US Army Corps of Engineers
Buffalo District

Cuyahoga River Bulkhead Technical Assistance
Cleveland, OH

Conceptual Designs and Cost Estimates
for Bulkhead Repair and Slope Stability Improvements
in the Vicinity of Riverbed Street

August 2009

Table of Contents

1. Executive Summary

The bulkhead and slope stability issues in the vicinity of Riverbed Street/Irishtown Bend are documented to date back to at least the 1960s. Currently a landslide is slowly but actively moving towards the river below, as a result of historic geologic processes and relatively recent land use. The height of the slope (over 100 vertical feet) and length of the site (approximately 2,500 linear feet) combine to make this a challenging engineering project due to the size of the failure area and the corresponding magnitude of engineering measures required to stabilize the area. In addition, a number of diverse stakeholder groups have an interest in solving various parts of the overall problem to meet a number of similar, but disparate goals. There is not one agency or entity that has jurisdiction over the site itself, or responsibility for solving the problems that have already caused damage to existing infrastructure and threaten to cause further damage while posing a safety risk to the public. For these reasons the problems have persisted without an entity that has the authority and capability to develop plans to stabilize the area.

The US Army Corps of Engineers was granted specific authority to assist with this problem. The Corps was charged to develop conceptual designs (30% design) and cost estimates for measures to address the bulkhead and slope stability issues. Presented in this report is a discussion of the existing condition and how this translates into risks to the public, as well as a number of potential solutions to the existing problems at the site.

In general, the failure at the site will continue if not addressed, and continue to impinge on the Cuyahoga River and cause additional damage to Riverbed Street and the sewerline under Riverbed Street. Future damage is possible at the structures at the top of the slope along West 25th Street as well at to Franklin Avenue. The most likely mode of failure is a gradual rotational/translational movement which will continue at a rate of several inches to a few feet per year. The risk of a catastrophic, deep full slope failure that blocks the Cuyahoga River is very small, given the accepted slow rate of movement. A sudden catastrophic deep failure is extremely unlikely because the factors leading to such a failure, such as a complete loss of the toe of the slope and a major increase in the driving forces (soil and water) towards the top of the slope, do not exist

Provided with each conceptual design are cost estimates, engineering drawings and a discussion of the alternative. Each conceptual alternative will require additional evaluation and analysis prior to final design, and some alternatives may be determined to be unfeasible during the detailed design phase. The selection of an alternative to pursue for construction, if any, is at the discretion of local non-Federal stakeholders.

2. Study Authority and Funding

Section 534 of the Water Resources Development Act of 2000 (Public Law 106-541) directed the Corps to provide technical assistance to non-Federal interests to evaluate the structural integrity of the bulkhead system along the Cuyahoga River including design, plans and specifications and cost estimates for repair.

This technical assistance is provided to the city of Cleveland at 100% Federal cost with General Investigations funds appropriated to the US Army Corps of Engineers.

3. Purpose and Scope

The purpose of this technical assistance is to develop conceptual design solutions and cost estimates for the bulkhead and slope stability problem in the vicinity of Riverbed Street, adjacent to the Cuyahoga River, in Cleveland, OH. This project site was identified by the city of Cleveland and the USACE team along with a coalition of stakeholders in May 2008 (see section 5.2). Consensus was reached that the Riverbed Street project site was the highest priority bulkhead issue from a public safety and economic perspective.

The USACE team was charged with reviewing a number of prior studies that focused on various component issues of the overall bulkhead/slope stability problem in the vicinity of Riverbed Street. Conceptual-level (30%) engineering solutions and cost estimates were developed based on these prior reports as well as the available data and site investigations performed by the team. These conceptual designs were based on input from the city of Cleveland and other stakeholders regarding future land use plans for the project site (see section 7.2).

Prioritization and selection of an alternative to pursue, if any, is solely the responsibility of the city of Cleveland and other stakeholders. This report offers guidance on the engineering methods to achieve each alternative, and the feasibility and costs associated for construction. This technical assistance did not include an economic analysis of the costs avoided or benefits associated with each alternative.

4. Project Location

4.1. Cuyahoga River

The Cuyahoga River is located in Cuyahoga County in northeast Ohio (Figure 4.1) within the City of Cleveland. The river includes a 5.8 mile-long Federal navigation channel (Figure 4.2) that is dredged twice yearly to an average depth of 23 feet.

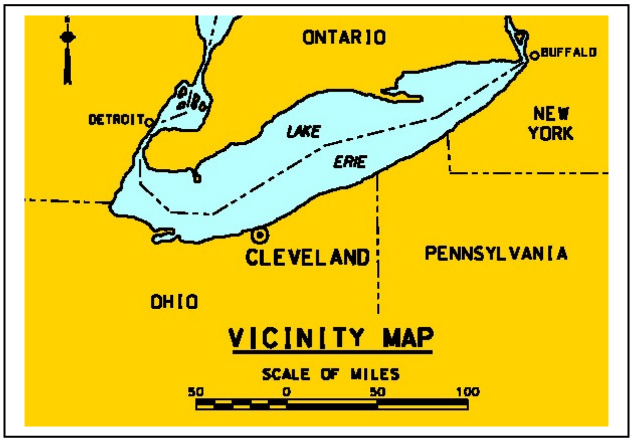


Figure 4.1 Project Location Map

4.2. Riverbed Street and Vicinity (Irishtown Bend)

The project site is along the left descending bank of the Cuyahoga River, bounded downstream by the Detroit-Superior Bridge and upstream by the Columbus Rd. Bridge. The riverward project site boundary is the Federal Navigation channel and the landward boundary is West 25th Street and Franklin Avenue (Figure 4.3). Riverbed Street runs through the center of this site. Historically this area has been referred to as "Irishtown Bend" in reference to a 19th century Irish-American neighborhood.

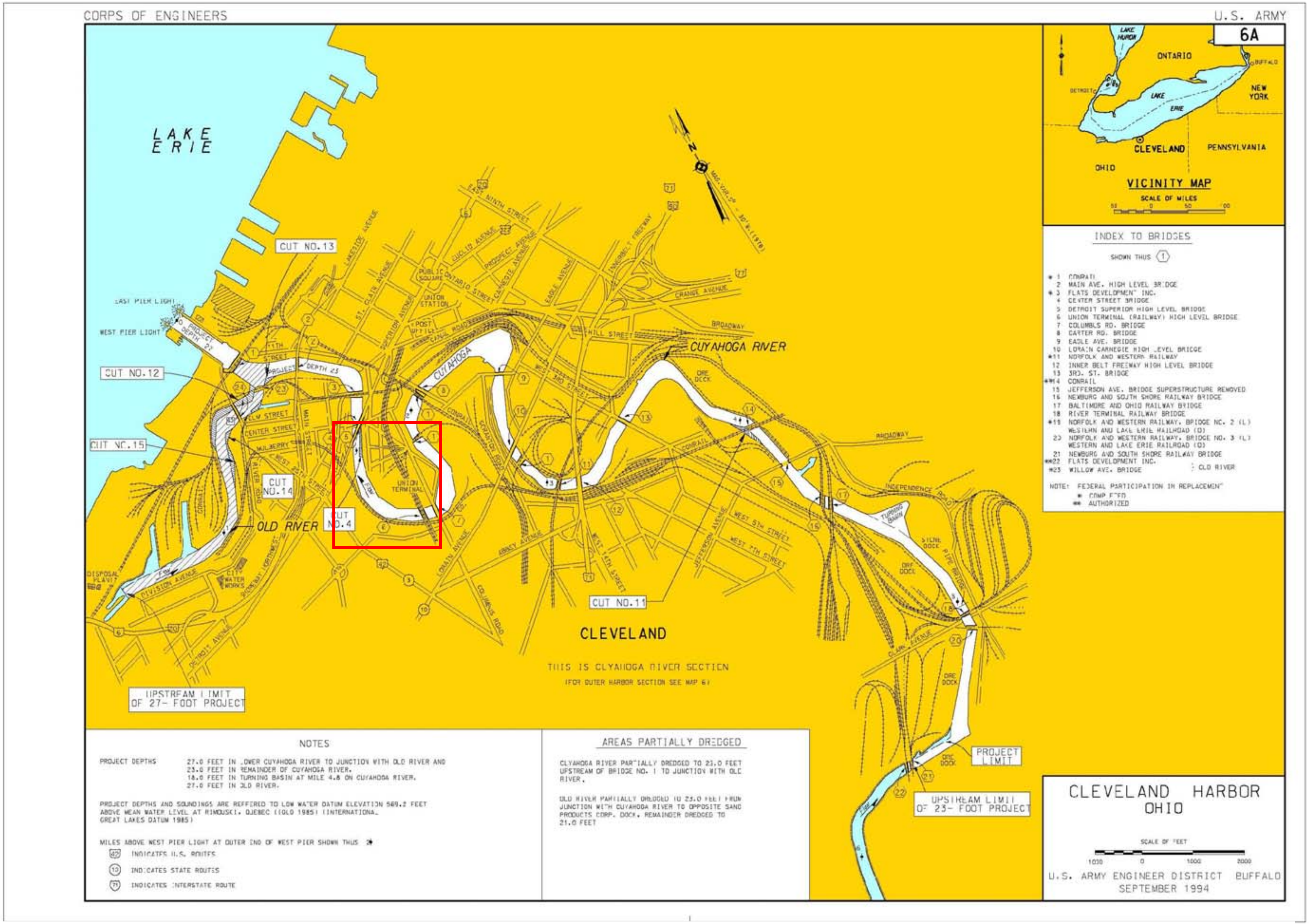


Figure 4.2 Location of Cuyahoga River (Cleveland Harbor), Cleveland, Ohio with project location indicated.

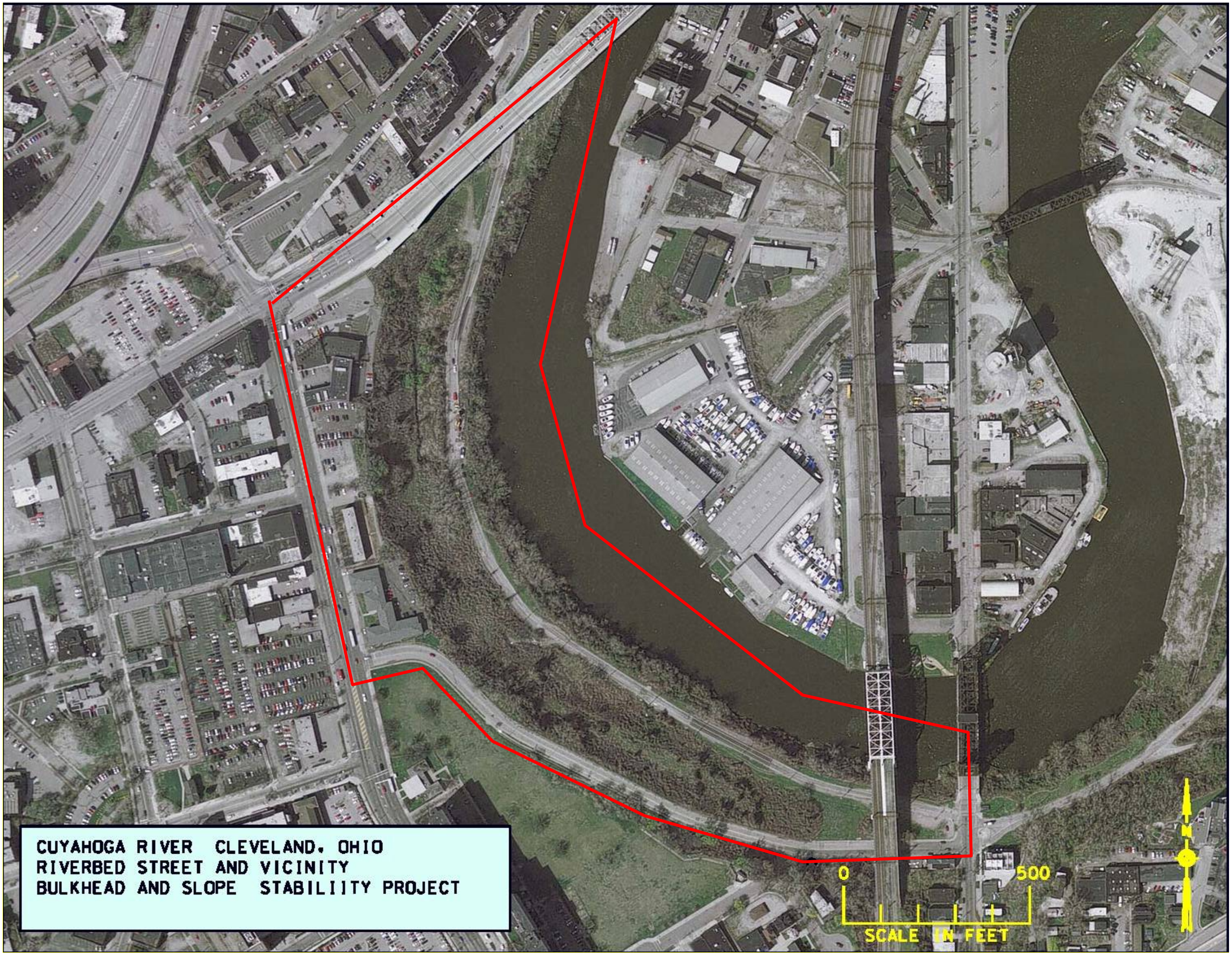


Figure 4.3 Project site: Riverbed St. and vicinity (Irish Town Bend)

5. Background

5.1. Bulkhead System

Vertical sheet pilings, or bulkheads, that were installed in the 1940s and 1950s, stabilize the majority of the navigable portion of the Cuyahoga River. Other types of riverbank along the navigable portion of the river include concrete slabs, stone riprap and natural vegetation. Previous studies and recent inspections by the United States Army Corps of Engineers and others indicate that some bulkheads and surrounding riverbank show indications of potential failure and in one case, the bulkheads have yielded into the Federal channel. If a failed bulkhead, riverbank, or some other impediment obstructs the Federal channel, the Federal government has the authority to remove the obstruction. Field investigations indicate that a concrete cribwall structure exists over much of the Riverbed Street site (see image 6.1.1).

5.2. Site Identification

At a meeting in May 2008 the USACE team met with the Cleveland Harbormaster and stakeholders from the city of Cleveland, North-East Ohio Regional Sewer District (NEORSD), Cuyahoga County Municipal Housing Authority, Cuyahoga County Emergency Management, Cuyahoga County Planning, Cleveland-Cuyahoga Port Authority, Flats Oxbow Association, Arcelor Mittal Company and Cuyahoga Remedial Action Plan. The Riverbed Street site was identified as having the highest perceived risk to navigation in the Cuyahoga River Federal Navigation channel as well as additional risks associated with infrastructure on the slope adjacent to the bulkhead. Based on these reasons this site was selected as the focus of the bulkhead technical assistance effort.

5.3. Site History

In the 19th century the project site was the location of an Irish-American neighborhood which was part of a larger Irish-American community on the West side of Cleveland. By the 1950s the majority of these structures had been demolished or destroyed by fire or neglect.

Image 5.3.1: Housing structures along Riverbed Street, May 1922,
Source: Cleveland Union Terminal Collection, Cleveland State University Library

Image 5.3.2: Housing structures on Irishtown Bend, Sep 1926,
Source: Cleveland Union Terminal Collection, Cleveland State University Library

Image 5.3.3: 1955 Aerial. Source: BBC&M Engineering, Inc

Image 5.3.4: Riverview Terrace 1963. Source: BBC&M Engineering, Inc

6. Existing Conditions

6.1. General

The project site consists of an active landslide along the slope comprising the west bank of the Cuyahoga River between West 25th Street and the riverbank. This landslide is slowly but actively moving towards the river below, as a result of historic geologic processes and relatively recent land use. Within the slide mass, more abrupt, isolated slope failure has occurred along Riverbed Street, resulting in the failure of that street and movement of soil masses towards the river. Along the upper slope, small scarps and poor drainage are typical in general. The most prominent upslope scarps exist along Franklin Avenue as well as at the top of the slope near West 25th Street. Standing water is visible just upslope of Riverbed Street as well as in other locations where buildings formerly stood and their foundations remain intact.

Image 6.1.1: Existing Cribwall. Source: USACE Field Inspection, 17 Apr 2008

Image 6.1.2.: Riverbed St., Downstream Failure. Source: USACE Field Inspection, 19 Apr 2006

Image 6.1.3: Riverbed St., Downstream Failure. Source: USACE Field Inspection, 19 Nov 2007

Image 6.1.4: Riverbed St., Downstream Failure. Source: USACE Field Inspection, 20 Aug 2008

Image 6.1.5: Riverbed St., Upstream Failure. Source: USACE Field Inspection, 8 Jan 2007

Image 6.1.6: Riverbed Street, Upstream Failure. Source: USACE Field Inspection, 20 Aug 2008

Image 6.1.7: Upper Slope Scarp Failure along Franklin Ave.
Source: USACE Field Inspection, 30 Jun 2008

Image 6.1.8: Upper Slope Scarp Failure in parking lot along West 25th Street.
Source: USACE Field Inspection, 30 Jun 2008

6.2. Geologic History

Geologic history of the Cuyahoga river Valley plays a dominant role in the current subsurface conditions of the project site. The current Cuyahoga River flows over the edge of a buried ancient river valley which extends down near sea level. Simply stated, a series of natural processes produced steep slopes which, coupled with a change in the elevation of Lake Erie of 170 feet, caused ancient slope instability/landslides and the potential for continuing landslides in the present time. These ancient slides can be (and have been) reactivated and accelerated by related changes in the project extent, including filling at the top of the slope, poor site drainage, and infrastructure development (such as the large sewer line that runs along Riverbed Street). To attempt to understand the current issues along this reach, the geologic history of the site must be understood and accepted.

6.3. Current Conditions

Current site conditions along the project reach include the Riverbed Street slope failure at the bottom of the slope, scarping along Franklin Avenue as well as behind buildings along the east side of West 25th Street, and poor drainage over much of the site. As previously discussed, geology played a dominant role leading to the current conditions. More recently, man has altered the site, leading to reactivation and acceleration of ancient slides and initiation of some new slides. Based on historic photographs, it appears that extensive fills were placed along the west bank of the Cuyahoga River near West 25th Street in the late 1950's to early 1960's. The placement of these fills appears to correspond to the reactivation of the deep slide which had apparently been dormant or moving much more slowly before these fill were placed. These scarps have progressed fairly slowly, as compared to the sudden failure of Riverbed Street along two reaches which occurred several years ago. The Riverbed Street failures are likely the result of a combination of factors, including loss of support in the toe of the slope, at the river, as well as poor drainage which causes an increase in the water table near the bottom of the slope and increases pore pressures in the foundation soils. This loss of the toe is not related to US Army Corps of Engineers dredging activities, as no dredging has been conducted in this area of the river in recent years. Another possible factor in the Riverbed failures is leakage from pipes within the slope, further compounding the existing drainage problem. The Riverbed slope failure is a relatively shallow, localized failure. The overall slope behaves much differently. Based on the available subsurface information, the overall slope appears to be slowly creeping downward, following a deep (on the order of 100 feet) failure plane/slip surface. While this deeper failure is much slower and much less dramatic/sudden than the Riverbed failure, it will continue indefinitely into the future, as it has been documented to occur just upstream near the I-90 bridge. One major consideration is whether or not this deeper failure has a significant impact on the nearby infrastructure, including the Cuyahoga River, the Riverbed Street sewer line, and the development along the top of the slope near West 25th Street and Franklin Avenue.

6.4. Risks

Risks associated with this project vary depending on the perception of the user/owner/responsible party. The risk of a catastrophic, deep full slope failure that blocks the Cuyahoga River is very small, given the slow failure mode. A sudden catastrophic deep failure is extremely unlikely because the factors leading to such a failure, such as a complete loss of the toe of the slope and a major increase in the driving forces (soil and water) towards the top of the slope, do not exist. The likelihood of a significant seismic event is extremely low and therefore was not considered. There is no point in discussing the degree of risk to Riverbed Street, since the road has failed in two sections already. More moderate risks can be associated with the likelihood of some material entering the river from the slope, continued loss of parking lots along West 25th Street, progressive scarping along Franklin Avenue and limited damage to buildings along west 25th Street. Perhaps the greatest current risk related to slope instability is to the utilities that run across the site, in particular the major sewer line that runs along Riverbed Street. Risk can be controlled to some extent by alteration of the factors leading to the risk, which is discussed in Section 7.

7. Alternative Selection

7.1. Existing Condition Briefing

The USACE team performed an initial review of prior reports, all available data and conducted a site visit. Based on this initial phase of study the team presented their findings to the city of Cleveland and stakeholders in February 2009. The presentation focused on the existing condition of the Riverbed St. project site, the risks to the Cuyahoga River and all of the infrastructure and the public, as well as a discussion on the methods to address these risks. The content of the presentation is described in section 6, above, and the presentation is attached as appendix D.

7.2. Performance Objectives

Based on the input from the USACE team regarding the existing condition of the project site, in March 2009 the city of Cleveland provided performance objectives to define the alternatives for which the USACE team should design conceptual solutions. These alternatives are:

A) Protect just the Cuyahoga River
B) Protect the Cuyahoga River with a Green Bulkhead (for larval-fish habitat)
C) Protect the Cuyahoga River plus Riverbed Street and the sewerline under it
D) Protect everything (the Cuyahoga River, Riverbed St. and the sewerline under it, Franklin Ave. and the structures at the top of the slope, along West 25th St.).

Upon further investigation the Green Bulkhead alternative was determined to be a viable add-on for each other alternative, therefore Alternative B was deleted and Alternative A, C and D each have a Green Bulkhead add-on version.

7.3. Factor of Safety Definition

The factor of safety is a measure of the likelihood of failure of a given system or entity. In this case, the factor of safety relates to the likelihood of slope failure of a given type. The factor of safety is determined by summing the forces which resist slope failure and dividing by the sum of the forces which promote slope failure. The former include soil mass at the toe of the slope as well as any walls or other reinforcing structures which try to hold the slope back. The latter include soil mass towards the top of the slope as well as a high groundwater table. Both of these factors promote failure of the slope. A third component of the factor of safety is the strength of the soil layer(s) along the most likely failure plane(s) beneath the slope. A factor of safety of 1.0 implies that the slope is on the brink of instability. The Riverbed Street slide has a factor of safety of around unity, since it failed and remains in a state of equilibrium (temporarily). The overall slope also has a factor of safety of around unity as well, since it is in a constant state of movement, which is defined as failure, albeit very slow and almost imperceptible. The factor of safety against a catastrophic slide into the river is something above unity, although its exact value is difficult to calculate/predict because of a lack of subsurface information that would better define it. A factor of safety below unity indicates a pending slope failure. A factor of safety above 1.0 is desirable to provide some assurance of a stable slope. How much above 1.0 is judgmental, depending on consequences of failure and the willingness of the responsible party/client to accept the consequences. The methods discussed in Section 8 involve a variation in acceptable minimum factors of safety (FOS's) that relate to the degree of confidence/protection afforded by each different scenario. The factor of safety is not a definite parameter, rather it is a probabilistic measure of how likely the slope, in this case, can be expected to be stable/unstable.

7.4. Engineering Methods

Several design alternatives which were initially considered during the brainstorming phase of this study were not included in the 30% design. These include a caisson wall and several soil improvement techniques. The caisson wall was dismissed because preliminary analyses indicated it would be infeasible due to its immense size and cost. The soil improvement methods were dropped because they did not provide a sufficient degree of confidence for the structural wall design.

8. Conceptual Alternatives

8.1. Alternative 0: No Action

Assumes that the current conditions at the project site will continue indefinitely, with no alterations made to any part of the site.

8.1.1. Description

The existing site condition consists of a heavily vegetated slope which overlies the partially failed Riverbed Street and a partially failed bulkhead on the Cuyahoga

River bank. A major sewer line which runs along Riverbed Street has shown signs of distress in recent years. At various locations at the top of the slope (near West 25th Street) and mid-slope along Franklin Avenue, scarps ranging in height from a few inches to several feet exist. The overall slope has been creeping downward slowly. The localized failures at the bottom of the slope occurred suddenly, the result of a lack of support at the toe of the slope.

If nothing is done to rectify the situation, the following chain of events can be expected to occur:

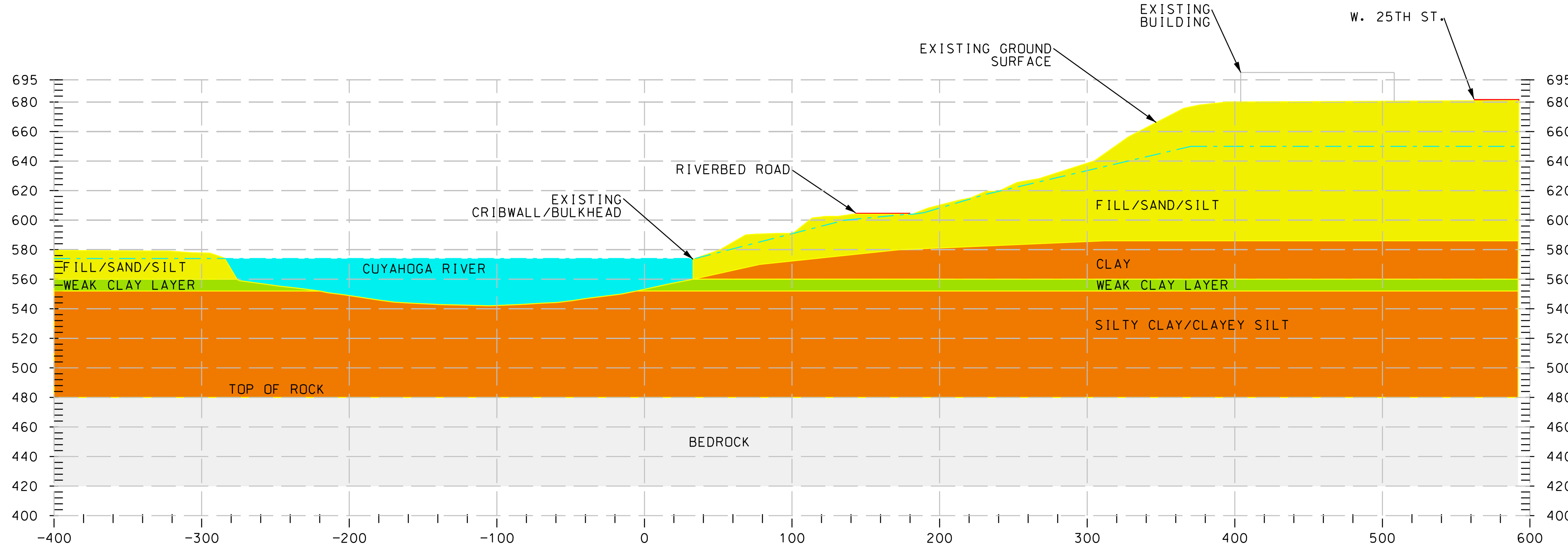
- Erosion will continue along the bottom of the slope on the river
- The existing bulkhead will continue to move (inches to feet per year), with additional localized movements/failures, internal failures of the cribwall/bulkhead, and unknown but likely impingement on the federal channel anticipated to occur over time
- Riverbed Street will never be reopened, and the situation can only get worse, as existing scarps continue to move and, likely, more failures will initiate
- Cracking and differential settlement will continue along Franklin Avenue, resulting in damage to utilities and increased jeopardy to public safety when driving on Franklin Avenue, with likely road closure
- Mid-slope utilities will be lost and not be recovered, especially sewer lines, and repairs will only be temporary
- The movement of the crest will continue and possibly accelerate, leading to additional damage to buildings due to differential settlement and loss of foundation support

The risk for the events above is very high to certain. It is up to the City of Cleveland to decide whether this risk is acceptable. The No Action method has a zero implementation cost, with the use/value of the project site reduced to virtually none, other than an abandoned open space.

8.1.2. Costs

There are no direct costs associated with the No Action alternative.

8.1.3. Cross-section

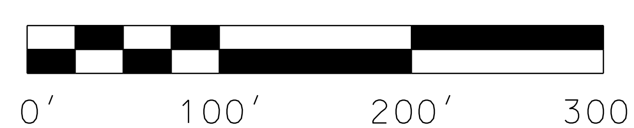


NO ACTION ALTERNATIVE

SCALE: 1"=100'

NOTES:

1. SEE FIGURES IN STRUCTURAL DESIGN APPENDIX FOR FURTHER DETAILS OF PROPOSED LOWER AND UPPER STABILITY WALLS.



SCALE: 1"=100'

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

CROSS-SECTION FOR
EXISTING CONDITIONS
NO ACTION ALTERNATIVE

US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
AUGUST 2009

8.2. Alternative A: Protect the Cuyahoga River only

8.2.1. Alternative A1: Bulkhead and mid-slope wall with excavation and retaining wall

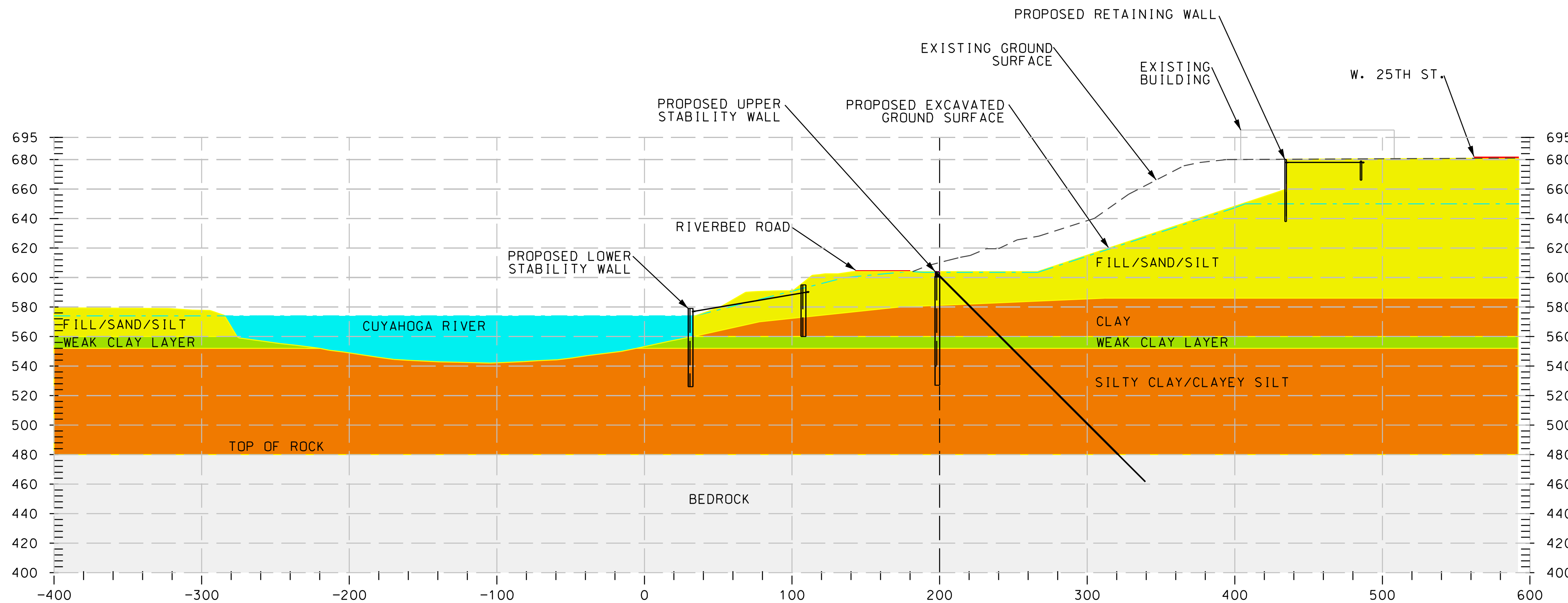
8.2.1.1. Description

A steel sheet-pile lower stability wall/bulkhead system and tied back to an anchor wall approximately seventy-five feet landward would be constructed just riverward of the existing crib-wall bulkhead system. An upper stability wall would be constructed up-slope from the existing Riverbed Street right-of-way and tied back to bedrock. Fill would be excavated up-slope from the upper wall and a retaining wall would be constructed at the top of the slope, just riverward from the existing structures. This alternative achieves a slope stability factor of safety of 1.2. For details refer to Appendix B.

