, the groundwater conditions may vary at different times of the year from those encountered during this investigation.

5.0 QUALIFICATION OF FINDINGS -

Our review of the subsurface conditions has been based on our understanding of the site and project information and the data obtained during our field investigation. The general subsurface conditions were based on interpretation of the subsurface data at specific boring locations. Regardless of the thoroughness of a subsurface investigation, there is the possibility that conditions between borings will differ from those at the boring locations, that conditions are not as anticipated by the designers, or that the construction process has altered the soil conditions. The nature and extent of variations in the surrounding area of the borings may not become evident until the course of construction.

Our professional services have been performed, our findings derived, and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. This warranty is in lieu of all other warranties either expressed or implied. TTL is not responsible for the conclusions, opinions, or recommendations of others based on this data.

LEGEND

APPROXIMATE SITE LOCATION

N

APPROXIMATE SCALE – FEET

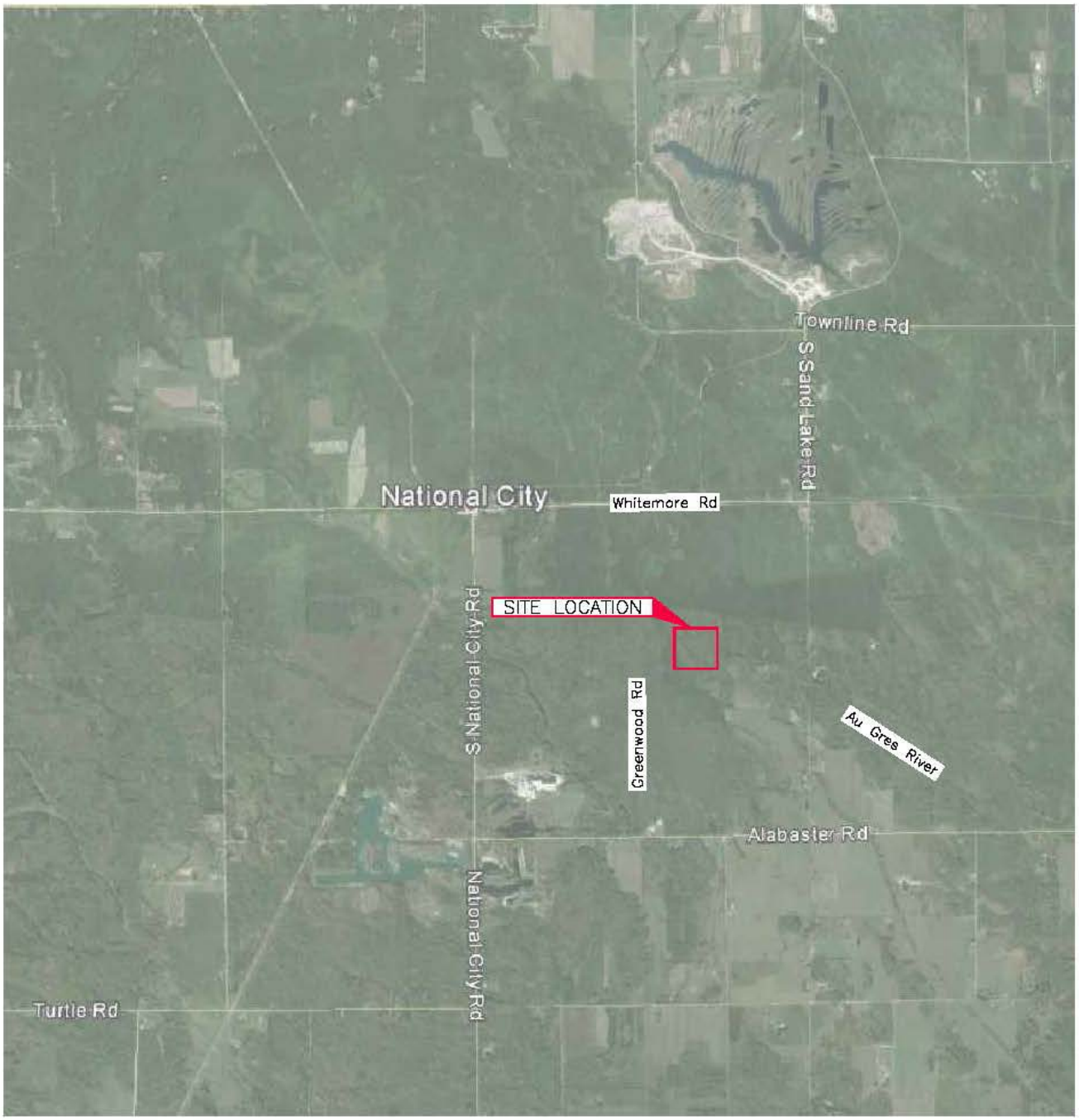
0 5,000 10,000

PLATE 1.1
SITE LOCATION MAP
LITTLE MANISTEE SEA LAMPREY TRAP
MANISTEE COUNTY, MICHIGAN

PREPARED FOR
US ARMY CORPS OF ENGINEERS
DETROIT, MICHIGAN

DRAWN	CLW/09–16–15	CHECKED	KDC/09–16–15
REVISED		APPROVED	
JOB NO.	10835.05		
DRAWING NUMBER	**1083505–01G**		

TTL associates inc
Environmental, Geotechnical Engineering & Testing



LEGEND

APPROXIMATE SITE LOCATION

N

APPROXIMATE SCALE – FEET

0 5,000 10,000

PLATE 1.2
SITE LOCATION MAP
EAST AU GRES SEA LAMPREY TRAP
IOSCO COUNTY, MICHIGAN

PREPARED FOR
US ARMY CORPS OF ENGINEERS
DETROIT, MICHIGAN

DRAWN	CLW/09–16–15	CHECKED	KDC/09–16–15
REVISED		APPROVED	
JOB NO.	10835.05		
DRAWING NUMBER	**1083505–02G**		

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LEGEND

LM-15-01 APPROXIMATE TEST BORING LOCATION

N

APPROXIMATE SCALE - FEET

0 50 100

PLATE 2.1
TEST BORING LOCATION PLAN
LITTLE MANISTEE SEA LAMPREY TRAP
MANISTEE COUNTY, MICHIGAN

PREPARED FOR
US ARMY CORPS OF ENGINEERS
DETROIT, MICHIGAN

DRAWN	CLW/09-16-15	CHECKED	KDC/09-16-15
REVISED		APPROVED	
JOB NO.	10835.05		
DRAWING NUMBER	**1083505-03G**		

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LEGEND

AG-15-01 APPROXIMATE TEST BORING LOCATION

N

APPROXIMATE SCALE - FEET

0 50 100

PLATE 2.2
TEST BORING LOCATION PLAN
EAST AU GRES SEA LAMPREY TRAP
IOSCO COUNTY, MICHIGAN

PREPARED FOR
US ARMY CORPS OF ENGINEERS
DETROIT, MICHIGAN

DRAWN	CLW/09-16-15	CHECKED	KDC/09-16-15
REVISED		APPROVED	
JOB NO.	10835.05		
DRAWING NUMBER	**1083505-04G**		

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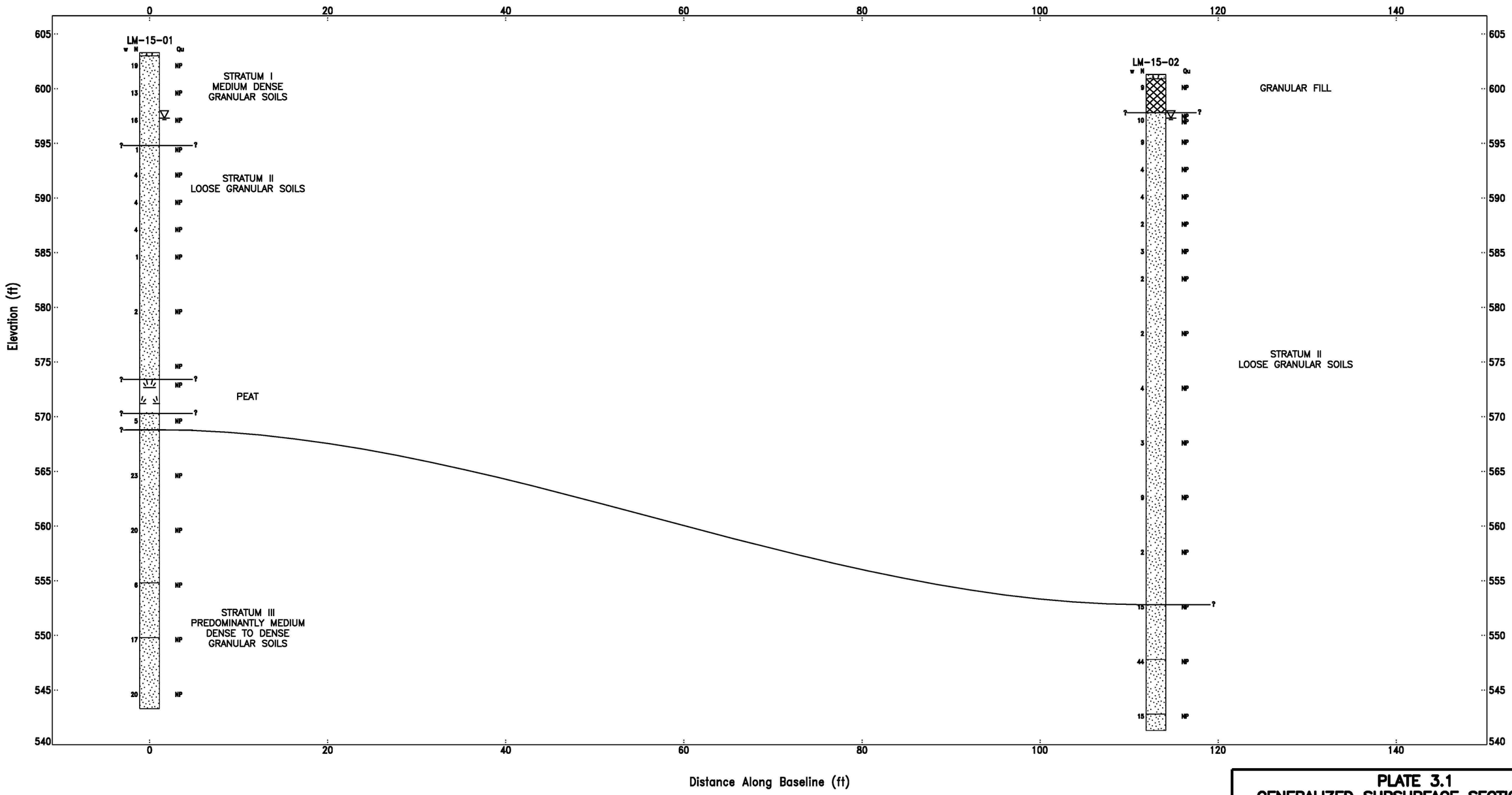

LEGEND

- Topsoil
- USCS Poorly-graded Sand
- USCS Peat
- Fill (made ground)

NOTES:

1. GROUND SURFACE ELEVATIONS WERE SURVEYED BY TTL ASSOCIATES, INC. UTILIZING A HAND HELD GPS UNIT.
2. DEMARCATIONS BETWEEN STRATA ARE INTERPRETED AND MAY BE TRANSITIONAL. STRATA BOUNDARIES BETWEEN BORINGS ARE INFERRED AND MAY NOT BE CONTINUOUS.
3. DRAWING EXHIBITS AN APPARENT DISTORTION OF APPROXIMATELY 1.2 TIMES WHEN COMPARING HORIZONTAL SCALE (APPROX. 1"=11') TO VERTICAL SCALE (APPROX. 1"=9').

W MOISTURE CONTENT

N SPT N-VALUE
ST: SHELBY TUBE SAMPLE
SSR: SPLIT-SPOON REFUSAL

QU UNCONFINED COMPRESSIVE STRENGTH (TSF)
NP: NON-PLASTIC
NI: NOT INTACT

▽ DEPTH OF GROUNDWATER INITIALLY ENCOUNTERED DURING DRILLING

▼ DEPTH OF GROUNDWATER OBSERVED UPON COMPLETION OF DRILLING

PLATE 3.1
GENERALIZED SUBSURFACE SECTION A-A'
LITTLE MANISTEE SEA LAMPREY TRAP
MANISTEE COUNTY, MICHIGAN

PREPARED FOR
US ARMY CORPS OF ENGINEERS
DETROIT, MICHIGAN

DRAWN	CLW/09-16-15	CHECKED	KDC/09-16-15
REVISED		APPROVED	
JOB NO.	10835.05		
DRAWING NUMBER	1083505-05G		

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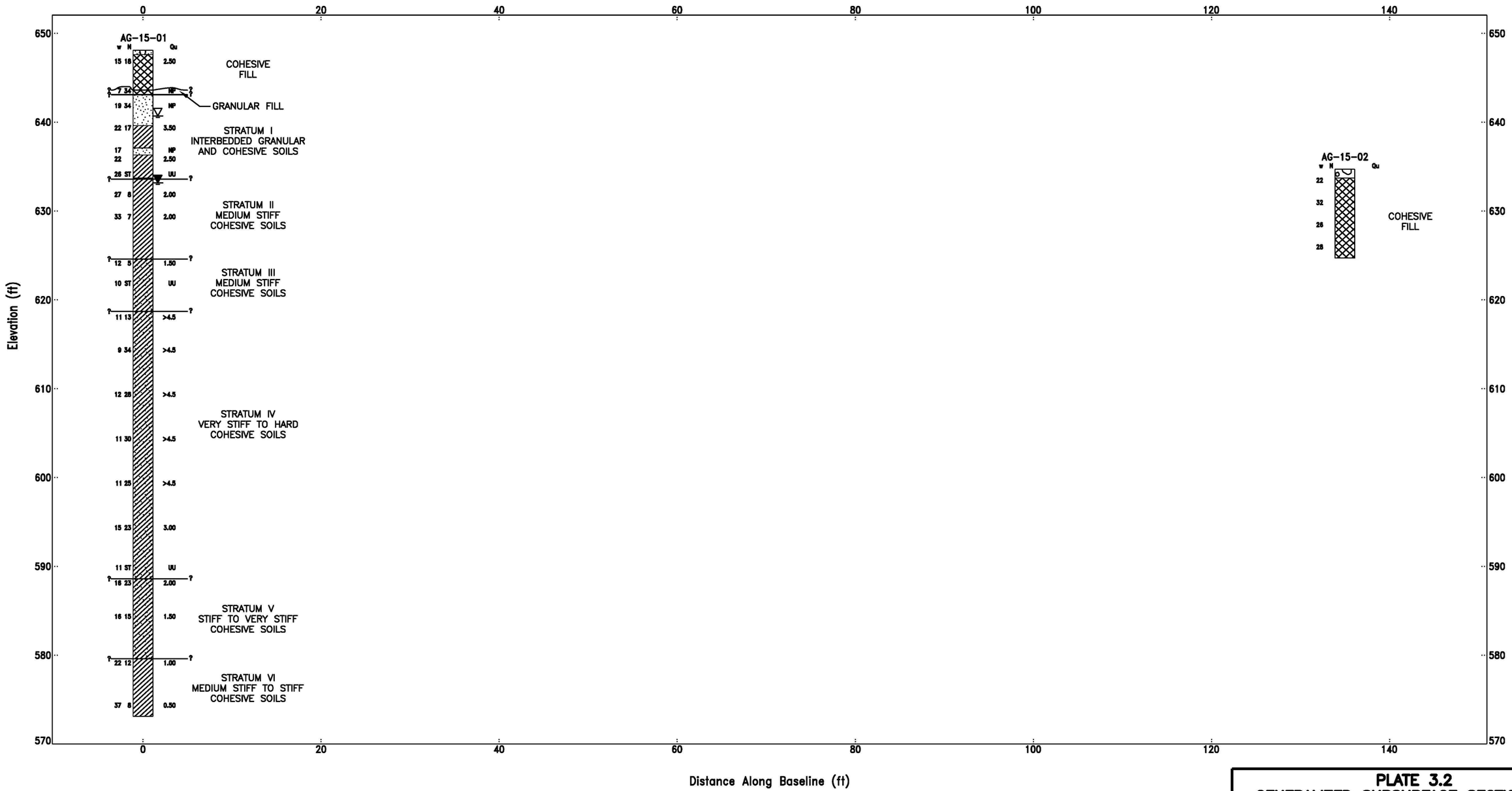

LEGEND

- Topsoil
- USCS Low Plasticity Clay
- USCS Low Plasticity Sandy Clay
- Fill (made ground)
- USCS Poorly-graded Gravel
- USCS Poorly-graded Sand

NOTES:

1. GROUND SURFACE ELEVATIONS WERE SURVEYED BY TTL ASSOCIATES, INC. UTILIZING A HAND HELD GPS UNIT.
2. DEMARCATIONS BETWEEN STRATA ARE INTERPRETED AND MAY BE TRANSITIONAL. STRATA BOUNDARIES BETWEEN BORINGS ARE INFERRED AND MAY NOT BE CONTINUOUS.
3. DRAWING EXHIBITS AN APPARENT DISTORTION OF APPROXIMATELY 1 TIMES WHEN COMPARING HORIZONTAL SCALE (APPROX. 1"=11') TO VERTICAL SCALE (APPROX. 1"=11').

W MOISTURE CONTENT

N SPT N-VALUE
ST: SHELBY TUBE SAMPLE
SSR: SPLIT-SPOON REFUSAL

QU UNCONFINED COMPRESSIVE STRENGTH (TSF)
NP: NON-PLASTIC
NI: NOT INTACT

▽ DEPTH OF GROUNDWATER INITIALLY ENCOUNTERED DURING DRILLING

▼ DEPTH OF GROUNDWATER OBSERVED UPON COMPLETION OF DRILLING

PLATE 3.2
GENERALIZED SUBSURFACE SECTION B-B'
EAST AU GRES SEA LAMPREY TRAP
IOSCO COUNTY, MICHIGAN

PREPARED FOR
US ARMY CORPS OF ENGINEERS
DETROIT, MICHIGAN

DRAWN	CLW/09-16-15	CHECKED	KDC/09-16-15
REVISED		APPROVED	
JOB NO.	10835.05		
DRAWING NUMBER	**1083505-06G**		

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Toledo, Ohio 43624
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Fax: 419-241-1808

BORING NUMBER LM-15-01

Michigan Central (FIPS 2112) based on North American Datum 1983 (NAD83)
Northing: 326809.719; Easting: 19205616.957

CLIENT US Army Corps of Engineers
PROJECT NAME Little Manistee Sea Lamprey Trap
PROJECT NUMBER 10835.05
PROJECT LOCATION Manistee County, Michigan
DRILLING CONTRACTOR TTL Associates NW JG
RIG NO. CME 550X
GROUND ELEVATION 603.3 ft (NAVD88)
DRILLING METHOD 3-1/4 in. HSA
GROUND WATER LEVELS:
DATE STARTED 8/10/15 **COMPLETED** 8/11/15
AT TIME OF DRILLING 6.0 ft / Elev 597.3 ft
LOGGED BY KDC(F)/KKC(L) **CHECKED BY** CAS
AT END OF DRILLING N/A: Water Used to Flush Heaving Sands
NOTES A bulk sample was taken from auger cuttings from 3 - 8'.
0hrs AFTER DRILLING Borehole Sealed w/Cement/Bentonite Grout

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL MC LL (20 40 60 80) / ▲ SPT N VALUE ▲ (20 40 60 80)
	0	TOPSOIL - 4 Inches (0.3')						
		Moist Medium Dense Brown POORLY GRADED SAND w/Trace Silt, Gravel, and Organics (SP)	SS 1	39	5-7-12 (19)	NP		
600								
	5		SS 2	67	4-4-9 (13)	NP		
		∇ @6.0': Wet	SS 3	78	7-8-8 (16)	NP		
595		(8.5')						
	10	Wet Very Loose Brown POORLY GRADED SAND w/Trace Silt (SP) (Free Water Noted in Jar) (w/Trace Organics Noted in SS-4 and SS-5 Samples)	SS 4	100	1-1-0 (1)	NP		
		@11': (Free Water Noted in Jar)	SS 5	78	1-2-2 (4)	NP		
590								
	15	@13.5': w/Trace Gravel	SS 6	100	2-2-2 (4)	NP		
		@16': Gray/Brown	SS 7	56	1-2-2 (4)	NP		
585								
	20	@18.5': (Free Water Noted in Jar)	SS 8	100	0-0-1 (1)	NP		
580								
	25	@23.5': (Free Water Noted in Jar)	SS 9	100	1-1-1 (2)	NP		
575								
		@28.5': Brown	SS 10a	100	2-3	NP		
	30	(29.9')	SS 10b	100	4	NP		
		Moist Loose Black PEAT w/Sand and Silt (PT) Loss on Ignition = 28.4%						

(Continued Next Page)

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Telephone: 419-324-2222
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BORING NUMBER LM-15-01

CLIENT US Army Corps of Engineers
PROJECT NAME Little Manistee Sea Lamprey Trap
PROJECT NUMBER 10835.05
PROJECT LOCATION Manistee County, Michigan

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL MC LL (20 40 60 80) ▲ SPT N VALUE ▲ (20 40 60 80)
570	35		33.0' Wet Loose Gray/Brown POORLY GRADED SAND w/Trace Silt and Organics (SP) (Free Water Noted in Jar) 34.5'	SS 11	100	2-2-3 (5)	NP		▲
565	40		Moist Medium Dense Brown POORLY GRADED SAND w/Trace Silt and Gravel (SP)	SS 12	89	5-7-16 (23)	NP		▲
560	45			SS 13	100	8-9-11 (20)	NP		▲
555	50		48.5' Moist Loose Brown POORLY GRADED SAND w/Trace Silt, Gravel, and Organics (SP)	SS 14	100	3-2-4 (6)	NP		▲
550	55		53.5' Moist Medium Dense Brown POORLY GRADED SAND w/Trace Silt and Gravel (SP)	SS 15	100	9-5-12 (17)	NP		▲
545	60		@58.5': Wet, (Free Water Noted in Jar) 60.0'	SS 16	100	9-9-11 (20)	NP		▲
			Bottom of hole at 60.0 feet.						

TTL Associates, Inc.
1915 N 12th Street
Toledo, Ohio 43624
Telephone: 419-324-2222
Fax: 419-241-1808

BORING NUMBER LM-15-02

Michigan Central (FIPS 2112) based on North American Datum 1983 (NAD83)
Northing: 326942.799; Easting: 19205629.515

CLIENT US Army Corps of Engineers
PROJECT NAME Little Manistee Sea Lamprey Trap
PROJECT NUMBER 10835.05
PROJECT LOCATION Manistee County, Michigan
DRILLING CONTRACTOR TTL Associates NW JG
RIG NO. CME 550X
GROUND ELEVATION 601.3 ft (NAVD88)
DRILLING METHOD 3-1/4 in. HSA
GROUND WATER LEVELS:
DATE STARTED 8/11/15 **COMPLETED** 8/11/15
AT TIME OF DRILLING 4.0 ft / Elev 597.3 ft
LOGGED BY KDC(F)/KKC(L) **CHECKED BY** CAS
AT END OF DRILLING N/A: Water Used to Flush Heaving Sands
NOTES A bulk sample was taken from auger cuttings from 1 - 4'.
0hrs AFTER DRILLING Backfilled w/Cuttings

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL MC LL (20 40 60 80) ▲ SPT N VALUE ▲ (20 40 60 80)
	0		TOPSOIL - 5 Inches 0.4'						
600			FILL - Moist Loose Brown POORLY GRADED SAND w/Trace Gravel and Silt 3.5'	SS 1	100	3-4-5 (9)	NP		▲
			▽ Moist Loose Dark Brown POORLY GRADED SAND w/ Trace Silt (SP) (w/Organics Noted in SS-2a Sample, Loss on Ignition =5.8%) @4': Wet, Brown, w/Trace Gravel	SS 2a	83	4	NP		
	5			SS 2b	92	5-5	NP		
595				SS 3	100	3-4-5 (9)	NP		▲
	10		@8.5': Very Loose, (Free Water Noted in Jar)	SS 4	100	2-2-2 (4)	NP		▲
590				SS 5	100	2-2-2 (4)	NP		▲
	15		@13.5': Gray/Brown, (Free Water Noted in Jar)	SS 6	100	1-1-1 (2)	NP		▲
585			@16': Brown/Gray	SS 7	100	1-1-2 (3)	NP		▲
	20		@18.5': Gray/Brown, (Free Water Noted in Jar)	SS 8	100	1-1-1 (2)	NP		▲
580									
	25			SS 9	100	1-1-1 (2)	NP		▲
575									
	30		@29.5': Brown/Gray	SS 10	100	5-2-2 (4)	NP		▲

(Continued Next Page)

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BORING NUMBER LM-15-02

CLIENT US Army Corps of Engineers
PROJECT NAME Little Manistee Sea Lamprey Trap
PROJECT NUMBER 10835.05
PROJECT LOCATION Manistee County, Michigan

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL MC LL (20 40 60 80) / ▲ SPT N VALUE ▲ (20 40 60 80)
570									
	35		@33.5': Brown	SS 11	100	1-1-2 (3)	NP		▲
565									
	40		@38.5': Loose	SS 12	100	3-4-5 (9)	NP		▲
560									
	45		@43.5': Very Loose	SS 13	100	1-1-1 (2)	NP		▲
555			48.5'						
	50		Moist Medium Dense Brown POORLY GRADED SAND w/Trace Silt (SP)	SS 14	100	3-5-10 (15)	NP		▲
550			53.5'						
	55		Moist Dense Brown POORLY GRADED SAND w/Trace Silt (SP)	SS 15	100	11-20-24 (44)	NP		▲
545			58.5'						
	60		Moist Medium Dense Brown POORLY GRADED SAND w/Trace Silt (SP) 60.0'	SS 16	100	3-5-10 (15)	NP		▲

Bottom of hole at 60.0 feet.

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BORING NUMBER AG-15-01

Michigan Central (FIPS 2112) based on North American Datum 1983 (NAD83)
Northing: 330799.924; Easting: 19860302.530

CLIENT US Army Corps of Engineers
PROJECT NAME East Au Gres Sea Lamprey Trap
PROJECT NUMBER 10835.05
PROJECT LOCATION Iosco County, Michigan
DRILLING CONTRACTOR TTL Associates NW JG
RIG NO. CME 550X
GROUND ELEVATION 648.1 ft (NAVD88)
DRILLING METHOD 3-1/4 in. HSA
GROUND WATER LEVELS:
DATE STARTED 8/12/15 **COMPLETED** 8/12/15
AT TIME OF DRILLING 7.4 ft / Elev 640.7 ft
LOGGED BY KDC(F)/KKC(L) **CHECKED BY** CAS
AT END OF DRILLING 15.0 ft / Elev 633.1 ft
NOTES
0hrs AFTER DRILLING Backfilled w/Cuttings and Bentonite Chips

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL MC LL (20 40 60 80) / ▲ SPT N VALUE ▲ (20 40 60 80)
	0	TOPSOIL - 6 Inches (0.5')						
645		FILL - Moist Very Stiff Brown LEAN CLAY w/Sand, Trace Gravel, and Organics (4.5')	SS 1	67	5-8-10 (18)	2.50		15
	5	FILL - Moist Dense Gray CRUSHED STONE w/Sand and Clay (5.0')	SS 2	100	10-15-19 (34)	NP		7
640		Moist Dense Brown POORLY GRADED SAND w/Trace Silt (SP) ▽ @7.4': Wet (8.5')	SS 3	78	10-15-19 (34)	NP		19
	10	Moist Very Stiff Brown LEAN CLAY w/Trace Sand (CL) (11.0')	SS 4	100	3-6-11 (17)	3.50		22
635		Moist Medium Dense Brown POORLY GRADED SAND w/Trace Silt (SP) (11.8')	SS 5a	100	5-12	NP		17
			SS 5b	100	12	2.50		22
	15	Moist Very Stiff Brown LEAN CLAY w/Sand (CL) (14.4') ▼ Moist POORLY GRADED SAND w/Trace Silt (SP) (14.5')	ST 1	75		UU	96	26
630		Moist Medium Stiff Brown LEAN CLAY w/Sand (CL)	SS 6	100	3-3-5 (8)	2.00		27
	20	@18.5': w/Trace Sand	SS 7	100	2-3-4 (7)	2.00		33
625		(23.5')						
	25	Moist Medium Stiff Gray/Brown SANDY LEAN CLAY w/Trace Gravel (CL)	SS 8	100	2-2-3 (5)	1.50		12
620			ST 2	58		UU	128	10
	30	(29.4') Moist Very Stiff to Hard Gray/Brown SANDY LEAN CLAY w/Trace Gravel (CL)	SS 9	100	4-4-9 (13)	>4.5		11

(Continued Next Page)

TTL Associates, Inc.
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BORING NUMBER AG-15-01

Michigan Central (FIPS 2112) based on North American Datum 1983 (NAD83)
Northing: 330799.924; Easting: 19860302.530

CLIENT US Army Corps of Engineers
PROJECT NAME East Au Gres Sea Lamprey Trap
PROJECT NUMBER 10835.05
PROJECT LOCATION Iosco County, Michigan
DRILLING CONTRACTOR TTL Associates NW JG
RIG NO. CME 550X
GROUND ELEVATION 648.1 ft (NAVD88)
DRILLING METHOD 3-1/4 in. HSA
GROUND WATER LEVELS:
DATE STARTED 8/12/15 **COMPLETED** 8/12/15
AT TIME OF DRILLING 7.4 ft / Elev 640.7 ft
LOGGED BY KDC(F)/KKC(L) **CHECKED BY** CAS
AT END OF DRILLING 15.0 ft / Elev 633.1 ft
NOTES
0hrs AFTER DRILLING Backfilled w/Cuttings and Bentonite Chips

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL MC LL (20 40 60 80) / ▲ SPT N VALUE ▲ (20 40 60 80)
	0	TOPSOIL - 6 Inches (0.5')						
645		FILL - Moist Very Stiff Brown LEAN CLAY w/Sand, Trace Gravel, and Organics (4.5')	SS 1	67	5-8-10 (18)	2.50		15
	5	FILL - Moist Dense Gray CRUSHED STONE w/Sand and Clay (5.0')	SS 2	100	10-15-19 (34)	NP		7
640		Moist Dense Brown POORLY GRADED SAND w/Trace Silt (SP) ▽ @7.4': Wet (8.5')	SS 3	78	10-15-19 (34)	NP		19
	10	Moist Very Stiff Brown LEAN CLAY w/Trace Sand (CL) (11.0')	SS 4	100	3-6-11 (17)	3.50		22
635		Moist Medium Dense Brown POORLY GRADED SAND w/Trace Silt (SP) (11.8')	SS 5a	100	5-12	NP		17
			SS 5b	100	12	2.50		22
	15	Moist Very Stiff Brown LEAN CLAY w/Sand (CL) (14.4') ▼ Moist POORLY GRADED SAND w/Trace Silt (SP) (14.5')	ST 1	75		UU	96	26
630		Moist Medium Stiff Brown LEAN CLAY w/Sand (CL)	SS 6	100	3-3-5 (8)	2.00		27
	20	@18.5': w/Trace Sand	SS 7	100	2-3-4 (7)	2.00		33
625		(23.5')						
	25	Moist Medium Stiff Gray/Brown SANDY LEAN CLAY w/Trace Gravel (CL)	SS 8	100	2-2-3 (5)	1.50		12
620			ST 2	58		UU	128	10
	30	(29.4') Moist Very Stiff to Hard Gray/Brown SANDY LEAN CLAY w/Trace Gravel (CL)	SS 9	100	4-4-9 (13)	>4.5		11

(Continued Next Page)

TTL Associates, Inc.
1915 N 12th Street
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Telephone: 419-324-2222
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BORING NUMBER AG-15-01

CLIENT US Army Corps of Engineers **PROJECT NAME** East Au Gres Sea Lamprey Trap

PROJECT NUMBER 10835.05 **PROJECT LOCATION** Iosco County, Michigan

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL MC LL 20 40 60 80 ▲ SPT N VALUE ▲ 20 40 60 80
615									
	35		@33.5': Brown	SS 10	100	7-12-22 (34)	>4.5		9
610									
	40			SS 11	100	6-10-18 (28)	>4.5		12
605									
	45			SS 12	100	5-12-18 (30)	>4.5		11
600									
	50			SS 13	100	5-10-15 (25)	>4.5		11
595									
	55			SS 14	100	5-10-13 (23)	3.00		15
590			@58': Gray/Brown	ST 3	89		UU	128	11
	60		59.5' Moist Stiff to Very Stiff Gray SANDY LEAN CLAY (CL)	SS 15	100	6-9-14 (23)	2.00		16
585									
	65			SS 16	100	3-7-8 (15)	1.50		16

(Continued Next Page)

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BORING NUMBER AG-15-01

CLIENT US Army Corps of Engineers **PROJECT NAME** East Au Gres Sea Lamprey Trap

PROJECT NUMBER 10835.05 **PROJECT LOCATION** Iosco County, Michigan

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL MC LL 20 40 60 80 ▲ SPT N VALUE ▲ 20 40 60 80
580			68.5'						
	70		Moist Medium Stiff to Stiff Gray LEAN CLAY w/Trace Sand and Gravel (CL)	SS 17	100	5-6-6 (12)	1.00		22
575									
	75		75.0'	SS 18	100	3-3-5 (8)	0.50		37
			Bottom of hole at 75.0 feet.						

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BORING NUMBER AG-15-02

Michigan Central (FIPS 2112) based on North American Datum 1983 (NAD83)
Northing: 330750.530; Easting: 19860404.810

CLIENT US Army Corps of Engineers
PROJECT NAME East Au Gres Sea Lamprey Trap
PROJECT NUMBER 10835.05
PROJECT LOCATION Iosco County, Michigan
DRILLING CONTRACTOR TTL Associates NW JG
RIG NO. Hand Auger
GROUND ELEVATION 634.7 ft (NAVD88)
DRILLING METHOD Hand Auger
GROUND WATER LEVELS:
DATE STARTED 8/12/15
COMPLETED 8/12/15
AT TIME OF DRILLING None
LOGGED BY KDC(F)/KKC(L)
CHECKED BY CAS
AT END OF DRILLING None
NOTES
0hrs AFTER DRILLING Backfilled w/Cuttings and Bentonite Chips

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL MC LL 20 40 60 80 ▲ SPT N VALUE ▲ 20 40 60 80
	0		FILL - RIP RAP w/Sand 1.0'						
			FILL - Moist Brown LEAN CLAY w/Sand and Trace Gravel	AU 1	100		NI		22
630	5		@3.5': w/Trace Sand	AU 2	100		NI		32
				AU 3	100		NI		26
625	10		10.0'	AU 4	100		NI		28

Bottom of hole at 10.0 feet.

LEGEND KEY

Unified Soil Classification System Soil Symbols

- GW - WELL GRADED GRAVEL Includes Gravel-Sand mixtures, little or no fines.
- GP - POORLY GRADED GRAVEL Includes Gravel-Sand mixtures, little or no fines.
- GM - SILTY GRAVEL Includes Gravel-Sand-Silt mixtures.
- GC - CLAYEY GRAVEL Includes Gravel-Sand-Clay mixtures.
- SW - WELL GRADED SAND Includes Gravelly Sands, little or no fines.
- SP - POORLY GRADED SAND Includes Gravelly Sands, little or no fines.
- SM - SILTY SAND Includes Sand-Silt mixtures.
- SC - CLAYEY SAND Includes Sand-Clay mixtures.
- ML - SILT Includes Silt with Sand and Sandy Silt.
- CL - LEAN CLAY Includes Sandy Lean Clay and Lean Clay with Sand and Gravel.
- MH - ELASTIC SILT Includes Sandy Elastic Silt and Elastic Silt with Sand.
- CH - FAT CLAY Includes Sandy Fat Clay and Fat Clay with Sand.
- CL-ML - SILTY CLAY Includes Clayey Silt of low plasticity.
- OL - ORGANIC SILT and ORGANIC CLAY of low plasticity.
- OH - ORGANIC SILT and ORGANIC CLAY of medium to high plasticity.
- Pt - PEAT Includes humus, swamp and other soils with high organic content.
- FILL MATERIAL - Includes controlled and non-controlled soil and non-soil materials.
- TOPSOIL
- ASPHALT - Bituminous Asphalt
- CONCRETE - Includes broken concrete rubble.

Sample Symbols

- SS - Split Spoon
- ST - Shelby Tube
- RC - Rock Core
- GS - Geoprobe Sleeve
- AU - Auger Cuttings
- GB - Grab

Notes:

1. Exploratory borings were drilled during the period from August 10 through 12, 2015, using 3¼-inch inside diameter hollow-stem augers.

2. These logs are subject to the limitations, conclusions, and recommendations in the report and should not be interpreted separate from the report.

3. Boring locations and elevations were established by TTL Associates, Inc. (TTL), using on northing and easting coordinates indicated on the provided boring location plan dated June 26, 2015, furnished by the US Army Corps of Engineers. Ground surface elevations at the boring locations were surveyed by TTL referencing the North American Vertical Datum of 1988 (NAVD88).

4. Unconfined Compressive Strength (tsf):
   NP = Non-Plastic
   UU = Unconsolidated-Undrained Triaxial Test
   NI = Not Intact

PROJECT: Little Manistee and East Au Gres Sea Lamprey Traps	TTL Associates, Inc.	PROJECT NO: 10835.05

TABULATION OF TEST DATA

Boring Number	Sample Number	Sample Interval Depth (Feet)		Standard Penetration (Blows per Foot)	Natural Moisture Content (% of Dry Weight)	In-Place Dry Density (Pounds per Cubic Foot)	Unconfined Compressive Strength (Pounds per Square Foot)	Loss on Ignition (Percent)	Particle Size Distribution (%)						Atterberg Limits (%)			Unified Soil Classification
									Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index	
AG-15-01	SS-1	1.0-2.5		18	15.3		*5,000											
	SS-2	3.5-5.0		34	6.9													
	SS-3	6.0-7.5		34	19.0													
	SS-4	8.5-10.0		17	22.0		*7,000		0	0	1	3	19	77				
	SS-5a	11.0-12.0		24	17.4													
	SS-5b	12.0-12.5			21.9		*5,000											
	ST-1	14.0-16.0			26.3	95.6	UU		0	0	0	2	21	77	48	24	24	CL
	SS-6	16.0-17.5		8	26.9		*4,000											
	SS-7	18.5-20.0		7	32.7		*4,000											
	SS-8	23.5-25.0		5	12.2		*3,000											
	ST-2	26.0-28.0			10.5	128.2	UU		3	5	8	30	34	20	20	11	9	CL
	SS-9	28.5-30.0		13	11.1		*9,000+											
	SS-10	33.5-35.0		34	9.0		*9,000+		3	3	8	30	29	27				
	SS-11	38.5-40.0		28	12.0		*9,000+											
	SS-12	43.5-45.0		30	10.8		*9,000+											
	SS-13	48.5-50.0		25	11.3		*9,000+											
	SS-14	53.5-55.0		23	14.6		*6,000											

*Unconfined compressive strength derived from a calibrated hand penetrometer

PROJECT: Little Manistee and East Au Gres Sea Lamprey Traps	TTL Associates, Inc.	PROJECT NO: 10835.05

TABULATION OF TEST DATA

Boring Number	Sample Number	Sample Interval Depth (Feet)		Standard Penetration (Blows per Foot)	Natural Moisture Content (% of Dry Weight)	In-Place Dry Density (Pounds per Cubic Foot)	Unconfined Compressive Strength (Pounds per Square Foot)	Loss on Ignition (Percent)	Particle Size Distribution (%)						Atterberg Limits (%)			Unified Soil Classification
									Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index	
AG-15-01	ST-3	58.0-59.5			10.8	128.1	UU		5	3	6	24	33	29	21	12	9	CL
	SS-15	59.5-61.0		23	16.2		*4,000											
	SS-16	63.5-65.0		15	16.3		*3,000											
	SS-17	68.5-70.0		12	22.1		*2,000											
	SS-18	73.5-75.0		8	37.0		*1,000											
AG-15-02	AU-1	1.0-2.5			22.1										32	19	13	
	AU-2	3.5-5.0			32.1													
	AU-3	6.0-7.5			26.4				0	0	1	3	28	68	42	19	23	CL
	AU-4	8.5-10.0			27.8													

*Unconfined compressive strength derived from a calibrated hand penetrometer

PROJECT: Little Manistee and East Au Gres Sea Lamprey Traps	TTL Associates, Inc.	PROJECT NO: 10835.05