8.2.1.2. Costs

$80,465,000 total, including mobilization/demobilization and contingencies. Real estate and relocation costs are not included in this estimate. For details refer to Appendix C.

8.2.1.3. Cross section

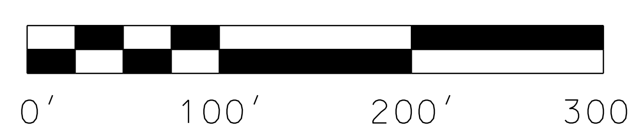


ALTERNATIVE A WITH EXCAVATION

SCALE: 1″=100′

NOTES:

1. SEE FIGURES IN STRUCTURAL DESIGN APPENDIX FOR FURTHER DETAILS OF PROPOSED LOWER AND UPPER STABILITY WALLS, AS WELL AS THE RETAINING WALL.



SCALE: 1″=100′

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

CROSS-SECTION FOR ALTERNATIVE A WITH EXCAVATION

US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
AUGUST 2009

8.2.2. Alternative A2: Bulkhead and mid-slope wall without excavation

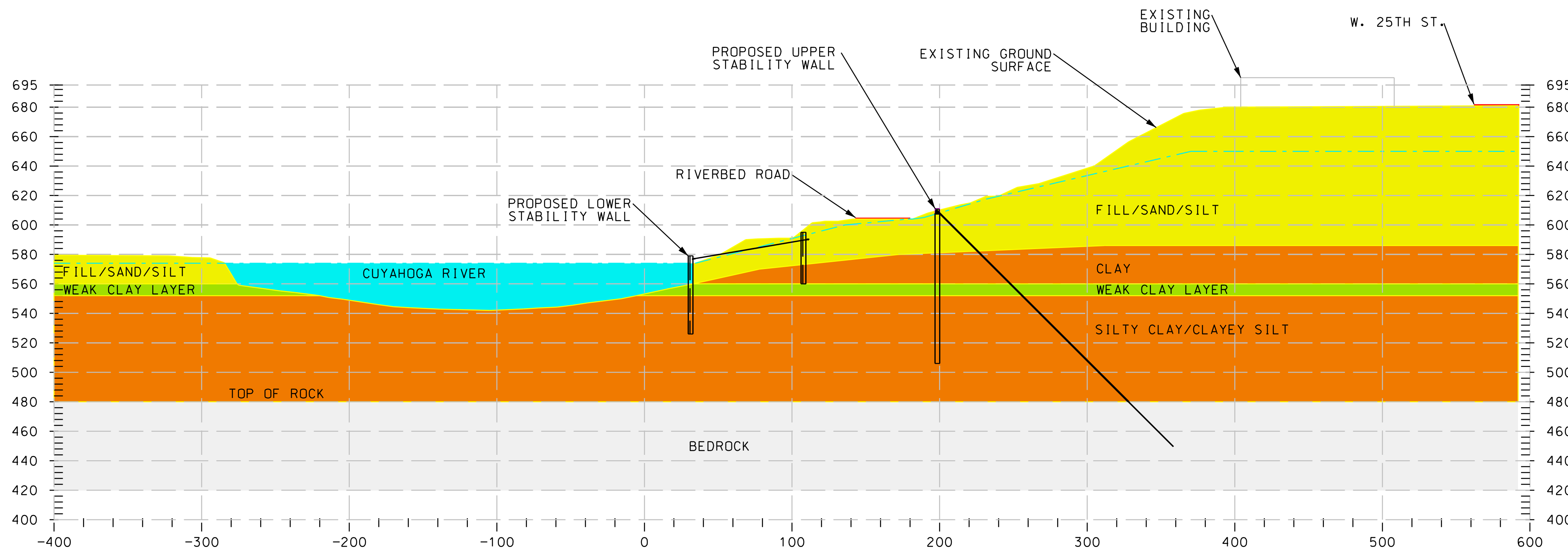
8.2.2.1. Description

A steel sheet-pile lower stability wall/bulkhead system and tied back to an anchor wall approximately seventy-five feet landward would be constructed just riverward of the existing crib-wall bulkhead system. An upper stability wall would be constructed up-slope from the existing Riverbed Street right-of-way and tied back to bedrock. The upper stability wall would be more robust than for Alternative A1. This alternative achieves a slope stability factor of safety of 1.2. For details refer to Appendix B.

8.2.2.2. Costs

$166,715,000 total, including mobilization/demobilization and contingencies. Real estate and relocation costs are not included in this estimate. For details refer to Appendix C.

8.2.2.3. Cross section

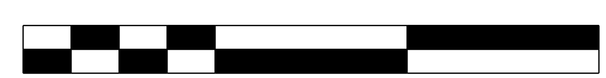


ALTERNATIVE A WITHOUT EXCAVATION

SCALE: 1″=100′

NOTES:

1. SEE FIGURES IN STRUCTURAL DESIGN APPENDIX FOR FURTHER DETAILS OF PROPOSED LOWER AND UPPER STABILITY WALLS.



SCALE: 1″=100′

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

CROSS-SECTION FOR ALTERNATIVE A WITHOUT EXCAVATION

US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
AUGUST 2009

8.2.3. Alternative A3: Excavation only (theoretical)

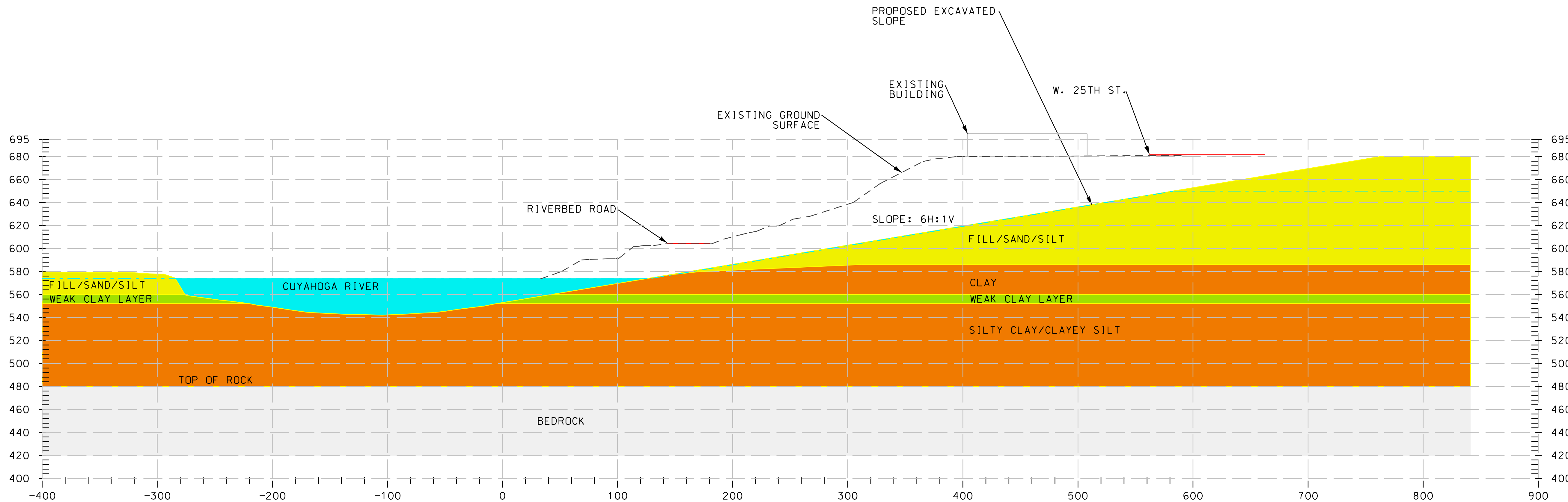
8.2.3.1. Description

This alternative does not achieve the objectives set forth by the city of Cleveland and is only intended for illustrative purposes. Displayed is the slope excavated back to a stable geometry (achieving a factor of safety of 1.2) without any structural components. This slope would eliminate all infrastructure currently in place on the slope as well as the structures along West 25th Street and both West 25th Street and Franklin Avenues themselves. For details refer to Appendix B.

8.2.3.2. Costs

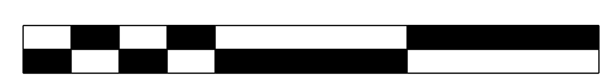
No cost estimate prepared, not a viable alternative.

8.2.3.3. Cross section



ALTERNATIVE A SLOPE CUTBACK UNCONSTRAINED

SCALE: 1″=100′



SCALE: 1″=100′

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

CROSS-SECTION FOR ALTERNATIVE A SLOPE CUTBACK UNCONSTRAINED

US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
AUGUST 2009

8.3. Alternative B: Green Bulkhead add-on

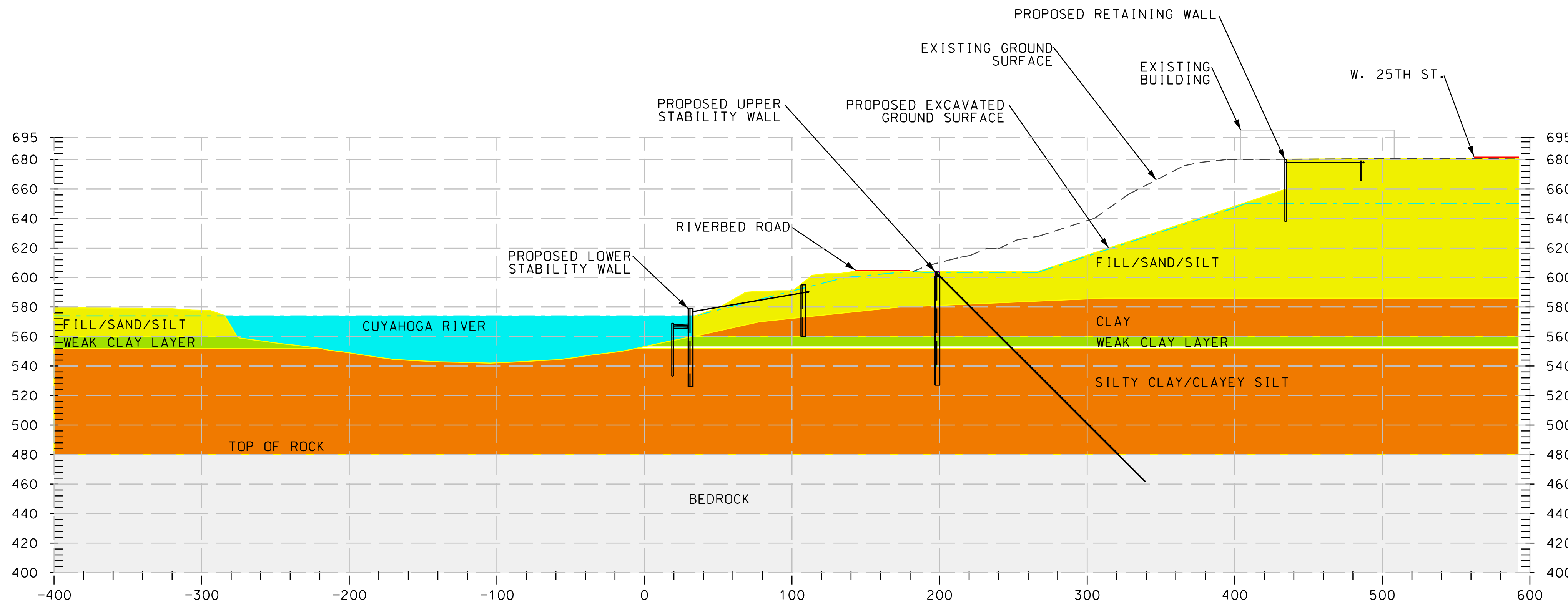
8.3.1.1. Description

A Green Bulkhead addition to provide larval fish habitat on the riverward side of any constructed bulkhead system is a possible add-on to any of the presented alternatives. For details refer to Appendix B.

8.3.1.2. Costs

$3,250,000 additional for each alternative. For details refer to Appendix C.

8.3.1.3. Cross section



ALTERNATIVE A WITH EXCAVATION AND GREEN BULKHEAD

SCALE: 1"=100'

NOTES:

1. SEE FIGURES IN STRUCTURAL DESIGN APPENDIX FOR FURTHER DETAILS OF PROPOSED LOWER AND UPPER STABILITY WALLS, AS WELL AS THE RETAINING WALL AND GREEN BULKHEAD.

0' 100' 200' 300'

SCALE: 1"=100'

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

CROSS-SECTION FOR ALTERNATIVE A WITH EXCAVATION AND GREEN BULKHEAD

US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
AUGUST 2009

8.4. Alternative C: Protect the Cuyahoga River plus Riverbed Street

8.4.1. Alternative C1: Bulkhead and mid-slope wall with excavation and retaining wall

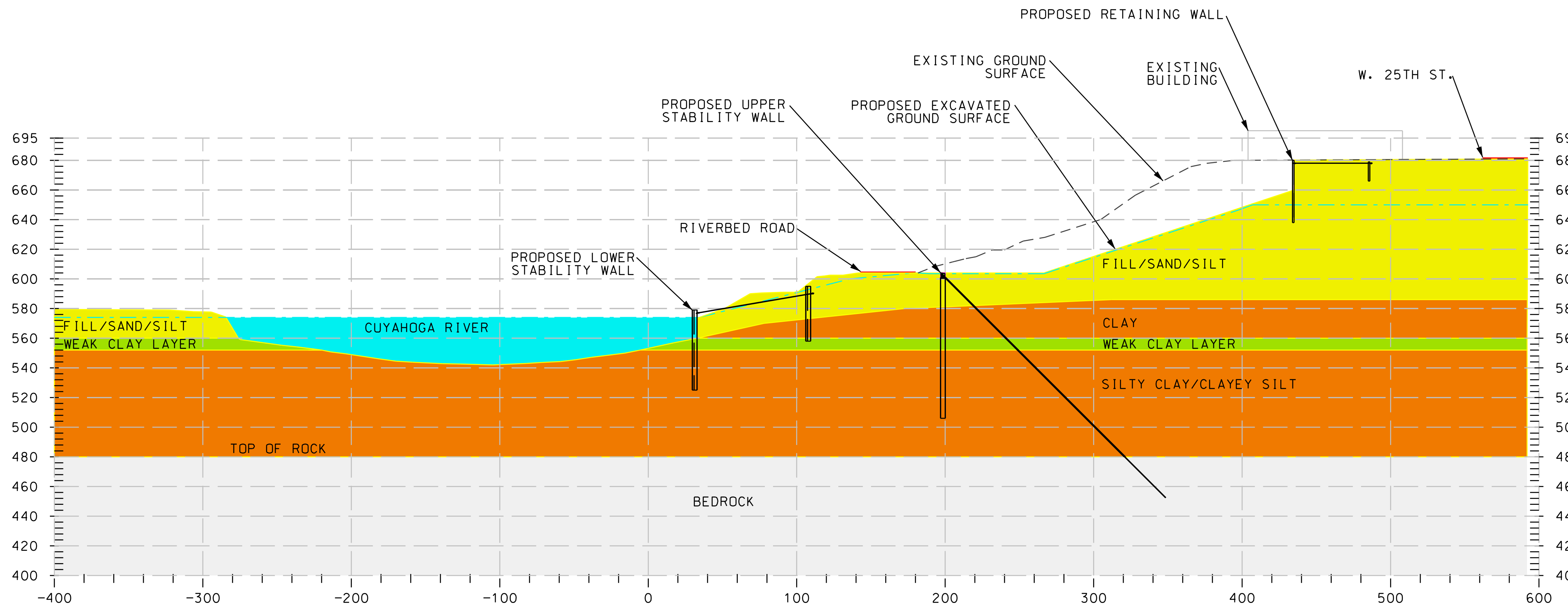
8.4.1.1. Description

A steel sheet-pile lower stability wall/bulkhead system and tied back to an anchor wall approximately seventy-five feet landward would be constructed just riverward of the existing crib-wall bulkhead system. An upper stability wall would be constructed up-slope from the existing Riverbed Street right-of-way and tied back to bedrock. Fill would be excavated up-slope from the upper wall and a retaining wall would be constructed at the top of the slope, just riverward from the existing structures. The components of this alternative are similar those of alternative A1, but more robust to increase the factor of safety. This alternative achieves a slope stability factor of safety of 1.3. For details refer to Appendix B

8.4.1.2. Costs

$153,715,000 total, including mobilization/demobilization and contingencies. Real estate and relocation costs are not included in this estimate. For details refer to Appendix C.

8.4.1.3. Cross section

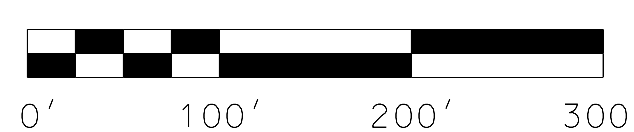


ALTERNATIVE C WITH EXCAVATION

SCALE: 1"=100'

NOTES:

1. SEE FIGURES IN STRUCTURAL DESIGN APPENDIX FOR FURTHER DETAILS OF PROPOSED LOWER AND UPPER STABILITY WALLS, AS WELL AS THE RETAINING WALL.



SCALE: 1"=100'

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

CROSS-SECTION FOR ALTERNATIVE C WITH EXCAVATION

US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
AUGUST 2009

8.4.2. Alternative C2: Bulkhead and mid-slope wall without excavation

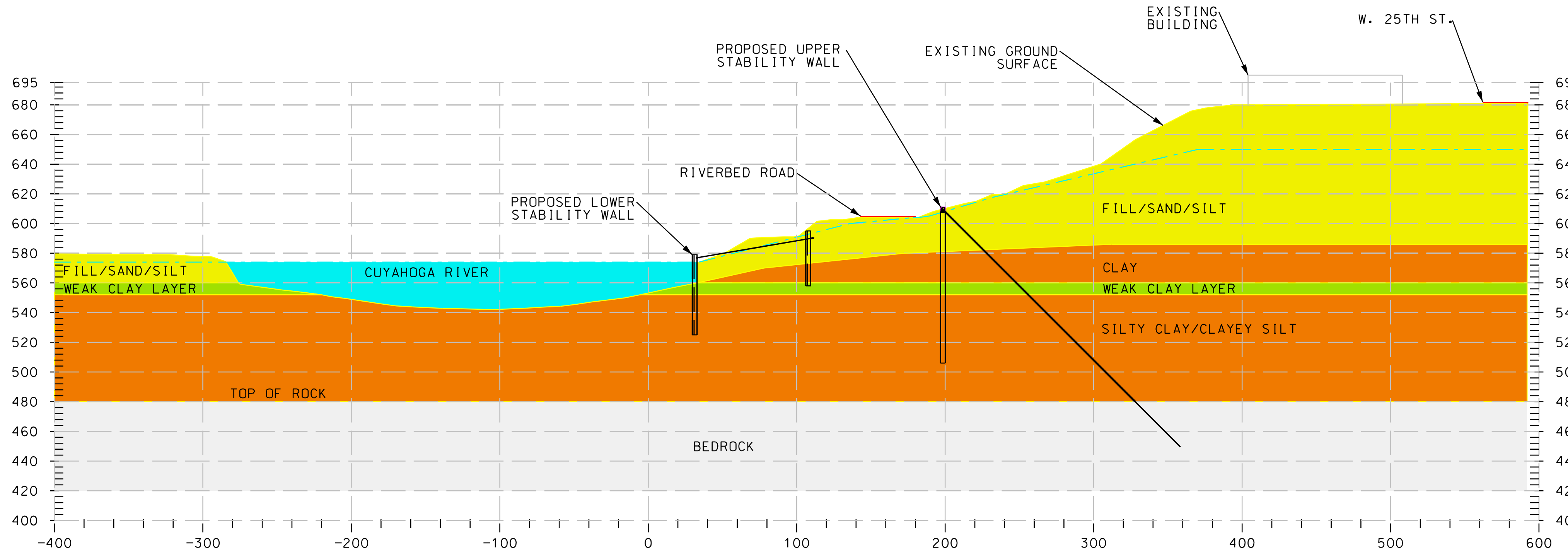
8.4.2.1. Description

A steel sheet-pile lower stability wall/bulkhead system and tied back to an anchor wall approximately seventy-five feet landward would be constructed just riverward of the existing crib-wall bulkhead system. An upper stability wall would be constructed up-slope from the existing Riverbed Street right-of-way and tied back to bedrock. The components of this alternative are similar those of alternative A2, but more robust to increase the factor of safety. This alternative achieves a slope stability factor of safety of 1.3. For details refer to Appendix C

8.4.2.2. Costs

$178,965,000 total, including mobilization/demobilization and contingencies. Real estate and relocation costs are not included in this estimate. For details refer to Appendix C.

8.4.2.3. Cross section

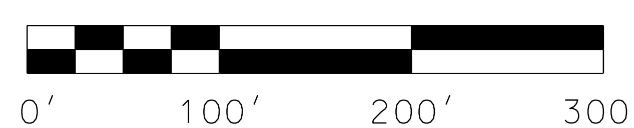


ALTERNATIVE C WITHOUT EXCAVATION

SCALE: 1"=100'

NOTES:

1. SEE FIGURES IN STRUCTURAL DESIGN APPENDIX FOR FURTHER DETAILS OF PROPOSED LOWER AND UPPER STABILITY WALLS.



SCALE: 1"=100'

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

CROSS-SECTION FOR ALTERNATIVE C WITHOUT EXCAVATION

US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
AUGUST 2009

8.5. Alternative D: Protect Everything (the Cuyahoga River, Riverbed Street plus Franklin Avenue and the structures along West 25th Street)

8.5.1. Alternative D1: Bulkhead and mid-slope wall without excavation

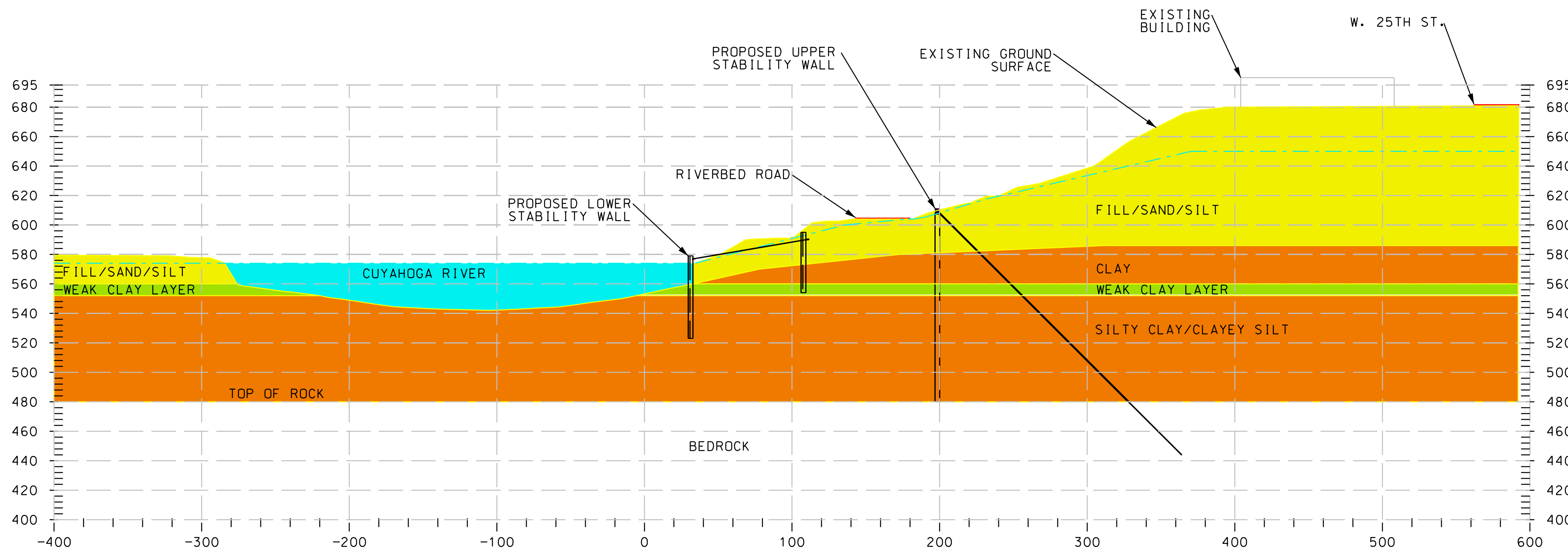
8.5.1.1. Description

The existing crib-wall bulkhead system would be removed and replaced by a steel sheet-pile lower stability wall/bulkhead system and tied back to a wall approximately sixty feet landward. An upper stability wall would be constructed up-slope from the existing Riverbed Street right-of-way and tied back to bedrock. The components of this alternative are similar those of alternative C2, but more robust to increase the factor of safety. This alternative achieves factor of safety of 1.5. For details refer to Appendix C

8.5.1.2. Costs

$219,215,000 total, including mobilization/demobilization and contingencies. Real estate and relocation costs are not included in this estimate. For details refer to Appendix C.

8.5.1.3. Cross section

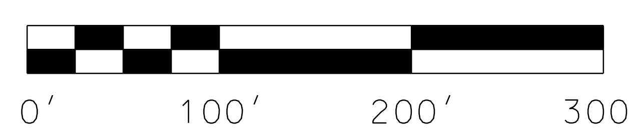


ALTERNATIVE D CONSTRAINED BY W. 25TH AVENUE

SCALE: 1″=100′

NOTES:

1. SEE FIGURES IN STRUCTURAL DESIGN APPENDIX FOR FURTHER DETAILS OF PROPOSED LOWER AND UPPER STABILITY WALLS.



SCALE: 1″=100′

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

CROSS-SECTION FOR ALTERNATIVE D CONSTRAINED BY W. 25TH AVENUE

US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
AUGUST 2009

9. Summary and Recommendations

9.1. Prioritization and Alternative Selection

The intent of the USACE effort was to develop concepts and costs for the presented alternatives in order to provide the city of Cleveland and other stakeholders a basis to select a course of action to remedy the problems at the site. This report does not recommend which of the presented alternatives should be pursued. Alternatives should be evaluated for prioritization based on the cost estimates and risks associated with each alternative as presented in this report and also based on analysis of future land use plans and real estate values in the vicinity of the site.

9.2. Advancing the Design

The designs presented in this report are at a conceptual (30%) level and would need to be finalized prior to construction. Advancing the design for one or more of the presented alternatives to 100% design would require additional exploration and data gathering and analysis as well as a significant amount of detailed design work. Monitoring of the site in the interim will help to mitigate the current risk as well as help to provide data to future design work. The conceptual designs presented in this report are based largely on previously gathered data and were developed for the portion of the slope that presented the greatest risk. Detailed designs would apply the selected alternative to the contours and gradient of the site and the existing site conditions.

1. GENERAL

This appendix documents the 30% level of the geotechnical design for the Cuyahoga River Bulkhead Technical Assistance Study. The direction of the study was initially determined by the Project Delivery Team (PDT). The PDT determined the levels of stability to be provided and basic components of each alternative design. The 30% level design presented in this appendix is preliminary.

2. DESCRIPTION OF EXISTING STUDY AREA

The existing project site consists of approximately 2500 feet of the west bank of the Cuyahoga River in Cleveland, Ohio from the Detroit/Superior Avenue Bridge to the Columbus Road Bridge. The site is bounded by the western navigation limit of the federal channel in the Cuyahoga River and by Franklin Avenue and West 25th Street on the landward side. An overall plan of the study area is shown in Figure 4.3 of the main section of this report.

3. PURPOSE OF STUDY

The purpose of the study is to establish and evaluate several possible alternatives to stabilize the west bank of the Cuyahoga River within the study area. The study involves three levels of slope stability as follows:

Case A – Only provide acceptable stability for the west bank to assure navigation on the Cuyahoga River will not be affected by any future instability of the west bank. This case may include removal of existing soils and structures as part of the stability improvement features.

Case C – Same as Case A, except also assures that Riverbed Road will not be affected by any future instability of the west bank. This case may include removal of existing soils and structures as part of the stability improvement features.

Case D – Provides acceptable stability for the entire west bank of the Cuyahoga River within the study area from the Cuyahoga River up to and beyond the top of the existing slope along Detroit Avenue, West 25th Street and Franklin Avenue. This case provides for improvements to the existing west bank without the removal of any existing infrastructure.

Soil improvement techniques were considered as possible stability alternatives but not implemented in this design. It was decided that a greater certainty for the structural design alternatives precluded further consideration of the soil improvement methods.

4. DESCRIPTION OF THE SITE

The project site is affected by historic slope instability. Starting at the top of the slope, this includes a prominent scarp which runs along buildings on the riverward side of West 25th Street and Franklin Avenue. This scarp, which has been visible since the early 1960's, ranges from a few inches to several feet in height. The scarp cuts across Franklin Avenue in a "stair-step" pattern. Evidence of scarping in the mid-slope is not readily visible, due to heavy vegetation and existing old structures, but indicators of slope instability along the mid-slope are evident, including leaning utility poles, pavement cracking, standing water, and leaning trees. The upper slope has and continues to exhibit extremely slow but persistent downward movement, towards the Cuyahoga River, which is termed "drained creep." More recently, relatively sudden/abrupt slope failures occurred in two locations near the bottom of the slope, along Riverbed Road, which are clear evidence of slope instability at the toe of the slope. Erosion and undermining of the riverbank, as well as the subsidence of the existing bulkhead along the riverbank, are evident. This report considers slope stability of the entire slope, including the upper slope, the toe, and the overall slope.