TABULATION OF TEST DATA

Boring Number	Sample Number	Sample Interval Depth (Feet)		Standard Penetration (Blows per Foot)	Natural Moisture Content (% of Dry Weight)	In-Place Dry Density (Pounds per Cubic Foot)	Unconfined Compressive Strength (Pounds per Square Foot)	Loss on Ignition (Percent)	Particle Size Distribution (%)						Atterberg Limits (%)			Unified Soil Classification
									Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index	
LM-15-01	SS-1	1.0-2.5		19														
	SS-2	3.5-5.0		13														
	SS-3	6.0-7.5		16					1	1	15	80	- 3 -		NON-PLASTIC			SP
	SS-4	8.5-10.0		1														
	SS-5	11.0-12.5		4														
	SS-6	13.5-15.0		4														
	SS-7	16.0-17.5		4														
	SS-8	18.5-20.0		1														
	SS-9	23.5-25.0		2														
	SS-10a	28.5-29.5		7														
	SS-10b	29.5-30.0						28.4	41	17	13	23	- 6 -		NON-PLASTIC			SP-/M
	SS-11	33.5-35.0		5														
	SS-12	38.5-40.0		23														
	SS-13	43.5-45.0		20														
	SS-14	48.5-50.0		6														
	SS-15	53.5-55.0		27														
	SS-16	58.5-60.0		20														

*Unconfined compressive strength derived from a calibrated hand penetrometer

PROJECT: Little Manistee and East Au Gres Sea Lamprey Traps	TTL Associates, Inc.	PROJECT NO: 10835.05

TABULATION OF TEST DATA

Boring Number	Sample Number	Sample Interval Depth (Feet)		Standard Penetration (Blows per Foot)	Natural Moisture Content (% of Dry Weight)	In-Place Dry Density (Pounds per Cubic Foot)	Unconfined Compressive Strength (Pounds per Square Foot)	Loss on Ignition (Percent)	Particle Size Distribution (%)						Atterberg Limits (%)			Unified Soil Classification
									Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index	
LM-15-02	SS-1	1.0-2.5		9					6	12	37	42	- 3 -		NON-PLASTIC			SP
	SS-2a	3.5-4.0		10				5.8										
	SS-2b	4.0-5.0																
	SS-3	6.0-7.5		9														
	SS-4	8.5-10.0		4														
	SS-5	11.0-12.5		4														
	SS-6	13.5-15.0		2														
	SS-7	16.0-17.5		3														
	SS-8	18.5-20.0		2														
	SS-9	23.5-25.0		2					15	9	19	56	- 1 -		NON-PLASTIC			SP
	SS-10	28.5-30.0		4														
	SS-11	33.5-35.0		3														
	SS-12	38.5-40.0		9														
	SS-13	43.5-45.0		2														
	SS-14	48.5-50.0		15														
	SS-15	53.5-55.0		44														
	SS-16	58.5-60.0		15														

*Unconfined compressive strength derived from a calibrated hand penetrometer

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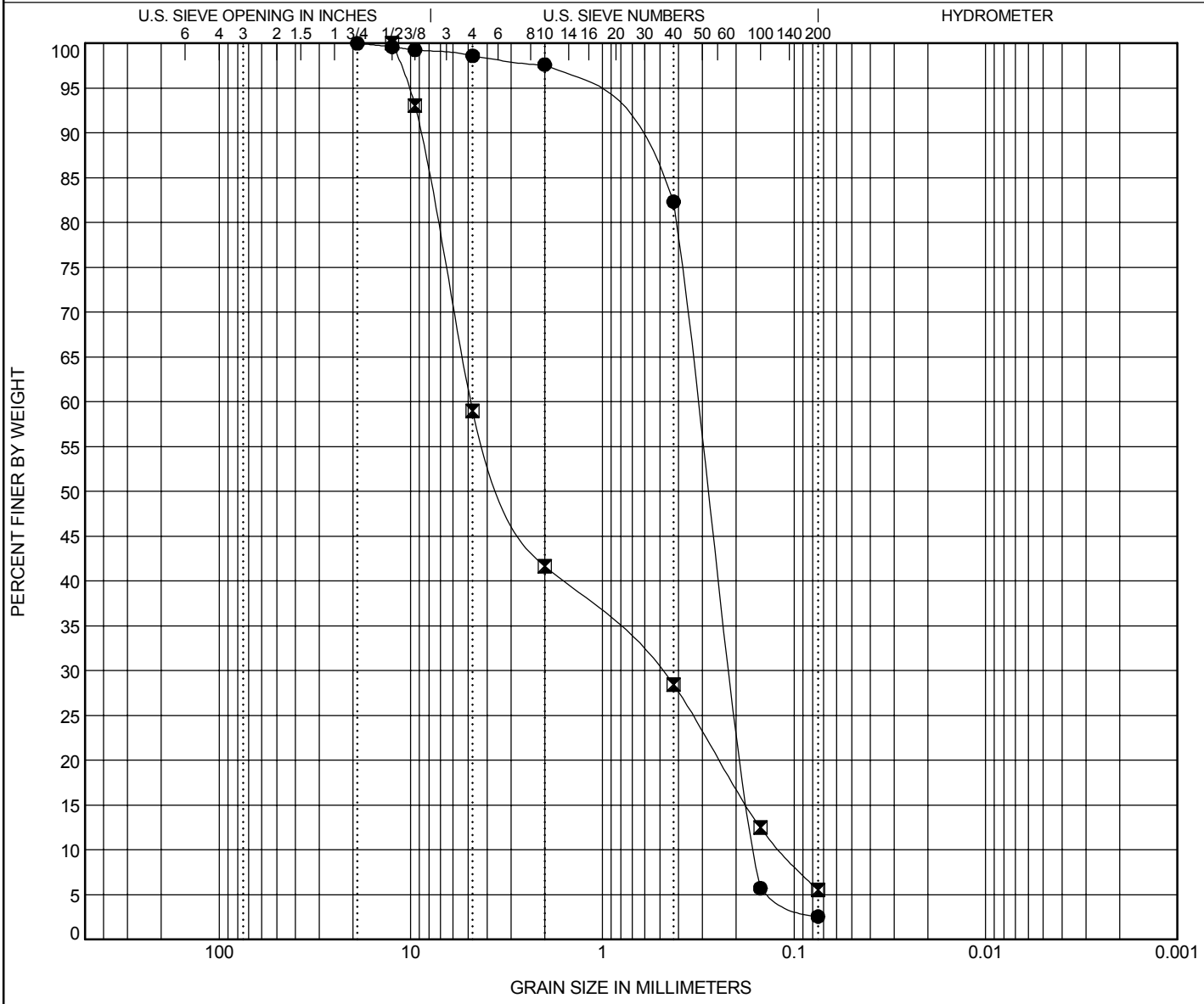
GRAIN SIZE DISTRIBUTION

CLIENT US Army Corps of Engineers **PROJECT NAME** Little Manistee Sea Lamprey Trap

PROJECT NUMBER 10835.05 **PROJECT LOCATION** Manistee County, Michigan



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		USCS Classification	LL	PL	PI	Cc	Cu
●	**LM-15-01**	**6.0**	**POORLY GRADED SAND (SP)**	**NP**	**NP**	**NP**	**0.9**	**2.0**
⊠	**LM-15-01**	**29.5**	**PEAT w/Sand and Silt (PT)**	**NP**	**NP**	**NP**	**0.5**	**41.5**

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**LM-15-01**	**6.0**	**19**	**0.314**	**0.209**	**0.159**	**1.4**	**96.0**	**2.6**	
⊠	**LM-15-01**	**29.5**	**12.5**	**4.845**	**0.508**	**0.117**	**41.0**	**53.5**	**5.6**	

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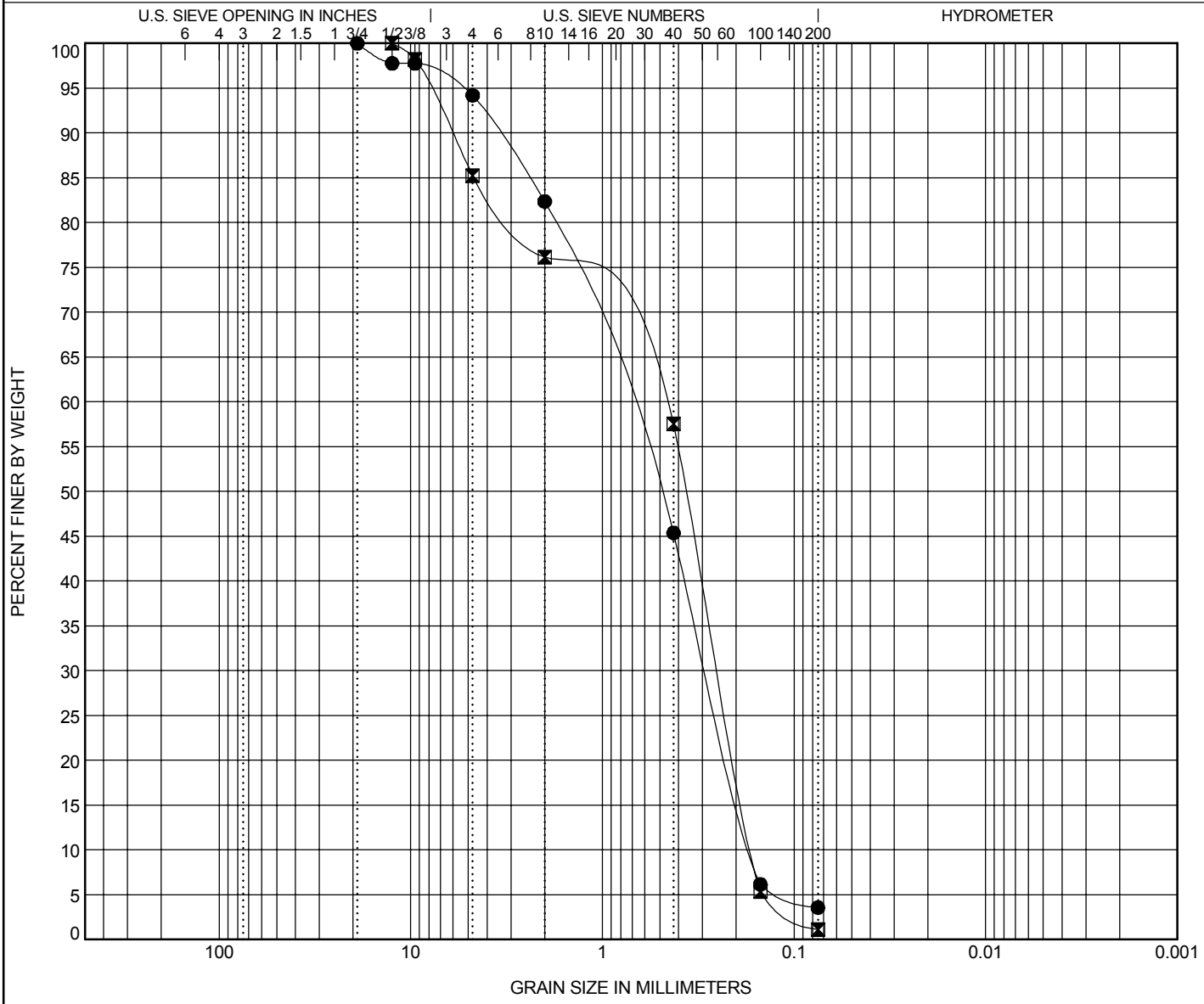
Toledo, Ohio 43624
Telephone: 419-324-2222
Fax: 419-241-1808

GRAIN SIZE DISTRIBUTION

CLIENT US Army Corps of Engineers **PROJECT NAME** Little Manistee Sea Lamprey Trap

PROJECT NUMBER 10835.05 **PROJECT LOCATION** Manistee County, Michigan



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		USCS Classification	LL	PL	PI	Cc	Cu
●	**LM-15-02**	**1.0**	**POORLY GRADED SAND (SP)**	**NP**	**NP**	**NP**	**0.6**	**4.7**
⊠	**LM-15-02**	**23.5**	**POORLY GRADED SAND (SP)**	**NP**	**NP**	**NP**	**0.7**	**3.2**

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**LM-15-02**	**1.0**	**19**	**0.784**	**0.283**	**0.166**	**5.8**	**90.6**	**3.6**	
⊠	**LM-15-02**	**23.5**	**12.5**	**0.522**	**0.245**	**0.164**	**14.8**	**84.1**	**1.1**	

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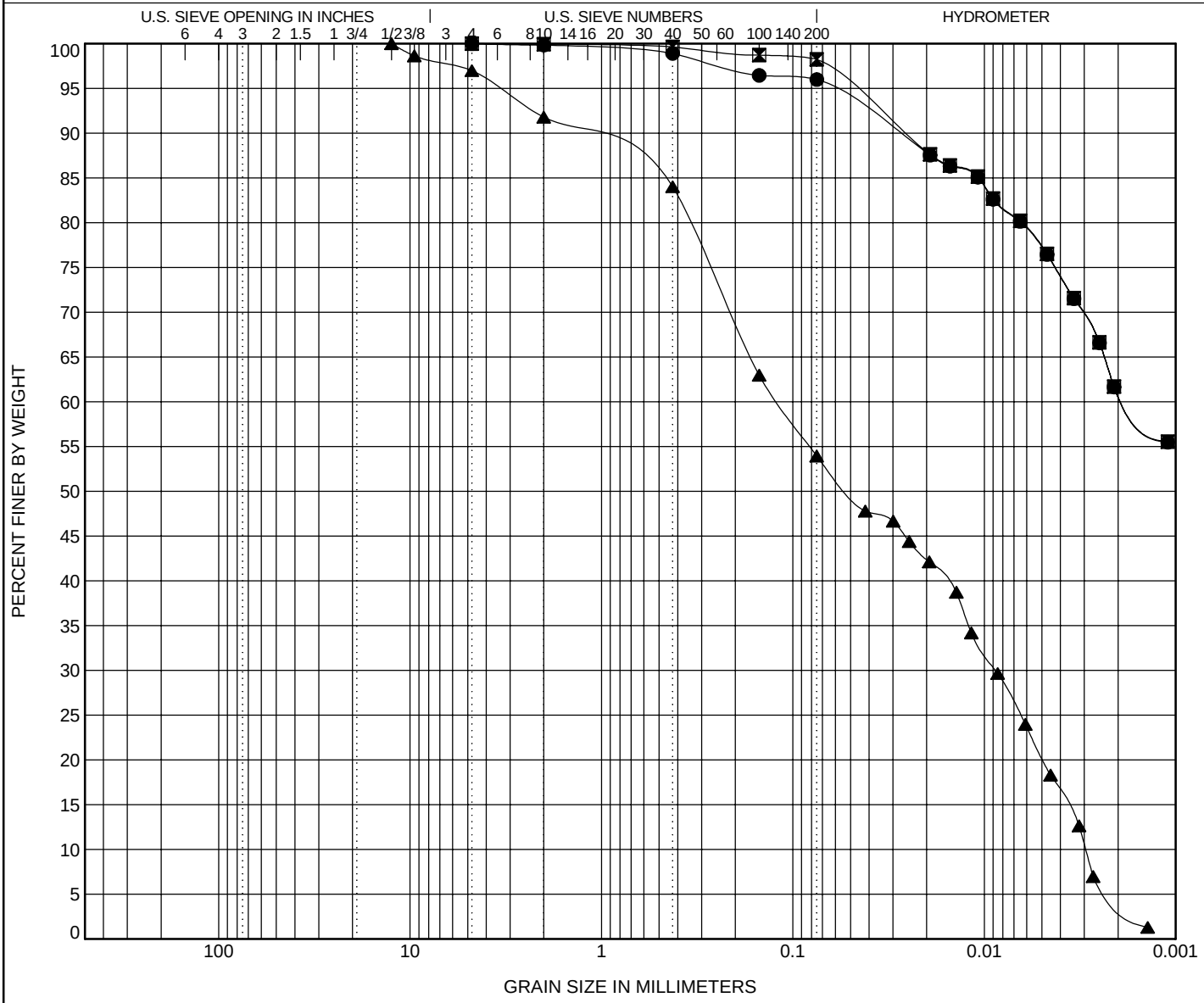
GRAIN SIZE DISTRIBUTION

CLIENT US Army Corps of Engineers **PROJECT NAME** East Au Gres Sea Lamprey Trap

PROJECT NUMBER 10835.05 **PROJECT LOCATION** Iosco County, Michigan



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		USCS Classification	LL	PL	PI	Cc	Cu
●	**AG-15-01**	**8.5**	**LEAN CLAY w/Trace Sand (CL)**					
⊠	**AG-15-01**	**14.0**	**LEAN CLAY (CL)**	**48**	**24**	**24**		
▲	**AG-15-01**	**26.0**	**SANDY LEAN CLAY (CL)**	**20**	**11**	**9**	**0.2**	**40.4**

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**AG-15-01**	**8.5**	**4.75**	**0.002**			**0.0**	**4.0**	**18.8**	**77.1**
⊠	**AG-15-01**	**14.0**	**4.75**	**0.002**			**0.0**	**1.7**	**21.0**	**77.2**
▲	**AG-15-01**	**26.0**	**12.5**	**0.119**	**0.009**	**0.003**	**3.0**	**43.0**	**33.7**	**20.3**

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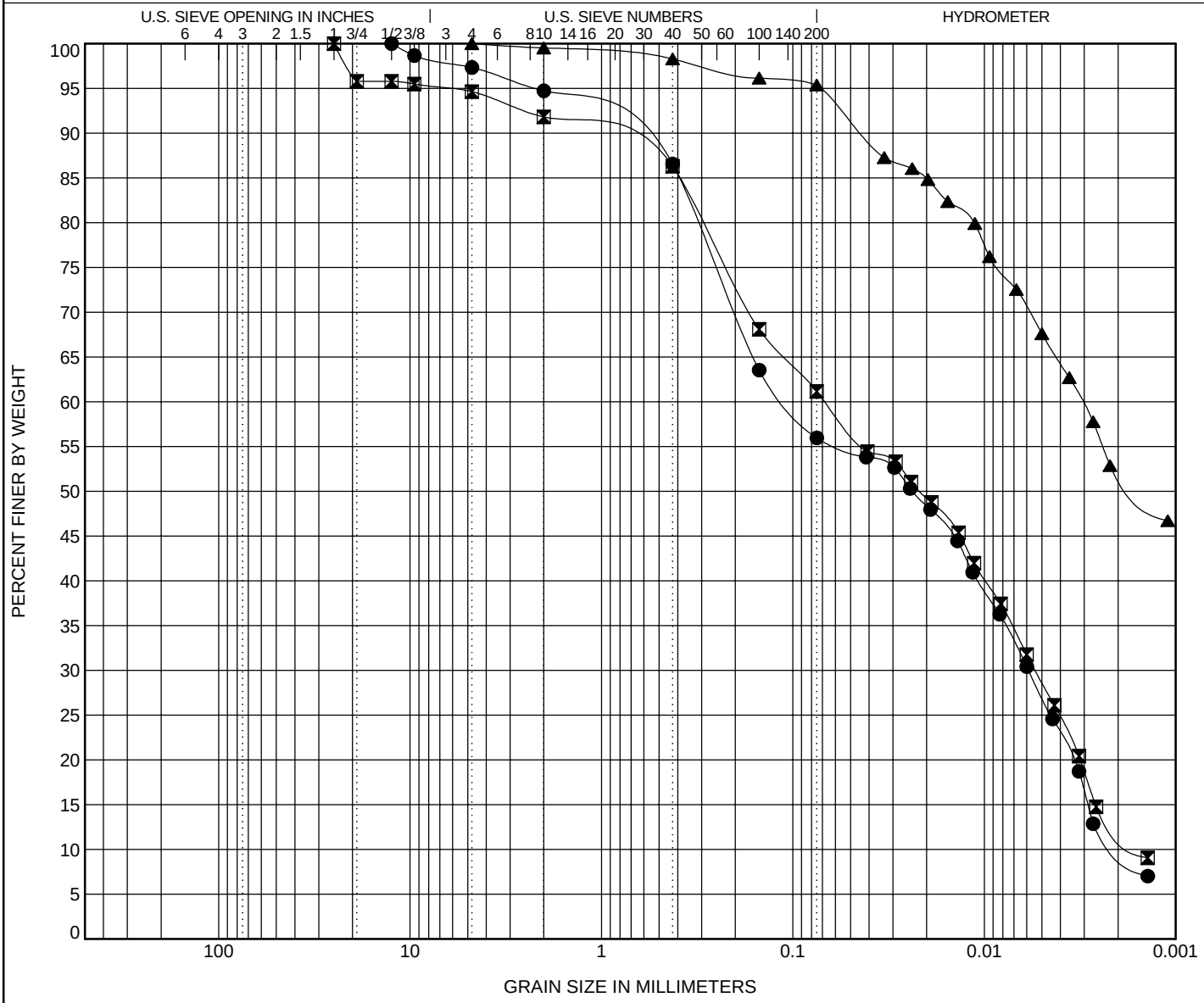
GRAIN SIZE DISTRIBUTION

CLIENT US Army Corps of Engineers **PROJECT NAME** East Au Gres Sea Lamprey Trap

PROJECT NUMBER 10835.05 **PROJECT LOCATION** Iosco County, Michigan



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		USCS Classification	LL	PL	PI	Cc	Cu
●	**AG-15-01**	**33.5**	**SANDY LEAN CLAY (CL)**				**0.2**	**55.5**
⊠	**AG-15-01**	**58.0**	**SANDY LEAN CLAY (CL)**	**21**	**12**	**9**	**0.3**	**43.6**
▲	**AG-15-02**	**6.0**	**LEAN CLAY (CL)**	**42**	**19**	**23**		

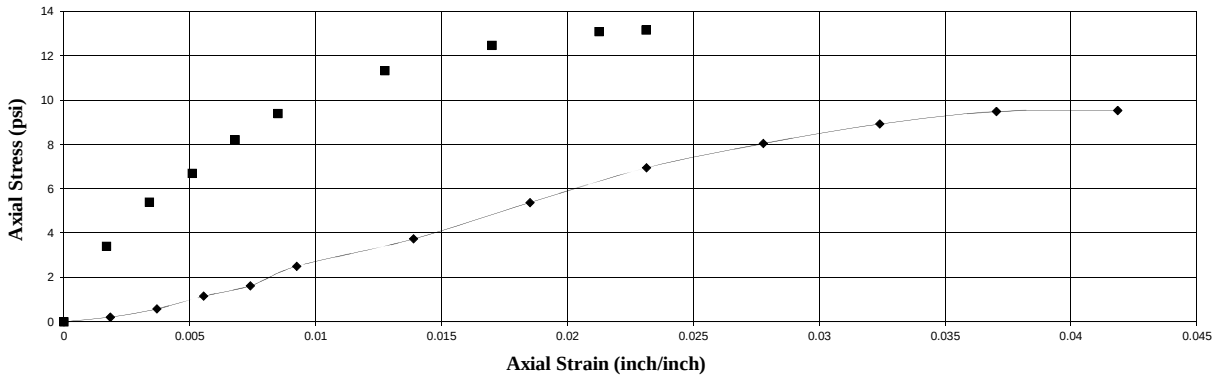
	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**AG-15-01**	**33.5**	**12.5**	**0.109**	**0.006**	**0.002**	**2.7**	**41.4**	**29.0**	**27.0**
⊠	**AG-15-01**	**58.0**	**25**	**0.068**	**0.005**	**0.002**	**5.4**	**33.5**	**32.5**	**28.7**
▲	**AG-15-02**	**6.0**	**4.75**	**0.003**			**0.0**	**4.6**	**27.8**	**67.6**

Unconsolidated - Undrained Triaxial Shear Strength Test

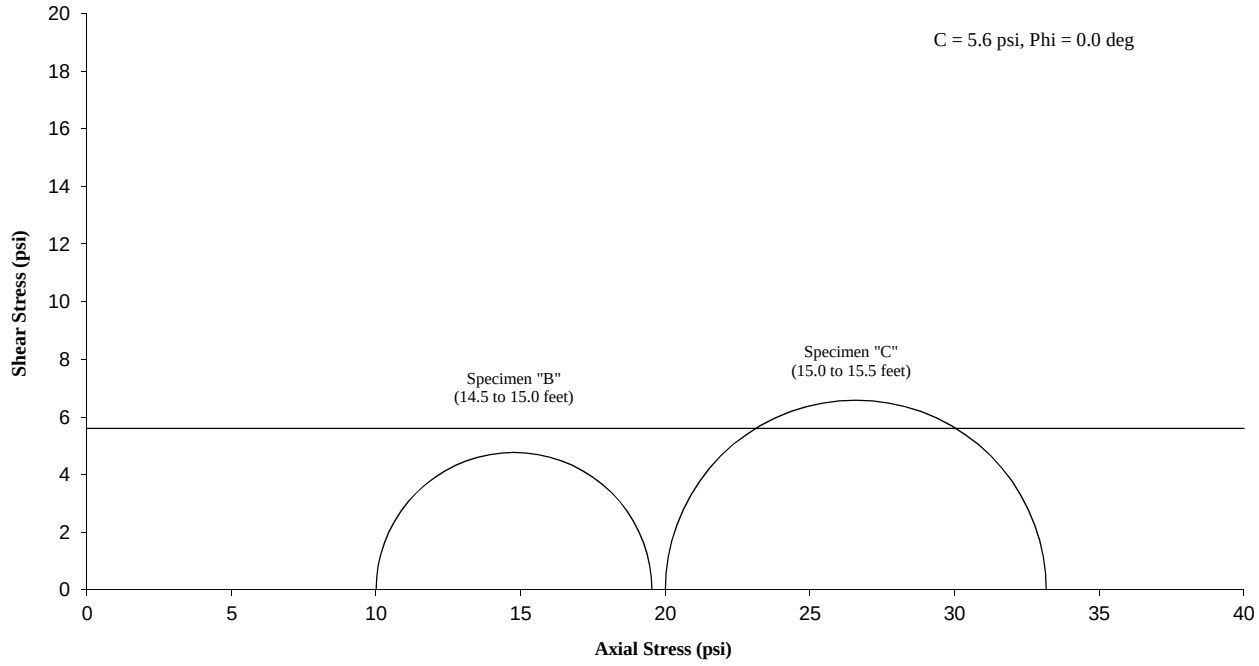
ASTM D 2850

General Sample Data		Triaxial Specimen Data			
TTL Project No.:	10835.05	Symbol	◆	■	●
Project:	East Au Gres Sea Lamprey Trap	Init. Specimen Height (in.)	5.40	5.88	-
Sample ID:	AG-15-01 (ST-1)	Init. Specimen Diameter (in.)	2.88	2.88	-
Sample Interval:	14.0 to 16.0 feet	Init. Moisture Content (%)	26.3	26.4	-
		Init. Dry Unit Weight (pcf)	95.7	96.2	-
Soil Description:	Brown LEAN CLAY w/Trace Sand (CL)				
Liquid Limit:	48	Init. Void Ratio	0.79	0.78	-
Plastic Limit:	24	Init. Degree of Saturation (%)	91	93	-
Plasticity Index:	24	Minor Principal Stress (psi)	10.0	20.0	-
Specific Gravity:	2.75 (Assumed)	Deviator Stress at Failure (psi)	9.5	13.2	-
Rate of Strain:	0.03 Inches per Minute	Major Principal Stress (psi)	19.5	33.2	-
Failure Criteria:	Peak Deviator Stress or Deviator Stress at 15% Axial Strain	Axial Strain at Failure (%)	4.2	2.3	-

Stress/Strain



Mohr Circle Plot



UNCONSOLIDATED, UNDRAINED COMPRESSIVE STRENGTH OF COHESIVE SOILS IN TRIAXIAL COMPRESSION (ASTM D 2850)

Project:	East Au Gres Sea Lamprey Trap	Date:	8/23/2015
Client:	US Army Corps of Engineers	File:	10835.05AG-15-01ST-1
Sample ID:	AG-15-01 (ST-1)	Depth:	14.0 to 16.0 feet
TTL Project No.:	10835.05	Specimen ID:	"B" (14.5 to 15.0 feet)

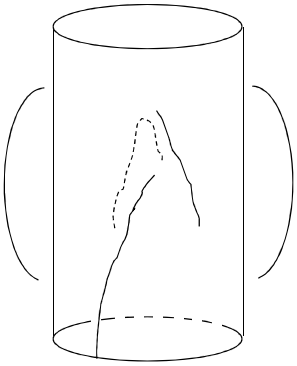
SAMPLE PROPERTIES

Visual Description: Brown LEAN CLAY w/Trace Sand (CL)

Diameter:	2.88 in.	Initial Dry Unit Weight of Sample:	95.7 pcf
Area:	6.514 in^2	Initial Moisture Content:	26.3 %
Length:	5.40 in.	Specific Gravity (assumed):	2.75
Initial Void Ratio:	0.79	Initial Degree of Saturation:	91 %
Chamber Pressure:	10 psi	Proving Ring Number:	1155-12-13322

STRESS-STRAIN DATA

Speciman Deformation (in)	Vertical Strain	Proving Ring Reading	Piston Load (lbs)	Corrected Area (in^2)	Deviator Stress (psi)
0.000	0.000	0.0	0.0	6.514	0.0
0.010	0.002	2.0	1.4	6.526	0.2
0.020	0.004	5.5	3.8	6.539	0.6
0.030	0.006	11.0	7.5	6.551	1.2
0.040	0.007	15.5	10.6	6.563	1.6
0.050	0.009	24.0	16.5	6.575	2.5
0.075	0.014	36.0	24.7	6.606	3.7
0.100	0.019	52.0	35.7	6.637	5.4
0.125	0.023	67.5	46.3	6.669	6.9
0.150	0.028	78.5	53.9	6.701	8.0
0.175	0.032	87.5	60.0	6.733	8.9
0.200	0.037	93.5	64.1	6.765	9.5
0.226	0.042	94.5	64.8	6.799	9.5



Sketch of Tested Specimen

RESULTS

Maximum Deviator Stress 9.5 psi

UNCONSOLIDATED, UNDRAINED COMPRESSIVE STRENGTH OF COHESIVE SOILS IN TRIAXIAL COMPRESSION (ASTM D 2850)

Project:	East Au Gres Sea Lamprey Trap	Date:	8/23/2015
Client:	US Army Corps of Engineers	File:	10835.05AG-15-01ST-1
Sample ID:	AG-15-01 (ST-1)	Depth:	14.0 to 16.0 feet
TTL Project No.:	10835.05	Specimen ID:	"C" (15.0 to 15.5 feet)

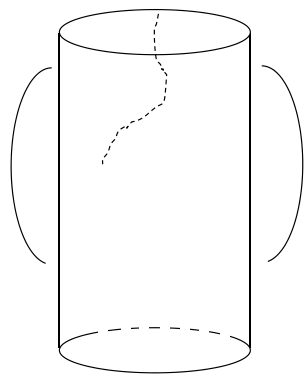
SAMPLE PROPERTIES

Visual Description: Brown LEAN CLAY w/Trace Sand (CL)

Diameter:	2.88 in.	Initial Dry Unit Weight of Sample:	96.2 pcf
Area:	6.514 in^2	Initial Moisture Content:	26.4 %
Length:	5.88	Specific Gravity (assumed):	2.75
Initial Void Ratio:	0.78	Initial Degree of Saturation:	93 %
Chamber Pressure:	20 psi	Proving Ring Number:	1155-12-13322

STRESS-STRAIN DATA

Speciman Deformation (in)	Vertical Strain	Proving Ring Reading	Piston Load (lbs)	Corrected Area (in^2)	Deviator Stress (psi)
0.000	0.000	0.0	0.0	6.514	0.0
0.010	0.002	32.5	22.3	6.525	3.4
0.020	0.003	51.5	35.3	6.537	5.4
0.030	0.005	64.0	43.9	6.548	6.7
0.040	0.007	78.5	53.9	6.559	8.2
0.050	0.009	90.0	61.7	6.570	9.4
0.075	0.013	109.0	74.8	6.599	11.3
0.100	0.017	120.5	82.7	6.627	12.5
0.125	0.021	127.0	87.1	6.656	13.1
0.136	0.023	128.0	87.8	6.669	13.2



Sketch of Tested Specimen

RESULTS

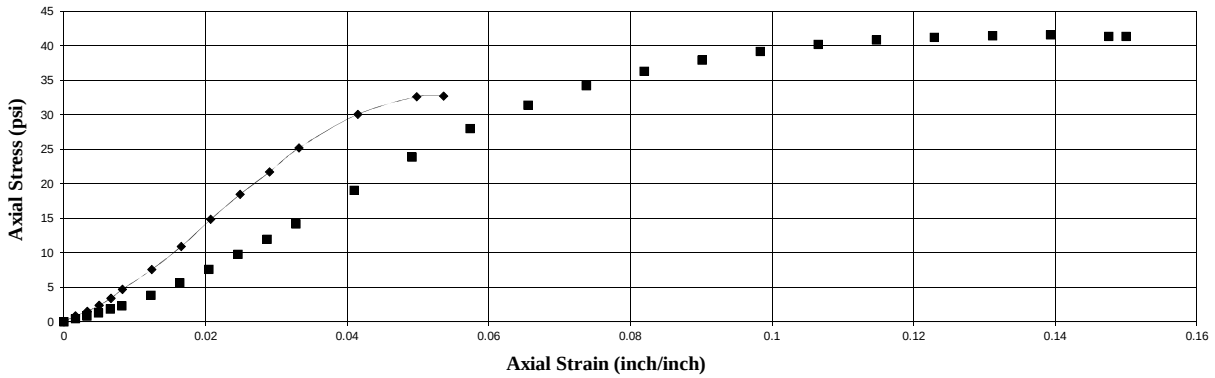
Maximum Deviator Stress 13.2 psi

Unconsolidated - Undrained Triaxial Shear Strength Test

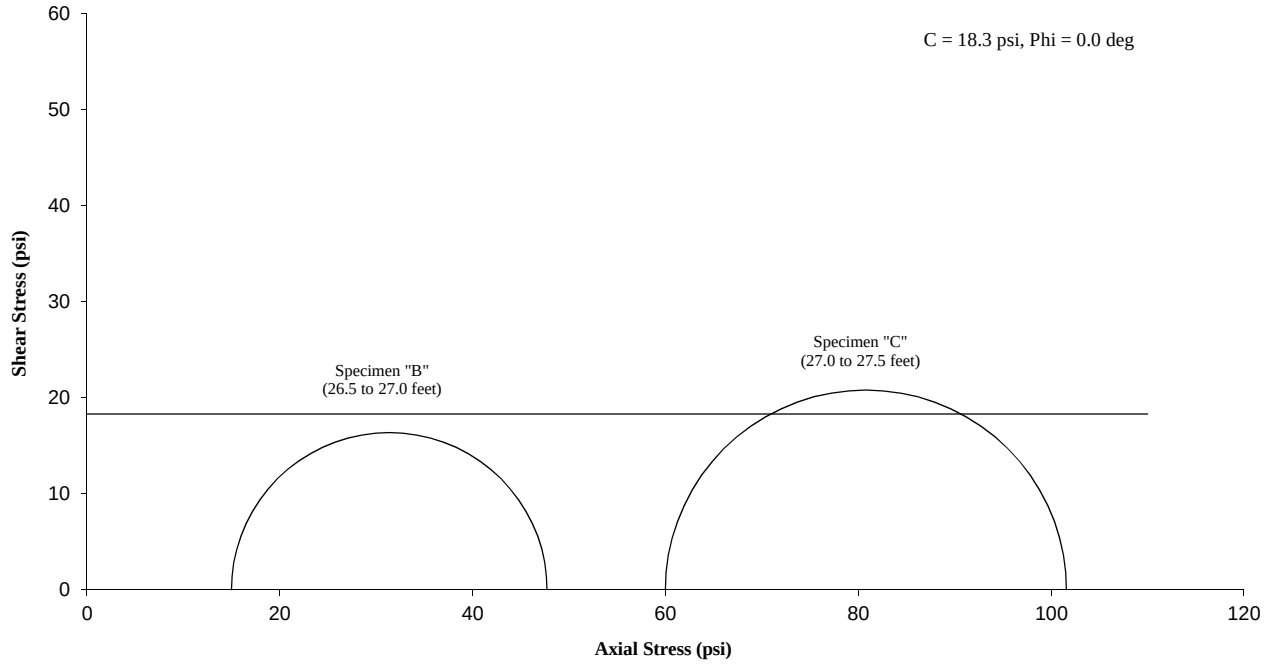
ASTM D 2850

General Sample Data		Triaxial Specimen Data			
TTL Project No.:	10835.05	Symbol	◆	■	●
Project:	East Au Gres Sea Lamprey Trap	Init. Specimen Height (in.)	6.02	6.10	-
Sample ID:	AG-15-01 (ST-2)	Init. Specimen Diameter (in.)	2.88	2.88	-
Sample Interval:	26.0 to 28.0 feet	Init. Moisture Content* (%)	10.5	11.4	-
Soil Description:	Gray/Brown SANDY LEAN CLAY w/Trace Gravel (CL)	Init. Dry Unit Weight (pcf)	128.3	125.8	-
Liquid Limit:	20	Init. Void Ratio	0.34	0.36	-
Plastic Limit:	11	Init. Degree of Saturation (%)	86	86	-
Plasticity Index:	9	Minor Principal Stress (psi)	15.0	60.0	-
Specific Gravity:	2.75 (Assumed)	Deviator Stress at Failure (psi)	32.7	41.6	-
Rate of Strain:	0.03 Inches per Minute	Major Principal Stress (psi)	47.7	101.6	-
Failure Criteria:	Peak Deviator Stress or Deviator Stress at 15% Axial Strain	Axial Strain at Failure (%)	5.4	13.9	-

Stress/Strain



Mohr Circle Plot



UNCONSOLIDATED, UNDRAINED COMPRESSIVE STRENGTH OF COHESIVE SOILS IN TRIAXIAL COMPRESSION (ASTM D 2850)

Project:	East Au Gres Sea Lamprey Trap	Date:	8/23/2015
Client:	US Army Corps of Engineers	File:	10835.05AG-15-01ST-2
Sample ID:	AG-15-01 (ST-2)	Depth:	26.0 to 28.0 feet
TTL Project No.:	10835.05	Specimen ID:	"B" (26.5 to 27.0 feet)

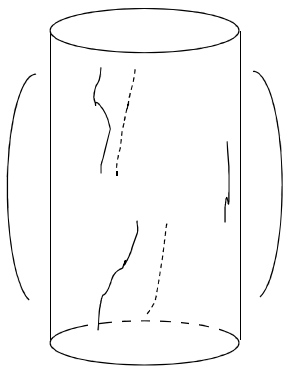
SAMPLE PROPERTIES

Visual Description: Gray/Brown SANDY LEAN CLAY w/Trace Gravel (CL)

Diameter:	2.88 in.	Initial Dry Unit Weight of Sample:	128.3 pcf
Area:	6.514 in^2	Initial Moisture Content:	10.5 %
Length:	6.02 in.	Specific Gravity (assumed):	2.75
Initial Void Ratio:	0.34	Initial Degree of Saturation:	86 %
Chamber Pressure:	15 psi	Proving Ring Number:	1155-12-13322

STRESS-STRAIN DATA

Speciman Deformation (in)	Vertical Strain	Proving Ring Reading	Piston Load (lbs)	Corrected Area (in^2)	Deviator Stress (psi)
0.000	0.000	0.0	0.0	6.514	0.0
0.010	0.002	8.0	5.5	6.525	0.8
0.020	0.003	14.5	9.9	6.536	1.5
0.030	0.005	22.5	15.4	6.547	2.4
0.040	0.007	32.5	22.3	6.558	3.4
0.050	0.008	45.0	30.9	6.569	4.7
0.075	0.012	73.0	50.1	6.597	7.6
0.100	0.017	105.5	72.4	6.624	10.9
0.125	0.021	144.0	98.8	6.653	14.8
0.150	0.025	180.0	123.5	6.681	18.5
0.175	0.029	212.5	145.8	6.709	21.7
0.200	0.033	247.5	169.8	6.738	25.2
0.250	0.042	298.0	204.4	6.797	30.1
0.300	0.050	326.0	223.6	6.856	32.6
0.323	0.054	328.5	225.4	6.884	32.7



Sketch of Tested Specimen

RESULTS

Maximum Deviator Stress 32.7 psi

UNCONSOLIDATED, UNDRAINED COMPRESSIVE STRENGTH OF COHESIVE SOILS IN TRIAXIAL COMPRESSION (ASTM D 2850)

Project:	East Au Gres Sea Lamprey Trap	Date:	8/23/2015
Client:	US Army Corps of Engineers	File:	10835.05AG-15-01ST-2
Sample ID:	AG-15-01 (ST-2)	Depth:	26.0 to 28.0 feet
TTL Project No.:	10835.05	Specimen ID:	"C" (27.0 to 27.5 feet)

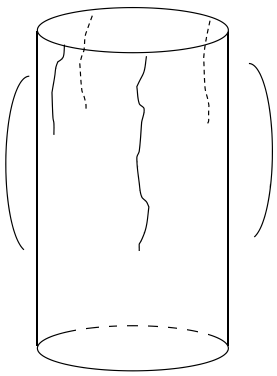
SAMPLE PROPERTIES

Visual Description: Gray/Brown SANDY LEAN CLAY w/Trace Gravel (CL)

Diameter:	2.88 in.	Initial Dry Unit Weight of Sample:	125.8 pcf
Area:	6.514 in^2	Initial Moisture Content:	11.4 %
Length:	6.10	Specific Gravity (assumed):	2.75
Initial Void Ratio:	0.36	Initial Degree of Saturation:	86 %
Chamber Pressure:	60 psi	Proving Ring Number:	1155-12-13322