5. GEOLOGY AND RELATED PROCESSES

The primary geologic influence on the project site is the Cuyahoga River, which flows along the western edge of an ancient buried river valley. The bedrock in the downtown Cleveland vicinity is Devonian shale (Ohio formations). The Ohio shale typically contains pockets of natural gas, which is trapped by overlying sediments. The ancient Cuyahoga River valley exists nearly 600 feet below the present ground surface, near sea level.

A long series of complex glacial processes deposited various soils along the project site, including sands and silts as well as lacustrine clays. At one point in time, Lake Erie dropped about 170 feet below its current elevation. This caused the Cuyahoga River to rapidly downcut through various soil layers, forming bluffs which exist today. The combination of steep slopes and potentially unstable soils created a potential for slope instability in this vicinity, including landslides and soil mass creep. Recent subsurface explorations have encountered slickensides which, as planes of weakness, confirm this history. It is likely that ancient slides were triggered by rapid drawdown of the Cuyahoga River. Movement in the slide zones likely mobilized failure surfaces/zones with soil at or near its residual strength. The reactivation of these planes of weakness could be (and likely was) reactivated by man-made activities such as filling at the top of the slope and/or removal of material at the toe by dredging. The current overall slope behavior, which consists of an extremely slow but persistent creep, was caused, most likely, by placing large amount of fill near the top of the slope. The current slope will likely continue to creep downward at a faster rate than prior to the 1960's filling indefinitely, if nothing else intervenes.

The recent failures near the toe, along and through Riverbed Street, affect the lower slope in general. These are likely due to a loss of support at the toe, in combination with other factors, including saturation of the foundation (and surface) soils and a weakening of the bulkhead that supports the riverbank. While the Riverbed Road toe failures are localized, they could have a long-term effect on the slope above due to the loss of support at the toe.

6. PAST WORK BY OTHERS

Numerous previous geotechnical investigations were performed over much of the past century in and near the project vicinity. BBC&M Engineering, Inc., a Cleveland area geotechnical A/E firm, not only conducted several of these studies but also consolidated nearly a dozen of the past studies by a variety of firms and individuals into a comprehensive draft (draft final) report (Ref. 1) . This consolidated report serves as the primary geotechnical reference for the preparation of this Technical Assistance report, as the Corps has not performed any investigations/studies of its own for this study. In addition, representatives of BBC&M briefed the Buffalo District Technical Assistance PDT in 2009 on their report and experience with the project site.

7. GEOTECHNICAL DESIGN PARAMETERS

The 2006 BBC&M report includes borings and lab testing performed for five previous studies, ranging from 1960 to 2005. The borings and related lab testing of soil samples from the borings were used to develop geotechnical parameters which were used by BBC&M for their slope stability analyses. These parameters, shown in Table 1 below, were excerpted from the 2006 BBC&M report and used by BBC&M for their slope stability analyses. These values were used in the analysis done for this report. A reliability analysis is not included. These are considered to be representative values.

Material	Drained Strength Property	Mean Value	Standard Deviation	Relative Minimum Value	Relative Maximum Value
Fill	Phi’	30	3	21	39
Fill	Gamma	125	4	113	137
Sand	Phi’	33	2	27	39
Sand	Gamma	125	4	113	137
Silt	Phi’	30	2	24	36
Silt	Gamma	125	4	113	137
Clay	Phi’ (fully softened)	30	2	24	36
Clay	Phi’ (residual)	16	2	10	22
Clay	Gamma	130	4	118	142

Table 1 - Soil properties used for stability analyses

Note that the fill material is a heterogeneous mixture which may include but is not limited to sand, silt, clay, building debris, vegetation. Refer to the attached report by BBC&M for details shown in the boring logs.

Instantaneous historic water levels for the Cuyahoga River at the project site vary from a high of 574.73 to a low of 566.31. Since this is a function of the level of Lake Erie, rapid fluctuations are unlikely with regard to the stability analysis (i.e., rapid drawdown case).

7. SELECTION OF CROSSECTION FOR SLOPE STABILITY ANALYSIS

Since the 2006 BBC&M report included pertinent crossection topography as well as soil stratigraphy, it was used to provide the basis for the Corps slope stability analysis for this report. Crossection A-A from that report was selected, shown below as Figure 1. Note that the apparent failure surface drawn on this section was based on actual inclinometer measurements obtained by BBC&M. This is considered to represent a likely failure geometry for the purposes of this report. The high piezometric surface was selected because of supporting visual evidence (i.e., cattails visible on portions of the slope and observations of wet/saturated soils even in dry weather) and a lack of water well measurements. The selected crossection for slope stability analysis is considered to be slightly on the conservative side and realistic for this report.

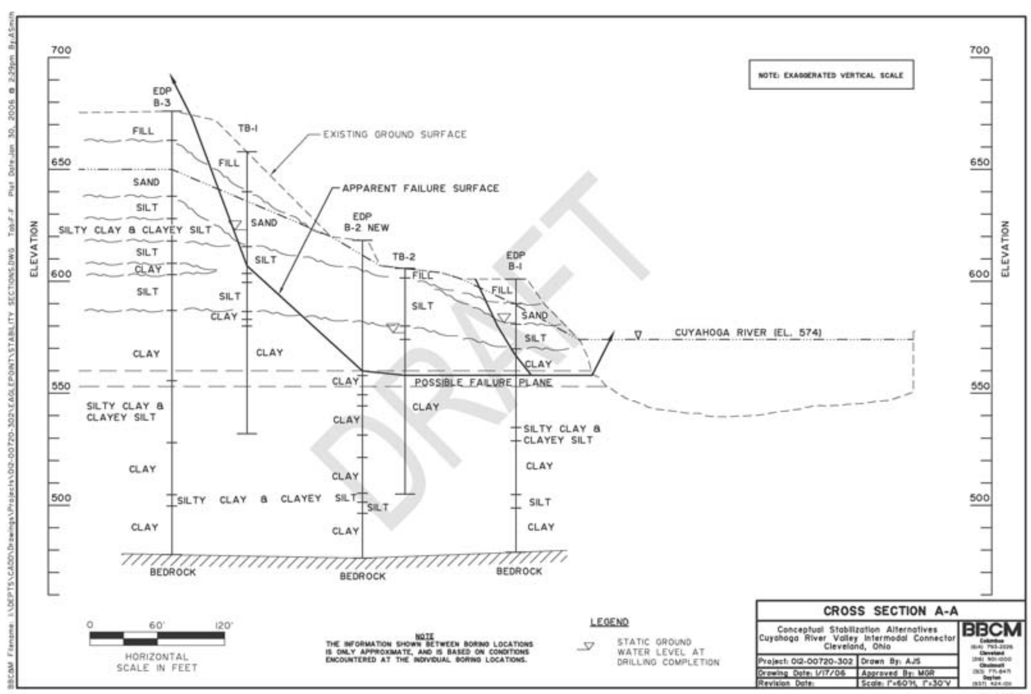


Figure 1 - Typical Crossection for Slope Stability Analysis

8. SLOPE STABILITY CASES

Global stability analyses were performed on each of the design cases using the computer stability package SLOPE/W (Geo-Slope International Ltd) using Spencer's Method with optimization. As previously discussed, the geotechnical design parameters, including shear strengths, and design crossection were based on the 2006 BBC&M report. A total of nine design crossections were analyzed (not optimized) as follow:

SLOPE STABILITY FIGURES

FIGURE 1

Alternative A – Wall at Riverbank
Force Needed – 41 kips/ft
Factor of Safety – 1.21

Cuyahoga River Bulkhead Technical Assistance
Cross Section 1 - STA. 16+00

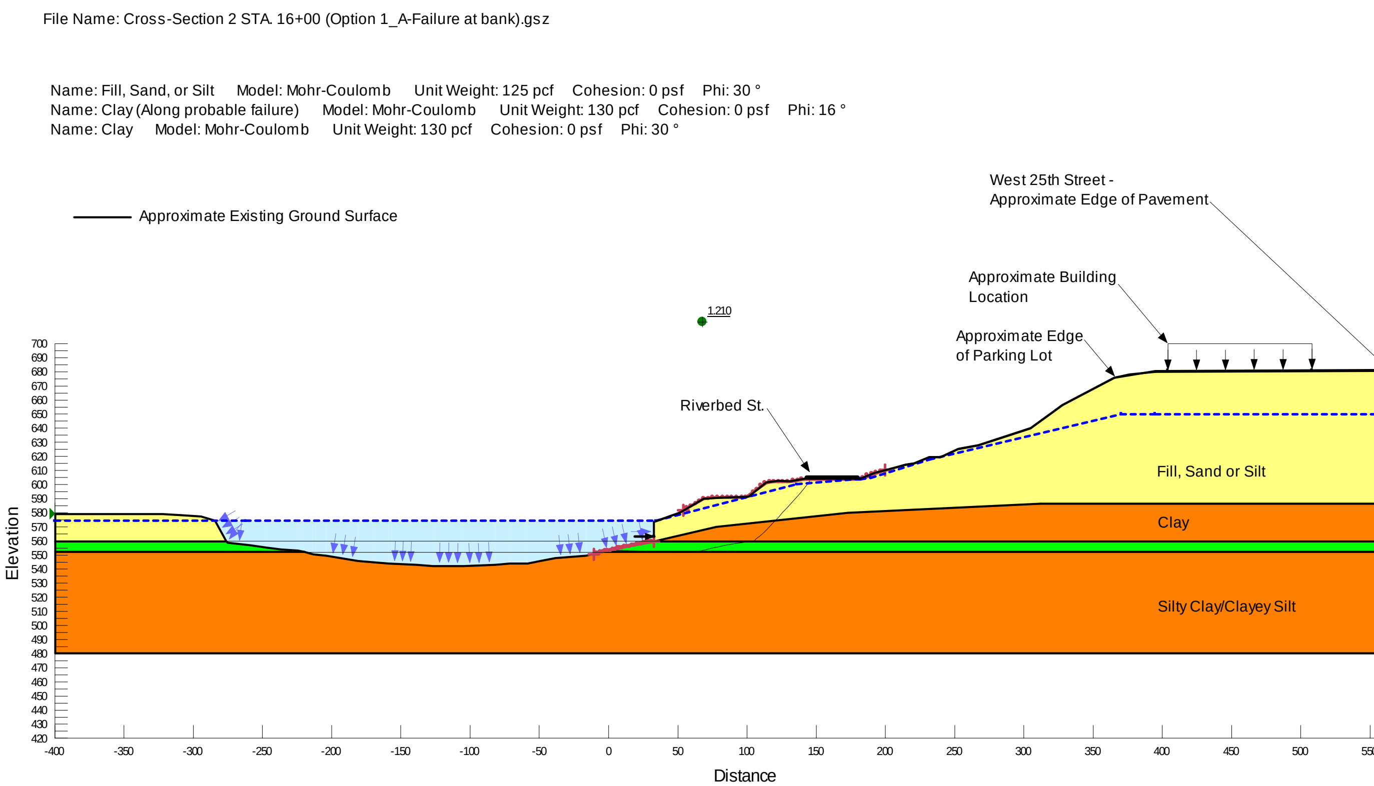


FIGURE 2

Alternative A – Upslope Wall Without Excavation

Force Needed – 95 kips/ft
Factor of Safety – 1.20

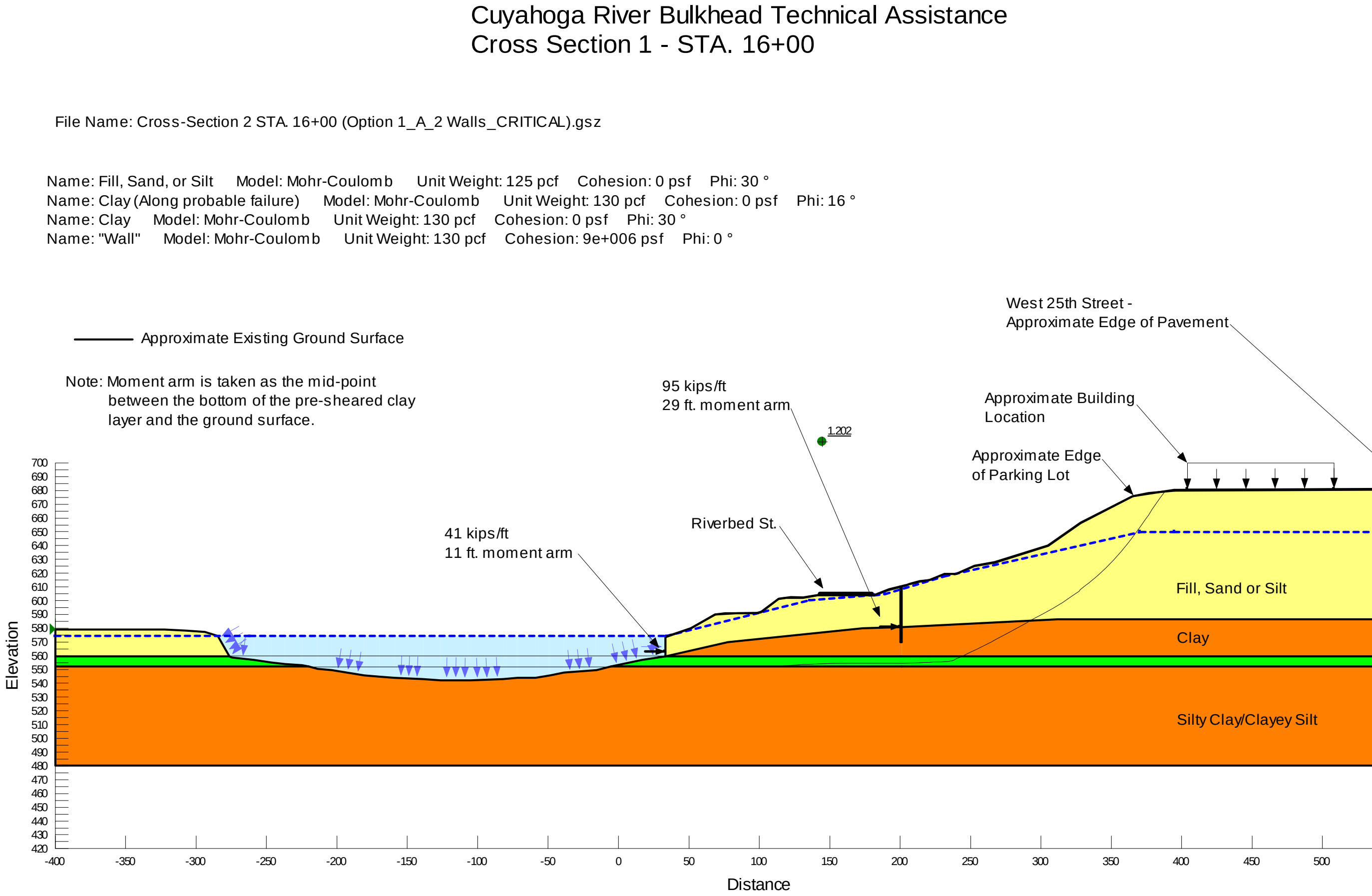


FIGURE 3

Alternative A – Upslope Wall With Excavation
Force Needed – 40 kips/ft
Factor of Safety – 1.21

Cuyahoga River Bulkhead Technical Assistance
Cross Section 1 - STA. 16+00

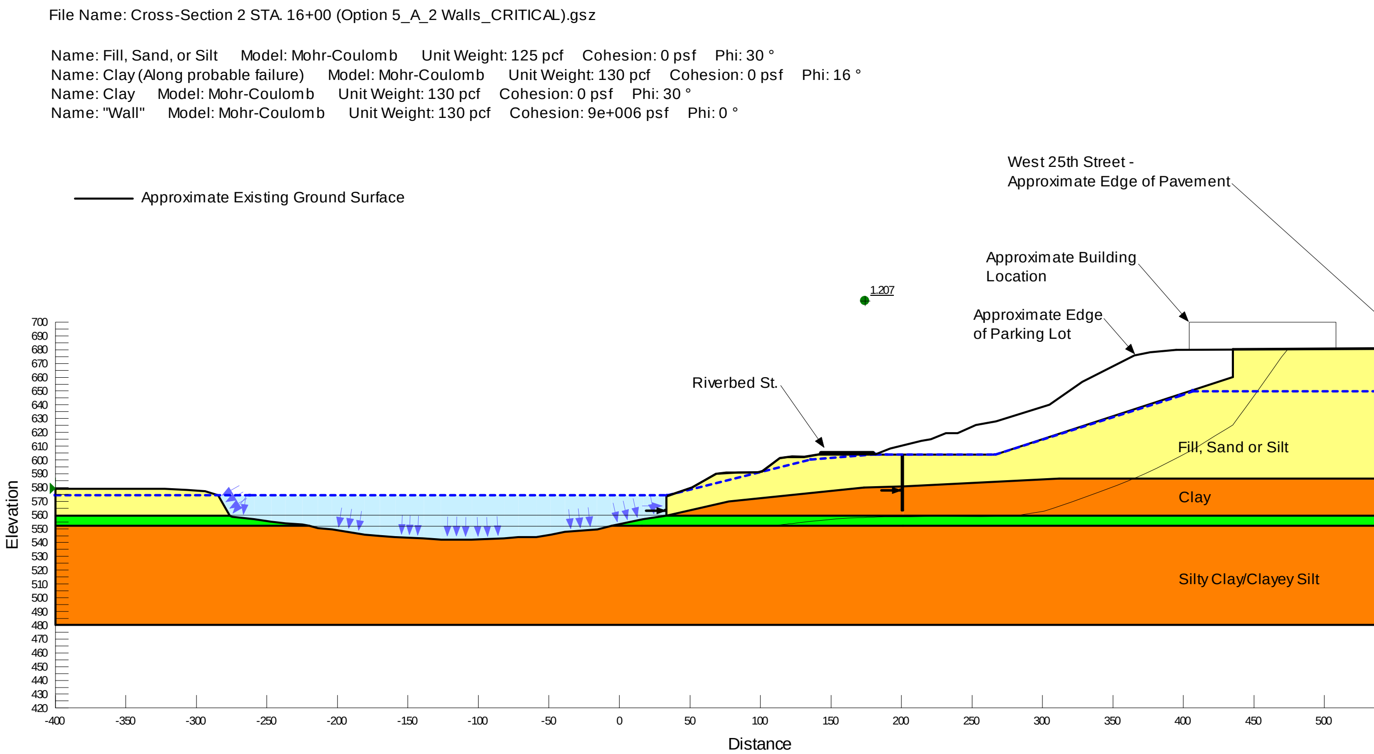


FIGURE 4

Alternative C – Wall at Riverbank
Force Needed – 46 kips/ft
Factor of Safety – 1.30

Cuyahoga River Bulkhead Technical Assistance
Cross Section 1 - STA. 16+00

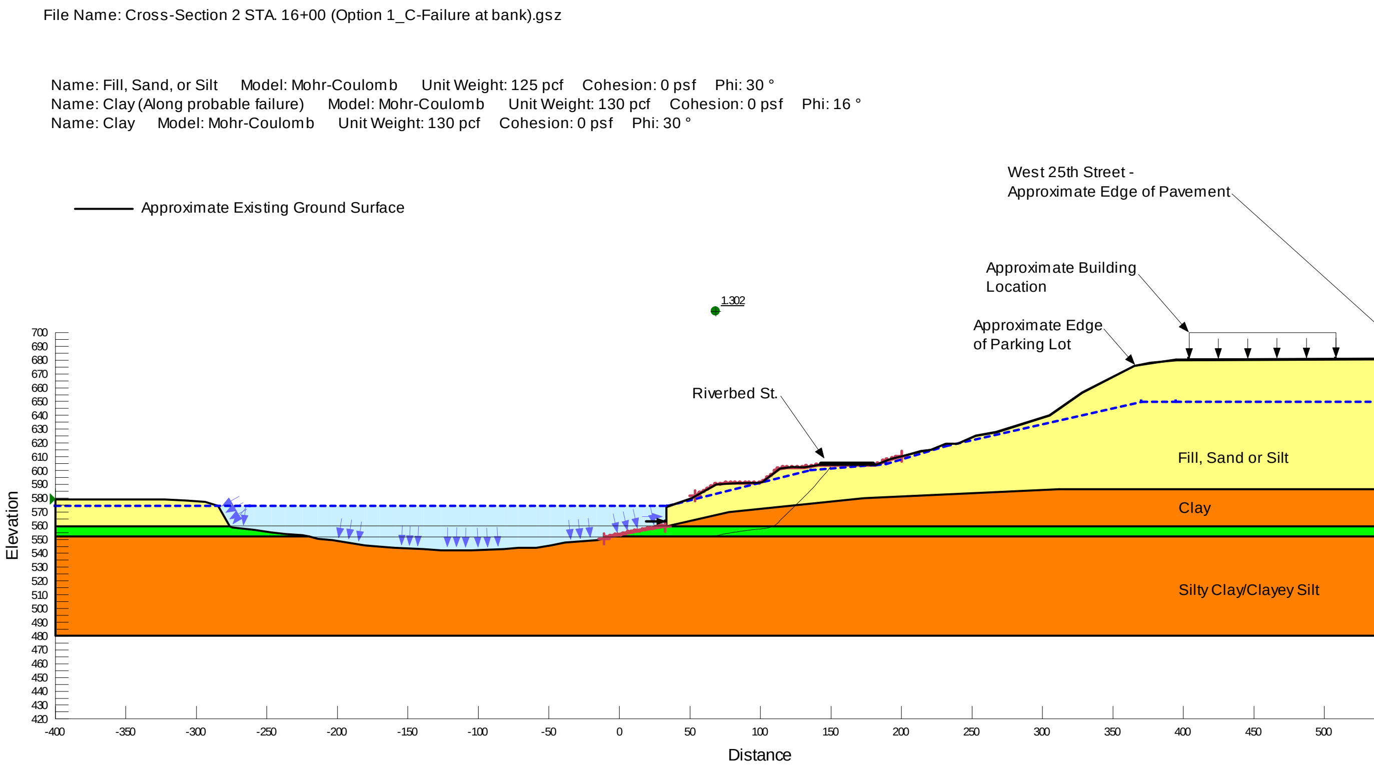


FIGURE 5

Alternative C – Upslope Wall Without Excavation
Force Needed – 110 kips/ft
Factor of Safety – 1.31

Cuyahoga River Bulkhead Technical Assistance
Cross Section 1 - STA. 16+00

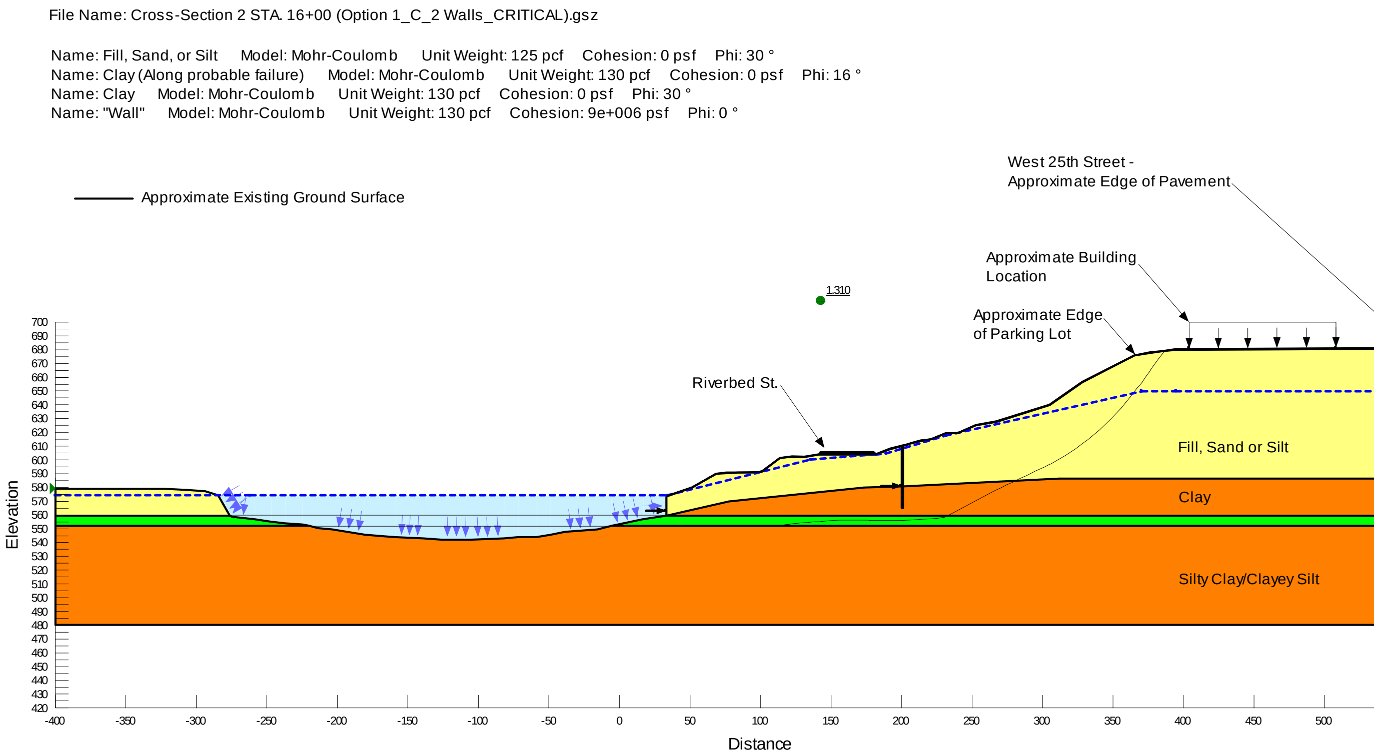


FIGURE 6

Alternative C – Upslope Wall With Excavation
Force Needed – 85 kips/ft
Factor of Safety – 1.30

Cuyahoga River Bulkhead Technical Assistance
Cross Section 1 - STA. 16+00

File Name: Cross-Section 2 STA. 16+00 (Option 5_C_2 Walls_CRITICAL).gsz

Name: Fill, Sand, or Silt Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 30 °
Name: Clay (Along probable failure) Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 0 psf Phi: 16 °
Name: Clay Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 0 psf Phi: 30 °
Name: "Wall" Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 9e+006 psf Phi: 0 °

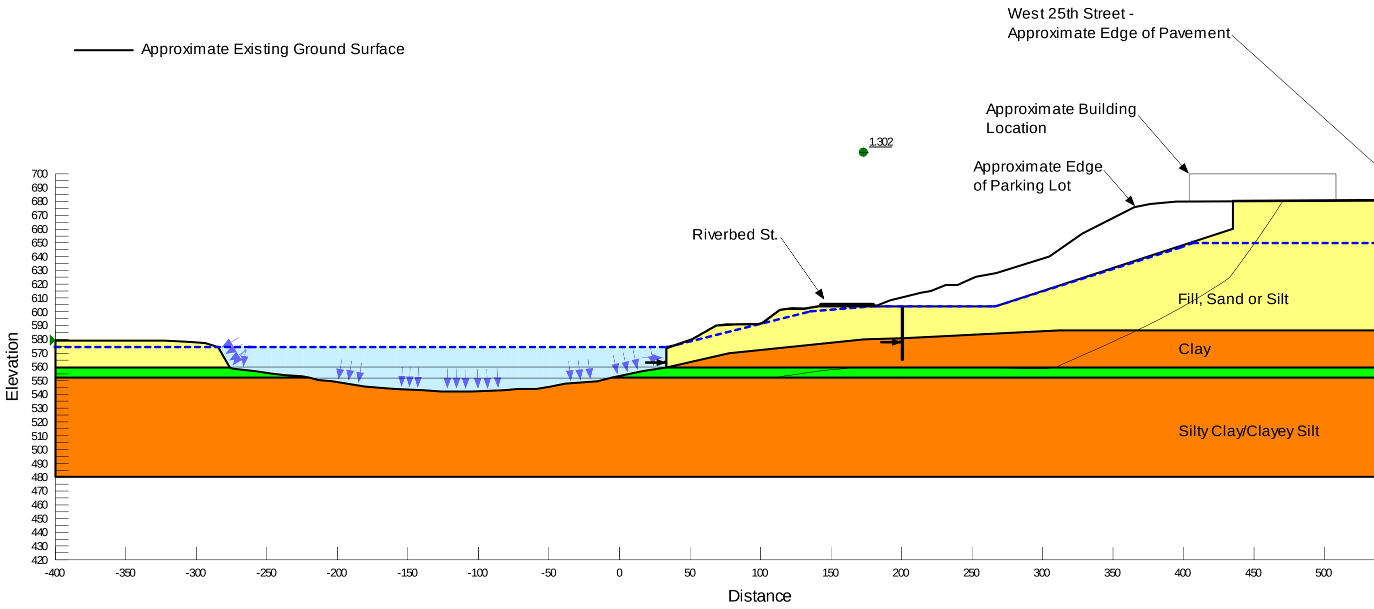


FIGURE 7

Alternative D – Wall at Riverbank
Force Needed – 57 kips/ft
Factor of Safety – 1.52