STRESS-STRAIN DATA

Speciman Deformation (in)	Vertical Strain	Proving Ring Reading	Piston Load (lbs)	Corrected Area (in^2)	Deviator Stress (psi)
0.000	0.000	0.0	0.0	6.514	0.0
0.010	0.002	4.5	3.1	6.525	0.5
0.020	0.003	8.0	5.5	6.536	0.8
0.030	0.005	12.5	8.6	6.547	1.3
0.040	0.007	18.0	12.3	6.557	1.9
0.050	0.008	22.5	15.4	6.568	2.3
0.075	0.012	37.0	25.4	6.595	3.8
0.100	0.016	55.0	37.7	6.623	5.7
0.125	0.020	74.0	50.8	6.651	7.6
0.150	0.025	95.5	65.5	6.679	9.8
0.175	0.029	117.0	80.3	6.707	12.0
0.200	0.033	139.5	95.7	6.735	14.2
0.250	0.041	189.0	129.7	6.793	19.1
0.300	0.049	238.5	163.6	6.851	23.9
0.350	0.057	282.5	193.8	6.911	28.0
0.400	0.066	319.5	219.2	6.972	31.4
0.450	0.074	351.0	240.8	7.033	34.2
0.500	0.082	376.0	257.9	7.096	36.3
0.550	0.090	396.0	271.7	7.160	37.9
0.600	0.098	413.0	283.3	7.225	39.2
0.650	0.107	427.5	293.3	7.291	40.2
0.700	0.115	438.5	300.8	7.359	40.9
0.750	0.123	446.5	306.3	7.428	41.2
0.800	0.131	453.5	311.1	7.498	41.5
0.850	0.139	459.0	314.9	7.569	41.6
0.900	0.148	461.0	316.2	7.642	41.4
0.915	0.150	462.5	317.3	7.664	41.4



Sketch of Tested Specimen

RESULTS

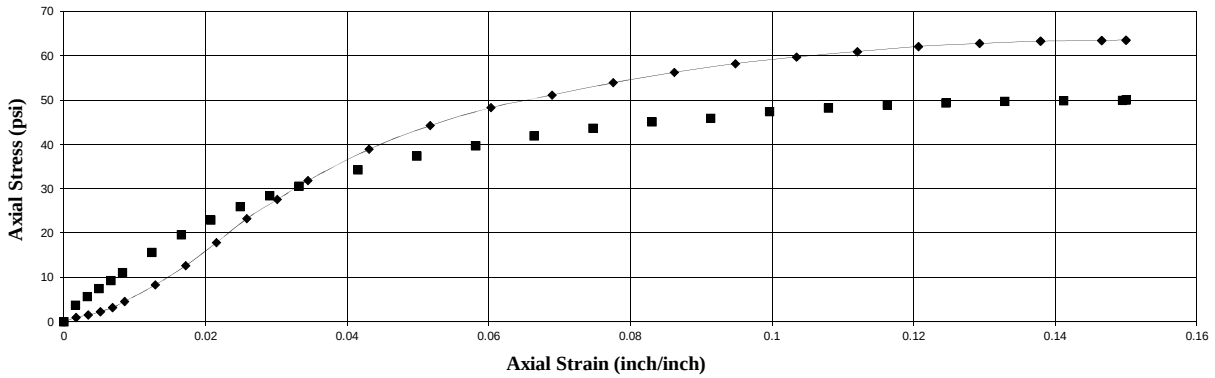
Maximum Deviator Stress 41.6 psi

Unconsolidated - Undrained Triaxial Shear Strength Test

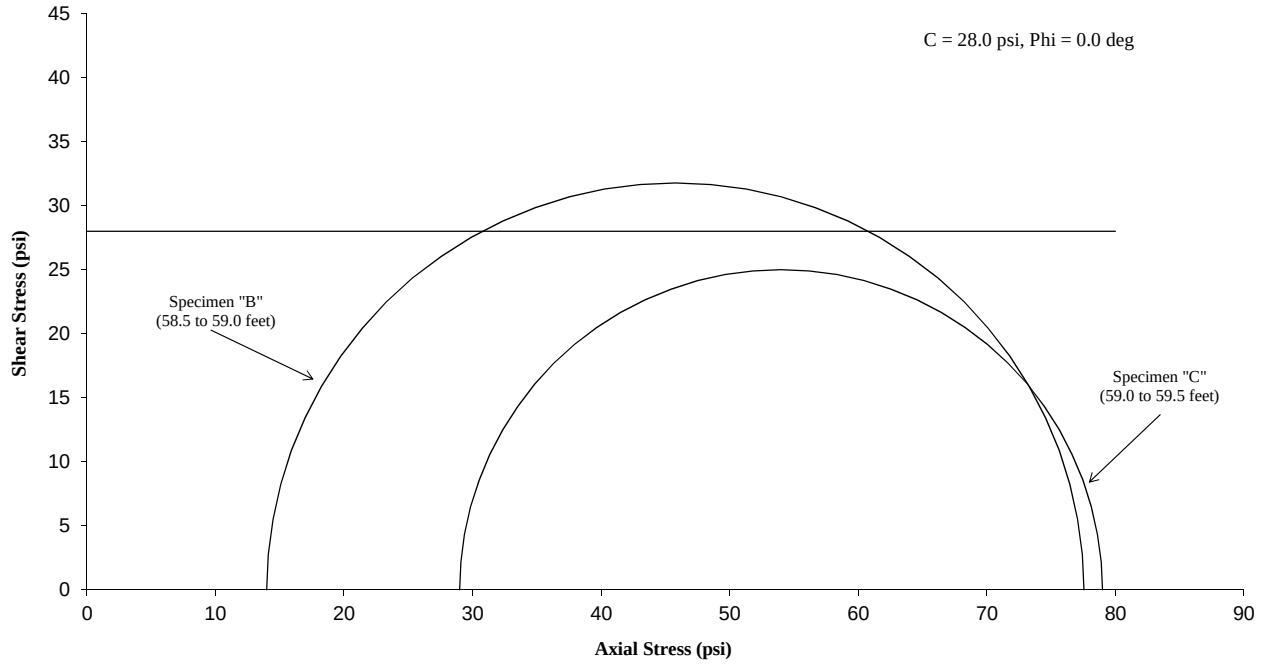
ASTM D 2850

General Sample Data		Triaxial Specimen Data			
TTL Project No.:	10835.05	Symbol	◆	■	●
Project:	East Au Gres Sea Lamprey Trap	Init. Specimen Height (in.)	5.80	6.02	-
Sample ID:	AG-15-01 (ST-3)	Init. Specimen Diameter (in.)	2.88	2.88	-
Sample Interval:	58.0 to 59.5 feet	Init. Moisture Content* (%)	10.8	10.6	-
Soil Description:	Gray/Brown SANDY LEAN CLAY w/Trace Gravel (CL)	Init. Dry Unit Weight (pcf)	128.3	128.4	-
Liquid Limit:	21	Init. Void Ratio	0.34	0.34	-
Plastic Limit:	12	Init. Degree of Saturation (%)	88	87	-
Plasticity Index:	9	Minor Principal Stress (psi)	14.0	29.0	-
Specific Gravity:	2.75 (Assumed)	Deviator Stress at Failure (psi)	63.6	50.0	-
Rate of Strain:	0.03 Inches per Minute	Major Principal Stress (psi)	77.6	79.0	-
Failure Criteria:	Peak Deviator Stress or Deviator Stress at 15% Axial Strain	Axial Strain at Failure (%)	15.0	15.0	-

Stress/Strain



Mohr Circle Plot



UNCONSOLIDATED, UNDRAINED COMPRESSIVE STRENGTH OF COHESIVE SOILS IN TRIAXIAL COMPRESSION (ASTM D 2850)

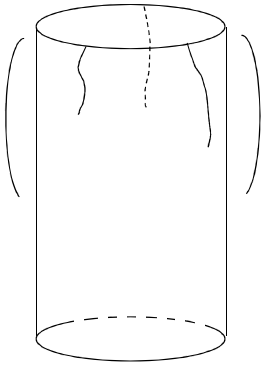
Project:	East Au Gres Sea Lamprey Trap	Date:	8/23/2015
Client:	US Army Corps of Engineers	File:	10835.05AG-15-01ST-3
Sample ID:	AG-15-01 (ST-3)	Depth:	58.0 to 59.5 feet
TTL Project No.:	10835.05	Specimen ID:	"B" (58.5 to 59.0 feet)

SAMPLE PROPERTIES

Visual Description:	Gray/Brown SANDY LEAN CLAY w/Trace Gravel (CL)		
Diameter:	2.88 in.	Initial Dry Unit Weight of Sample:	128.3 pcf
Area:	6.514 in^2	Initial Moisture Content:	10.8 %
Length:	5.80 in.	Specific Gravity (assumed):	2.75
Initial Void Ratio:	0.34	Initial Degree of Saturation:	88 %
Chamber Pressure:	14 psi	Proving Ring Number:	1155-12-13322

STRESS-STRAIN DATA

Speciman Deformation (in)	Vertical Strain	Proving Ring Reading	Piston Load (lbs)	Corrected Area (in^2)	Deviator Stress (psi)
0.000	0.000	0.0	0.0	6.514	0.0
0.010	0.002	9.0	6.2	6.526	0.9
0.020	0.003	14.5	9.9	6.537	1.5
0.030	0.005	21.5	14.7	6.548	2.3
0.040	0.007	30.5	20.9	6.560	3.2
0.050	0.009	44.0	30.2	6.571	4.6
0.075	0.013	80.0	54.9	6.600	8.3
0.100	0.017	122.5	84.0	6.629	12.7
0.125	0.022	173.0	118.7	6.658	17.8
0.150	0.026	227.0	155.7	6.687	23.3
0.175	0.030	270.0	185.2	6.717	27.6
0.200	0.034	313.0	214.7	6.747	31.8
0.250	0.043	386.0	264.8	6.808	38.9
0.300	0.052	443.0	303.9	6.870	44.2
0.350	0.060	488.0	334.8	6.933	48.3
0.400	0.069	521.5	357.7	6.997	51.1
0.450	0.078	555.0	380.7	7.062	53.9
0.500	0.086	584.5	401.0	7.129	56.2
0.550	0.095	610.5	418.8	7.197	58.2
0.600	0.103	632.5	433.9	7.266	59.7
0.650	0.112	651.5	446.9	7.337	60.9
0.700	0.121	670.5	460.0	7.409	62.1
0.750	0.129	684.5	469.6	7.482	62.8
0.800	0.138	697.0	478.1	7.557	63.3
0.850	0.147	706.0	484.3	7.633	63.4
0.870	0.150	710.0	487.1	7.664	63.6



Sketch of Tested Specimen

RESULTS

Maximum Deviator Stress 63.6 psi

UNCONSOLIDATED, UNDRAINED COMPRESSIVE STRENGTH OF COHESIVE SOILS IN TRIAXIAL COMPRESSION (ASTM D 2850)

Project:	East Au Gres Sea Lamprey Trap	Date:	8/23/2015
Client:	US Army Corps of Engineers	File:	10835.05AG-15-01ST-3
Sample ID:	AG-15-01 (ST-3)	Depth:	58.0 to 59.5 feet
TTL Project No.:	10835.05	Specimen ID:	"C" (59.0 to 59.5 feet)

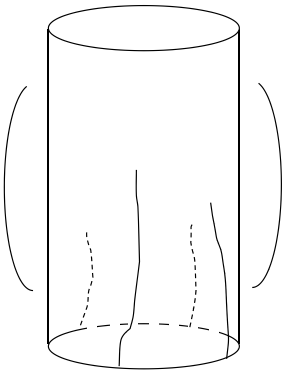
SAMPLE PROPERTIES

Visual Description: Gray/Brown SANDY LEAN CLAY w/Trace Gravel (CL)

Diameter:	2.88 in.	Initial Dry Unit Weight of Sample:	128.4 pcf
Area:	6.514 in^2	Initial Moisture Content:	10.6 %
Length:	6.02	Specific Gravity (assumed):	2.75
Initial Void Ratio:	0.34	Initial Degree of Saturation:	87 %
Chamber Pressure:	29 psi	Proving Ring Number:	1155-12-13322

STRESS-STRAIN DATA

Speciman Deformation (in)	Vertical Strain	Proving Ring Reading	Piston Load (lbs)	Corrected Area (in^2)	Deviator Stress (psi)
0.000	0.000	0.0	0.0	6.514	0.0
0.010	0.002	36.0	24.7	6.525	3.8
0.020	0.003	54.5	37.4	6.536	5.7
0.030	0.005	71.5	49.0	6.547	7.5
0.040	0.007	89.5	61.4	6.558	9.4
0.050	0.008	106.5	73.1	6.569	11.1
0.075	0.012	150.5	103.2	6.597	15.7
0.100	0.017	189.5	130.0	6.624	19.6
0.125	0.021	223.0	153.0	6.653	23.0
0.150	0.025	253.5	173.9	6.681	26.0
0.175	0.029	278.5	191.1	6.709	28.5
0.200	0.033	301.0	206.5	6.738	30.6
0.250	0.042	340.0	233.2	6.797	34.3
0.300	0.050	373.5	256.2	6.856	37.4
0.350	0.058	400.0	274.4	6.917	39.7
0.400	0.066	426.5	292.6	6.978	41.9
0.450	0.075	448.0	307.3	7.041	43.7
0.500	0.083	467.0	320.4	7.104	45.1
0.550	0.091	480.0	329.3	7.169	45.9
0.600	0.100	500.0	343.0	7.236	47.4
0.650	0.108	513.0	351.9	7.303	48.2
0.700	0.116	525.5	360.5	7.372	48.9
0.750	0.125	535.5	367.4	7.441	49.4
0.800	0.133	544.5	373.5	7.513	49.7
0.850	0.141	551.5	378.3	7.585	49.9
0.900	0.150	558.0	382.8	7.660	50.0
0.903	0.150	558.5	383.1	7.664	50.0



Sketch of Tested Specimen

RESULTS

Maximum Deviator Stress 50.0 psi

DIRECT SHEAR (ASTM D 3080) REPORT

Device Used: Karol-Warner Direct Shear Machine Model utilizing a 2.5 inch diameter shear box

Project Name:	Little Manistee Sea Lamprey Trap
Tested By:	KKC
Date:	8/25/2005
TTL Project Number:	10835.05

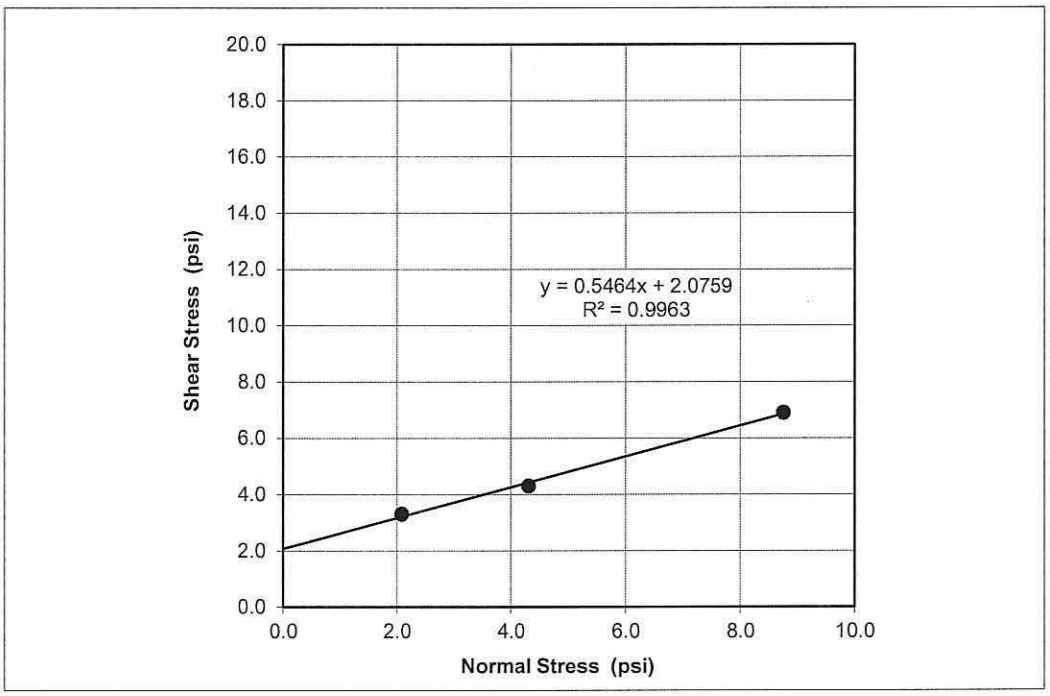
Boring Number:	LM-15-01
Depth:	3 to 8 feet
Soil Description:	Brown POORLY GRADED SAND w/Trace Silt, Gravel, and Organics

Preparation Method:	Recompacted, Trimmed Sample

DIRECT SHEAR TEST DATA

ASTM D 3080

Project Number:	10835.05	Boring Number.:	LM-15-01
Project Name:	Little Manistee Sea Lamprey Trap	Sample Number:	BS-1
Project Location:	Manistee County, Michigan	Sample Depth:	3 to 8 feet



Trial Number	Normal Stress (psi)	Shear Stress (psi)	ϕ (degrees)
1	2.1	3.3	28.7
2	4.3	4.3	
3	8.8	6.9	

Atterberg Limits:

Liquid Limit: No Test

Plastic Limit: No Test

Plasticity Index: No Test

Particle Size Analysis:

% Gravel: No Test

% Sand: No Test

% Silt: No Test

% Clay: No Test

Soil Classification: Brown POORLY GRADED SAND w/Trace Silt, Gravel, and Organics

Project No. 10835.05
Boring No. LM-15-01
Depth 3 to 8 feet

Slope from s vs σ' Graph= 0.863

ϕ= 40.778

	Shear Strength	Normal Stress
Trial 1	3.3	2.1
Trial 2	4.3	4.3
Trial 3	6.9	8.8

TRIAL 1

Initial Moisture Content

Mass of Container, gm	30.4
Initial mass Container + Soil, gm	161.3
Final Mass Container + Soil, gm	152.5
Mass of Soil, gm	122.1
Moisture Content, %	7.2

Initial Dry Unit Weight

Initial Height, in.	1.000
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1389.8
Mass of Soil, gm	158.5
Unit Weight, pcf	114.7

Final Moisture Content

Mass of Container, gm	37.4
Initial mass Container + Soil, gm	192.4
Final Mass Container + Soil, gm	166.7
Mass of Soil, gm	129.3
Moisture Content, %	19.9

Final Dry Unit Weight

Final Height, in.	0.983
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1412.4
Mass of Soil, gm	181.1
Unit Weight, pcf	119.3

TRIAL 2

Initial Moisture Content

Mass of Container, gm	30.4
Initial mass Container + Soil, gm	133.3
Final Mass Container + Soil, gm	126.4
Mass of Soil, gm	96.0
Moisture Content, %	7.2

Initial Dry Unit Weight

Initial Height, in.	1.000
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1390.4
Mass of Soil, gm	159.1
Unit Weight, pcf	115.2

Final Moisture Content

Mass of Container, gm	36.4
Initial mass Container + Soil, gm	209.5
Final Mass Container + Soil, gm	186.0
Mass of Soil, gm	149.6
Moisture Content, %	15.7

Final Dry Unit Weight

Final Height, in.	0.993
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1414.1
Mass of Soil, gm	182.8
Unit Weight, pcf	123.5

TRIAL 3

Initial Moisture Content

Mass of Container, gm	24.8
Initial mass Container + Soil, gm	173.6
Final Mass Container + Soil, gm	162.5
Mass of Soil, gm	137.7
Moisture Content, %	8.1

Initial Dry Unit Weight

Initial Height, in.	1.000
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1391.2
Mass of Soil, gm	159.9
Unit Weight, pcf	114.8

Final Moisture Content

Mass of Container, gm	36.2
Initial mass Container + Soil, gm	187.8
Final Mass Container + Soil, gm	167.5
Mass of Soil, gm	131.3
Moisture Content, %	15.5

Final Dry Unit Weight

Final Height, in.	0.981
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1414.3
Mass of Soil, gm	183
Unit Weight, pcf	125.4