Cuyahoga River Bulkhead Technical Assistance
Cross Section 1 - STA. 16+00

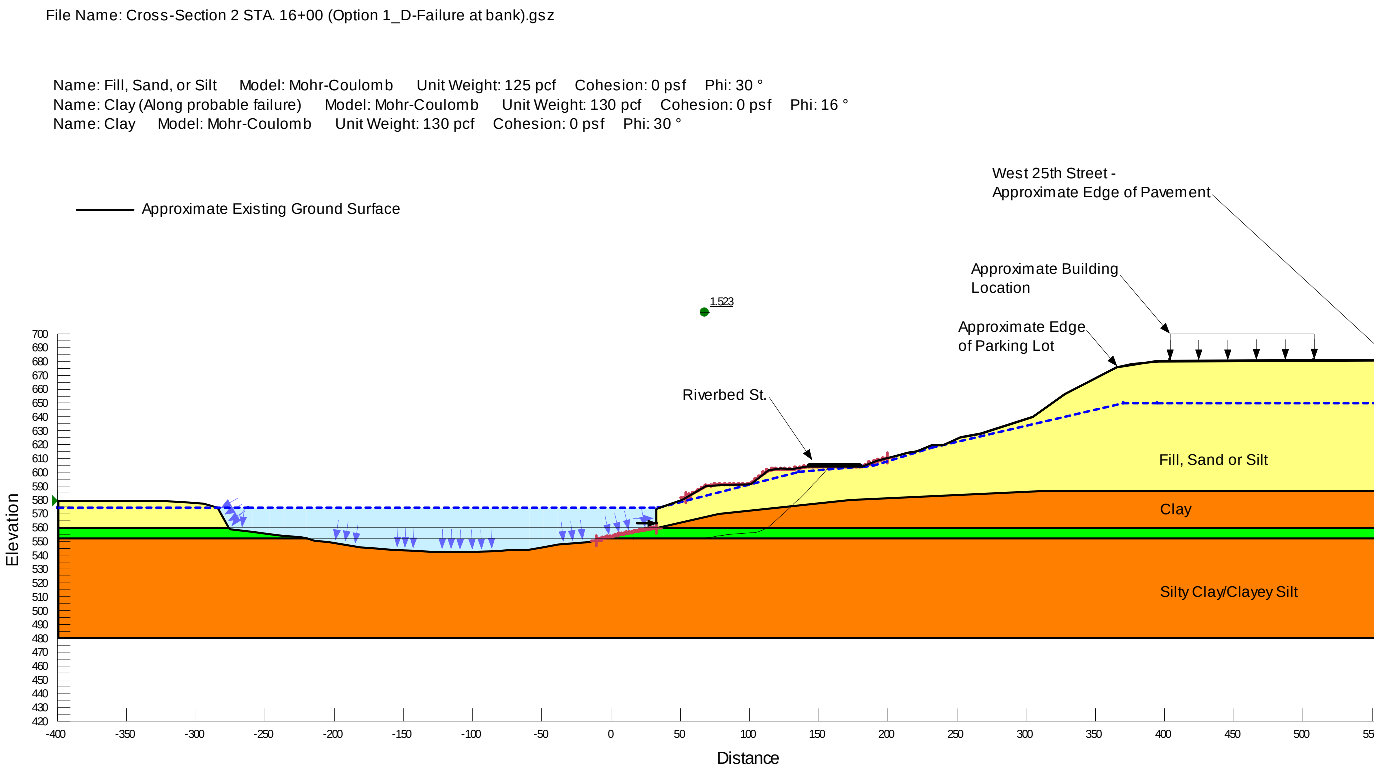


FIGURE 8

Alternative D – Upslope Wall Without Excavation
Force Needed – 145 kips/ft
Factor of Safety – 1.53

Cuyahoga River Bulkhead Technical Assistance
Cross Section 1 - STA. 16+00

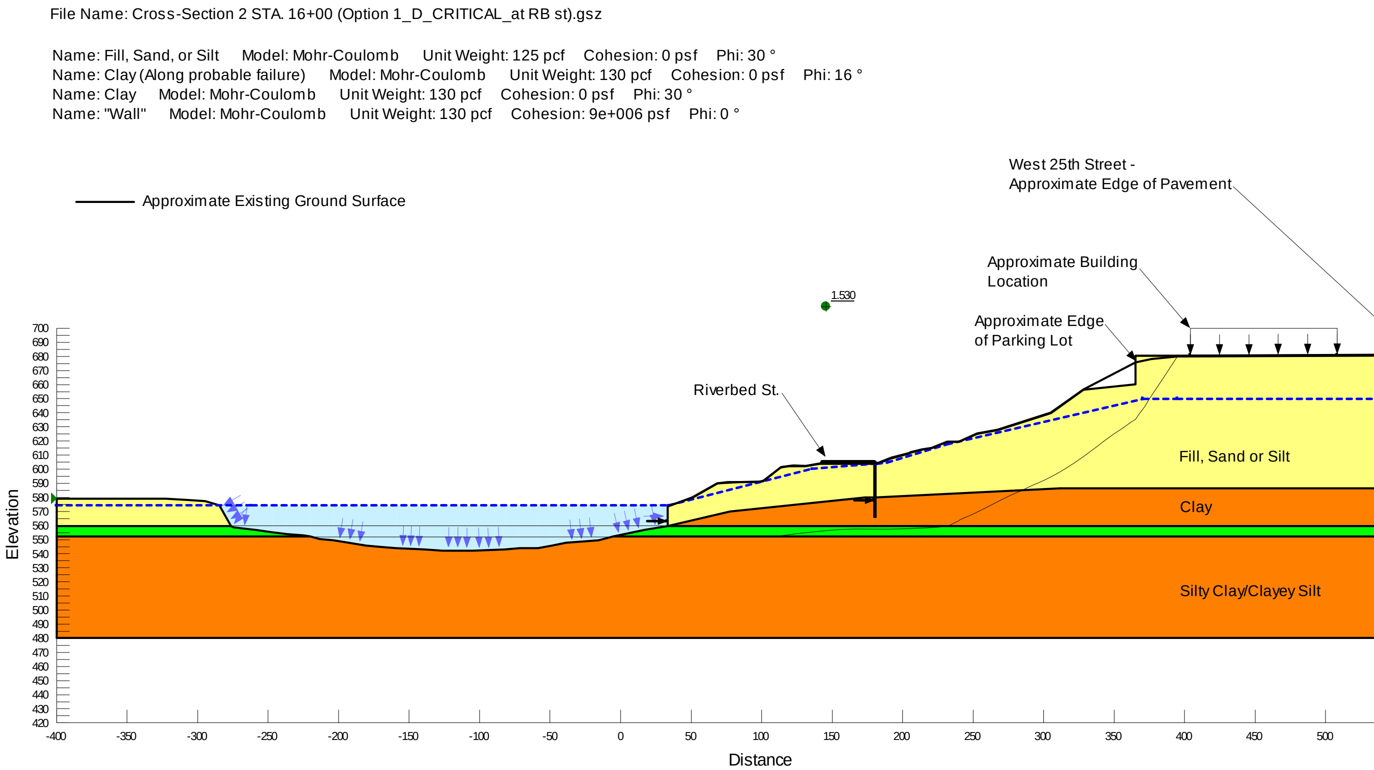


FIGURE 9

Alternative A – Slope Cutback Without Constraints
Factor of Safety – 1.27

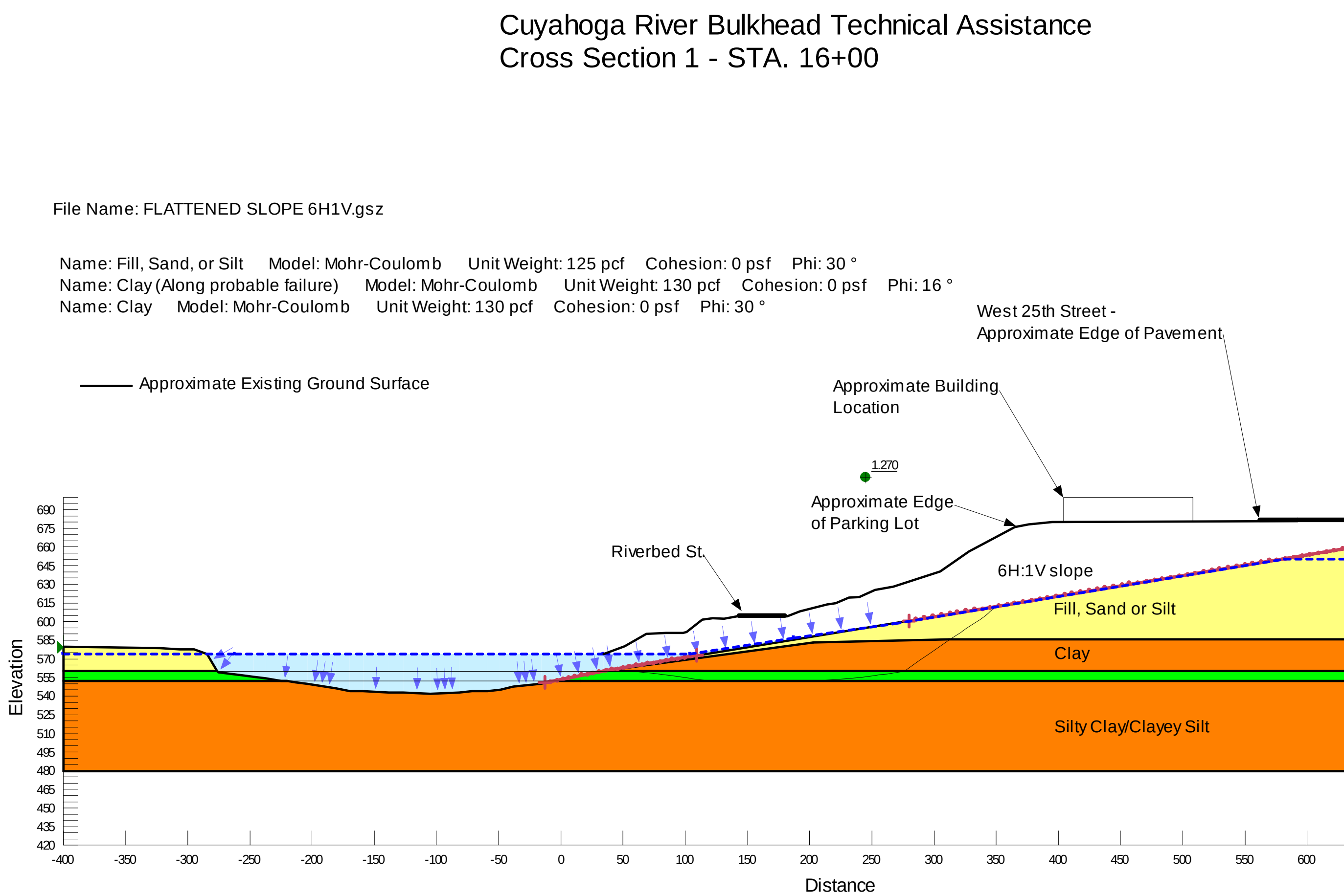


Figure 10

9. DISCUSSION OF SLOPE W ANALYSES

Stability analysis using the Slope W program was performed for each case and alternative. The objective was to determine the load capacity of the three retaining walls, applicable to Alternatives A, C, or D, which would be provided for use in the structural design of the wall. The only difference is the target factor of safety, which was established as 1.2 for Alternative A, 1.3 for Alternative C and 1.5 for Alternative C.

To determine the load capacity needs of the riverbank wall and upslope wall, it was necessary to first stabilize the lower slope failure. Using the Slope/W software package from GeoStudio, a point load was placed at mid-height of the riverbank wall. The mid-height distance was taken as the mid point between the bottom of the pre-sheared clay layer (El. 552 ft.) and the ground surface (El. 574 ft.), which is El. 563 ft. Spencer's method of analysis was used to determine the factor of safety against global stability. The method used to determine the critical slip surface was the entry-exit method with optimization to find the critical circular or non-circular slip surface. The entry limit was placed from the river's edge to the point on the slope just behind the upslope wall approximately 20 feet landward of Riverbed St. The exit limit was placed on the face of the pre-sheared clay layer.

Trial and error was then used to determine the force needed to achieve factors of safety of 1.2, 1.3 and 1.5 for Alternatives A, C, and D respectively. After performing trial and error, the forces necessary to stabilize a lower slope failure for Alternatives A, C, and D were 41 kips/ft, 46 kips/ft, and 57 kips/ft respectively. The corresponding factors of safety were 1.21, 1.30, and 1.52.

The next step was to determine the necessary capacity of the upslope wall. In doing so, five options were looked at which included various areas of excavation as well as a retaining structure somewhere near West 25th St. at the crest of the slope. Again, to determine the force needed, a point load was placed at the mid-height between the bottom of the pre-sheared clay (El. 552 ft.) and the ground surface (El. 610 ft.) which is El. 581 ft.

Option 1

This option included no excavation and no retaining structure. The forces for each alternative were found to be 95 kips/ft, 110 kips/ft, and 145 kips/ft for A, C, and D, respectively. The lower slope forces input were the forces determined in the lower slope stability analysis.

Option 2

Option 2 included placing a retaining wall structure approximately ten feet off the existing buildings beyond the crest of the slope. This would include losing part of the parking lot. The retaining wall will be designed for a stick-up height of 20 feet. The ground surface will be cut approximately horizontal from the bottom of the stick-up of the wall to the face of the slope. This option would only satisfy Alternatives A and C. The new forces needed and the corresponding factors of safety were 85 kips/ft and 108 kips/ft, with FOS being 1.20 and 1.30.

Option 3

This option includes the same retaining structure described above, but placed 70 feet from the crest of the slope. This distance represents the furthest that excavation can occur without sacrificing West 25th St. The distance from the crest of the slope to West 25th St. is 90 feet, so we assumed a 20 foot easement. The slope was the excavated at an approximately horizontal grade from the bottom of the wall stick-up to the face of the slope. Also, the 200 psf surcharge representing the existing buildings and structures would be removed. Again, this option would not satisfy Alternative D. The new forces needed and the corresponding factors of safety were 80 kips/ft and 102 kips/ft, with FOS being 1.21 and 1.30.

Option 4

This option is an extension of Option 2. The retaining wall remains in the same location. The difference is the slope is excavated at a 3H:1V slope from the bottom of the stick-up of the retaining wall (El. 660 ft.) to El. 604 ft., which is the approximate Riverbed St. elevation. The location of the force representing the upslope wall is moved down three feet to elevation 578 ft. to accommodate the drop in ground surface elevation from 610 feet to 604 feet. The new forces needed and the corresponding factors of safety were 85 kips/ft and 100 kips/ft, with FOS being 1.20 and 1.32. Note: This option would not satisfy Alternative D.

Option 5

Option 5 is an extension of Option 3. The retaining wall remains in the same location. The difference is the slope is excavated at a 3H:1V slope from the bottom of the stick-up of the retaining wall (El. 660 ft.) to El. 604 ft., which is the approximate Riverbed St. elevation. The location of the force representing the upslope wall is moved down three feet to elevation 578 ft. to accommodate the drop in ground surface elevation from 610 feet to 604 feet. The new forces needed and the corresponding factors of safety were 40 kips/ft and 85 kips/ft, with FOS being 1.21 and 1.30. Note: This option would not satisfy Alternative D.

Alternative A – Cutback of Slope with no Constraints

The GeoStudio program Slope/W was used to determine what degree of slope excavation would stabilize the project without the use of structural walls. An iterative procedure was used beginning with 5H:1V. The target factor of safety is 1.2. This is because the cutback of the slope would include the removal of Riverbed St. and W. 25^{th} St. Therefore, Alternatives C & D would be violated. The corresponding factor of safety for a 5H:1V slope was 1.09. The next slope trialed was 5.5H:1V and the factor of safety obtained was 1.15. When using a 6H:1V slope, the factor of safety obtained was 1.27. This factor of safety is greater than the specified 1.2, therefore a 6H:1V slope can be used to satisfactorily stabilize the slope.

10. FORCES FOR STRUCTURAL WALL DESIGN

The following Table 2 summarizes the forces that were determined by the Slope W analysis and applied to the structural design of the upper and lower walls:

Case	Upper Wall		Lower Wall
	With Excavation	Without Excavation	
A	40 Kips/Ft	95 Kips/Ft	41 Kips/Ft
B	85 Kips/Ft	110 Kips/Ft	46 Kips/Ft
D	N/A	145 Kips/Ft	57 Kips/Ft

Table 2

11. SUMMARY AND PATH FORWARD

Using available information from previous studies and reports, the Geotechnical Appendix provides a 30% design level assessment that characterizes the project site, its geologic history, and slope stability assessments for different cases with different stability criteria. This provides a preliminary screening of a selected variety of alternatives which can be used by the City of Cleveland for its own purposes. Since this study was based on available geotechnical design information and various assumptions were made by necessity in order to complete the analyses, it is not remotely close to a final design. The method used for analysis (Slope W) is state-of-thepractice and provides the best available computation for the stability analyses. To support a final design, additional site subsurface information is required, including but not limited to, borings, field soil testing, undisturbed samples, instrumentation/monitoring, and laboratory testing. This new information would be used to improve the knowledge of the site, develop more reliable/accurate geotechnical design parameters, and more accurately portray the failure plane geometry. The geotechnical analysis for a final design would follow the same approach that was used for the 30% design.

REFERENCE

1. Planning Level Study: Slope Stability Alternatives Analysis
Existing Slope between Detroit-Superior Bridge and Columbus Road
Cuyahoga River Valley Intermodal Connector Cleveland, OH, BBC&M Engineering Company, Cleveland, OH, January 2006.

ATTACHMENTS

SLOPE-W computer runs

SLOPE STABILITY FIGURES AND SLOPE/W OUTPUTS

SLOPE STABILITY FIGURES

FIGURE 1

Alternative A – Wall at Riverbank
Force Needed – 41 kips/ft
Factor of Safety – 1.21

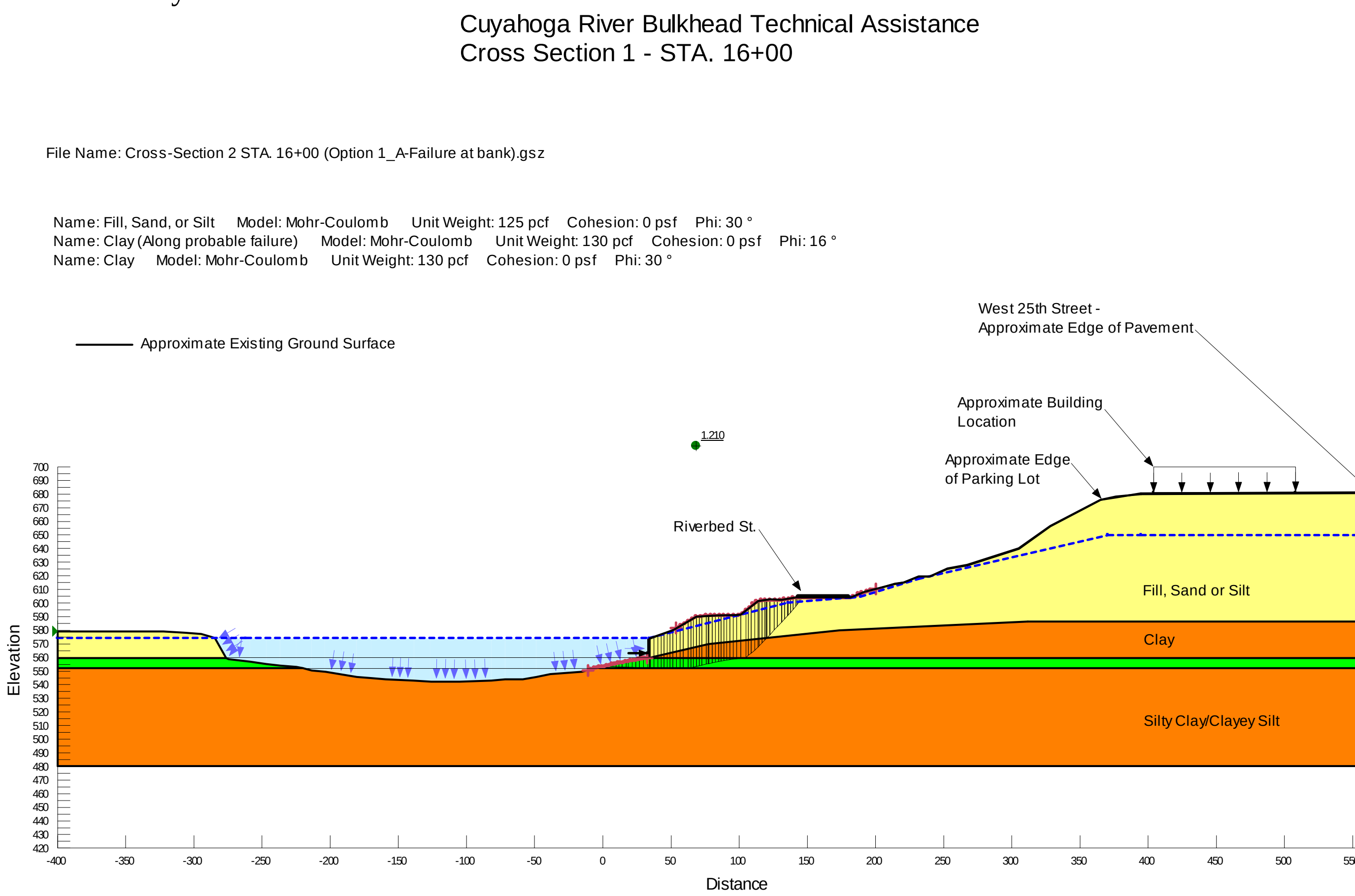
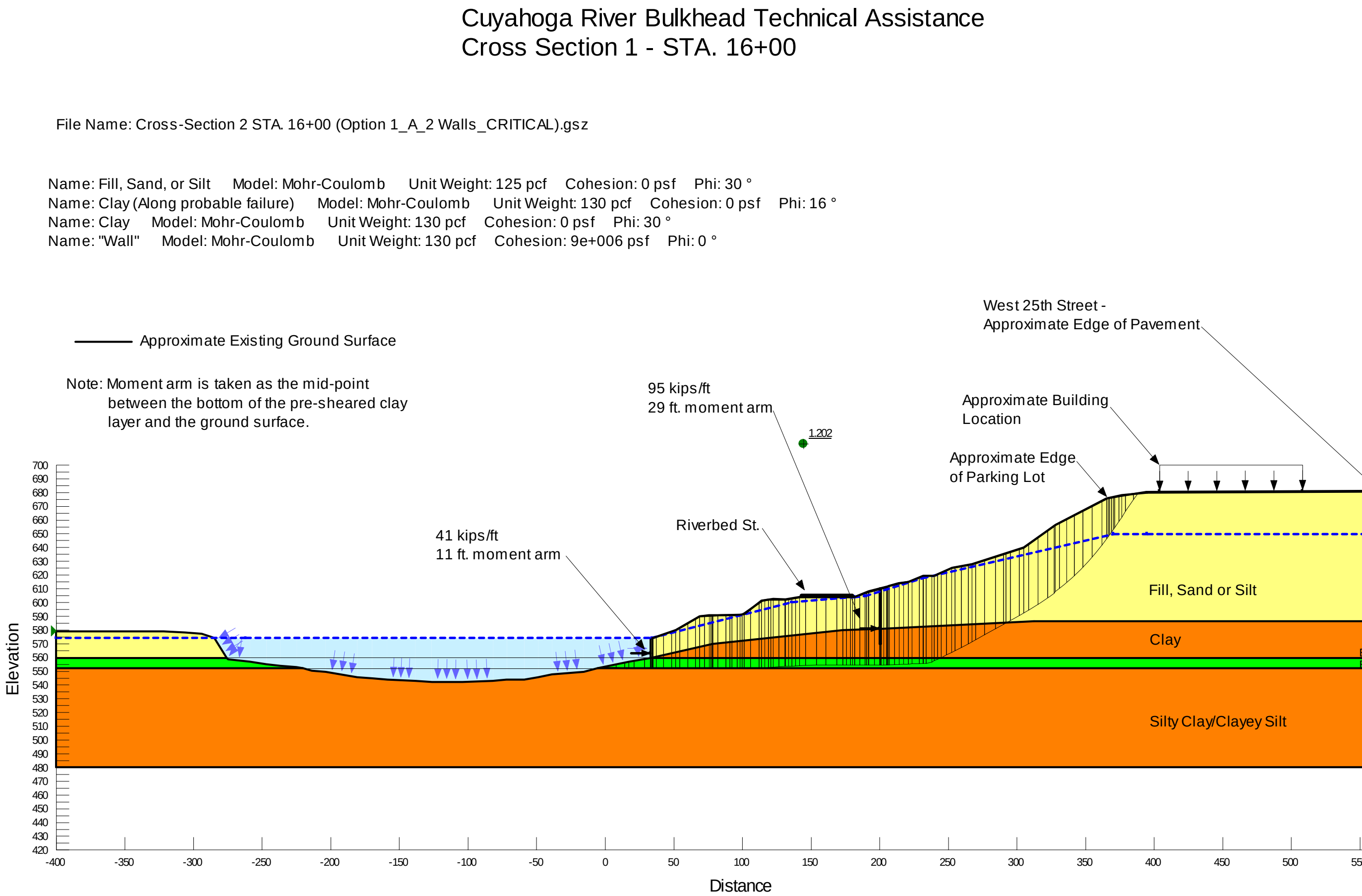


FIGURE 2

Alternative A – Upslope Wall Without Excavation
Force Needed – 95 kips/ft
Factor of Safety – 1.20



<u>FIGURE 3</u>

Alternative A – Upslope Wall With Excavation
Force Needed – 40 kips/ft
Factor of Safety – 1.21

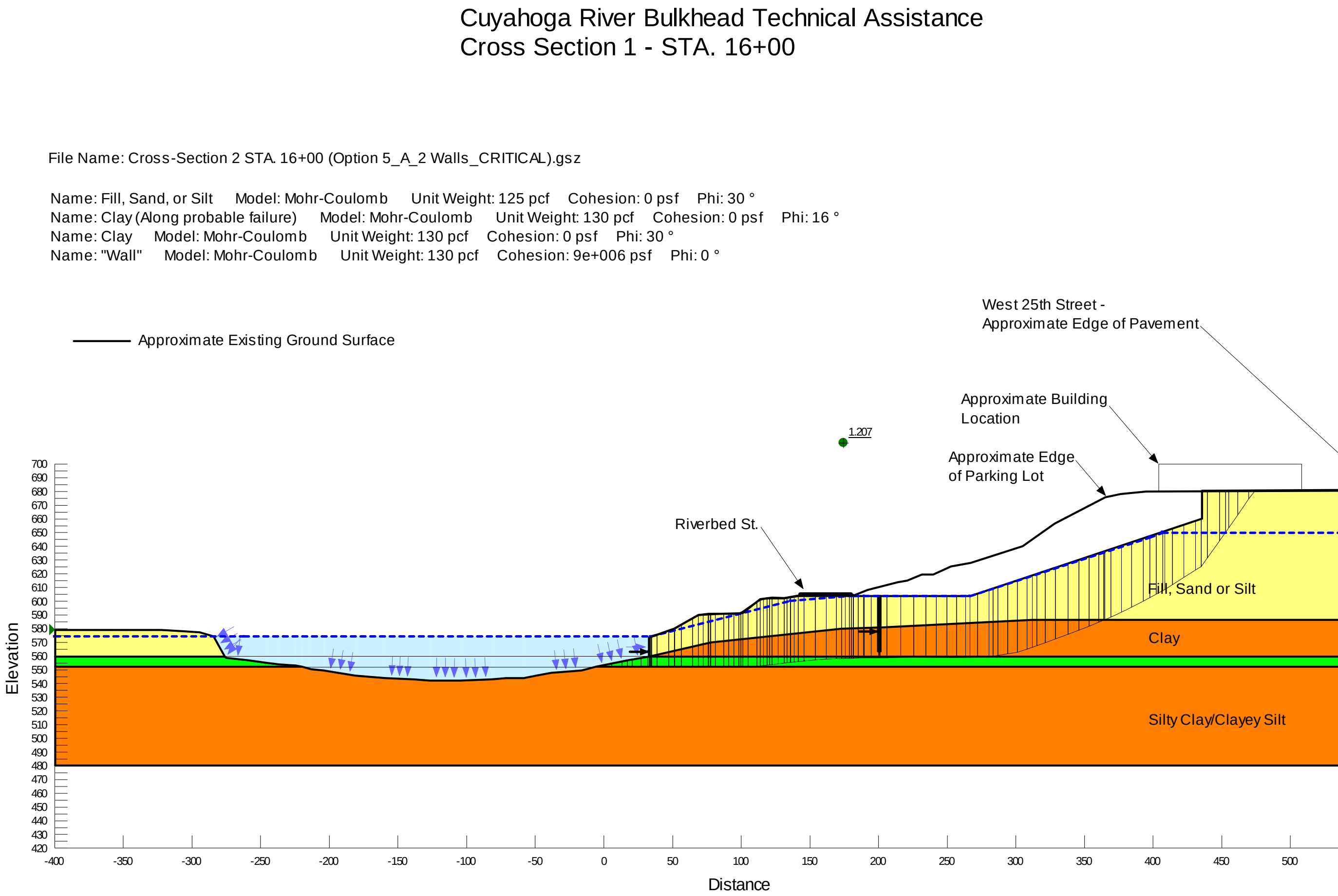
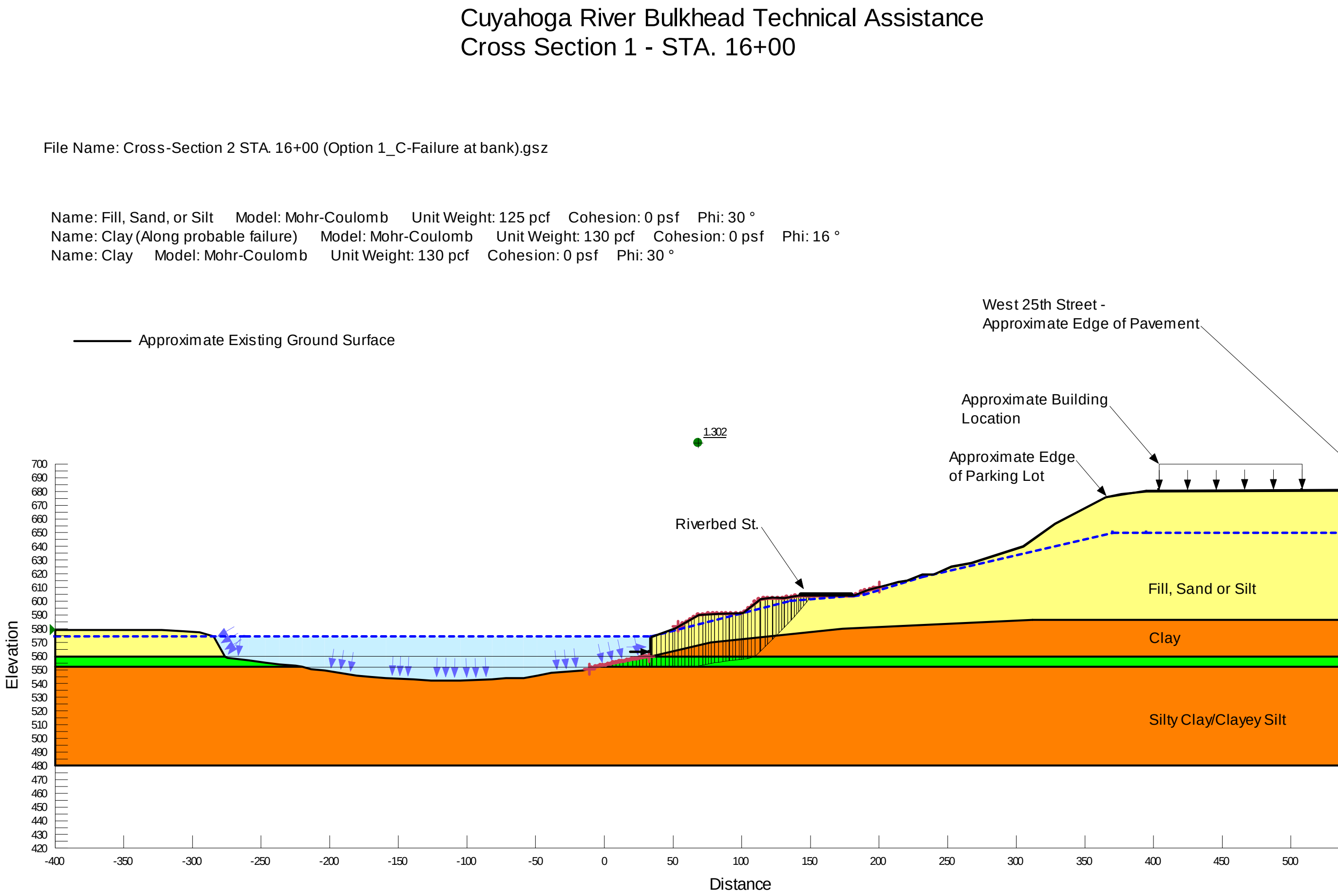


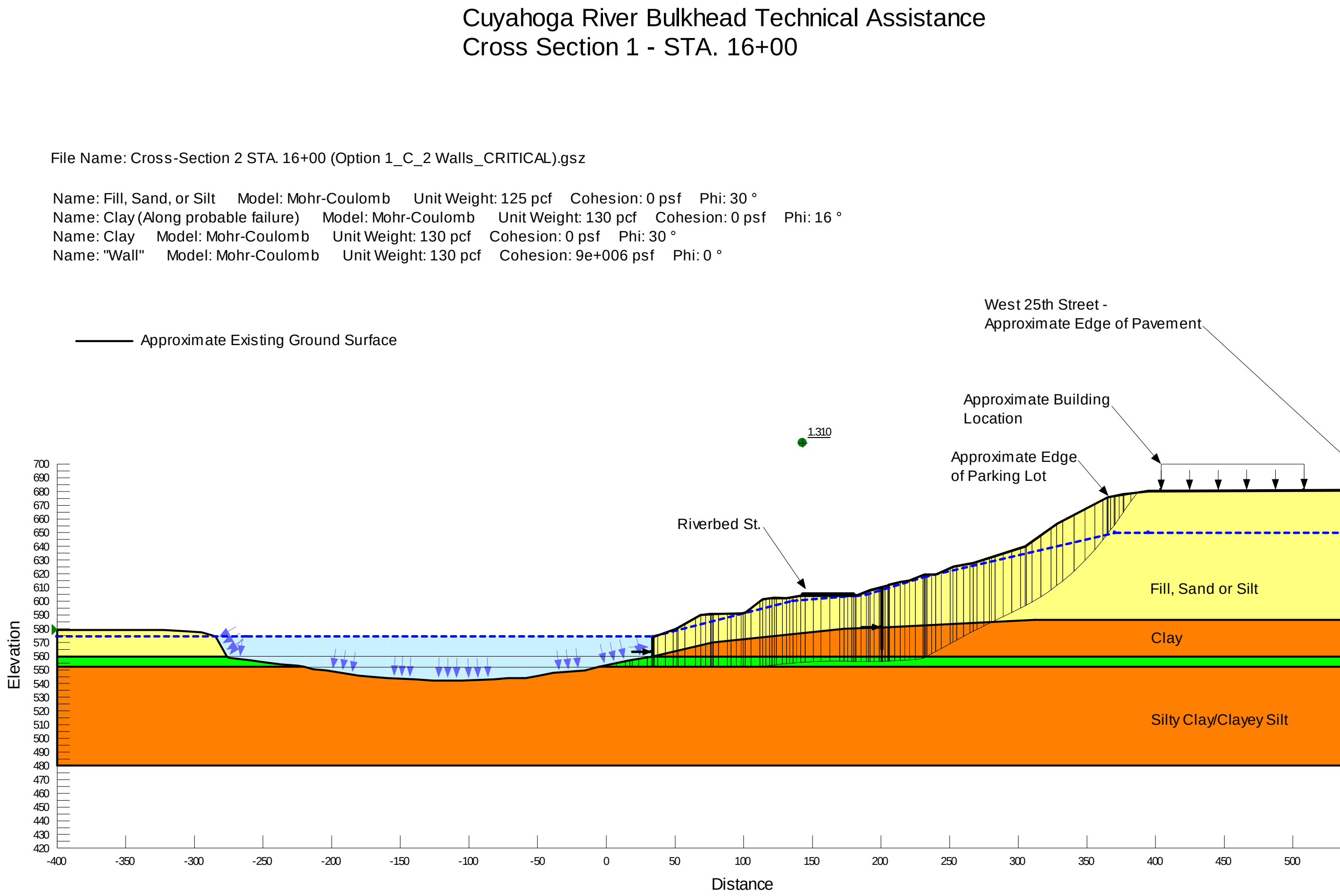
FIGURE 4

Alternative C – Wall at Riverbank
Force Needed – 46 kips/ft
Factor of Safety – 1.30



<u>FIGURE 5</u>

Alternative C – Upslope Wall Without Excavation
Force Needed – 110 kips/ft
Factor of Safety – 1.31



<u>FIGURE 6</u>

Alternative C – Upslope Wall With Excavation
Force Needed – 85 kips/ft
Factor of Safety – 1.30

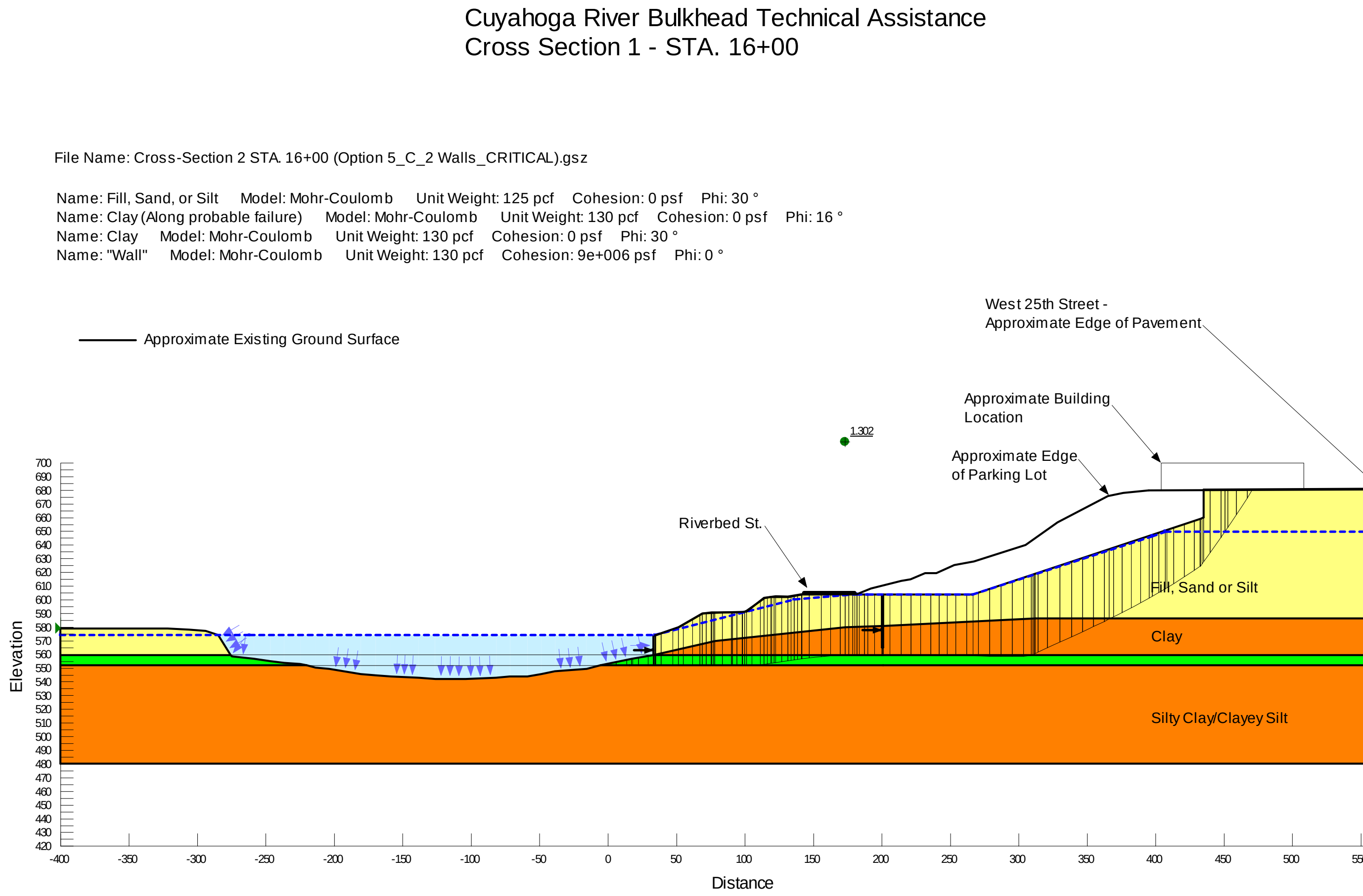


FIGURE 7

Alternative D – Wall at Riverbank
Force Needed – 57 kips/ft
Factor of Safety – 1.52

Cuyahoga River Bulkhead Technical Assistance
Cross Section 1 - STA. 16+00

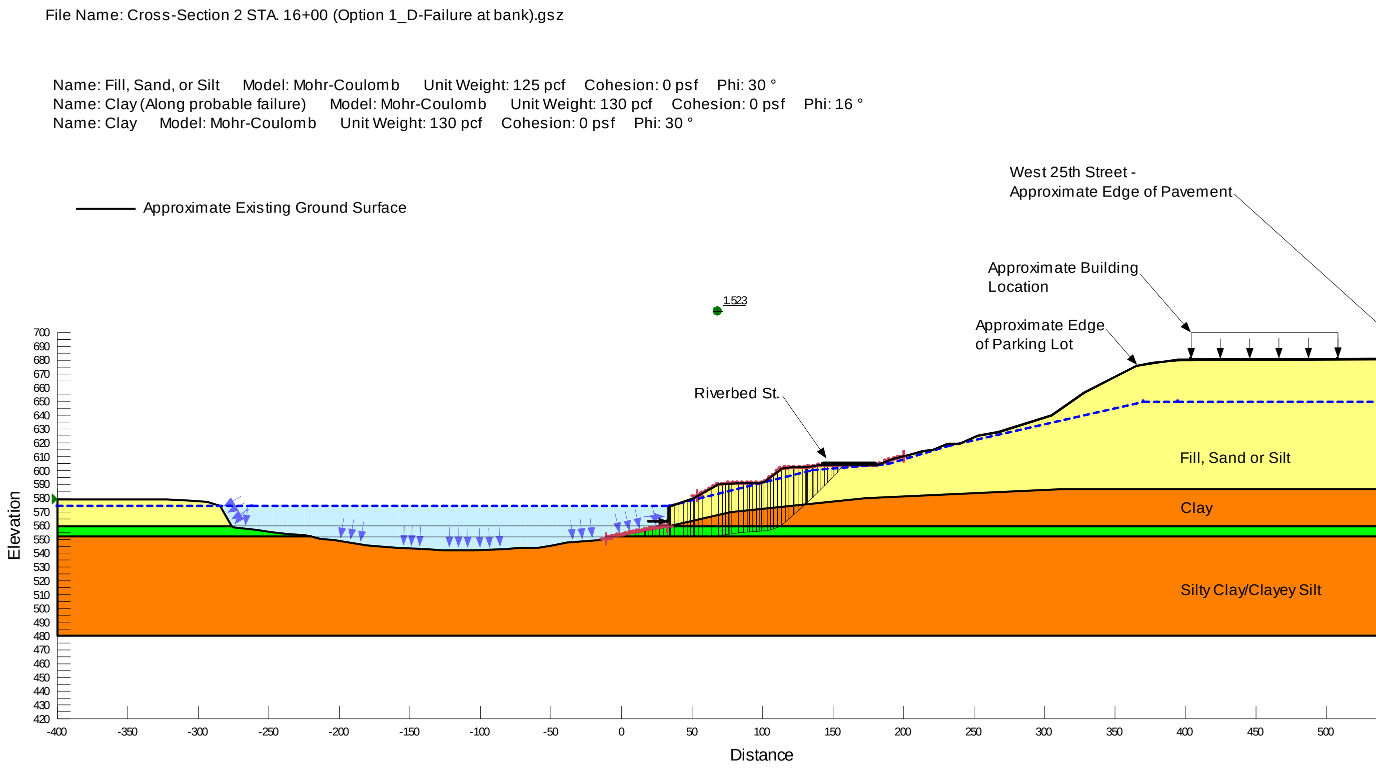


FIGURE 8

Alternative D – Upslope Wall Without Excavation
Force Needed – 145 kips/ft
Factor of Safety – 1.53

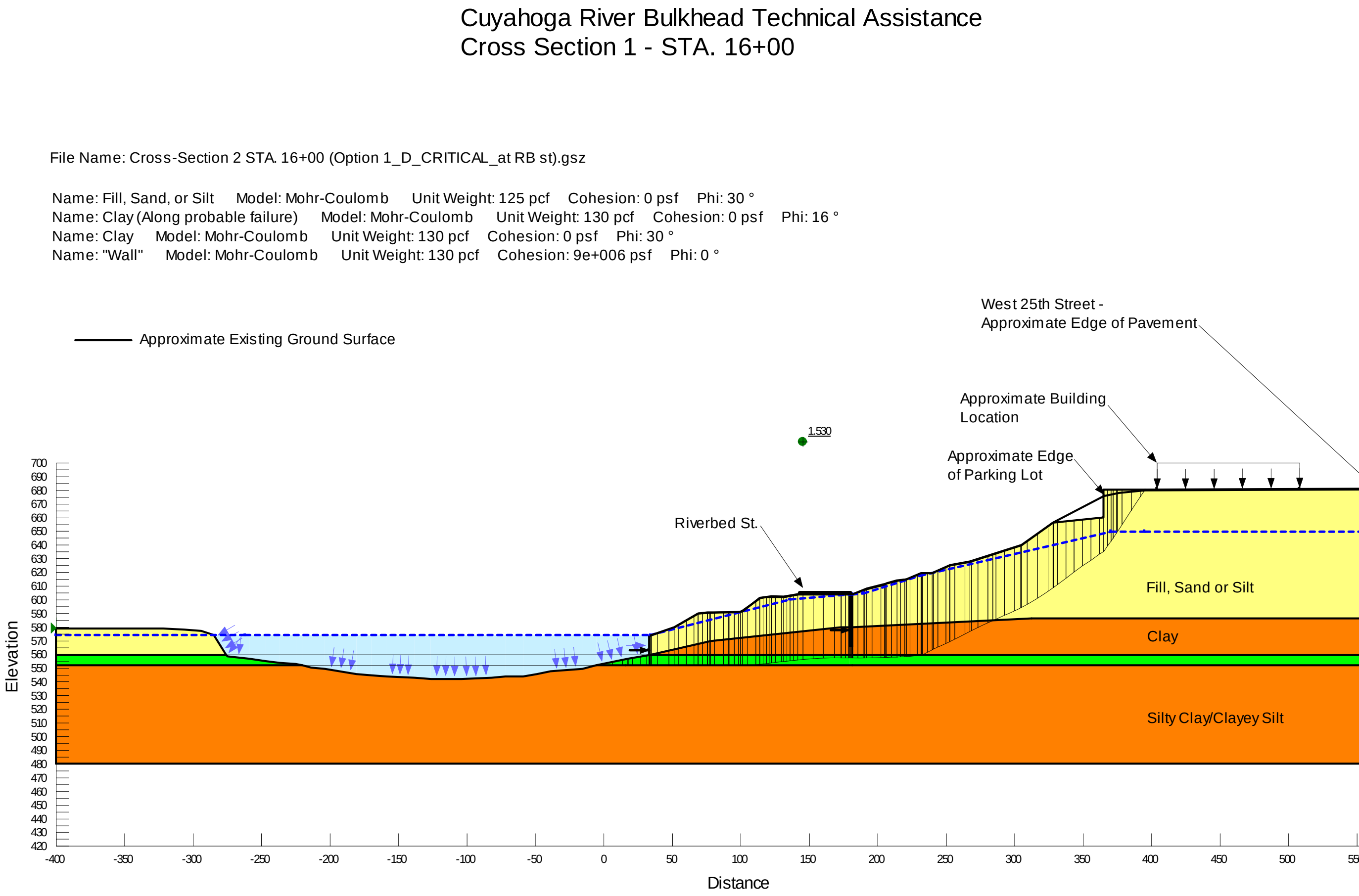
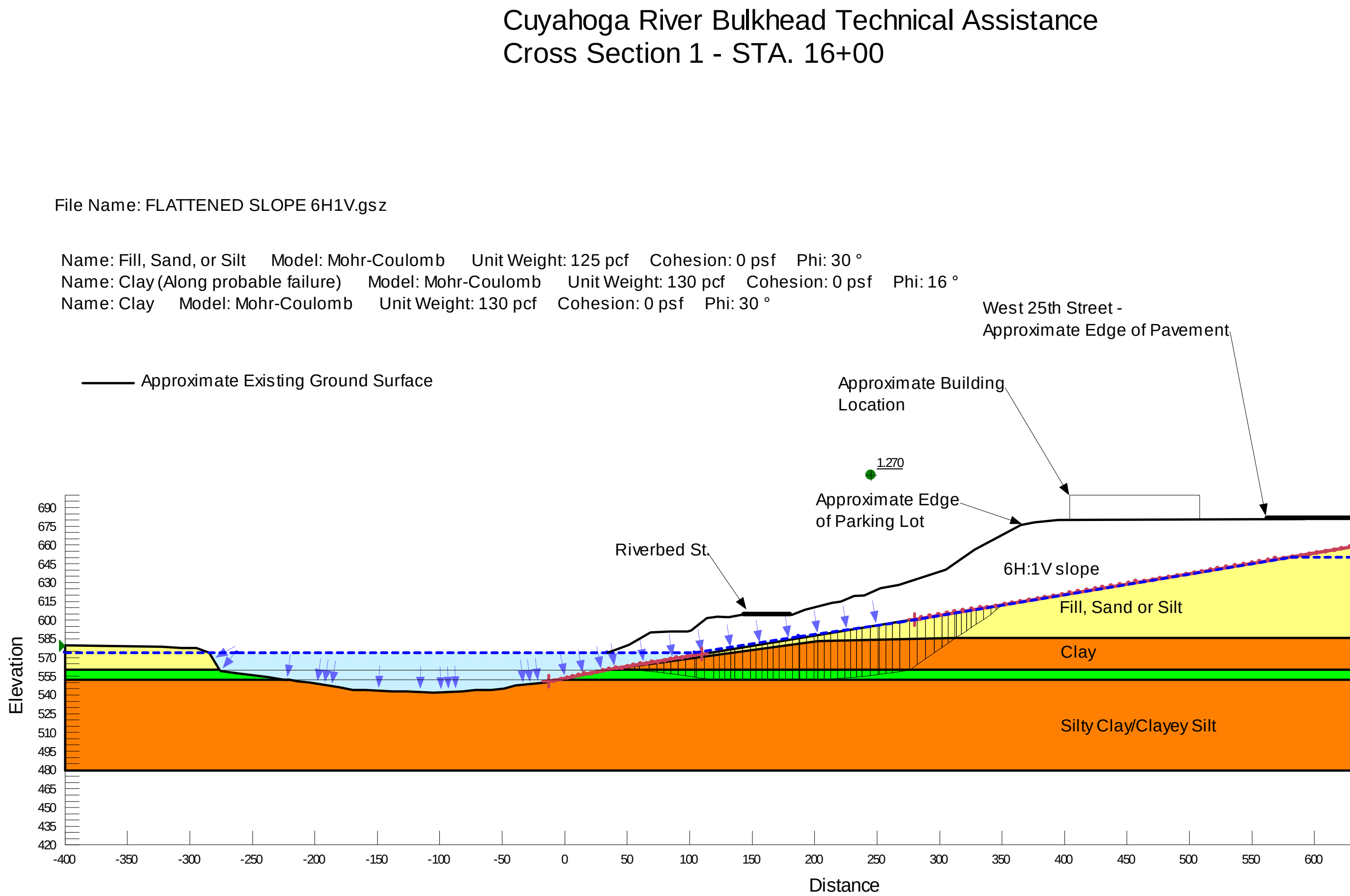


FIGURE 9

Alternative A – Slope Cutback Without Constraints
Factor of Safety – 1.27



SLOPE/W OUTPUTS

Alternative A – Wall at Riverbank

SLOPE/W Analysis

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File Information

Created By: Lovullo, Vincent M LRB
Revision Number: 78
Last Edited By: Lovullo, Vincent M LRB
Date: 5/27/2009
Time: 11:54:22 AM
File Name: Cross-Section 2 STA. 16+00 (Option 1_A-Failure at bank).gsz
Directory: C:\Documents and Settings\h5tddvml\My Documents\vlovullo\Projects\Cuyahoga River Technical Assistance\Slope Stability Analysis\SLOPE_W\CRITICAL FAILURE\[1] Files for Submittal\
Last Solved Date: 5/27/2009

Last Solved Time: 11:56:04 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Spencer
Settings
- Apply Phreatic Correction: No
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 60
- Optimization Tolerance: 0.01
- Minimum Slip Surface Depth: 0.1 ft
- Optimization Maximum Iterations: 8000
- Optimization Convergence Tolerance: 1e-007
- Starting Optimization Points: 8
- Ending Optimization Points: 32
- Complete Passes per Insertion: 1
- Driving Side Maximum Convex Angle: 5 °
- Resisting Side Maximum Convex Angle: 1 °

Materials

Fill, Sand, or Silt

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay (Along probable failure)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 16 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (-10.99998, 550.8937) ft
Left-Zone Right Coordinate: (32.5, 559.904) ft
Left-Zone Increment: 25
Right Projection: Range
Right-Zone Left Coordinate: (53.99998, 581.5264) ft
Right-Zone Right Coordinate: (199.99996, 610.1258) ft
Right-Zone Increment: 45
Radius Increments: 30

Slip Surface Limits

Left Coordinate: (-400, 579.5) ft
Right Coordinate: (592.5, 681) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-400	574
	-262	574
	34.3	574
	136	600
	178.6	604
	181.7	604
	189.3	605
	231.5	617.5
	370.3	650
	395	650
	592.57566	650

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 200 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	404	681
	508	681

Point Loads

	Coordinate (ft)	Magnitude (lbs)	Direction (°)
Point Load 1	(33, 563)	41000	180

Regions

	Material	Points
Region 1	Clay	6,5,8,67,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,3,4,7
Region 2	Clay (Along probable failure)	67,24,23,22,21,20,9,10,5,8
Region 3	Fill, Sand, or Silt	9,19,18,17,16,11,10
Region 4	Clay (Along probable failure)	39,40,1,2,4,3
Region 5	Fill, Sand, or Silt	1,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,
Region 6	Clay	1,12,13,14,15,2

Points

	X (ft)	Y (ft)
Point 1	33	560
Point 2	592	560
Point 3	16	552
Point 4	592	552
Point 5	-400	552
Point 6	-400	480
Point 7	592	480
Point 8	-229	552
Point 9	-276	560
Point 10	-400	560
Point 11	-400	579.5
Point 12	78	570

Point 13	173	580
Point 14	312	586
Point 15	592.1663	586
Point 16	-322.104	579
Point 17	-306.28	577.924
Point 18	-294.333	577.662
Point 19	-284.593	574.338
Point 20	-274.834	559.087
Point 21	-258.818	556.964
Point 22	-246.827	555.288
Point 23	-236.786	554.222
Point 24	-224.823	552.673
Point 25	-213.832	550.799
Point 26	-203.748	549.553
Point 27	-180.828	546.001
Point 28	-169.823	544.569
Point 29	-158.823	543.829
Point 30	-138.506	542.84
Point 31	-126.654	542.58
Point 32	-104.621	542.026
Point 33	-81.824	542.998
Point 34	-71.577	543.677
Point 35	-59.088	544.288
Point 36	-48.829	545.565
Point 37	-38.539	547.126
Point 38	-15.825	549.924
Point 39	-5.495	552
Point 40	17.17	556.961
Point 41	33	573.5
Point 42	51.357	580
Point 43	68.672	590
Point 44	75.878	590.5
Point 45	90.832	591
Point 46	98.217	591
Point 47	101.215	591.5

Point 48	113.744	601.5
Point 49	118.901	602
Point 50	122.3	602.5
Point 51	131.18	602.5
Point 52	141.454	604
Point 53	181.684	604
Point 54	192.082	608.1
Point 55	214.001	613.708
Point 56	220.751	614.965
Point 57	231.68	619.5
Point 58	239.825	619.5
Point 59	252.556	625.5
Point 60	267.154	628
Point 61	304.944	640.1
Point 62	328.067	656.5
Point 63	365.418	675.705
Point 64	376.199	678
Point 65	394.561	680
Point 66	592.5	681
Point 67	-220	552

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.210	(42.894, 688.609)	79.07829	(146.147, 604)	(0.825288, 553.383)
2	19481	1.352	(42.894, 688.609)	136.509	(150.02, 604)	(11.5874, 555.739)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Coh Str (p
1	Optimized	1.9277712	553.3702	1287.3199	1352.1689	18.59514	
2	Optimized	4.132737	553.34375	1288.9525	1388.6294	28.581901	

3	Optimized	6.352915	553.30265	1291.4995	1430.6714	39.90691
4	Optimized	8.588305	553.247	1294.9877	1471.7253	50.678699
5	Optimized	10.823695	553.19135	1298.476	1512.7793	61.450487
6	Optimized	13.059085	553.13565	1301.9195	1553.7885	72.222275
7	Optimized	15.67339	553.04545	1307.5569	1610.7131	86.928623
8	Optimized	17.938375	552.9511	1313.4532	1651.6664	96.981079
9	Optimized	20.0696	552.83895	1320.4596	1701.4642	109.25132
10	Optimized	22.795305	552.67865	1330.4581	1759.6605	123.07183
11	Optimized	25.52101	552.51835	1340.4566	1817.8569	136.89233
12	Optimized	28.37379	552.32865	1352.2844	1888.2448	153.68419
13	Optimized	31.405335	552.10575	1366.2079	1959.3731	170.0874
14	Optimized	32.973475	551.99495	1373.1197	1925.9512	319.1774
15	Optimized	33.65	552.0605	1369.0523	8285.825	1983.3527
16	Optimized	34.401295	552.1333	1366.0813	2753.3871	397.80353
17	Optimized	34.602875	552.14405	1368.6685	2827.8239	418.40605
18	Optimized	36.12186	552.15835	1391.9882	2895.6583	431.17046
19	Optimized	38.95926	552.18505	1435.5826	3023.622	455.36298
20	Optimized	41.49931	552.18965	1475.8102	3156.4121	481.90482
21	Optimized	43.796845	552.15135	1514.8489	3285.1899	507.63711
22	Optimized	46.14921	552.0923	1556.071	3403.2891	529.68127
23	Optimized	48.244475	552.03335	1593.1593	3516.5865	551.53388
24	Optimized	50.26028	552.0038	1627.1701	3581.2696	560.32901
25	Optimized	52.637055	552.00355	1665.1218	3728.8588	591.76707
26	Optimized	55.19717	552.00325	1705.9794	3922.0925	635.46021
27	Optimized	57.757285	552.00295	1746.837	4115.4433	679.18695
28	Optimized	60.83148	552.1306	1787.8885	4239.4837	702.98362
29	Optimized	63.550175	552.40135	1814.3639	4299.4139	712.57662
30	Optimized	65.39928	552.6872	1826.015	4395.5087	736.79046
31	Optimized	67.497915	553.109	1833.2153	4388.6126	732.74839
32	Optimized	69.67762	553.6268	1835.6563	4415.7435	739.82808
33	Optimized	71.688865	554.1046	1837.9299	4375.6413	727.67701
34	Optimized	74.286245	554.71505	1841.2797	4329.6519	713.52923
35	Optimized	76.54142	555.24145	1844.3942	4282.8404	699.21319
36	Optimized	77.60242	555.47965	1846.421	4286.7345	699.74863
37	Optimized	79.134415	555.80075	1850.8517	4253.9607	689.08044

38	Optimized	81.40324	556.27625	1857.4087	4205.1281	673.19771
39	Optimized	83.672065	556.75175	1863.9226	4156.2955	657.32735
40	Optimized	85.779155	557.1658	1871.6803	4146.2343	652.21784
41	Optimized	87.724505	557.5184	1880.7342	4110.8279	639.46907
42	Optimized	89.76459	557.85125	1892.5123	4117.0508	637.87616
43	Optimized	92.03976	558.18495	1907.9498	4080.0962	622.85295
44	Optimized	94.45528	558.53925	1924.416	4036.1863	605.54039
45	Optimized	96.94002	558.8951	1941.8428	3999.4742	590.0163
46	Optimized	99.716	559.2835	1961.8757	3981.8909	579.23003
47	Optimized	103.08485	559.75485	1986.2029	4137.2827	616.81221
48	Optimized	105.9058	560.76855	1967.9748	3486.0998	876.48983
49	Optimized	107.808	562.2727	1904.4293	3469.1928	903.41663
50	Optimized	110.05865	564.1647	1822.2938	3361.5915	888.71393
51	Optimized	112.5511	566.50545	1715.9835	3195.5913	854.25196
52	Optimized	114.23745	568.20305	1636.9761	3114.2106	852.88174
53	Optimized	115.77345	569.7706	1563.6506	2962.3278	807.52666
54	Optimized	117.8585	571.9122	1463.2815	2775.6412	757.69126
55	Optimized	119.273	573.3651	1395.136	2650.4677	724.76612
56	Optimized	119.9792	574.1006	1360.5508	2570.409	698.51194
57	Optimized	121.3067	575.5044	1294.1373	2456.5713	671.13157
58	Optimized	122.4206	576.68235	1238.3946	2360.5464	647.87464
59	Optimized	124.1391	578.47535	1153.9306	2205.1326	606.91177
60	Optimized	126.92555	581.3696	1017.7694	1944.0831	534.80748
61	Optimized	129.64705	584.21495	883.63395	1674.7771	456.76671
62	Optimized	131.26105	585.91695	803.16887	1520.2991	414.03533
63	Optimized	132.3745	587.1102	746.49412	1417.7709	387.56183
64	Optimized	134.4393	589.3258	641.16343	1239.7323	345.58391
65	Optimized	135.73585	590.73625	573.84034	1106.8823	307.75194
66	Optimized	136.87795	592.04475	501.56653	999.57532	287.52551
67	Optimized	138.68045	594.1977	377.75908	802.01263	244.9429
68	Optimized	140.5295	596.4919	245.44329	613.79488	212.66789
69	Optimized	141.8887	598.17835	148.17467	470.7765	186.25426
70	Optimized	143.0518	599.7241	58.533523	316.36033	148.85638
71	Optimized	144.9634	602.36525	-95.075085	113.65055	65.616178