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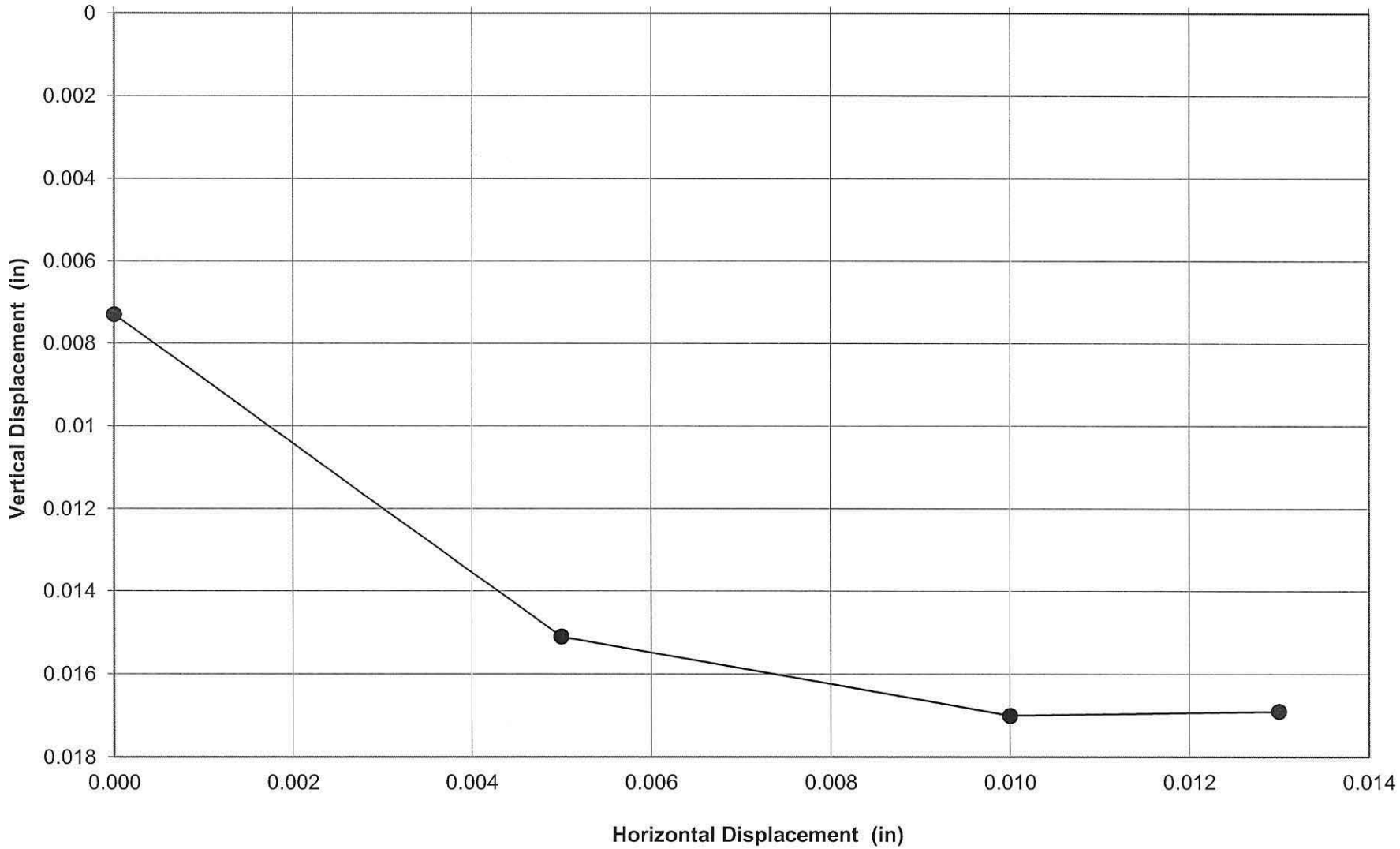
Trial 1

Project No. 10835.05
Boring No. LM-15-01
Depth 3 to 8 feet

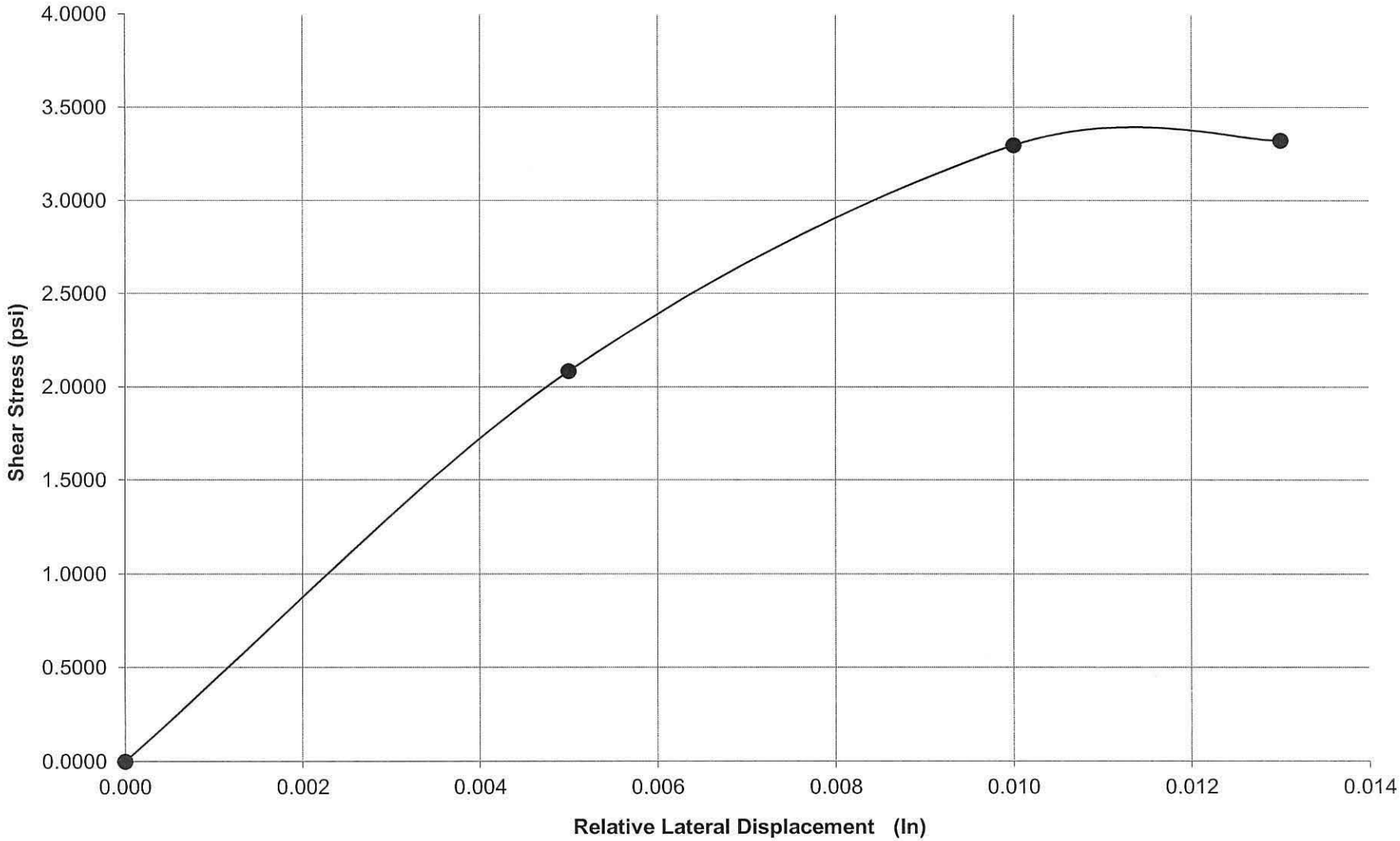
Normal Load= 300 Lbs/ft^2
Displacement Rate= 0.0017 in/min

Vertical Displacement	Horizontal Displacement	Corrected Area	Horizontal Shear Force	Shear Stress
0.0073	0.000	4.9087	0.0	0.0000
0.0151	0.005	4.8962	10.2	2.0832
0.0170	0.010	4.8837	16.1	3.2967
0.0169	0.013	4.8762	16.2	3.3222

Horizontal vs Vertical Displacement - Trial 1



Trial 1

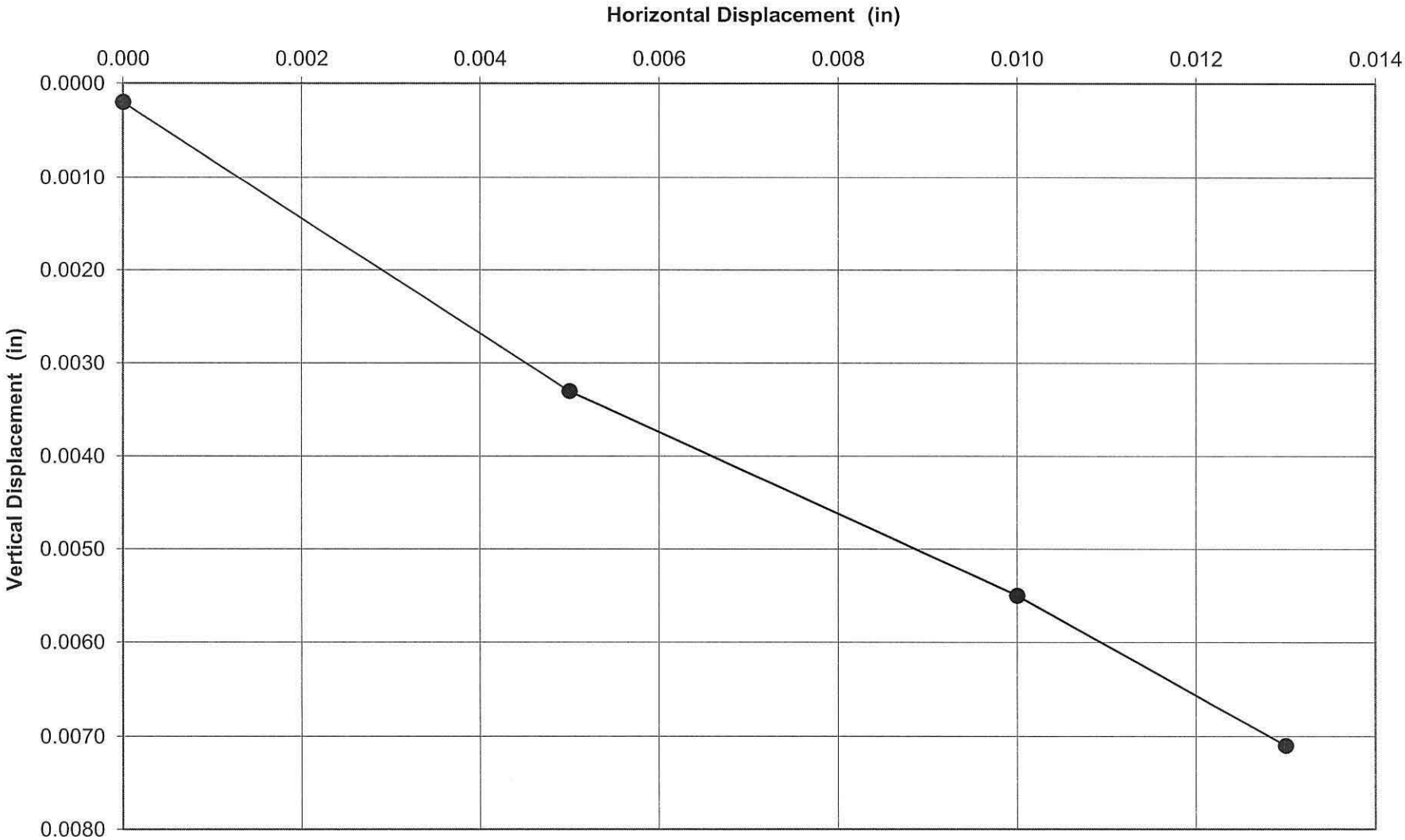

4.0000
3.5000
3.0000
2.5000
2.0000
1.5000
1.0000
0.5000
0.0000
Shear Stress (psi)
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
Relative Lateral Displacement (In)

Trial 2

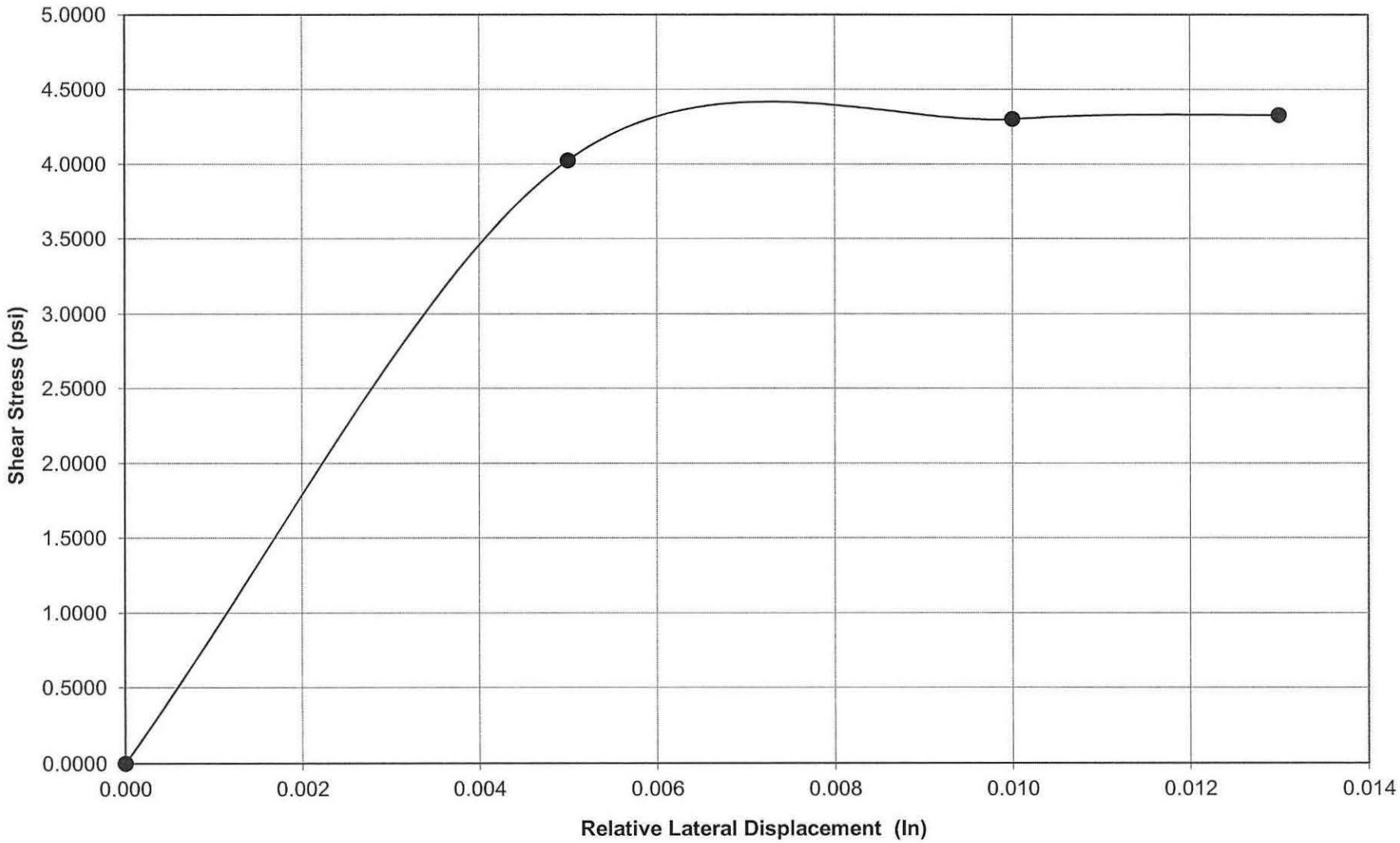
		Project No.	10835.05
		Boring No.	LM-15-01
Normal Load=	620 Lbs/ft^2	Depth	3 to 8 feet
Displacement Rate=	0.0017 in./min		

Vertical Displacement	Horizontal Displacement	Corrected Area	Horizontal Shear Force	Shear Stress
0.0002	0.000	4.9087	0.0	0.0000
0.0033	0.005	4.8962	19.7	4.0235
0.0055	0.010	4.8837	21.0	4.3000
0.0071	0.013	4.8762	21.1	4.3271

Horizontal vs Vertical Displacement - Trial 2



Trial 2

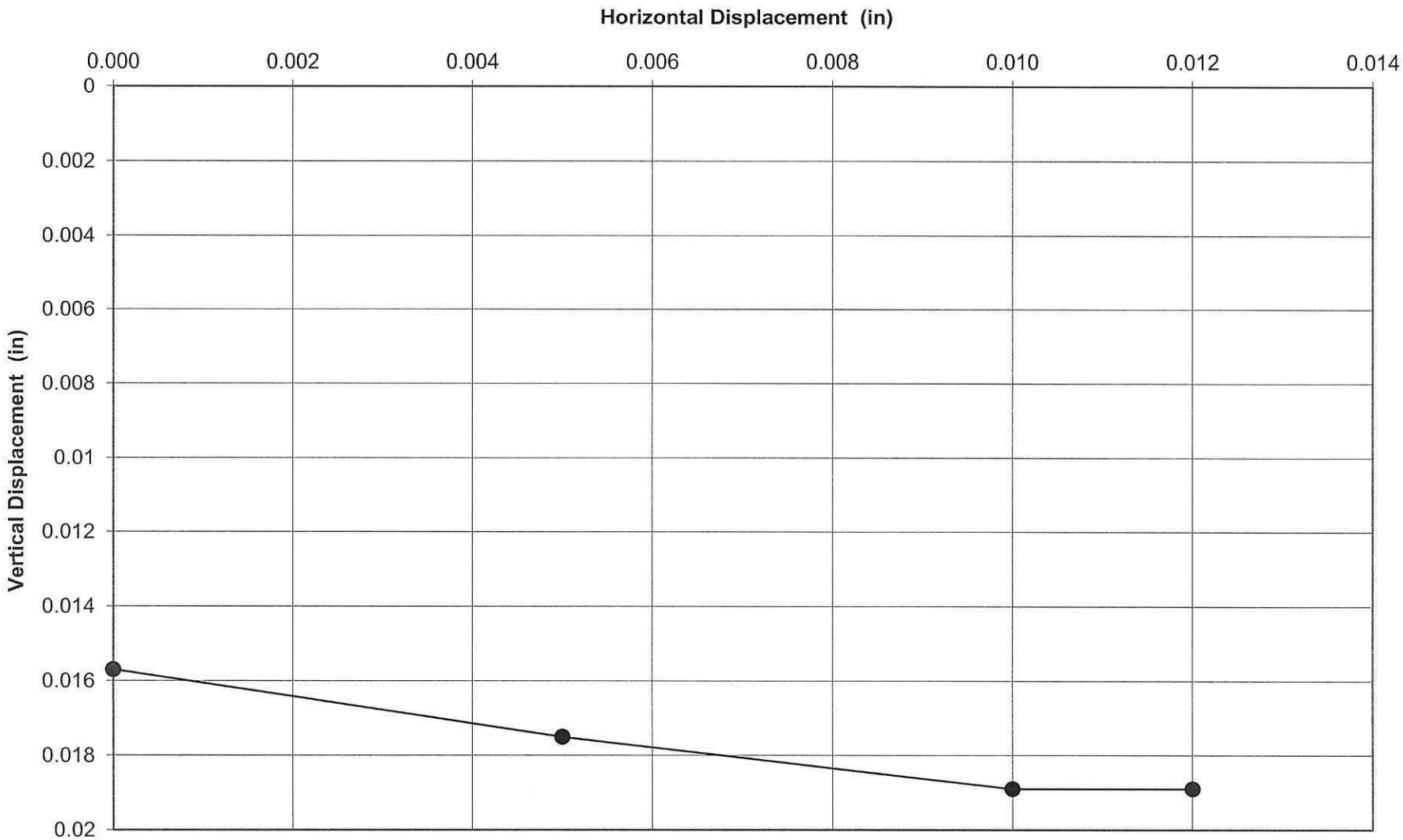

5.0000
4.5000
4.0000
3.5000
3.0000
2.5000
2.0000
1.5000
1.0000
0.5000
0.0000
Shear Stress (psi)
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
Relative Lateral Displacement (In)