Slices of Slip Surface: 19481

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesiv Strengt (psf)
1	19481	12.983015	555.4256	1159.0249	1292.971	38.408416	0
2	19481	15.77434	554.82925	1196.2708	1415.8557	62.96496	0
3	19481	18.300715	554.3392	1226.8546	1511.7114	81.68137	0
4	19481	20.562145	553.9446	1251.4434	1592.3654	97.757819	0
5	19481	22.823575	553.589	1273.6427	1666.7709	112.7277	0
6	19481	25.085	553.2721	1293.4232	1735.0425	126.63229	0
7	19481	27.346425	552.9937	1310.8009	1797.3924	139.52787	0
8	19481	29.607855	552.7535	1325.7977	1853.8722	151.42294	0
9	19481	31.869285	552.5513	1338.3926	1904.6288	162.36563	0
10	19481	33.65	552.41555	1346.9011	8657.0053	2096.1387	0
11	19481	34.50158	552.359	1353.6106	2844.5727	427.5265	0
12	19481	35.89272	552.2855	1380.3728	2910.5197	438.76255	0
13	19481	38.27184	552.1841	1424.6677	3021.4431	457.86799	0
14	19481	40.65096	552.12425	1466.3528	3125.7762	475.83199	0
15	19481	43.03008	552.1059	1505.472	3223.5435	492.64908	0
16	19481	45.4092	552.129	1541.9891	3314.9067	508.37594	0
17	19481	47.78832	552.1936	1575.9141	3399.9118	523.02291	0
18	19481	50.16744	552.29975	1607.2166	3478.6091	536.61315	0
19	19481	52.439185	552.43905	1634.7527	3578.4902	557.35775	0
20	19481	54.60356	552.6081	1658.7322	3699.6716	585.22995	0
21	19481	56.767935	552.81185	1680.5622	3815.0596	612.05727	0
22	19481	58.93231	553.05045	1700.2299	3924.7156	637.86103	0
23	19481	61.096685	553.3241	1717.6776	4028.6573	662.66276	0
24	19481	63.26106	553.633	1732.8985	4126.9126	686.4725	0
25	19481	65.425435	553.9774	1745.9301	4219.5058	709.28641	0
26	19481	67.58981	554.35755	1756.768	4306.424	731.1021	0
27	19481	69.873	554.79875	1765.6361	4318.5932	732.04865	0
28	19481	72.275	555.3056	1772.3246	4256.7015	712.3836	0
29	19481	74.677	555.85785	1776.1975	4190.077	692.16882	0
30	19481	76.939	556.41865	1777.3001	4118.0242	671.19184	0
31	19481	79.065725	556.9848	1775.8699	4040.8674	649.47759	0

32	19481	81.19717	557.58925	1772.1734	3959.0879	627.08763	0
33	19481	83.328615	558.2313	1766.0887	3873.3679	604.25258	0
34	19481	85.460065	558.91155	1757.6761	3783.7956	580.98042	0
35	19481	87.591515	559.63065	1746.7791	3690.206	557.26871	0
36	19481	89.74462	560.39735	1733.2992	3517.3885	1030.0444	0
37	19481	92.062835	561.26995	1715.8178	3399.765	972.2274	0
38	19481	94.5245	562.2481	1694.0644	3266.5896	907.89787	0
39	19481	96.986165	563.28225	1668.7889	3129.0118	843.06009	0
40	19481	99.716	564.4998	1636.3816	2996.7776	785.42505	0
41	19481	102.4679	565.79385	1599.5479	2960.607	785.80785	0
42	19481	104.9737	567.0414	1561.657	3006.9157	834.42048	0
43	19481	107.4795	568.3541	1519.7284	3043.3593	879.66872	0
44	19481	109.9853	569.7341	1473.5832	3069.8145	921.58454	0
45	19481	112.4911	571.1838	1423.1036	3086.1432	960.15639	0
46	19481	114.62185	572.46855	1376.9217	3032.9302	956.09694	0
47	19481	116.37755	573.5714	1336.1027	2914.6094	911.35131	0
48	19481	118.0782	574.6751	1294.3942	2798.967	868.66551	0
49	19481	120.6005	576.39495	1227.286	2631.3326	810.62667	0
50	19481	123.41	578.38265	1148.084	2428.9345	739.49936	0
51	19481	125.63	580.03935	1080.0982	2244.5708	672.30852	0
52	19481	127.85	581.76785	1007.6558	2055.5755	605.01673	0
53	19481	130.07	583.5717	930.54081	1861.8442	537.68826	0
54	19481	132.385	585.53915	844.67335	1669.6703	476.31224	0
55	19481	134.795	587.68265	749.36599	1477.8694	420.60163	0
56	19481	137.3635	590.0873	626.53567	1261.8589	366.80403	0
57	19481	140.0905	592.77765	474.65075	1020.0511	314.88706	0
58	19481	142.4883	595.2641	333.53257	787.23472	261.94506	0
59	19481	144.55685	597.52195	204.76389	565.4766	208.25758	0
60	19481	146.6254	599.88555	69.396612	337.79198	154.95814	0
61	19481	148.83965	602.5474	-83.728523	110.21579	63.633118	0

Alternative A – Upslope Wall Without Excavation

SLOPE/W Analysis

File Information

Created By: Lovullo, Vincent M LRB
Revision Number: 140
Last Edited By: Lovullo, Vincent M LRB
Date: 6/3/2009
Time: 3:15:17 PM
File Name: Cross-Section 2 STA. 16+00 (Option 1_A_2 Walls_CRITICAL).gsz
Directory: C:\Documents and Settings\h5tddvml\My Documents\vlovullo\Projects\Cuyahoga River Technical Assistance\Slope Stability Analysis\SLOPE_W\CRITICAL FAILURE\
Last Solved Date: 6/3/2009
Last Solved Time: 3:15:22 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf

View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Spencer
Settings
  Apply Phreatic Correction: No
  PWP Conditions Source: Piezometric Line
  Use Staged Rapid Drawdown: No
SlipSurface
  Direction of movement: Right to Left
  Use Passive Mode: No
  Slip Surface Option: Fully-Specified
  Critical slip surfaces saved: 1
  Optimize Critical Slip Surface Location: No
  Tension Crack
    Tension Crack Option: (none)
FOS Distribution
  FOS Calculation Option: Constant
Advanced
  Number of Slices: 60
  Optimization Tolerance: 0.01
  Minimum Slip Surface Depth: 0.1 ft
  Optimization Maximum Iterations: 8000
  Optimization Convergence Tolerance: 1e-007
  Starting Optimization Points: 8
  Ending Optimization Points: 32
  Complete Passes per Insertion: 1
  Driving Side Maximum Convex Angle: 5 °
  Resisting Side Maximum Convex Angle: 1 °

Materials

Fill, Sand, or Silt

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
  Piezometric Line: 1

Clay (Along probable failure)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 16 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

"Wall"

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 9e+006 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Limits

Left Coordinate: (-400, 579.5) ft
Right Coordinate: (592.5, 681) ft

Fully Specified Slip Surfaces

Fully Specified Slip Surface 1

	X (ft)	Y (ft)
	-1.25853	552.9273
	1.84381	552.8605
	7.97428	552.7106
	14.10476	552.5607
	21.00427	552.3919
	28.67281	552.2043

	32.75353	552.1121
	33.65	552.1175
	34.50158	552.1227
	37.19288	552.1389
	42.60121	552.1365
	48.4384	552.1017
	54.34257	552.0665
	60.1641	552.047
	65.83603	552.0435
	72.275	552.0395
	76.939	552.0367
	78.43728	552.0358
	81.86392	552.0338
	87.84264	552.0304
	92.33097	552.0277
	96.02347	552.0258
	99.716	552.0238
	105.83775	552.0206
	112.10225	552.1472
	116.3225	552.4788
	120.6005	552.8149
	126.46215	553.2754
	130.90215	553.6142
	133.59	553.7268
	138.727	553.942
	145.92465	554.2435
	153.8333	554.4507
	160.7093	554.4905
	168.57365	554.5021
	175.8	554.4884
	180.142	554.4801
	181.692	554.4772
	185.5	554.47

	190.4209	554.4607
	191.8119	554.4624
	196.041	554.5228
	200.5	554.5865
	203	554.6222
	205.5	554.6579
	206.9069	554.678
	210.9074	554.8197
	217.376	555.0891
	223.43825	555.3415
	228.81275	555.5652
	231.59	555.6808
	233.802	555.773
	237.8745	556.7864
	242.23735	558.8558
	248.60285	561.875
	254.829	564.8282
	259.615	567.287
	264.641	570.0484
	269.86915	572.9209
	276.4561	576.5371
	284.1997	580.7858
	290.0606	584.0245
	295.2733	586.9447
	301.72045	590.5564
	308.37805	594.2861
	315.3025	598.6328
	322.2833	603.4788
	326.92035	606.8854
	330.78725	610.2024
	336.2277	614.8691
	341.66815	619.5358
	347.8659	625.5802

	354.8209	633.0023
	361.8582	641.616
	366.44075	647.9272
	368.88175	651.289
	371.3078	654.6303
	374.2573	658.942
	379.0866	666.2138
	384.86185	674.91
	388	679.2854

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-400	574
	-262	574
	34.3	574
	136	600
	178.6	604
	181.7	604
	189.3	605
	231.5	617.5
	370.3	650
	395	650
	592.57566	650

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 200 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	404	681
	508	681

Point Loads

	Coordinate (ft)	Magnitude (lbs)	Direction (°)
Point Load 1	(33, 563)	41000	180
Point Load 2	(200, 581)	95000	180

FullySpecFixedPoints
[1]
flag: Yes

Regions

	Material	Points
Region 1	Clay	6,5,8,67,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,3,69,70,4,7
Region 2	Clay (Along probable failure)	67,24,23,22,21,20,9,10,5,8
Region 3	Fill, Sand, or Silt	9,19,18,17,16,11,10
Region 4	Clay (Along probable failure)	39,40,1,68,69,3
Region 5	Clay	1,68,78,76,13,12
Region 6	Clay	71,79,77,14,15,2
Region 7	Clay (Along probable failure)	70,71,2,4

Region 8	"Wall"	79,77,75,72,76,78
Region 9	Fill, Sand, or Silt	76,13,12,1,41,42,43,44,45,46,47,48,49,50,51,52,53,54,74,73,55,56,57,58,59,60,61,
Region 10	Clay	78,68,71,79
Region 11	Clay (Along probable failure)	68,69,70,71

Points

	X (ft)	Y (ft)
Point 1	33	560
Point 2	592	560
Point 3	16	552
Point 4	592	552
Point 5	-400	552
Point 6	-400	480
Point 7	592	480
Point 8	-229	552
Point 9	-276	560
Point 10	-400	560
Point 11	-400	579.5
Point 12	78	570
Point 13	173	580
Point 14	312	586
Point 15	592.1663	586
Point 16	-322.104	579
Point 17	-306.28	577.924
Point 18	-294.333	577.662
Point 19	-284.593	574.338
Point 20	-274.834	559.087
Point 21	-258.818	556.964

Point 22	-246.827	555.288
Point 23	-236.786	554.222
Point 24	-224.823	552.673
Point 25	-213.832	550.799
Point 26	-203.748	549.553
Point 27	-180.828	546.001
Point 28	-169.823	544.569
Point 29	-158.823	543.829
Point 30	-138.506	542.84
Point 31	-126.654	542.58
Point 32	-104.621	542.026
Point 33	-81.824	542.998
Point 34	-71.577	543.677
Point 35	-59.088	544.288
Point 36	-48.829	545.565
Point 37	-38.539	547.126
Point 38	-15.825	549.924
Point 39	-5.495	552
Point 40	17.17	556.961
Point 41	33	573.5
Point 42	51.357	580
Point 43	68.672	590
Point 44	75.878	590.5
Point 45	90.832	591
Point 46	98.217	591
Point 47	101.215	591.5
Point 48	113.744	601.5
Point 49	118.901	602
Point 50	122.3	602.5
Point 51	131.18	602.5
Point 52	141.454	604
Point 53	181.684	604
Point 54	192.082	608.1
Point 55	214.001	613.708
Point 56	220.751	614.965

Point 57	231.68	619.5
Point 58	239.825	619.5
Point 59	252.556	625.5
Point 60	267.154	628
Point 61	304.944	640.1
Point 62	328.067	656.5
Point 63	365.418	675.705
Point 64	376.199	678
Point 65	394.561	680
Point 66	592.5	681
Point 67	-220	552
Point 68	200	560
Point 69	200	552
Point 70	201	552
Point 71	201	560
Point 72	200	610
Point 73	206	611.71
Point 74	205	611.46
Point 75	201	610
Point 76	200	581.1655
Point 77	201	581.2086
Point 78	200	570
Point 79	201	570

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	1	1.202	(162.608, 710.875)	204.769	(388, 679.285)	(-1.25853, 552.927)

Slices of Slip Surface: 1

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesi Streng (psf)
1	1	0.2926405	552.8939	1317.0234	1413.1222	27.555874	0

2	1	4.909045	552.78555	1323.7769	1498.377	50.065748	0
3	1	11.03952	552.63565	1333.135	1611.0726	79.697321	0
4	1	15.63738	552.5232	1340.1466	1695.6079	101.92687	0
5	1	19.087135	552.4388	1345.4078	1749.2231	115.79217	0
6	1	24.83854	552.2981	1354.2204	1844.6495	140.62827	0
7	1	30.71317	552.1582	1362.9166	1940.633	165.65749	0
8	1	32.876765	552.11285	1365.7397	1958.7828	170.05237	0
9	1	33.325	552.11555	1365.5906	18735.045	4980.6108	0
10	1	33.975	552.1195	1365.3438	2834.1011	421.15937	0
11	1	34.40079	552.1221	1366.7765	2845.2187	423.93648	0
12	1	34.60237	552.1233	1369.9323	2853.1658	425.31036	0
13	1	35.94802	552.1314	1390.896	2914.3749	436.85056	0
14	1	39.897045	552.1377	1453.4983	3105.3943	473.67354	0
15	1	45.519805	552.1191	1544.3629	3378.449	525.91574	0
16	1	49.8977	552.093	1615.8144	3587.6151	565.40475	0
17	1	52.849785	552.0754	1664.0078	3773.0819	604.76725	0
18	1	57.253335	552.05675	1735.4446	4108.5186	680.46803	0
19	1	63.000065	552.04525	1827.7726	4544.6604	779.05503	0
20	1	67.254015	552.0426	1895.8586	4869.5844	852.70214	0
21	1	70.4735	552.0406	1947.3211	4995.2803	873.98823	0
22	1	74.0765	552.0384	2004.9398	5029.4185	867.25533	0
23	1	76.4085	552.037	2042.2243	5049.2931	862.2631	0
24	1	77.4695	552.0364	2059.1894	5054.3827	858.85783	0
25	1	78.21864	552.03595	2071.1896	5057.8565	856.41295	0
26	1	80.1506	552.0348	2102.0877	5065.894	849.85777	0
27	1	84.85328	552.0321	2177.2215	5085.5359	833.94572	0
28	1	89.33732	552.0295	2248.9422	5104.4354	818.7995	0
29	1	91.581485	552.02815	2284.8356	5110.5759	810.268	0
30	1	94.17722	552.02675	2326.3372	5109.8172	798.15005	0
31	1	97.120235	552.0252	2373.389	5109.1164	784.45719	0
32	1	98.9665	552.0242	2402.8686	5125.3502	780.65905	0
33	1	100.4655	552.0234	2426.8846	5157.9053	783.10758	0
34	1	103.5264	552.0218	2475.7985	5416.4717	843.22447	0
35	1	108.97005	552.0839	2558.8199	5933.8192	967.76549	0
36	1	112.92315	552.2117	2613.8413	6196.829	1027.4052	0

37	1	115.03325	552.3775	2637.1698	6274.2442	1042.9143	0
38	1	117.61175	552.5801	2665.6656	6279.6594	1036.2961	0
39	1	119.75075	552.74815	2689.2711	6289.5332	1032.3585	0
40	1	121.45025	552.88165	2708.101	6304.1982	1031.1643	0
41	1	124.38105	553.1119	2740.3763	6290.0991	1017.8666	0
42	1	128.68215	553.4448	2788.2903	6251.8696	993.16538	0
43	1	131.0411	553.62	2814.9865	6303.9903	1000.4558	0
44	1	132.385	553.6763	2832.9092	6319.3531	999.72168	0
45	1	134.795	553.7773	2865.0802	6351.2753	999.65036	0
46	1	137.3635	553.8849	2885.5877	6385.6712	1003.6328	0
47	1	140.0905	553.9991	2894.4186	6422.6782	1011.7122	0
48	1	143.68935	554.14985	2906.2004	6429.6667	1010.3377	0
49	1	149.879	554.3471	2930.0889	6440.8615	1006.6978	0
50	1	157.2713	554.4706	2965.6281	6472.9866	1005.7188	0
51	1	164.64145	554.4963	3007.2381	6481.2657	996.16138	0
52	1	170.7868	554.4979	3043.1339	6490.2116	988.43363	0
53	1	174.4	554.49105	3064.7445	6491.7741	982.68492	0
54	1	177.2	554.4857	3081.4945	6492.1313	977.98436	0
55	1	179.371	554.48155	3089.9421	6492.8538	975.76922	0
56	1	180.913	554.47865	3090.1367	6493.5023	975.89939	0
57	1	181.688	554.4772	3090.2446	6493.9886	976.0079	0
58	1	181.696	554.4772	3090.2446	6494.4886	976.15127	0
59	1	183.6	554.4736	3106.0469	6593.4089	999.98496	0
60	1	187.4	554.4664	3137.6258	6790.777	1047.5242	0
61	1	189.86045	554.46175	3163.9697	6918.446	1076.5788	0
62	1	191.1164	554.46155	3187.2012	6974.977	1086.1272	0
63	1	191.94695	554.46435	3202.3396	6984.8497	1084.6173	0
64	1	194.0615	554.49455	3239.629	7053.5869	1093.6348	0
65	1	198.0205	554.5511	3309.0839	12427.123	2614.5556	0
66	1	200.25	554.58295	3348.4585	7398.6453	1161.3724	0
67	1	200.75	554.59005	3357.2576	7414.2437	1163.3221	0
68	1	202	554.6079	3379.2053	7302.7551	1125.0598	0
69	1	204	554.6365	3414.4017	7365.7487	1133.0305	0
70	1	205.25	554.65435	3436.4495	7404.8447	1137.919	0
71	1	205.75	554.66145	3445.2486	7419.8432	1139.6967	0

72	1	206.45345	554.6715	3457.581	7440.9656	1142.2172	0
73	1	208.90715	554.74885	3498.1185	7453.8928	1134.3	0
74	1	212.4542	554.8841	3555.2317	7532.5826	1140.487	0
75	1	215.6885	555.0188	3606.6509	7603.4821	1146.0729	0
76	1	219.0635	555.15935	3660.2363	7664.1748	1148.1109	0
77	1	222.09465	555.28555	3708.3513	7758.4662	1161.3518	0
78	1	226.1255	555.45335	3772.3411	7950.1364	1197.9635	0
79	1	230.15635	555.62115	3836.291	8141.8007	1234.5851	0
80	1	231.545	555.67895	3858.3258	8207.6708	1247.1546	0
81	1	231.635	555.6827	3859.4265	8211.7583	1248.0111	0
82	1	232.741	555.7288	3872.6497	8207.763	1243.0737	0
83	1	235.83825	556.2797	3883.534	7605.274	1067.1918	0
84	1	238.84975	557.249	3867.0701	7016.424	903.0627	0
85	1	241.03115	558.2837	3834.5101	6960.3961	896.33339	0
86	1	243.4435	559.4279	3798.1842	6953.2877	904.71136	0
87	1	246.62625	560.9375	3750.404	6779.0226	1748.5738	0
88	1	250.5794	562.81255	3691.1738	6764.7902	1774.5533	0
89	1	253.6925	564.28915	3644.6266	6718.9219	1774.9452	0
90	1	257.222	566.0576	3585.8061	6498.8322	1681.8364	0
91	1	262.128	568.6677	3494.5573	6227.7754	1578.0242	0
92	1	265.8975	570.73875	3420.4715	6071.5148	1530.5805	0
93	1	268.51155	572.175	3368.9738	5982.6157	1508.9869	0
94	1	273.1626	574.729	3277.6143	5858.4245	1490.0315	0
95	1	280.3279	578.66145	3136.9026	5666.6227	1460.5345	0
96	1	287.13015	582.40515	3002.7402	5475.629	1427.723	0
97	1	291.05515	584.58165	2924.2544	5354.386	1403.0371	0
98	1	293.6615	586.04175	2871.2301	5284.5357	1393.3226	0
99	1	298.4969	588.75055	2772.8514	5158.6862	1377.4624	0
100	1	303.33225	591.45935	2674.4763	5032.8437	1361.604	0
101	1	306.661	593.3242	2606.8216	5011.4183	1388.2946	0
102	1	311.84025	596.45945	2486.7644	4932.676	1412.1477	0
103	1	318.7929	601.0558	2301.4941	4825.8652	1457.4464	0
104	1	324.6018	605.1821	2128.9974	4730.7192	1502.1048	0
105	1	327.49365	607.3772	2034.205	4514.3585	1431.9172	0
106	1	329.4271	609.0357	1958.9936	4452.3724	1439.5529	0

107	1	333.50745	612.53575	1800.1475	4301.6312	1444.2323	0
108	1	338.94795	617.20245	1588.5049	4100.7312	1450.4345	0
109	1	344.76705	622.558	1339.3498	3700.3941	1363.1496	0
110	1	351.3434	629.29125	1015.2868	3255.3672	1293.311	0
111	1	358.33955	637.30915	617.15808	2669.0833	1184.6796	0
112	1	363.6381	644.0673	272.86291	2163.9884	1091.8418	0
113	1	365.92935	647.2229	109.4328	1970.2385	1074.3367	0
114	1	366.95215	648.63155	36.477637	1867.5107	1057.1474	0
115	1	368.1727	650.31245	-50.577595	1760.2312	1016.27	0
116	1	369.5909	652.26565	-151.73923	1648.3435	951.67154	0
117	1	370.8039	653.9363	-245.62653	1552.6265	896.40931	0
118	1	372.78255	656.78615	-423.44841	1345.613	776.89005	0
119	1	375.22815	660.40385	-649.18747	1124.318	649.12533	0
120	1	377.6428	664.03975	-876.08934	912.7591	526.98171	0
121	1	381.97425	670.5619	-1283.0461	521.58111	301.135	0
122	1	386.43095	677.0977	-1690.8999	135.75672	78.379181	0

Alternative A – Upslope Wall With Excavation

SLOPE/W Analysis

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File Information

Created By: Lovullo, Vincent M LRB
Revision Number: 138
Last Edited By: Lovullo, Vincent M LRB
Date: 6/3/2009

Time: 3:14:08 PM
File Name: Cross-Section 2 STA. 16+00 (Option 5_A_2 Walls_CRITICAL).gsz
Directory: C:\Documents and Settings\h5tddvml\My Documents\vlovullo\Projects\Cuyahoga River Technical Assistance\Slope Stability Analysis\SLOPE_W\CRITICAL FAILURE\
Last Solved Date: 6/3/2009
Last Solved Time: 3:14:10 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

- Kind: SLOPE/W
- Method: Spencer
- Settings
  - Apply Phreatic Correction: No
  - PWP Conditions Source: Piezometric Line
  - Use Staged Rapid Drawdown: No
- SlipSurface
  - Direction of movement: Right to Left
  - Use Passive Mode: No
  - Slip Surface Option: Fully-Specified
  - Critical slip surfaces saved: 1
  - Optimize Critical Slip Surface Location: No
  - Tension Crack
    - Tension Crack Option: (none)
- FOS Distribution
  - FOS Calculation Option: Constant
- Advanced
  - Number of Slices: 60
  - Optimization Tolerance: 0.01
  - Minimum Slip Surface Depth: 0.1 ft
  - Optimization Maximum Iterations: 8000
  - Optimization Convergence Tolerance: 1e-007
  - Starting Optimization Points: 8
  - Ending Optimization Points: 32
  - Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Fill, Sand, or Silt

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay (Along probable failure)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 16 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

"Wall"

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 9e+006 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Limits

Left Coordinate: (-400, 579.5) ft
Right Coordinate: (592.5, 681) ft

Fully Specified Slip Surfaces

Fully Specified Slip Surface 1

	X (ft)	Y (ft)
	-5.198	552.065
	-1.78855	552.0501
	5.4877	552.1204
	13.14791	552.1505
	20.52175	552.1415
	27.22527	552.1333
	31.78851	552.1277
	33.65	552.1255
	38.66504	552.1194
	47.19354	552.1089
	51.6926	552.1034
	56.18915	552.1215
	64.51105	552.1586
	72.275	552.1932
	76.5232	552.2121
	77.58419	552.217
	81.01614	552.2334
	87.43214	552.2208
	94.5245	552.1645
	99.716	552.1233
	105.075	552.0807
	111.3395	552.3619
	116.3225	553.0079
	120.6005	553.5625
	126.74	554.3586
	133.36555	555.2177
	135.77555	555.5232
	138.727	555.8153
	145.6501	556.5006

	154.0423	557.3314
	161.9288	557.869
	169.32235	558.1141
	175.81275	558.3228
	180.142	558.4564
	181.692	558.5042
	185.23675	558.6137
	189.13675	558.7253
	194.75	558.7643
	200.5	558.8043
	206.09845	558.8431
	216.0232	558.8829
	225.6758	558.8917
	234.3306	558.9132
	241.9876	558.9474
	249.64455	558.9815
	256.72975	559.0123
	263.24325	559.0397
	272.1944	559.0773
	280.5887	559.5506
	286.8332	560.59
	293.92235	561.77
	301.0115	562.95
	308.27805	564.9583
	315.11655	567.564
	321.34965	569.9392
	328.9517	572.6652
	337.92275	575.7422
	346.0074	578.7339
	353.2056	581.6404
	360.40385	584.5468
	364.7617	586.3063
	369.28015	588.4208

	376.79965	592.0368
	384.3192	595.6528
	392.7895	600.0293
	402.25	605.1876
	408.45115	608.5687
	414.06775	612.0209
	422.39865	617.3428
	430.72955	622.6647
	434.9475	625.399
	439.38725	631.6043
	448.1618	643.8681
	455.10605	653.5738
	461.6547	662.922
	469.6381	674.4709
	474	680.2476

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-400	574
	-262	574
	34.3	574
	136	600
	178.6	604
	181.7	604
	189.5	603.5
	266.5	603.5
	397.5	646.5
	407	650
	592.57566	650

Point Loads

	Coordinate (ft)	Magnitude (lbs)	Direction (°)
Point Load 1	(33, 563)	41000	180
Point Load 2	(200, 578)	40000	180

Regions

	Material	Points	
Region 1	Clay	6,5,8,58,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,3,60,61,4,7	7
Region 2	Clay (Along probable failure)	58,24,23,22,21,20,9,10,5,8	1
Region 3	Fill, Sand, or Silt	9,19,18,17,16,11,10	2
Region 4	Clay (Along probable failure)	39,40,1,59,60,3	1
Region 5	Clay	1,59,67,65,13,12	2
Region 6	Clay	62,68,66,14,15,2	9
Region 7	Clay (Along probable failure)	61,62,2,4	3
Region 8	"Wall"	68,66,64,63,65,67	
Region 9	Fill, Sand, or Silt	65,13,12,1,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,15,14,66,64,63	2
Region 10	Clay	62,68,67,59	
Region	Clay	62,59,60,61	

11	(Along probable failure)		

Points

	X (ft)	Y (ft)
Point 1	33	560
Point 2	592	560
Point 3	16	552
Point 4	592	552
Point 5	-400	552
Point 6	-400	480
Point 7	592	480
Point 8	-229	552
Point 9	-276	560
Point 10	-400	560
Point 11	-400	579.5
Point 12	78	570
Point 13	173	580
Point 14	312	586
Point 15	592.1663	586
Point 16	-322.104	579
Point 17	-306.28	577.924
Point 18	-294.333	577.662
Point 19	-284.593	574.338
Point 20	-274.834	559.087
Point 21	-258.818	556.964
Point 22	-246.827	555.288
Point 23	-236.786	554.222
Point 24	-224.823	552.673
Point 25	-213.832	550.799
Point 26	-203.748	549.553
Point 27	-180.828	546.001
Point 28	-169.823	544.569

Point 29	-158.823	543.829
Point 30	-138.506	542.84
Point 31	-126.654	542.58
Point 32	-104.621	542.026
Point 33	-81.824	542.998
Point 34	-71.577	543.677
Point 35	-59.088	544.288
Point 36	-48.829	545.565
Point 37	-38.539	547.126
Point 38	-15.825	549.924
Point 39	-5.495	552
Point 40	17.17	556.961
Point 41	33	573.5
Point 42	51.357	580
Point 43	68.672	590
Point 44	75.878	590.5
Point 45	90.832	591
Point 46	98.217	591
Point 47	101.215	591.5
Point 48	113.744	601.5
Point 49	118.901	602
Point 50	122.3	602.5
Point 51	131.18	602.5
Point 52	141.454	604
Point 53	181.684	604
Point 54	266.5	604
Point 55	435	660
Point 56	435	680
Point 57	592.5	681
Point 58	-220	552
Point 59	200	560
Point 60	200	552
Point 61	201	552
Point 62	201	560
Point 63	200	603.5

Point 64	201	603.5
Point 65	200	581.1655
Point 66	201	581.2086
Point 67	200	563
Point 68	201	563

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	1	1.207	(208.685, 712.293)	230.208	(474, 680.248)	(-5.198, 552.065)

Slices of Slip Surface: 1

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	1	-3.493276	552.05755	1369.2101	1455.2642	24.67561	0
2	1	1.849575	552.08525	1367.4812	1526.5392	45.609153	0
3	1	9.317805	552.13545	1364.3124	1632.9714	77.036721	0
4	1	15.158955	552.14805	1363.5687	1720.3232	102.29772	0
5	1	18.845875	552.14355	1363.8539	1767.3145	115.69048	0
6	1	23.87351	552.1374	1364.2226	1834.2588	134.78074	0
7	1	29.50689	552.1305	1364.6654	1909.1247	156.12119	0
8	1	32.394255	552.127	1364.8471	1947.5176	167.07806	0
9	1	33.325	552.1259	1364.9374	17047.679	4496.9538	0
10	1	33.975	552.1251	1364.999	2832.3055	420.74339	0
11	1	34.50158	552.12445	1368.2545	2847.7294	424.23261	0
12	1	36.6841	552.1218	1403.2227	2948.8526	443.20223	0
13	1	42.92929	552.11415	1503.3114	3241.9512	498.54694	0
14	1	49.27527	552.10635	1605.0581	3539.8417	554.79027	0
15	1	51.5248	552.1036	1641.1189	3650.1755	576.08771	0
16	1	53.940875	552.11245	1679.1183	3826.0138	615.61236	0
17	1	60.3501	552.14005	1779.6239	4307.8675	724.96218	0
18	1	66.591525	552.16785	1877.4614	4777.4677	831.56342	0
19	1	70.4735	552.18515	1938.3098	4950.2697	863.66561	0

20	1	74.0765	552.2012	1994.7899	4982.1872	856.62239	0
21	1	76.2006	552.21065	2028.0332	4999.6404	852.09466	0
22	1	77.053695	552.21455	2041.4684	5002.9171	849.18174	0
23	1	77.792095	552.218	2053.0299	5005.8355	846.7034	0
24	1	79.50807	552.2262	2079.8866	5011.9788	840.76388	0
25	1	84.22414	552.2271	2155.077	5043.1639	828.14558	0
26	1	89.13207	552.2073	2234.5805	5076.5199	814.91299	0
27	1	92.67825	552.17915	2292.9273	5086.9086	801.16124	0
28	1	96.37075	552.14985	2353.6431	5089.8875	784.60547	0
29	1	98.9665	552.12925	2396.3225	5108.5123	777.70791	0
30	1	100.4655	552.11735	2421.0048	5142.6006	780.40503	0
31	1	103.145	552.09605	2465.0775	5363.561	831.12677	0
32	1	108.20725	552.2213	2537.9505	5773.4187	927.75558	0
33	1	112.54175	552.51775	2588.6509	6009.5965	980.94037	0
34	1	115.03325	552.84075	2608.2679	6103.2784	1002.1781	0
35	1	117.61175	553.17505	2628.5365	6092.1249	993.16799	0
36	1	119.75075	553.45235	2645.3532	6088.5021	987.30706	0
37	1	121.45025	553.6727	2658.7066	6091.3984	984.30853	0
38	1	124.52	554.07075	2682.9442	6057.1732	967.54458	0
39	1	128.96	554.64645	2717.7889	5984.8087	936.80287	0
40	1	132.2728	555.076	2743.7943	5950.9603	919.64006	0
41	1	134.5706	555.37045	2762.0873	5960.5991	917.15851	0
42	1	135.8878	555.5343	2772.865	6016.0543	929.96957	0
43	1	137.3635	555.68035	2773.5417	6024.8372	932.294	0
44	1	140.0905	555.95025	2772.6608	6041.2476	937.25219	0
45	1	143.55205	556.2929	2771.6591	6023.3249	932.40016	0
46	1	149.8462	556.916	2769.5224	5945.4138	910.67219	0
47	1	157.98555	557.6002	2774.516	5917.6688	901.28454	0
48	1	165.6256	557.99155	2794.9564	5935.7001	900.59376	0
49	1	171.1612	558.17325	2816.1045	5915.3957	888.70745	0
50	1	174.40635	558.2776	2828.5085	5902.2018	881.36737	0
51	1	177.20635	558.3658	2839.4052	5892.9698	875.59556	0
52	1	179.371	558.4326	2843.3936	5884.4234	872.00125	0
53	1	180.913	558.4802	2840.4137	5878.5286	871.16541	0
54	1	181.688	558.5041	2838.9005	5875.5819	870.75439	0

55	1	181.696	558.5043	2838.8958	5875.4474	870.71715	0
56	1	183.4684	558.55905	2828.3674	5868.9755	871.88033	0
57	1	187.1868	558.6695	2806.8001	5859.9096	875.46508	0
58	1	189.3184	558.72655	2794.7017	5894.4202	888.82996	0
59	1	192.125	558.74605	2792.6943	5892.6194	888.88919	0
60	1	197.375	558.78255	2790.4087	7379.4405	1315.8837	0
61	1	200.25	558.80255	2789.1325	6003.2547	921.63472	0
62	1	200.75	558.80605	2788.9331	6002.8559	921.57755	0
63	1	203.54925	558.82545	2787.6433	5884.5889	888.03485	0
64	1	211.06085	558.863	2785.3374	5886.9522	889.37374	0
65	1	220.8495	558.8873	2783.8084	5891.8816	891.22565	0
66	1	230.0032	558.90245	2782.8401	5888.8525	890.63472	0
67	1	238.1591	558.9303	2781.0877	5883.1857	889.51228	0
68	1	245.8161	558.96445	2779.0163	5880.4815	889.33085	0
69	1	253.1872	558.9969	2777.0301	5877.9719	889.18073	0
70	1	259.9865	559.026	2775.1346	5875.8976	889.1295	0
71	1	264.8716	559.04655	2773.9064	5874.2088	888.99743	0
72	1	269.3472	559.06535	2831.0021	5993.7307	906.89784	0
73	1	276.39155	559.31395	2959.8104	6157.1432	916.8204	0
74	1	281.93865	559.7753	3044.6306	6118.6358	881.45683	0
75	1	285.0609	560.295	3076.2252	6195.5855	1800.9635	0
76	1	290.37775	561.18	3129.8158	6299.7056	1830.1368	0
77	1	297.4669	562.36	3201.4761	6438.7127	1869.0194	0
78	1	304.6448	563.95415	3248.9862	6248.3361	1731.6755	0
79	1	310.13905	565.6674	3254.5942	6020.3591	1596.8151	0
80	1	313.5583	566.97025	3243.3557	5996.1753	1589.3411	0
81	1	318.23315	568.7516	3227.8831	5962.8359	1579.0258	0
82	1	325.1507	571.3022	3210.4887	5970.6323	1593.5697	0
83	1	333.43725	574.2037	3199.1526	5974.3313	1602.2502	0
84	1	341.9651	577.23805	3184.4115	5881.2605	1557.0264	0
85	1	349.6065	580.18715	3156.9595	5754.4595	1499.6673	0
86	1	356.8047	583.0936	3123.0766	5684.6332	1478.9154	0
87	1	362.20345	585.2734	3097.5003	5632.334	1463.4869	0
88	1	364.3824	586.15315	3087.2788	5611.934	1457.6104	0
89	1	367.0209	587.36355	3065.9063	5456.6917	1380.3206	0

90	1	373.03985	590.2288	3010.2735	5339.7988	1344.9521	0
91	1	380.5594	593.8448	2938.7072	5218.1229	1316.0213	0
92	1	388.55435	597.84105	2853.1167	5014.8231	1248.0617	0
93	1	395.14475	601.3135	2771.3775	4833.7416	1190.7065	0
94	1	399.875	603.89265	2713.2124	4727.0041	1162.6632	0
95	1	404.625	606.48255	2660.9131	4620.7395	1131.5063	0
96	1	407.72555	608.1731	2609.9988	4549.0902	1119.5349	0
97	1	411.2594	610.2948	2477.5836	4345.2514	1078.2985	0
98	1	418.23315	614.68185	2203.8967	4076.4047	1081.093	0
99	1	426.5641	620.00375	1871.7999	3783.8601	1103.9285	0
100	1	432.83855	624.03185	1620.4138	3550.2565	1114.1952	0
101	1	434.97375	625.4357	1532.8371	2828.8215	748.23695	0
102	1	437.1936	628.53835	1339.162	3917.4831	1488.5944	0
103	1	443.7745	637.7362	765.27381	3115.1419	1356.697	0
104	1	450.35545	646.93405	191.3186	2312.9325	1224.9144	0
105	1	453.82755	651.7869	-111.5025	1924.6572	1111.2013	0
106	1	458.38035	658.2479	-514.66871	1471.8213	849.75641	0
107	1	465.6464	668.69645	-1166.6245	767.46927	443.09859	0
108	1	471.81905	677.35925	-1707.2473	200.57876	115.8042	0

Alternative C – Wall at Riverbank

SLOPE/W Analysis

File Information

Created By: Lovullo, Vincent M LRB
Revision Number: 87
Last Edited By: Lovullo, Vincent M LRB
Date: 5/27/2009
Time: 2:54:34 PM
File Name: Cross-Section 2 STA. 16+00 (Option 1_C-Failure at bank).gsz
Directory: C:\Documents and Settings\h5tddvml\My Documents\vlovullo\Projects\Cuyahoga River Technical Assistance\Slope Stability Analysis\SLOPE_W\CRITICAL FAILURE\[1] Files for Submittal\
Last Solved Date: 5/27/2009
Last Solved Time: 2:55:58 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Spencer
Settings
  Apply Phreatic Correction: No
  PWP Conditions Source: Piezometric Line
  Use Staged Rapid Drawdown: No
SlipSurface
  Direction of movement: Right to Left
  Use Passive Mode: No
  Slip Surface Option: Entry and Exit
  Critical slip surfaces saved: 1
  Optimize Critical Slip Surface Location: Yes
  Tension Crack
    Tension Crack Option: (none)
FOS Distribution
  FOS Calculation Option: Constant
Advanced
  Number of Slices: 60
  Optimization Tolerance: 0.01
  Minimum Slip Surface Depth: 0.1 ft
  Optimization Maximum Iterations: 8000
  Optimization Convergence Tolerance: 1e-007
  Starting Optimization Points: 8
  Ending Optimization Points: 32
  Complete Passes per Insertion: 1
  Driving Side Maximum Convex Angle: 5 °
  Resisting Side Maximum Convex Angle: 1 °

Materials

Fill, Sand, or Silt

Model: Mohr-Coulomb

Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay (Along probable failure)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 16 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (-10.99998, 550.8937) ft
Left-Zone Right Coordinate: (32.5, 559.904) ft
Left-Zone Increment: 25
Right Projection: Range
Right-Zone Left Coordinate: (53.99998, 581.5264) ft
Right-Zone Right Coordinate: (199.99996, 610.1258) ft
Right-Zone Increment: 45
Radius Increments: 30

Slip Surface Limits

Left Coordinate: (-400, 579.5) ft
Right Coordinate: (592.5, 681) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-400	574
	-262	574
	34.3	574
	136	600
	178.6	604
	181.7	604
	189.3	605
	231.5	617.5
	370.3	650
	395	650
	592.57566	650

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 200 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	404	681
	508	681

Point Loads

	Coordinate (ft)	Magnitude (lbs)	Direction (°)
Point Load 1	(33, 563)	46000	180

Regions

	Material	Points
Region 1	Clay	6,5,8,67,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,3,4,7
Region 2	Clay (Along probable failure)	67,24,23,22,21,20,9,10,5,8
Region 3	Fill, Sand, or Silt	9,19,18,17,16,11,10
Region 4	Clay (Along probable failure)	39,40,1,2,4,3
Region 5	Fill, Sand, or Silt	1,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,
Region 6	Clay	1,12,13,14,15,2

Points

	X (ft)	Y (ft)
Point 1	33	560
Point 2	592	560
Point 3	16	552
Point 4	592	552
Point 5	-400	552
Point 6	-400	480
Point 7	592	480
Point 8	-229	552
Point 9	-276	560
Point 10	-400	560
Point 11	-400	579.5
Point 12	78	570

Point 13	173	580
Point 14	312	586
Point 15	592.1663	586
Point 16	-322.104	579
Point 17	-306.28	577.924
Point 18	-294.333	577.662
Point 19	-284.593	574.338
Point 20	-274.834	559.087
Point 21	-258.818	556.964
Point 22	-246.827	555.288
Point 23	-236.786	554.222
Point 24	-224.823	552.673
Point 25	-213.832	550.799
Point 26	-203.748	549.553
Point 27	-180.828	546.001
Point 28	-169.823	544.569
Point 29	-158.823	543.829
Point 30	-138.506	542.84
Point 31	-126.654	542.58
Point 32	-104.621	542.026
Point 33	-81.824	542.998
Point 34	-71.577	543.677
Point 35	-59.088	544.288
Point 36	-48.829	545.565
Point 37	-38.539	547.126
Point 38	-15.825	549.924
Point 39	-5.495	552
Point 40	17.17	556.961
Point 41	33	573.5
Point 42	51.357	580
Point 43	68.672	590
Point 44	75.878	590.5
Point 45	90.832	591
Point 46	98.217	591
Point 47	101.215	591.5

Point 48	113.744	601.5
Point 49	118.901	602
Point 50	122.3	602.5
Point 51	131.18	602.5
Point 52	141.454	604
Point 53	181.684	604
Point 54	192.082	608.1
Point 55	214.001	613.708
Point 56	220.751	614.965
Point 57	231.68	619.5
Point 58	239.825	619.5
Point 59	252.556	625.5
Point 60	267.154	628
Point 61	304.944	640.1
Point 62	328.067	656.5
Point 63	365.418	675.705
Point 64	376.199	678
Point 65	394.561	680
Point 66	592.5	681
Point 67	-220	552

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.302	(48.128, 678.018)	81.40686	(150.697, 604)	(-1.16593, 552.948)
2	22334	1.469	(48.128, 678.018)	125.939	(150.02, 604)	(15.0593, 556.499)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Coh Stre (p
1	Optimized	0.033006	552.93425	1314.4989	1378.1764	18.259209	
2	Optimized	2.430882	552.90755	1316.167	1417.417	29.032979	

3	Optimized	4.8371375	552.8676	1318.678	1461.3149	40.900499
4	Optimized	7.2517725	552.81435	1321.9903	1504.4994	52.333643
5	Optimized	9.762845	552.741	1326.547	1555.7378	65.719399
6	Optimized	12.370355	552.64765	1332.3726	1607.4016	78.863278
7	Optimized	15.422055	552.5588	1337.9248	1661.382	92.749854
8	Optimized	18.96259	552.47335	1343.2513	1718.2976	107.54279
9	Optimized	21.997725	552.39915	1347.9027	1768.4409	120.5874
10	Optimized	24.482815	552.3372	1351.7645	1809.4729	131.24578
11	Optimized	26.936905	552.27665	1355.5496	1849.6881	141.69196
12	Optimized	29.36	552.21755	1359.2215	1889.4602	152.0435
13	Optimized	31.783095	552.15845	1362.8934	1929.2735	162.40688
14	Optimized	32.99732	552.12895	1364.7569	1933.6092	163.11579
15	Optimized	33.65	552.13735	1364.1954	8690.054	2100.6561
16	Optimized	34.50158	552.1483	1366.754	2814.0146	414.99532
17	Optimized	36.42497	552.173	1395.917	2898.254	430.78821
18	Optimized	39.728025	552.18785	1447.6733	3062.9659	463.1777
19	Optimized	42.890515	552.17335	1499.0247	3211.6762	491.09494
20	Optimized	45.80947	552.13705	1547.8433	3367.5056	521.77977
21	Optimized	48.484885	552.07895	1594.1804	3499.9772	546.47845
22	Optimized	50.589795	552.04625	1629.793	3585.8313	560.88497
23	Optimized	52.51454	552.03705	1661.0471	3709.8085	587.4729
24	Optimized	54.95842	552.02755	1700.6311	3893.1983	628.70852
25	Optimized	57.5311	552.01965	1742.1829	4087.9359	672.63385
26	Optimized	60.10378	552.01175	1783.6958	4282.2849	716.45887
27	Optimized	62.435785	552.0947	1815.7351	4342.0105	724.3978
28	Optimized	64.52712	552.2685	1838.2745	4472.5772	755.37413
29	Optimized	67.122395	552.64125	1856.3835	4490.237	755.24535
30	Optimized	70.119255	553.1941	1869.7063	4544.1419	766.88207
31	Optimized	72.641505	553.66605	1880.4969	4501.606	751.59092
32	Optimized	74.7915	554.076	1889.2234	4470.6291	740.20616
33	Optimized	75.87225	554.2821	1893.6145	4455.021	734.47148
34	Optimized	76.939	554.48555	1897.9373	4435.0165	727.49576
35	Optimized	79.083245	554.89445	1906.6157	4394.2252	713.31056
36	Optimized	81.71747	555.35135	1920.1141	4382.0942	705.96144
37	Optimized	84.819425	555.85205	1938.3502	4333.0824	686.67841

38	Optimized	87.4858	556.2428	1956.4989	4335.4308	682.14775	
39	Optimized	89.7166	556.5236	1974.5562	4309.7237	669.59851	
40	Optimized	90.923335	556.6755	1984.341	4295.4405	662.69712	
41	Optimized	92.178955	556.83265	1994.5618	4276.5873	654.36028	
42	Optimized	94.50753	557.124	2013.5243	4240.4945	638.57343	
43	Optimized	96.94441	557.3618	2037.5886	4268.6846	639.75648	
44	Optimized	98.950975	557.50705	2060.5507	4265.6192	632.29322	
45	Optimized	100.44997	557.659	2074.9298	4216.429	614.06501	
46	Optimized	102.792	557.9614	2093.4447	4349.3942	646.88312	
47	Optimized	105.7104	558.62375	2098.663	4320.4863	637.09758	
48	Optimized	108.4492	559.5604	2083.9047	4459.8512	681.2917	
49	Optimized	111.61205	561.63715	2004.7782	3752.1499	1008.8455	
50	Optimized	113.56075	563.41575	1924.8932	3643.6745	992.33882	
51	Optimized	115.4069	565.22655	1841.3384	3493.3482	953.7883	
52	Optimized	117.9854	567.781	1723.0832	3245.4547	878.94158	
53	Optimized	120.6005	570.41835	1600.2317	3018.793	819.00678	
54	Optimized	122.4429	572.27645	1513.6851	2860.2066	777.41455	
55	Optimized	123.85975	573.691	1448.0034	2730.8995	740.68039	
56	Optimized	126.11525	575.94025	1343.6484	2516.3966	677.08646	
57	Optimized	128.09325	577.92905	1251.0806	2321.341	617.91517	
58	Optimized	130.0862	579.949	1156.8469	2132.6623	563.38726	
59	Optimized	131.13135	581.0095	1107.3098	2022.6269	528.45859	
60	Optimized	132.385	582.31055	1046.1593	1915.8858	502.1368	
61	Optimized	134.795	584.81165	928.51821	1711.8421	452.25225	
62	Optimized	136.19065	586.26005	858.48375	1593.1701	424.17138	
63	Optimized	137.33075	587.52155	786.43624	1459.0416	388.32887	
64	Optimized	139.2297	589.6489	664.82022	1280.8608	355.67118	
65	Optimized	140.8166	591.483	559.70401	1104.4066	314.48417	
66	Optimized	142.30745	593.28495	455.99209	944.84848	282.24137	
67	Optimized	144.13445	595.53555	326.23599	729.13535	232.61406	
68	Optimized	146.0815	597.97365	185.51447	505.36291	184.66458	
69	Optimized	147.80755	600.186	57.575028	296.20847	137.77508	
70	Optimized	149.62855	602.58965	-81.744293	103.03449	59.48699	

Slices of Slip Surface: 22334

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesiv Strengt (psf)
1	22334	16.11464	556.2216	1109.3679	1238.6284	37.064862	0
2	22334	18.300715	555.66855	1143.8951	1340.5303	56.384226	0
3	22334	20.562145	555.13925	1176.9325	1441.642	75.904227	0
4	22334	22.823575	554.65365	1207.2273	1535.4906	94.127975	0
5	22334	25.085	554.21125	1234.8142	1622.2479	111.0948	0
6	22334	27.346425	553.8116	1259.734	1702.1935	126.87323	0
7	22334	29.607855	553.4543	1282.0345	1775.4544	141.48588	0
8	22334	31.869285	553.13895	1301.7229	1842.1708	154.97093	0
9	22334	33.65	552.9165	1315.6035	9259.7333	2277.9426	0
10	22334	34.50158	552.81935	1324.8874	2811.7794	426.35943	0
11	22334	35.89272	552.6813	1355.6981	2886.7203	439.01357	0
12	22334	38.27184	552.4718	1406.7397	3012.7303	460.51037	0
13	22334	40.65096	552.30765	1454.9002	3131.3816	480.7233	0
14	22334	43.03008	552.1887	1500.2906	3242.7831	499.65167	0
15	22334	45.4092	552.1148	1542.8584	3347.0971	517.35713	0
16	22334	47.78832	552.0859	1582.6387	3444.3712	533.84321	0
17	22334	50.16744	552.10195	1619.5889	3534.7526	549.16437	0
18	22334	52.439185	552.15825	1652.303	3645.613	571.57247	0
19	22334	54.60356	552.251	1681.0305	3777.0124	601.01314	0
20	22334	56.767935	552.38115	1707.4551	3902.1224	629.31072	0
21	22334	58.93231	552.54875	1731.5079	4021.0202	656.5071	0
22	22334	61.096685	552.75395	1753.2169	4133.7939	682.61949	0
23	22334	63.26106	552.997	1772.6124	4240.3535	707.61337	0
24	22334	65.425435	553.27805	1789.588	4340.84	731.55975	0
25	22334	67.58981	553.5974	1804.1788	4435.2652	754.45189	0
26	22334	69.873	553.9772	1816.9233	4454.1439	756.21084	0
27	22334	72.275	554.42235	1827.4413	4398.117	737.1294	0
28	22334	74.677	554.916	1834.9568	4336.601	717.33491	0
29	22334	76.939	555.42435	1839.3346	4269.5464	696.85202	0
30	22334	79.069335	555.94475	1840.8245	4196.2676	675.41244	0
31	22334	81.208	556.5069	1839.8827	4117.7983	653.1818	0

32	22334	83.346665	557.10945	1836.4155	4035.0682	630.45351	0
33	22334	85.485335	557.7531	1830.3471	3948.0394	607.23851	0
34	22334	87.624	558.43845	1821.6934	3856.6354	583.51025	0
35	22334	89.762665	559.1662	1810.4312	3760.8833	559.28314	0
36	22334	91.458565	559.7704	1799.7767	3679.8765	539.10994	0
37	22334	93.10711	560.3908	1787.3308	3521.5609	1001.2582	0
38	22334	95.151065	561.19295	1769.924	3410.0435	946.92346	0
39	22334	97.19502	562.03665	1749.8888	3295.1223	892.14096	0
40	22334	99.716	563.14215	1721.1124	3174.2738	838.9831	0
41	22334	102.2591	564.31235	1688.6646	3134.4113	834.70223	0
42	22334	104.34725	565.33025	1658.4219	3175.0031	875.59858	0
43	22334	106.4354	566.3965	1625.2005	3208.2938	913.99934	0
44	22334	108.5236	567.51255	1588.9084	3234.1269	949.86731	0
45	22334	110.61175	568.67985	1549.3826	3252.4395	983.26036	0
46	22334	112.6999	569.90005	1506.5199	3263.0576	1014.1375	0
47	22334	115.03325	571.3321	1454.4028	3177.0418	994.5661	0
48	22334	117.61175	572.99355	1391.843	2995.7681	926.02656	0
49	22334	119.29675	574.1176	1348.5596	2876.3991	882.09852	0
50	22334	120.99625	575.3137	1301.0894	2759.4469	841.98306	0
51	22334	123.41	577.06645	1230.2008	2575.5569	776.7417	0
52	22334	125.63	578.7609	1159.8843	2384.1021	706.80247	0
53	22334	127.85	580.53535	1084.5808	2187.2938	636.65164	0
54	22334	130.07	582.39425	1004.0091	1984.9985	566.37449	0
55	22334	132.385	584.43025	913.87298	1783.0931	501.84446	0
56	22334	134.795	586.6582	813.3099	1580.1699	442.74682	0
57	22334	137.3635	589.17075	683.72999	1350.9786	385.23618	0
58	22334	140.0905	591.99785	523.30066	1093.6207	329.27444	0
59	22334	142.5215	594.6644	371.14052	841.86363	271.77212	0
60	22334	144.6565	597.14745	228.71848	597.86794	213.12854	0
61	22334	146.7915	599.76755	77.732098	346.2101	155.00585	0
62	22334	148.9393	602.55675	-83.728345	108.23197	62.487757	0

Alternative C – Upslope Wall Without Excavation

SLOPE/W Analysis

File Information

Created By: Lovullo, Vincent M LRB
Revision Number: 115
Last Edited By: Lovullo, Vincent M LRB
Date: 6/3/2009
Time: 1:00:01 PM
File Name: Cross-Section 2 STA. 16+00 (Option 1_C_2 Walls_CRITICAL).gsz
Directory: C:\Documents and Settings\h5tddvml\My Documents\vlovullo\Projects\Cuyahoga River Technical Assistance\Slope Stability Analysis\SLOPE_W\CRITICAL FAILURE\
Last Solved Date: 6/3/2009
Last Solved Time: 1:00:04 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf

Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Spencer
Settings
  Apply Phreatic Correction: No
  PWP Conditions Source: Piezometric Line
  Use Staged Rapid Drawdown: No
SlipSurface
  Direction of movement: Right to Left
  Use Passive Mode: No
  Slip Surface Option: Fully-Specified
  Critical slip surfaces saved: 1
  Optimize Critical Slip Surface Location: No
  Tension Crack
    Tension Crack Option: (none)
FOS Distribution
  FOS Calculation Option: Constant
Advanced
  Number of Slices: 60
  Optimization Tolerance: 0.01
  Minimum Slip Surface Depth: 0.1 ft
  Optimization Maximum Iterations: 8000
  Optimization Convergence Tolerance: 1e-007
  Starting Optimization Points: 8
  Ending Optimization Points: 32
  Complete Passes per Insertion: 1
  Driving Side Maximum Convex Angle: 5 °
  Resisting Side Maximum Convex Angle: 1 °

Materials

Fill, Sand, or Silt

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
  Piezometric Line: 1

Clay (Along probable failure)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 16 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

"Wall"

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 9e+006 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Limits

Left Coordinate: (-400, 579.5) ft
Right Coordinate: (592.5, 681) ft

Fully Specified Slip Surfaces

Fully Specified Slip Surface 1

	X (ft)	Y (ft)
	-2.5	552.6556
	0.95817	552.6438
	7.4429	552.5258
	13.92764	552.4079
	18.79671	552.3193
	23.56756	552.2662

	29.85585	552.219
	33.65	552.1906
	34.50158	552.1842
	37.4788	552.1618
	43.03008	552.1202
	48.58136	552.0786
	52.29171	552.0508
	57.08781	552.0567
	64.8106	552.0825
	72.275	552.1074
	76.49916	552.1216
	77.56016	552.1267
	81.80495	552.1549
	88.22095	552.1691
	94.5245	552.1422
	99.716	552.1201
	105.38205	552.096
	111.64655	552.3225
	116.3225	552.8671
	120.6005	553.3654
	123.746	553.7317
	128.186	554.1577
	133.59	554.6228
	138.727	555.0648
	144.744	555.5826
	150.81135	555.9941
	156.36605	556.2509
	162.85725	556.3803
	169.78555	556.333
	175.8	556.2429
	180.142	556.1779
	181.692	556.1546
	185.5	556.0975

	190.691	556.0198
	194.85385	555.9574
	198.81285	555.9864
	200.5	556.0865
	203	556.2349
	205.5	556.3833
	210.0005	556.6504
	217.376	557.0883
	225.12465	557.5482
	230.49915	558.3397
	231.59	558.9193
	232.65185	559.4836
	236.72435	561.6477
	243.8701	565.4449
	250.2356	568.8998
	255.0352	571.5997
	259.9936	574.3889
	264.8134	576.9439
	269.7228	579.378
	274.8604	581.9251
	278.8927	583.9164
	283.2464	586.0515
	289.0268	588.8862
	295.17375	591.8984
	301.68725	595.0882
	305.808	597.1062
	309.89305	599.416
	316.3351	603.1894
	323.81155	608.3485
	332.2815	614.8618
	340.50675	621.9634
	348.5283	629.6848
	355.5374	637.3214

	361.53395	644.8735
	364.9751	649.2073
	367.2462	652.0674
	369.6872	655.2559
	373.2495	660.4063
	376.91035	665.6993
	381.89535	672.9068
	386.5	679.122

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-400	574
	-262	574
	34.3	574
	136	600
	178.6	604
	181.7	604
	189.3	605
	231.5	617.5
	370.3	650
	395	650
	592.57566	650

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 200 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	404	681
	508	681

Point Loads

	Coordinate (ft)	Magnitude (lbs)	Direction (°)
Point Load 1	(33, 563)	46000	180
Point Load 2	(200, 581)	1.1e+005	180

Regions

	Material	Points
Region 1	Clay	6,5,8,67,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,3,69,70,4,7
Region 2	Clay (Along probable failure)	67,24,23,22,21,20,9,10,5,8
Region 3	Fill, Sand, or Silt	9,19,18,17,16,11,10
Region 4	Clay (Along probable failure)	39,40,1,68,69,3
Region 5	Clay	1,68,78,76,13,12
Region 6	Clay	71,79,77,14,15,2
Region 7	Clay (Along probable failure)	70,71,2,4
Region 8	"Wall"	79,77,75,72,76,78

Region 9	Fill, Sand, or Silt	76,13,12,1,41,42,43,44,45,46,47,48,49,50,51,52,53,54,74,73,55,56,57,58,59,60,61,
Region 10	Clay	78,68,71,79
Region 11	Clay (Along probable failure)	68,69,70,71

Points

	X (ft)	Y (ft)
Point 1	33	560
Point 2	592	560
Point 3	16	552
Point 4	592	552
Point 5	-400	552
Point 6	-400	480
Point 7	592	480
Point 8	-229	552
Point 9	-276	560
Point 10	-400	560
Point 11	-400	579.5
Point 12	78	570
Point 13	173	580
Point 14	312	586
Point 15	592.1663	586
Point 16	-322.104	579
Point 17	-306.28	577.924
Point 18	-294.333	577.662
Point 19	-284.593	574.338
Point 20	-274.834	559.087
Point 21	-258.818	556.964
Point 22	-246.827	555.288
Point 23	-236.786	554.222