Trial 3

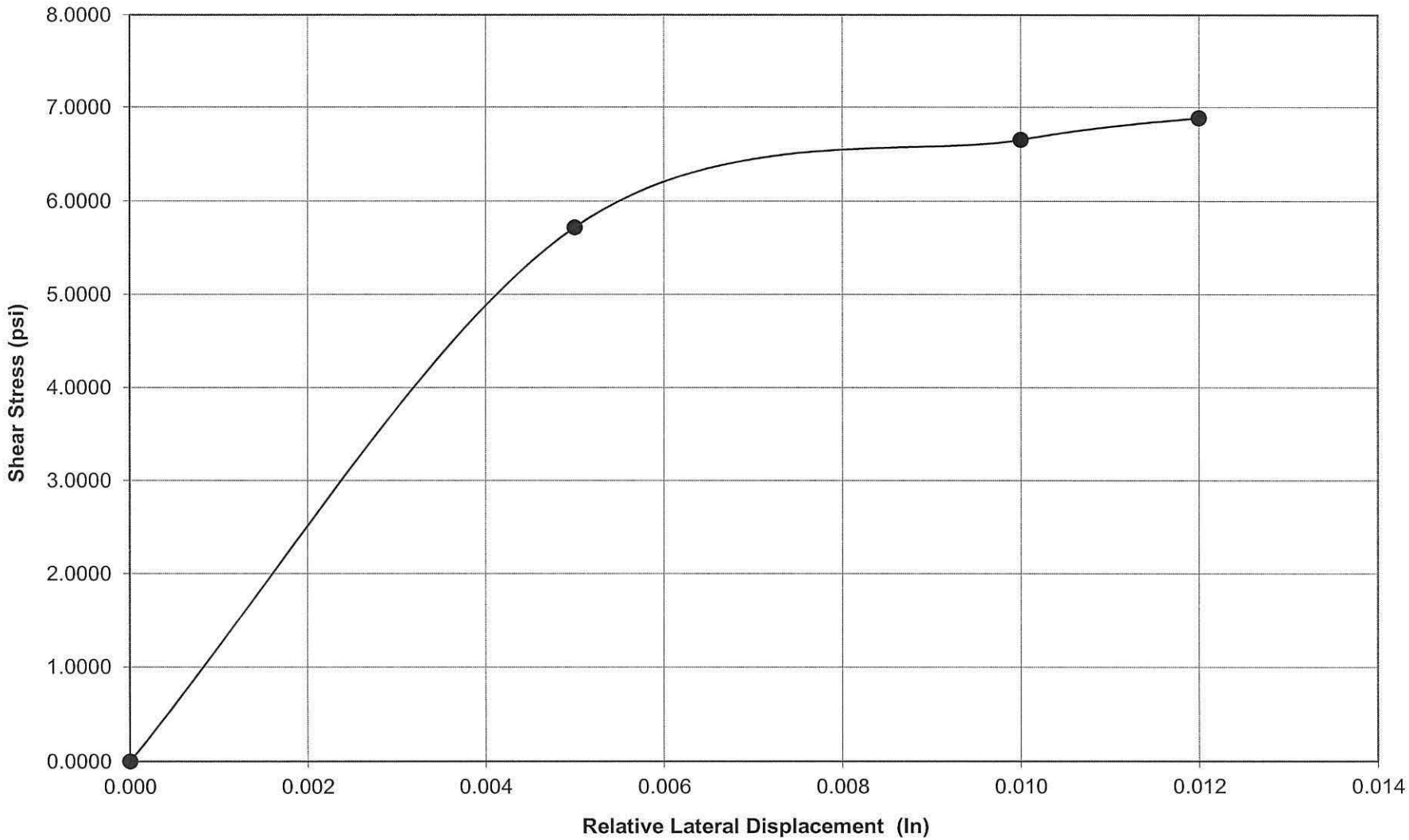
		Project No.	10835.05
		Boring No.	LM-15-01
Normal Load=	1260 Lbs/ft^2	Depth	3 to 8 feet
Displacement Rate=	0.0017 in/min		

Vertical Displacement	Horizontal Displacement	Corrected Area	Horizontal Shear Force	Shear Stress
0.0157	0.000	4.9087	0.0	0.0000
0.0175	0.005	4.8962	28.0	5.7187
0.0189	0.010	4.8837	32.5	6.6547
0.0189	0.012	4.8787	33.6	6.8870

Horizontal vs Vertical Displacement - Trial 3



Trial 3


8.0000
7.0000
6.0000
5.0000
4.0000
3.0000
2.0000
1.0000
0.0000
Shear Stress (psi)
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
Relative Lateral Displacement (In)

DIRECT SHEAR (ASTM D 3080) REPORT

Device Used: Karol-Warner Direct Shear Machine Model utilizing a 2.5 inch diameter shear box

Project Name:	Little Manistee Sea Lamprey Trap
Tested By:	KKC
Date:	8/25/2005
TTL Project Number:	10835.05

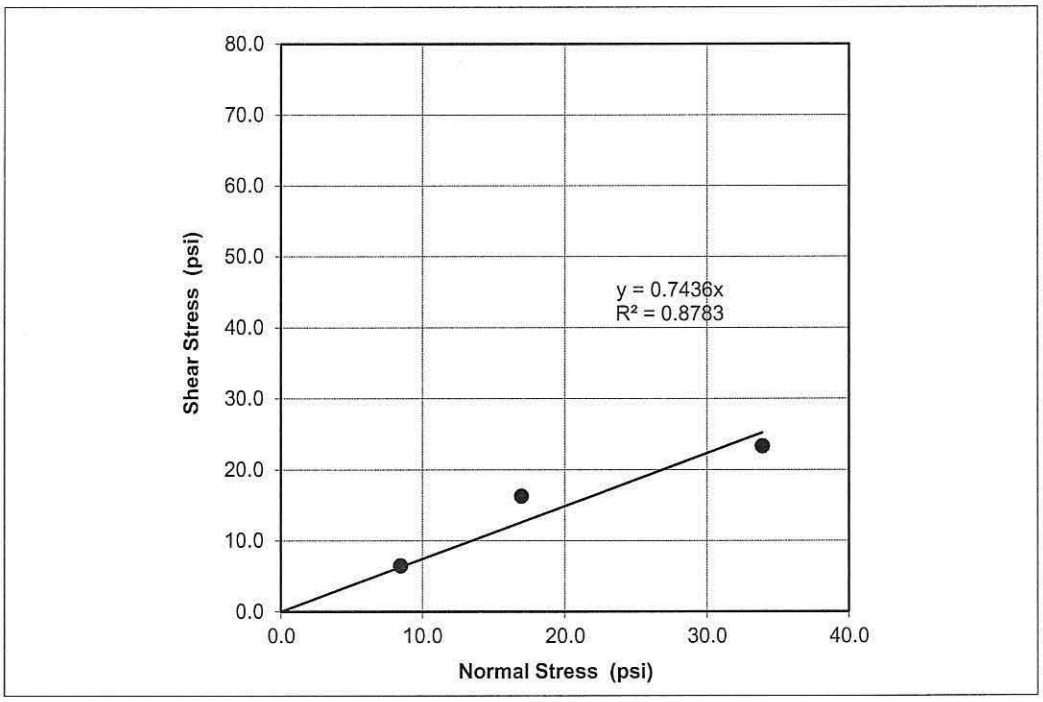
Boring Number:	LM-15-01
Depth:	33½ to 45 feet
Soil Description:	Brown POORLY GRADED SAND w/Trace Silt and Gravel

Preparation Method:	Recompacted, Trimmed Sample

DIRECT SHEAR TEST DATA

ASTM D 3080

Project Number:	10835.05	Boring Number.:	LM-15-01
Project Name:	Little Manistee Sea Lamprey Trap	Sample Number:	SS-11 to SS-13
Project Location:	Manistee County, Michigan	Sample Depth:	33½ to 45 feet



Trial Number	Normal Stress (psi)	Shear Stress (psi)	ϕ (degrees)
1	8.5	6.5	36.6
2	16.9	16.3	
3	33.9	23.3	

Atterberg Limits:

Liquid Limit: No Test

Plastic Limit: No Test

Plasticity Index: No Test

Particle Size Analysis:

% Gravel: No Test

% Sand: No Test

% Silt: No Test

% Clay: No Test

Soil Classification: Brown POORLY GRADED SAND w/Trace Silt and Gravel

Project No. 10835.05
Boring No. LM-15-01
Depth 33½ to 45 feet

Slope from s vs σ' Graph= 0.744

ϕ= 36.634

	Shear Strength	Normal Stress
Trial 1	6.5	8.5
Trial 2	16.3	16.9
Trial 3	23.3	33.9

TRIAL 1

Initial Moisture Content

Mass of Container, gm	32.4
Initial mass Container + Soil, gm	163.6
Final Mass Container + Soil, gm	137.2
Mass of Soil, gm	104.8
Moisture Content, %	25.2

Initial Dry Unit Weight

Initial Height, in.	1.000
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1416.1
Mass of Soil, gm	184.8
Unit Weight, pcf	114.6

Final Moisture Content

Mass of Container, gm	39.5
Initial mass Container + Soil, gm	189.1
Final Mass Container + Soil, gm	156.5
Mass of Soil, gm	117
Moisture Content, %	27.9

Final Dry Unit Weight

Final Height, in.	0.961
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1423.3
Mass of Soil, gm	192
Unit Weight, pcf	121.2

TRIAL 2

Initial Moisture Content

Mass of Container, gm	32.0
Initial mass Container + Soil, gm	110.5
Final Mass Container + Soil, gm	100.3
Mass of Soil, gm	68.3
Moisture Content, %	14.9

Initial Dry Unit Weight

Initial Height, in.	1.000
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1402.3
Mass of Soil, gm	171.0
Unit Weight, pcf	115.5

Final Moisture Content

Mass of Container, gm	40.2
Initial mass Container + Soil, gm	193.1
Final Mass Container + Soil, gm	167.6
Mass of Soil, gm	127.4
Moisture Content, %	20.0

Final Dry Unit Weight

Final Height, in.	0.970
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1421.5
Mass of Soil, gm	190.2
Unit Weight, pcf	126.7

TRIAL 3

Initial Moisture Content

Mass of Container, gm	31.0
Initial mass Container + Soil, gm	59.6
Final Mass Container + Soil, gm	55.0
Mass of Soil, gm	24
Moisture Content, %	19.2

Initial Dry Unit Weight

Initial Height, in.	1.000
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1408.2
Mass of Soil, gm	176.9
Unit Weight, pcf	115.2

Final Moisture Content

Mass of Container, gm	32.1
Initial mass Container + Soil, gm	189.4
Final Mass Container + Soil, gm	167.8
Mass of Soil, gm	135.7
Moisture Content, %	15.9

Final Dry Unit Weight

Final Height, in.	0.955
Mass Shear Box, gm	1231.3
Shear Box + Soil, gm	1414.3
Mass of Soil, gm	183
Unit Weight, pcf	128.3

associates inc

Trial 1

Project No. 10835.05
Boring No. LM-15-01
Depth 33½ to 45 feet

Normal Load= 1220 Lbs/ft^2
Displacement Rate= 0.0017 in/min

Vertical Displacement	Horizontal Displacement	Corrected Area	Horizontal Shear Force	Shear Stress
0.0296	0.000	4.9087	0.0	0.0000
0.0327	0.005	4.8962	23.7	4.8405
0.0330	0.010	4.8837	26.5	5.4262
0.0342	0.015	4.8712	27.8	5.7070
0.0350	0.020	4.8587	28.4	5.8451
0.0366	0.030	4.8337	29.4	6.0822
0.0379	0.040	4.8087	30.9	6.4258
0.0387	0.050	4.7838	31.3	6.5430
0.0380	0.052	4.7788	31.3	6.5498

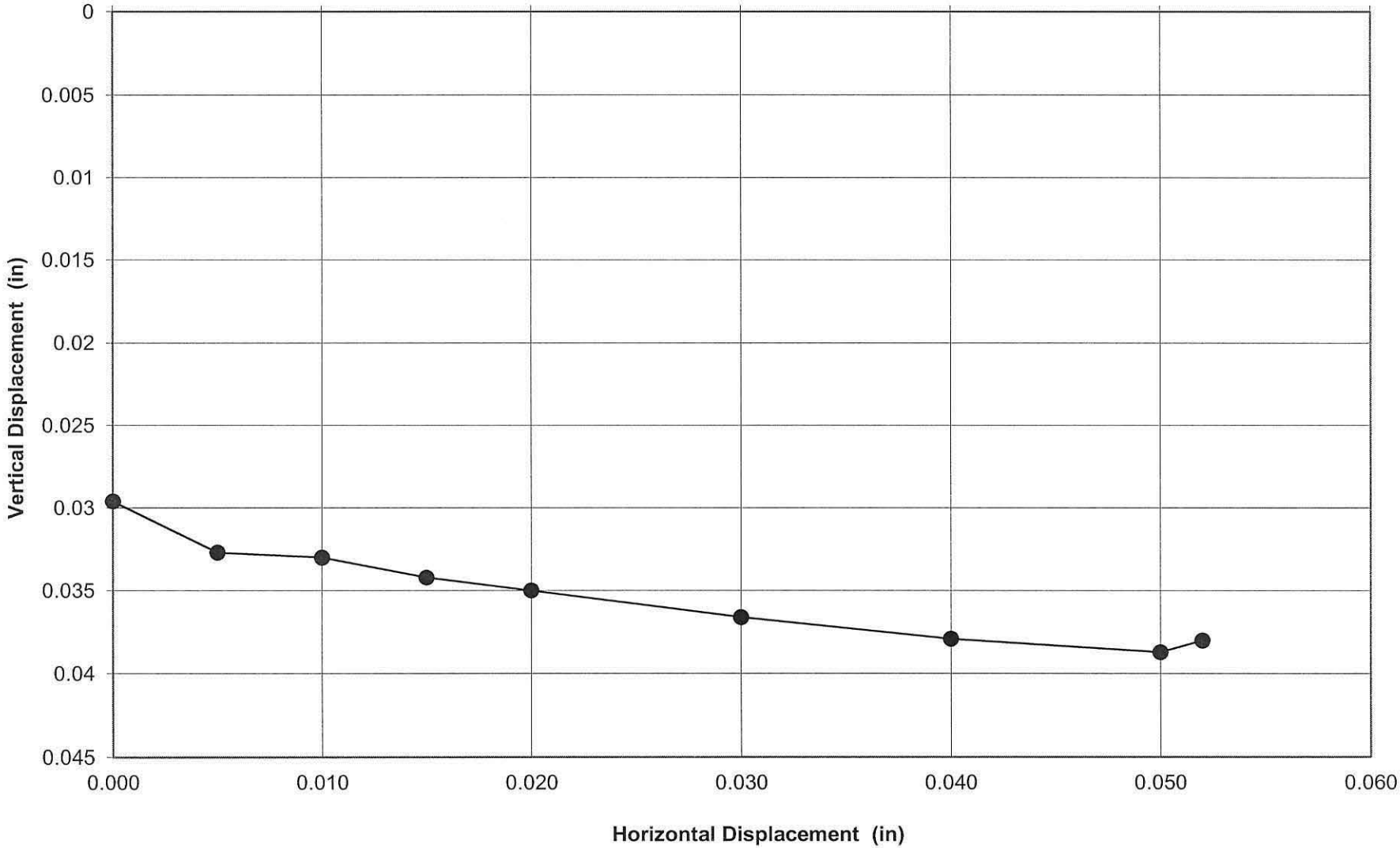
Trial 1

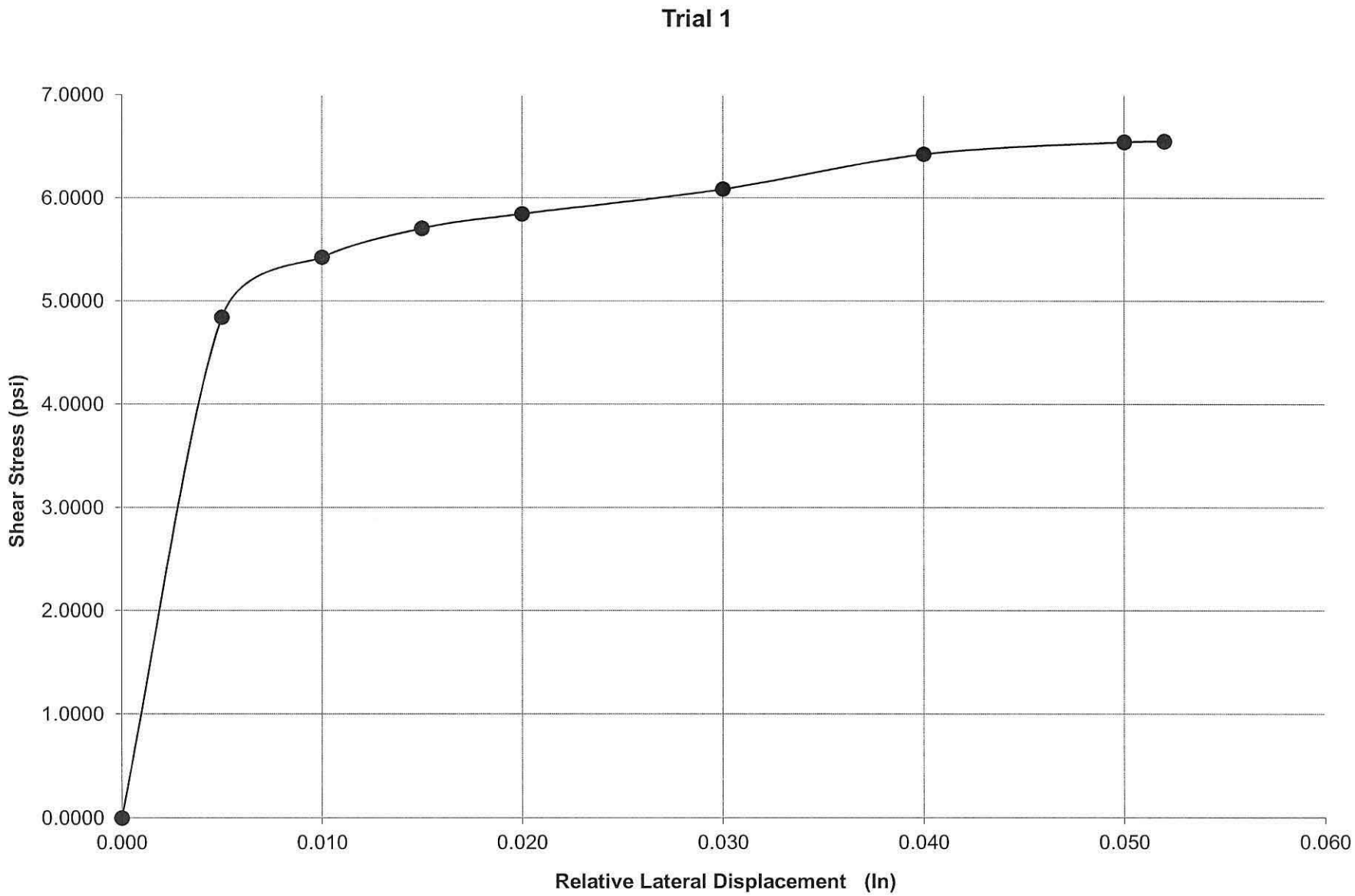
Project No. 10835.05
Boring No. LM-15-01
Depth 33½ to 45 feet

Normal Load= 1220 Lbs/ft^2
Displacement Rate= 0.0017 in/min

Vertical Displacement	Horizontal Displacement	Corrected Area	Horizontal Shear Force	Shear Stress
0.0296	0.000	4.9087	0.0	0.0000
0.0327	0.005	4.8962	23.7	4.8405
0.0330	0.010	4.8837	26.5	5.4262
0.0342	0.015	4.8712	27.8	5.7070
0.0350	0.020	4.8587	28.4	5.8451
0.0366	0.030	4.8337	29.4	6.0822
0.0379	0.040	4.8087	30.9	6.4258
0.0387	0.050	4.7838	31.3	6.5430
0.0380	0.052	4.7788	31.3	6.5498

Horizontal vs Vertical Displacement - Trial 1




Trial 1
7.0000
6.0000
5.0000
4.0000
3.0000
2.0000
1.0000
0.0000
Shear Stress (psi)
0.000
0.010
0.020
0.030
0.040
0.050
0.060
Relative Lateral Displacement (In)

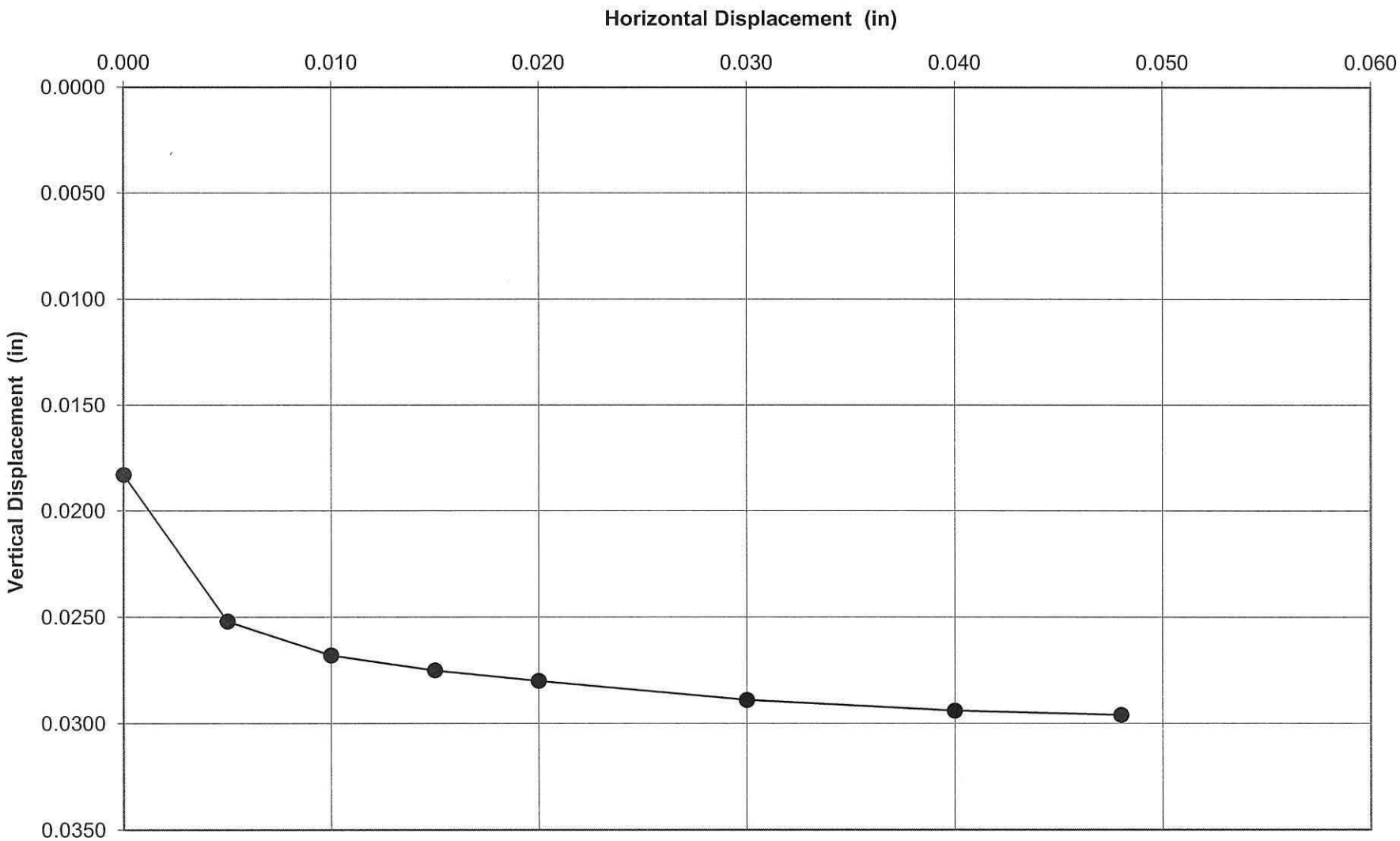
Trial 2

Project No. 10835.05
Boring No. LM-15-01
Depth 33½ to 45 feet

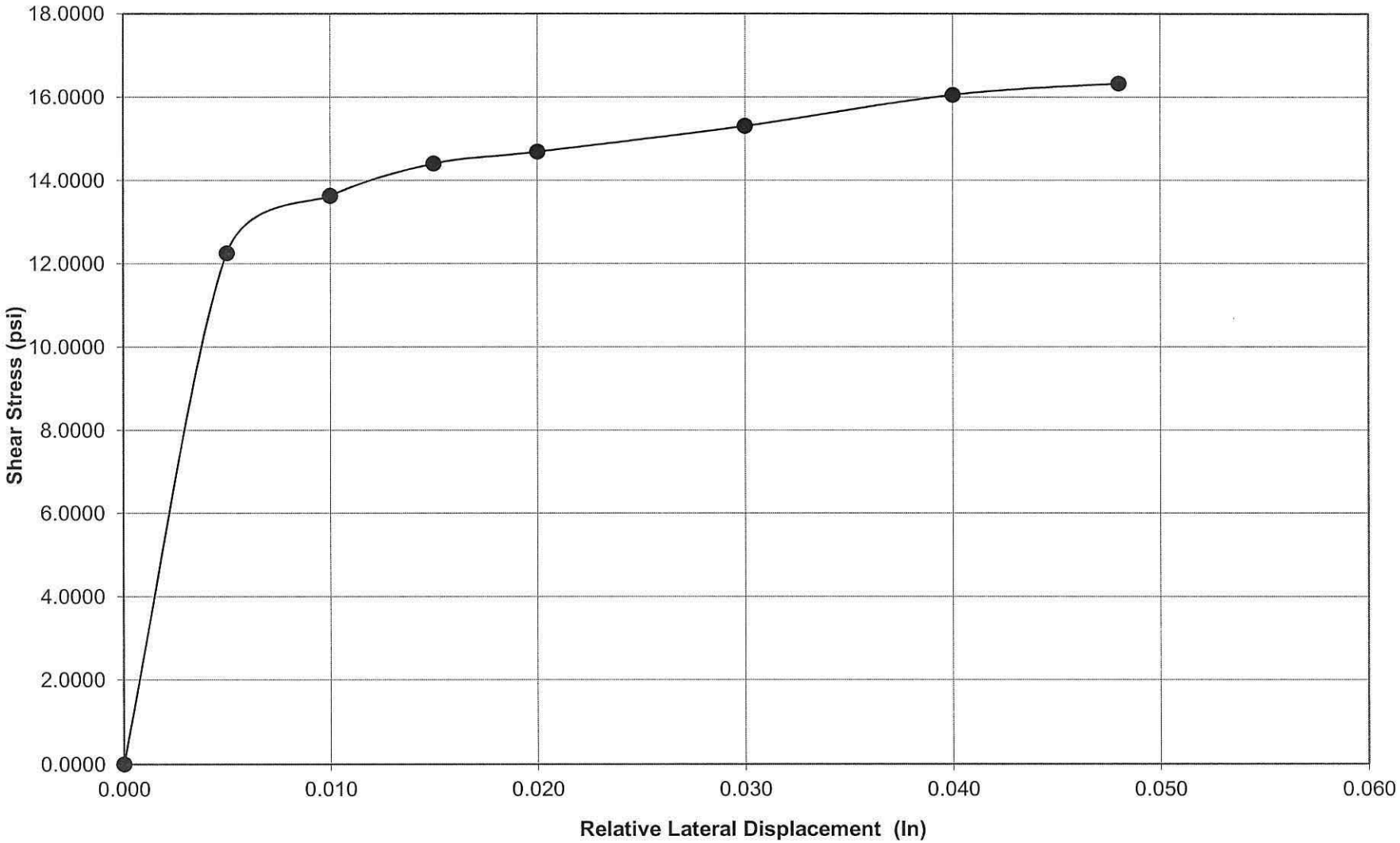
Normal Load= 2440 Lbs/ft^2
Displacement Rate= 0.0017 in./min

Vertical Displacement	Horizontal Displacement	Corrected Area	Horizontal Shear Force	Shear Stress
0.0183	0.000	4.9087	0.0	0.0000
0.0252	0.005	4.8962	60.0	12.2543
0.0268	0.010	4.8837	66.6	13.6371
0.0275	0.015	4.8712	70.2	14.4111
0.0280	0.020	4.8587	71.4	14.6952
0.0289	0.030	4.8337	74.0	15.3090
0.0294	0.040	4.8087	77.2	16.0541
0.0296	0.048	4.7888	78.2	16.3299

Horizontal vs Vertical Displacement - Trial 2



Trial 2


18.0000
16.0000
14.0000
12.0000
10.0000
8.0000
6.0000
4.0000
2.0000
0.0000
Shear Stress (psi)
0.000
0.010
0.020
0.030
0.040
0.050
0.060
Relative Lateral Displacement (In)

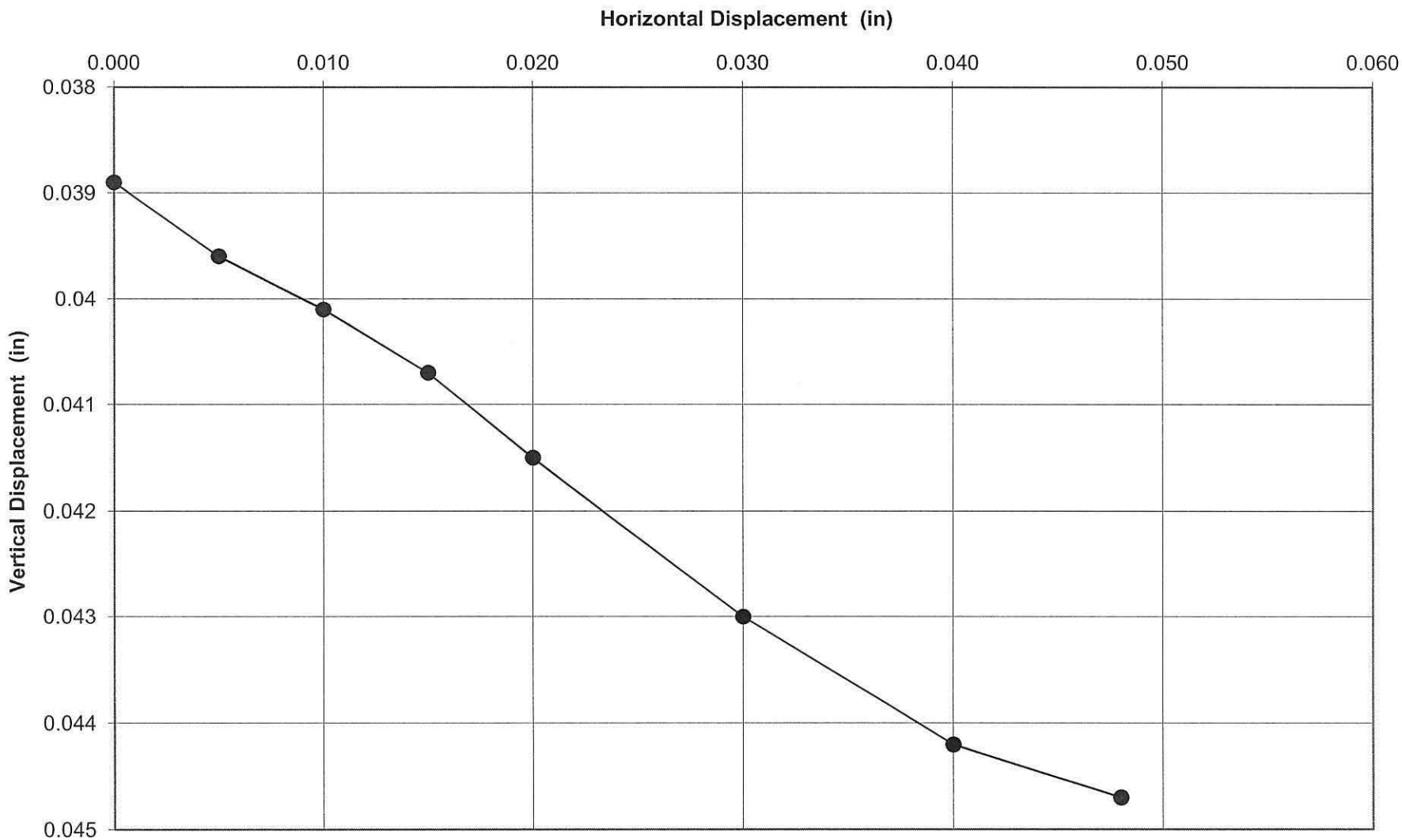
Trial 3

Project No. 10835.05
Boring No. LM-15-01
Depth 33½ to 45 feet

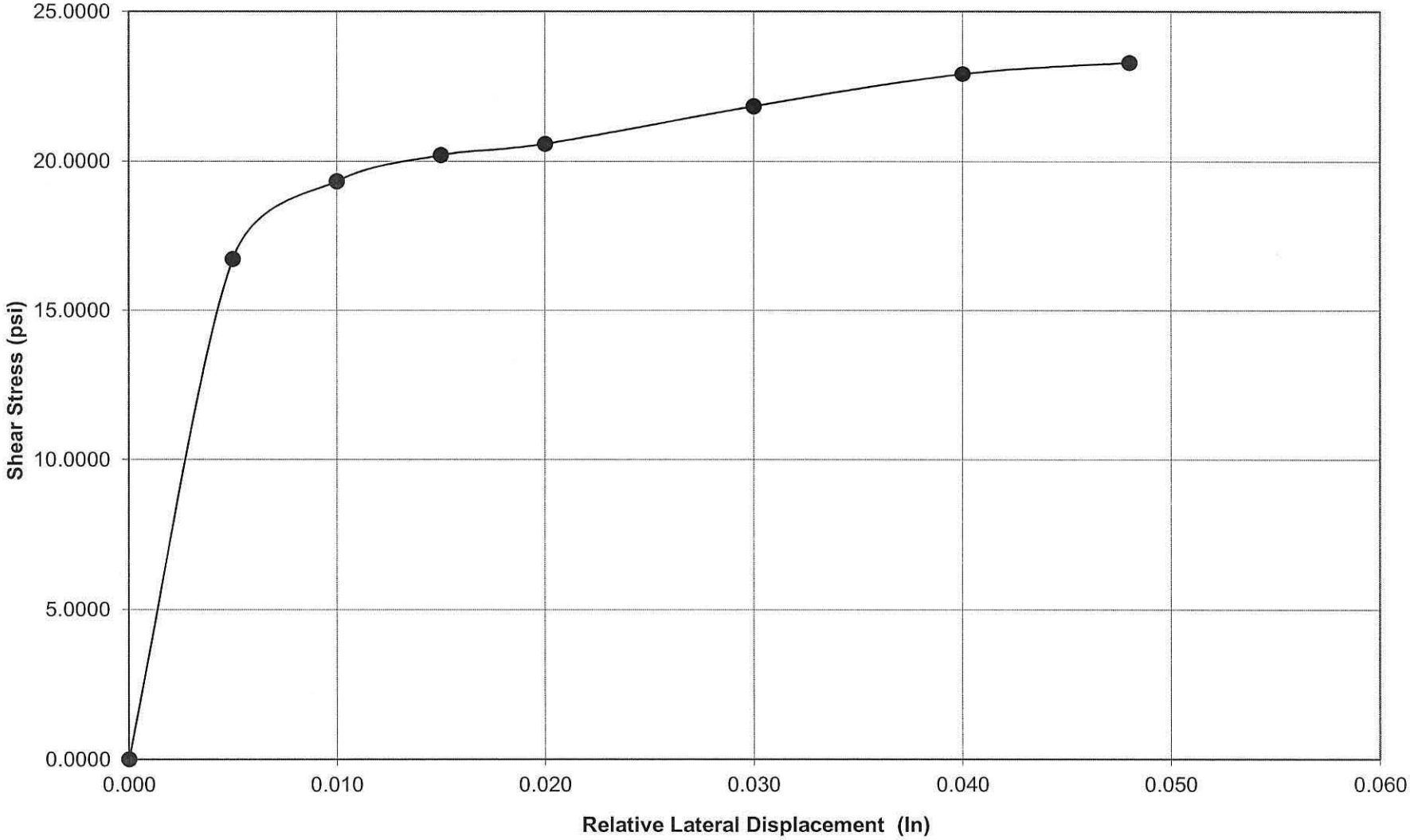
Normal Load= 4880 Lbs/ft^2
Displacement Rate= 0.0017 in/min

Vertical Displacement	Horizontal Displacement	Corrected Area	Horizontal Shear Force	Shear Stress
0.0389	0.000	4.9087	0.0	0.0000
0.0396	0.005	4.8962	81.9	16.7271
0.0401	0.010	4.8837	94.4	19.3295
0.0407	0.015	4.8712	98.4	20.2002
0.0415	0.020	4.8587	100.0	20.5815
0.0430	0.030	4.8337	105.5	21.8257
0.0442	0.040	4.8087	110.2	22.9166
0.0447	0.048	4.7888	111.6	23.3046

Horizontal vs Vertical Displacement - Trial 3



Trial 3


25.0000
20.0000
15.0000
10.0000
5.0000
0.0000
Shear Stress (psi)
0.000
0.010
0.020
0.030
0.040
0.050
0.060
Relative Lateral Displacement (In)

Survey Inputs

Boring	Northing	Easting
LM-15-01	326829.1	19205621.7
LM-15-02	326943.5	19205668.0
AG-15-01	330762.1	19860342.6
AG-15-02	330747.4	19860410.8

Raw Survey Data (International Feet)

Boring	Northing	Easting	Elevation
LM-15-01	326810.373	19205655.368	603.340
LM-15-02	326943.453	19205667.926	601.313
AG-15-01	330800.586	19860342.251	648.107
AG-15-02	330751.192	19860444.531	634.720

Survey Data Converted to Survey Feet

Boring	Northing	Easting	Elevation
LM-15-01	326809.719	19205616.957	603.340
LM-15-02	326942.799	19205629.515	601.313
AG-15-01	330799.924	19860302.530	648.107
AG-15-02	330750.530	19860404.810	634.720

TTL QC Checklist

Project: Little Manistee and East Au Gres Lamprey Traps **Task Order:** DC02

QA/QC Manager: Curtis E. Roupe, PE **Date:** August 4, 2015

Project Manager: Chett A. Siefring, PE **Date:** August 4, 2015

Task	Completed
Were the boring locations cleared with utilities?	Yes
Were the borings drilled at the required locations and/or did the Corps of Engineers Technical POC approve offsets?	Yes
Were the borings drilled within the provided real estate?	Yes
Were the borings drilled to the required depth?	Yes
Were the borings properly backfilled/grouted upon completion?	Yes
Are the boring logs on the Corps form?	Yes – Field Logs
Are the blow counts provided for each drive?	Yes
Were pocket penetrometer readings (Qp) or Torvane readings (Tv) taken on cohesive soils?	Yes
Were sufficient photographs taken to document the exploration process?	Yes
Was the groundwater elevation recorded on the boring logs for measurements obtained during and immediately after the drilling?	Yes
Is the survey data reported in the correct datums?	Yes
Were the borings logged in accordance with ASTM D 5434?	Yes
Were all laboratory test conducted?	Yes
Were the lab test results sheets included in the report?	Yes
Were the lab test conducted in accordance with proper ASTMs?	Yes
Were the boring logs modified to reflect the lab test results?	Yes
Were the soil samples labeled according to the instructions in the Scope of Work?	Yes
Does the final report meet the outline contained in the Scope of Work?	Yes
Were all of the boring logs and lab test included in the final report?	Yes
Is the final report and all electronic files contained on a CD, or provided otherwise to the CORP?	Yes – mailed separately
Was the final report signed?	Yes

, 10/6/15 , 10-6-15

QA/QC Manager Signature, Date **Project Manager Signature, Date**

ATTECHMENT D

HYDRAULIC DATA

Table 1: 25 year spillway, 10 year stoplogs

		Upstream					Downstream					
Flow Event	Flow (cfs)	Water-surface Elevation (ft)	Average Channel Bottom Elevation (ft)	Channel Velocity (ft/s)	Existing Condition Water-surface Elevation (ft)	Water-surface Elevation Change (ft)	Water-surface Elevation (ft)	Average Channel Bottom Elevation (ft)	Channel Velocity (ft/s)	Minimum Drop from Sill to Water-surface (ft)	Approximate Depth of Water over Spillway (ft)	Height From Water Surface to Catwalk (ft)
Low Flow	300	601.95	595.87	0.43	601.44	0.51	598.14	592.33	0.46	2.86	0.64	0.98
50%	410	602.11	595.87	0.56	601.76	0.35	598.67	592.33	0.55	2.33	0.8	0.82
20%	550	602.31	595.87	0.71	602.12	0.19	599.17	592.33	0.67	1.83	1	0.62
10%	650	602.44	595.87	0.82	602.34	0.1	599.5	592.33	0.74	1.5	1.13	0.49
4%	750	602.55	595.87	0.92	602.51	0.04	599.81	592.33	0.81	1.19	1.24	0.38
2%	850	602.66	595.87	1.01	602.67	-0.01	600.09	592.33	0.87	0.91	1.35	0.27
1%	900	602.71	595.87	1.06	602.75	-0.04	600.22	592.33	0.9	0.78	1.4	0.22
0.50%	1000	602.8	595.87	1.15	602.88	-0.08	600.47	592.33	0.96	0.53	1.49	0.13
0.20%	1100	602.9	595.87	1.24	602.99	-0.09	600.7	592.33	1.02	0.3	1.59	0.03

Stoplog Crest Elevation =	601	ft
Spillway Crest Elevation =	601.31	ft
Stoplog Height =	**3.06**	**ft**
Crest of Dam (no stoplogs) =	597.94	ft