Point 24	-224.823	552.673
Point 25	-213.832	550.799
Point 26	-203.748	549.553
Point 27	-180.828	546.001
Point 28	-169.823	544.569
Point 29	-158.823	543.829
Point 30	-138.506	542.84
Point 31	-126.654	542.58
Point 32	-104.621	542.026
Point 33	-81.824	542.998
Point 34	-71.577	543.677
Point 35	-59.088	544.288
Point 36	-48.829	545.565
Point 37	-38.539	547.126
Point 38	-15.825	549.924
Point 39	-5.495	552
Point 40	17.17	556.961
Point 41	33	573.5
Point 42	51.357	580
Point 43	68.672	590
Point 44	75.878	590.5
Point 45	90.832	591
Point 46	98.217	591
Point 47	101.215	591.5
Point 48	113.744	601.5
Point 49	118.901	602
Point 50	122.3	602.5
Point 51	131.18	602.5
Point 52	141.454	604
Point 53	181.684	604
Point 54	192.082	608.1
Point 55	214.001	613.708
Point 56	220.751	614.965
Point 57	231.68	619.5
Point 58	239.825	619.5

Point 59	252.556	625.5
Point 60	267.154	628
Point 61	304.944	640.1
Point 62	328.067	656.5
Point 63	365.418	675.705
Point 64	376.199	678
Point 65	394.561	680
Point 66	592.5	681
Point 67	-220	552
Point 68	200	560
Point 69	200	552
Point 70	201	552
Point 71	201	560
Point 72	200	610
Point 73	206	611.71
Point 74	205	611.46
Point 75	201	610
Point 76	200	581.1655
Point 77	201	581.2086
Point 78	200	565
Point 79	201	565

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	1	1.310	(161.164, 710.739)	204.199	(386.5, 679.122)	(-2.49999, 552.656)

Slices of Slip Surface: 1

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesiv Strengt (psf)
1	1	-0.7709105	552.6497	1332.2611	1423.494	26.160623	0
2	1	4.200535	552.5848	1336.3031	1511.5936	50.26375	0
3	1	10.68527	552.46685	1343.6714	1624.4689	80.517397	0

4	1	15.54882	552.3784	1349.1949	1709.1508	103.2157	0
5	1	17.983355	552.3341	1351.9535	1743.784	112.35559	0
6	1	21.182135	552.29275	1354.5386	1788.0404	124.30464	0
7	1	26.711705	552.2426	1357.66	1865.6375	145.66022	0
8	1	31.427925	552.20725	1359.8843	1932.2647	164.12742	0
9	1	33.325	552.19305	1360.7619	20477.888	5481.7477	0
10	1	33.975	552.18815	1361.0538	2831.766	421.71994	0
11	1	34.40079	552.18495	1362.8447	2843.5549	424.58681	0
12	1	34.60237	552.18345	1366.1976	2851.7968	425.9887	0
13	1	36.09098	552.17225	1390.6322	2922.4532	439.2426	0
14	1	40.25444	552.141	1458.9919	3121.8949	476.82978	0
15	1	45.80572	552.0994	1550.1395	3387.9522	526.98433	0
16	1	49.96918	552.0682	1618.5002	3587.3241	564.55118	0
17	1	51.824355	552.0543	1649.0214	3689.9181	585.2177	0
18	1	54.68976	552.05375	1694.7297	3896.7045	631.4061	0
19	1	60.949205	552.0696	1793.6423	4367.0503	737.91286	0
20	1	66.7413	552.08895	1884.7725	4804.4489	837.20375	0
21	1	70.4735	552.1014	1943.5363	4966.3893	866.78916	0
22	1	74.0765	552.11345	2000.2664	4999.1396	859.91304	0
23	1	76.18858	552.12055	2033.4421	5016.7146	855.43963	0
24	1	77.02966	552.12415	2046.7252	5017.5681	851.8755	0
25	1	77.78008	552.12815	2058.4304	5017.3957	848.46965	0
26	1	79.902475	552.14225	2091.4136	5024.6594	841.0947	0
27	1	85.01295	552.162	2171.7527	5051.1096	825.64231	0
28	1	89.526475	552.16355	2243.5978	5081.0509	813.62658	0
29	1	92.67825	552.1501	2294.7385	5087.834	800.90724	0
30	1	96.37075	552.13435	2354.6167	5089.1895	784.12611	0
31	1	98.9665	552.1233	2396.7088	5106.49	777.01726	0
32	1	100.4655	552.1169	2421.0581	5139.7785	779.58054	0
33	1	103.29855	552.10485	2466.9505	5375.4564	834.00064	0
34	1	108.51435	552.20925	2543.633	5824.433	940.75427	0
35	1	112.6953	552.44465	2595.675	6055.5174	992.09383	0
36	1	115.03325	552.71695	2615.9796	6140.7665	1010.7164	0
37	1	117.61175	553.01725	2638.3963	6133.8255	1002.2982	0
38	1	119.75075	553.2664	2656.9413	6133.2913	996.82731	0

39	1	121.45025	553.46435	2671.7359	6139.7382	994.43367	0
40	1	123.023	553.6475	2685.3793	6132.1416	988.34318	0
41	1	125.966	553.9447	2713.8882	6136.2347	981.34206	0
42	1	129.683	554.28655	2751.7514	6112.6737	963.72896	0
43	1	132.385	554.5191	2780.3444	6104.8183	953.27757	0
44	1	134.795	554.7265	2805.8564	6122.6051	951.06238	0
45	1	137.3635	554.9475	2819.2494	6141.9559	952.77073	0
46	1	140.0905	555.18215	2820.5982	6162.7743	958.35357	0
47	1	143.099	555.44105	2822.0619	6155.365	955.80927	0
48	1	147.7777	555.78835	2827.8549	6149.3552	952.42489	0
49	1	153.58875	556.1225	2841.0435	6151.9974	949.40078	0
50	1	159.61165	556.3156	2864.2324	6183.2979	951.72674	0
51	1	166.3214	556.35665	2900.9328	6236.3056	956.40275	0
52	1	171.3928	556.3089	2933.7028	6261.6434	954.27161	0
53	1	174.4	556.26385	2954.133	6267.8685	950.19837	0
54	1	177.2	556.22195	2973.1309	6273.2251	946.28679	0
55	1	179.371	556.18945	2983.3877	6277.7004	944.62895	0
56	1	180.913	556.1663	2984.8123	6281.2627	945.24192	0
57	1	181.688	556.15465	2985.5376	6283.165	945.57943	0
58	1	181.696	556.15455	2985.5395	6283.5439	945.68754	0
59	1	183.6	556.126	3002.8205	6386.1245	970.14682	0
60	1	187.4	556.06905	3037.8173	6590.3138	1018.662	0
61	1	189.9955	556.0302	3068.5991	6729.7269	1049.8115	0
62	1	191.3865	556.00935	3095.5551	6803.838	1063.333	0
63	1	193.4679	555.97815	3136.0011	6890.2924	1076.5257	0
64	1	196.83335	555.9719	3198.7019	6950.559	1075.8277	0
65	1	199.40645	556.0216	3243.0851	26726.358	6733.72	0
66	1	200.25	556.07165	3255.4749	7075.7566	1095.4481	0
67	1	200.75	556.10135	3262.8567	7088.1235	1096.8776	0
68	1	202	556.17555	3281.3731	6972.2254	1058.3349	0
69	1	204	556.29425	3310.9211	7022.6366	1064.3173	0
70	1	205.25	556.36845	3329.3397	7053.3846	1067.8527	0
71	1	205.75	556.39815	3336.7287	7065.3678	1069.1701	0
72	1	208.00025	556.5317	3370.1481	7118.5833	1074.8465	0
73	1	212.00075	556.76915	3429.2815	7213.3937	1085.0767	0

74	1	215.6885	556.9881	3483.6435	7287.316	1090.6855	0
75	1	219.0635	557.18845	3533.6337	7339.9727	1091.4501	0
76	1	222.93785	557.4184	3590.9048	7464.3711	1110.6986	0
77	1	227.8119	557.94395	3648.065	7437.6863	1086.6564	0
78	1	230.99955	558.6056	3665.7567	6730.8184	878.89232	0
79	1	231.545	558.8954	3657.5506	6722.4516	878.84622	0
80	1	231.635	558.9432	3655.9245	6720.8925	878.86541	0
81	1	232.16595	559.22535	3646.0496	6691.3147	873.21571	0
82	1	233.13775	559.7418	3627.9953	6633.7111	861.87512	0
83	1	235.17395	560.82385	3590.3897	6346.3349	1591.1457	0
84	1	238.27465	562.47155	3532.6521	6169.61	1522.4484	0
85	1	241.84755	564.37015	3466.4569	6060.7873	1497.8374	0
86	1	247.05285	567.17235	3367.6919	5982.6202	1509.7296	0
87	1	251.3958	569.55245	3282.6072	5893.6986	1507.5143	0
88	1	253.7956	570.9024	3233.4623	5824.8516	1496.1393	0
89	1	257.5144	572.9943	3157.2895	5664.9107	1447.7758	0
90	1	262.4035	575.6664	3061.8857	5520.4867	1419.4739	0
91	1	265.9837	577.52415	2998.3238	5443.0768	1411.4788	0
92	1	268.4384	578.7412	2958.2499	5372.8339	1394.0607	0
93	1	272.2916	580.65155	2895.3637	5290.5827	1382.8803	0
94	1	276.87655	582.92075	2820.6502	5196.5783	1371.7427	0
95	1	279.6244	584.27525	2776.3598	5144.5975	1367.3026	0
96	1	281.80125	585.3428	2741.5597	5101.9632	1362.7796	0
97	1	286.1366	587.46885	2672.2356	5019.8391	1355.3895	0
98	1	292.10025	590.3923	2576.945	4907.444	1345.5142	0
99	1	298.4305	593.4933	2475.9325	4788.3379	1335.0679	0
100	1	303.31565	595.88565	2398.0339	4695.9659	1326.7117	0
101	1	305.376	596.89465	2365.1804	4674.23	1333.1305	0
102	1	307.85055	598.2611	2316.0781	4587.8334	1311.5985	0
103	1	313.1141	601.3027	2203.1052	4609.5368	1389.354	0
104	1	320.07335	605.76895	2026.1565	4469.4338	1410.6268	0
105	1	325.9393	609.9847	1848.7996	4320.6402	1427.1178	0
106	1	330.17425	613.24135	1707.4677	4236.9757	1460.4121	0
107	1	336.39415	618.4126	1475.6861	3895.0713	1396.8327	0
108	1	344.51755	625.8241	1131.8514	3435.4323	1329.973	0

109	1	352.03285	633.5031	762.5051	2915.5174	1243.0422	0
110	1	358.5357	641.09745	383.63507	2352.9341	1136.9753	0
111	1	363.0331	646.7615	95.907296	2033.2131	1118.504	0
112	1	364.75365	648.9284	-14.168092	1914.6298	1105.412	0
113	1	365.19655	649.4862	-42.503554	1890.8409	1091.6775	0
114	1	366.3321	650.91625	-115.14642	1809.5798	1044.7614	0
115	1	368.4667	653.66165	-255.27966	1615.1525	932.50874	0
116	1	369.9936	655.6989	-360.08715	1420.0751	819.88072	0
117	1	371.77475	658.2741	-516.31142	1271.4055	734.04633	0
118	1	374.72425	662.53855	-782.41107	1025.2596	591.93388	0
119	1	376.55465	665.18505	-947.51825	870.03111	502.31269	0
120	1	379.40285	669.30305	-1204.5467	612.26937	353.49389	0
121	1	384.1977	676.0144	-1623.2547	200.12729	115.54354	0

Alternative C – Upslope Wall With Excavation

SLOPE/W Analysis

File Information

Created By: Lovullo, Vincent M LRB
Revision Number: 198
Last Edited By: Lovullo, Vincent M LRB
Date: 6/4/2009
Time: 10:11:30 AM
File Name: Cross-Section 2 STA. 16+00 (Option 5_C_2 Walls_CRITICAL).gsz

Directory: C:\Documents and Settings\h5tddvml\My Documents\vlovullo\Projects\Cuyahoga River Technical Assistance\Slope Stability Analysis\SLOPE_W\CRITICAL FAILURE\
Last Solved Date: 6/4/2009
Last Solved Time: 10:11:32 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Spencer
Settings
- Apply Phreatic Correction: No
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Fully-Specified
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 60
- Optimization Tolerance: 0.01
- Minimum Slip Surface Depth: 0.1 ft
- Optimization Maximum Iterations: 8000
- Optimization Convergence Tolerance: 1e-007
- Starting Optimization Points: 8
- Ending Optimization Points: 32
- Complete Passes per Insertion: 1
- Driving Side Maximum Convex Angle: 5 °
- Resisting Side Maximum Convex Angle: 1 °

Materials

Fill, Sand, or Silt

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay (Along probable failure)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 16 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

"Wall"

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 9e+006 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Limits

Left Coordinate: (-400, 579.5) ft
Right Coordinate: (592.5, 681) ft

Fully Specified Slip Surfaces

Fully Specified Slip Surface 1

	X (ft)	Y (ft)
	-4.66018	552.1827
	-1.39479	552.1058
	6.03113	552.1478
	13.45704	552.1898
	17.92189	552.2151
	22.22392	552.1779
	29.32419	552.0948
	32.93716	552.0542
	33.65	552.0635
	34.37105	552.0729
	38.73609	552.0645
	47.19354	552.046
	54.78744	552.0294
	61.64831	552.0144
	66.87537	552.029
	71.663	552.0878
	75.266	552.1266
	76.939	552.1323
	83.48483	552.1549
	89.90082	552.1619
	94.18606	552.1076
	97.87856	552.0631
	99.716	552.0526
	104.84355	552.0234
	111.10805	552.4064
	116.3225	553.2052
	119.49455	553.6911
	121.19405	553.9465
	126.74	554.7715

	133.59	555.7905
	138.40695	556.5071
	141.13395	556.9042
	146.94125	557.6135
	155.7852	558.5211
	162.49865	558.9959
	169.4277	559.2451
	175.8	559.2661
	180.142	559.2804
	181.692	559.2855
	183.4343	559.2913
	187.3343	559.3138
	194.75	559.3713
	200.5	559.4159
	205.8417	559.4574
	214.2266	559.4786
	221.31295	559.4458
	228.3993	559.4131
	235.48565	559.3804
	241.84725	559.3408
	247.7792	559.2875
	254.0062	559.2271
	261.80985	559.092
	270.57245	558.8959
	278.7173	558.7136
	286.95285	558.6639
	295.2791	558.7469
	303.60535	558.8299
	308.97855	559.4357
	311.0943	560.4224
	314.13245	561.8392
	320.88615	564.861
	330.1286	568.9155

	338.68655	572.876
	346.60565	576.6876
	354.57035	580.4443
	362.298	584.1613
	369.2014	587.5503
	375.51755	590.6511
	382.15705	594.0756
	389.11995	597.8238
	395.0507	601.1119
	402.25	605.268
	408.21195	608.7098
	413.19975	611.8489
	420.7514	616.7277
	428.30305	621.6064
	432.28945	624.331
	433.75	626.3095
	439.7868	634.4874
	447.6016	645.486
	452.56255	652.8816
	458.75085	662.0809
	466.86115	674.3126
	470.5	680.2254

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-400	574
	-262	574
	34.3	574
	136	600

	178.6	604
	181.7	604
	189.5	603.5
	266.5	603.5
	397.5	646.5
	407	650
	592.57566	650

Point Loads

	Coordinate (ft)	Magnitude (lbs)	Direction (°)
Point Load 1	(33, 563)	46000	180
Point Load 2	(200, 578)	85000	180

Regions

	Material	Points
Region 1	Clay	6,5,8,58,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,3,60,61,4,7
Region 2	Clay (Along probable failure)	58,24,23,22,21,20,9,10,5,8
Region 3	Fill, Sand, or Silt	9,19,18,17,16,11,10
Region 4	Clay (Along probable failure)	39,40,1,59,60,3
Region 5	Clay	1,59,67,65,13,12
Region 6	Clay	62,68,66,14,15,2
Region 7	Clay (Along probable	61,62,2,4

	failure)	
Region 8	"Wall"	68,66,64,63,65,67
Region 9	Fill, Sand, or Silt	65,13,12,1,41,42,43,44,45,46,47,48,49,50,51,52,53,54,69,55,56,57,15,14,66,64,63
Region 10	Clay	62,68,67,59
Region 11	Clay (Along probable failure)	62,59,60,61

Points

	X (ft)	Y (ft)
Point 1	33	560
Point 2	592	560
Point 3	16	552
Point 4	592	552
Point 5	-400	552
Point 6	-400	480
Point 7	592	480
Point 8	-229	552
Point 9	-276	560
Point 10	-400	560
Point 11	-400	579.5
Point 12	78	570
Point 13	173	580
Point 14	312	586
Point 15	592.1663	586
Point 16	-322.104	579
Point 17	-306.28	577.924
Point 18	-294.333	577.662
Point 19	-284.593	574.338
Point 20	-274.834	559.087

Point 21	-258.818	556.964
Point 22	-246.827	555.288
Point 23	-236.786	554.222
Point 24	-224.823	552.673
Point 25	-213.832	550.799
Point 26	-203.748	549.553
Point 27	-180.828	546.001
Point 28	-169.823	544.569
Point 29	-158.823	543.829
Point 30	-138.506	542.84
Point 31	-126.654	542.58
Point 32	-104.621	542.026
Point 33	-81.824	542.998
Point 34	-71.577	543.677
Point 35	-59.088	544.288
Point 36	-48.829	545.565
Point 37	-38.539	547.126
Point 38	-15.825	549.924
Point 39	-5.495	552
Point 40	17.17	556.961
Point 41	33	573.5
Point 42	51.357	580
Point 43	68.672	590
Point 44	75.878	590.5
Point 45	90.832	591
Point 46	98.217	591
Point 47	101.215	591.5
Point 48	113.744	601.5
Point 49	118.901	602
Point 50	122.3	602.5
Point 51	131.18	602.5
Point 52	141.454	604
Point 53	181.684	604
Point 54	266.5	604
Point 55	435	660

Point 56	435	680
Point 57	592.5	681
Point 58	-220	552
Point 59	200	560
Point 60	200	552
Point 61	201	552
Point 62	201	560
Point 63	200	603.5
Point 64	201	603.5
Point 65	200	581.1655
Point 66	201	581.2086
Point 67	200	565
Point 68	201	565
Point 69	432.5	659.1691
Point 70	432.5	680

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	1	1.302	(207.042, 712.236)	228.609	(470.5, 680.225)	(-4.66019, 552.183)

Slices of Slip Surface: 1

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	1	-3.027488	552.14425	1363.8053	1451.8253	25.239337	0
2	1	2.31817	552.1268	1364.9268	1525.0391	45.911456	0
3	1	9.744085	552.1688	1362.2355	1629.4038	76.609295	0
4	1	15.31352	552.2003	1360.2943	1707.6935	99.615104	0
5	1	17.545945	552.21295	1359.4855	1733.2044	107.16216	0
6	1	20.072905	552.1965	1360.5393	1774.3285	118.65213	0
7	1	25.774055	552.13635	1364.2914	1858.5345	141.72194	0
8	1	31.130675	552.0745	1368.1509	1936.9545	163.10181	0
9	1	32.96858	552.0546	1369.3933	1951.7753	166.99535	0

10	1	33.325	552.05925	1369.0989	17356.985	4584.4525	0
11	1	33.975	552.06775	1368.5761	2818.376	415.72345	0
12	1	34.335525	552.07245	1368.8492	2826.5014	417.97507	0
13	1	34.537105	552.0726	1372.0606	2847.2487	423.00335	0
14	1	36.719625	552.0684	1407.139	2948.2251	441.89932	0
15	1	42.964815	552.05525	1507.543	3241.2766	497.14011	0
16	1	49.27527	552.04145	1609.1145	3536.9536	552.79895	0
17	1	53.07222	552.03315	1670.19	3764.8144	600.62387	0
18	1	58.217875	552.0219	1752.9806	4155.7315	688.97773	0
19	1	64.26184	552.0217	1849.4264	4605.6307	790.32884	0
20	1	67.773685	552.04005	1904.3114	4853.6676	845.71428	0
21	1	70.1675	552.06945	1940.6424	4931.7571	857.68833	0
22	1	73.4645	552.1072	1990.892	4960.5782	851.54381	0
23	1	75.572	552.12765	2023.1907	4989.5131	850.57927	0
24	1	76.4085	552.1305	2036.3693	4994.5995	848.25886	0
25	1	77.4695	552.13415	2053.1458	4999.2177	844.77253	0
26	1	80.742415	552.14545	2104.7016	5011.9757	833.64743	0
27	1	86.692825	552.1584	2198.724	5039.2815	814.51676	0
28	1	90.36641	552.156	2257.4917	5076.9134	808.45617	0
29	1	92.50903	552.12885	2293.3648	5082.3876	799.73941	0
30	1	96.03231	552.08535	2352.2734	5086.6992	784.08397	0
31	1	98.04778	552.06215	2385.879	5079.6953	772.43939	0
32	1	98.9665	552.0569	2400.8955	5096.5161	772.95677	0
33	1	100.4655	552.04835	2425.3114	5130.0046	775.55829	0
34	1	103.02925	552.03375	2467.1162	5336.7558	822.85591	0
35	1	107.9758	552.2149	2534.6559	5708.0745	909.96313	0
36	1	112.42605	552.6083	2581.1677	5941.4257	963.53848	0
37	1	115.03325	553.0077	2597.8512	6035.8532	985.83123	0
38	1	117.61175	553.4027	2614.3382	6017.4593	975.82927	0
39	1	119.1978	553.64565	2624.4298	6008.0939	970.25009	0
40	1	120.34435	553.8188	2631.9342	6012.508	969.36393	0
41	1	121.74705	554.02875	2641.2192	6014.2024	967.18738	0
42	1	124.52	554.44125	2659.6971	5973.0127	950.07796	0
43	1	128.96	555.10175	2689.3254	5890.8079	918.01031	0
44	1	132.385	555.61125	2712.1879	5849.3261	899.55991	0

45	1	134.795	555.96975	2728.2742	5847.6796	894.47512	0
46	1	137.20345	556.32805	2732.1827	5846.4584	893.00419	0
47	1	139.77045	556.70565	2723.676	5851.0154	896.75015	0
48	1	141.294	556.92375	2718.9913	5890.9203	909.53601	0
49	1	144.19765	557.2784	2713.8068	5849.8257	899.23893	0
50	1	151.36325	558.0673	2706.6277	5784.7797	882.6459	0
51	1	159.14195	558.7585	2709.1243	5752.5617	872.69162	0
52	1	165.9632	559.1205	2726.4611	5767.1922	871.9156	0
53	1	171.21385	559.251	2749.0546	5808.5518	877.29671	0
54	1	174.4	559.2615	2767.0923	5807.826	871.91636	0
55	1	177.2	559.2707	2782.9137	5806.3975	866.97003	0
56	1	179.371	559.27785	2790.647	5805.7416	864.56447	0
57	1	180.913	559.28295	2790.3227	5805.4174	864.56447	0
58	1	181.688	559.2855	2790.235	5805.2188	864.53269	0
59	1	181.696	559.2855	2790.2347	5805.2181	864.53258	0
60	1	182.56715	559.2884	2786.5261	5805.1905	865.58811	0
61	1	185.3843	559.30255	2774.3127	5800.1597	867.64767	0
62	1	188.41715	559.3222	2761.0105	5795.1809	870.03435	0
63	1	192.125	559.35095	2754.9647	5792.3971	870.96972	0
64	1	197.375	559.39165	2752.2981	8733.4515	1715.0681	0
65	1	200.25	559.41395	2750.9175	5901.423	903.39291	0
66	1	200.75	559.41785	2750.7169	5901.0218	903.33538	0
67	1	203.42085	559.4386	2749.3646	5783.1249	869.91676	0
68	1	210.03415	559.468	2747.5493	5789.9133	872.38384	0
69	1	217.7698	559.4622	2747.9296	5805.0419	876.61284	0
70	1	224.85615	559.42945	2750.0467	5810.9696	877.7055	0
71	1	231.94245	559.39675	2752.0224	5816.8964	878.83849	0
72	1	238.66645	559.3606	2754.2853	5826.0946	880.82715	0
73	1	244.81325	559.31415	2757.161	5838.4856	883.55562	0
74	1	250.8927	559.2573	2760.7501	5848.7693	885.47524	0
75	1	257.908	559.15955	2766.8803	5876.882	891.77862	0
76	1	264.1549	559.0395	2774.2701	5903.4507	897.2781	0
77	1	268.53625	558.94145	2822.1639	6004.463	912.50959	0
78	1	274.6449	558.80475	2955.8519	6284.8523	954.5755	0
79	1	282.8351	558.68875	3130.76	6618.6238	1000.1289	0

80	1	291.116	558.7054	3299.4006	6936.2712	1042.8559	0
81	1	299.4422	558.7884	3464.7729	7279.0255	1093.7193	0
82	1	306.2919	559.1328	3583.5268	7301.1329	1066.0064	0
83	1	309.58355	559.71785	3614.4903	6708.9548	887.32341	0
84	1	310.64145	560.2112	3605.3906	6525.7651	1686.079	0
85	1	311.54715	560.6336	3597.573	6510.8946	1682.007	0
86	1	313.06625	561.342	3584.4337	6485.5473	1674.9588	0
87	1	317.5093	563.3501	3550.1218	6456.6346	1678.0759	0
88	1	325.50735	566.88825	3493.2317	6361.752	1656.141	0
89	1	334.4076	570.89575	3425.4667	6181.8952	1591.4248	0
90	1	342.64615	574.7818	3351.7078	6005.1289	1531.9534	0
91	1	350.58805	578.56595	3278.2566	5881.5347	1503.0033	0
92	1	358.4342	582.3028	3205.7864	5725.6348	1454.8352	0
93	1	364.1707	585.08065	3149.969	5602.022	1415.6935	0
94	1	367.6224	586.77515	3114.8575	5538.4087	1399.238	0
95	1	372.3595	589.1007	3066.8355	5456.3209	1379.57	0
96	1	378.83735	592.36335	2995.8692	5295.6783	1327.7954	0
97	1	385.63855	595.9497	2911.3569	5117.827	1273.9061	0
98	1	392.08535	599.46785	2823.9619	4946.431	1225.4081	0
99	1	396.27535	601.8189	2763.0203	4812.0017	1182.9799	0
100	1	399.875	603.89695	2713.0066	4718.954	1158.1343	0
101	1	404.625	606.63905	2651.1957	4596.6093	1123.185	0
102	1	407.606	608.35995	2598.3186	4517.8487	1108.2412	0
103	1	410.70585	610.27935	2478.5378	4349.6159	1080.2674	0
104	1	416.97555	614.2883	2228.4492	4107.9768	1085.1458	0
105	1	424.5272	619.16705	1924.0305	3835.9371	1103.8398	0
106	1	430.2962	622.9687	1686.7614	3578.9264	1092.442	0
107	1	432.3947	624.4736	1592.8589	2935.0081	774.89018	0
108	1	433.125	625.46285	1531.1065	2863.5612	769.29306	0
109	1	434.375	627.15615	1425.4519	2741.3889	759.75659	0
110	1	437.3934	631.2451	1170.3039	3812.0546	1525.2155	0
111	1	443.6942	639.9867	624.82629	2985.0514	1362.6766	0
112	1	449.1156	647.743	140.83662	2237.8732	1210.7246	0
113	1	451.59605	651.4408	-89.905411	1943.7045	1122.1983	0
114	1	455.6567	657.48125	-466.83377	1538.0133	887.97241	0

115	1	462.80605	668.19675	-1135.5104	807.63303	466.28715	0
116	1	468.6806	677.269	-1701.6202	191.10459	110.33429	0

Alternative D – Wall at Riverbank

SLOPE/W Analysis

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File Information

Created By: Lovullo, Vincent M LRB
Revision Number: 84
Last Edited By: Lovullo, Vincent M LRB
Date: 5/28/2009
Time: 8:55:04 AM
File Name: Cross-Section 2 STA. 16+00 (Option 1_D-Failure at bank).gsz
Directory: C:\Documents and Settings\h5tddvml\My Documents\vlovullo\Projects\Cuyahoga River Technical Assistance\Slope Stability Analysis\SLOPE_W\CRITICAL FAILURE\[1] Files for Submittal\
Last Solved Date: 5/28/2009
Last Solved Time: 8:56:38 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Spencer
Settings
Apply Phreatic Correction: No

PWP Conditions Source: Piezometric Line
Use Staged Rapid Drawdown: No
SlipSurface
Direction of movement: Right to Left
Use Passive Mode: No
Slip Surface Option: Entry and Exit
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: Yes
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 60
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 8000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 32
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Fill, Sand, or Silt

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay (Along probable failure)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 16 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay

Model: Mohr-Coulomb

Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (-10.99998, 550.8937) ft
Left-Zone Right Coordinate: (32.5, 559.904) ft
Left-Zone Increment: 25
Right Projection: Range
Right-Zone Left Coordinate: (53.99998, 581.5264) ft
Right-Zone Right Coordinate: (199.99996, 610.1258) ft
Right-Zone Increment: 45
Radius Increments: 30

Slip Surface Limits

Left Coordinate: (-400, 579.5) ft
Right Coordinate: (592.5, 681) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-400	574
	-262	574
	34.3	574
	136	600
	178.6	604
	181.7	604
	189.3	605
	231.5	617.5
	370.3	650
	395	650

	592.57566	650

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 200 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	404	681
	508	681

Point Loads

	Coordinate (ft)	Magnitude (lbs)	Direction (°)
Point Load 1	(33, 563)	57000	180

Regions

	Material	Points
Region 1	Clay	6,5,8,67,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,3,4,7
Region 2	Clay (Along probable failure)	67,24,23,22,21,20,9,10,5,8
Region 3	Fill, Sand, or Silt	9,19,18,17,16,11,10
Region 4	Clay (Along probable failure)	39,40,1,2,4,3
Region 5	Fill, Sand, or Silt	1,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,

Region 6	Clay	1,12,13,14,15,2

Points

	X (ft)	Y (ft)
Point 1	33	560
Point 2	592	560
Point 3	16	552
Point 4	592	552
Point 5	-400	552
Point 6	-400	480
Point 7	592	480
Point 8	-229	552
Point 9	-276	560
Point 10	-400	560
Point 11	-400	579.5
Point 12	78	570
Point 13	173	580
Point 14	312	586
Point 15	592.1663	586
Point 16	-322.104	579
Point 17	-306.28	577.924
Point 18	-294.333	577.662
Point 19	-284.593	574.338
Point 20	-274.834	559.087
Point 21	-258.818	556.964
Point 22	-246.827	555.288
Point 23	-236.786	554.222
Point 24	-224.823	552.673
Point 25	-213.832	550.799
Point 26	-203.748	549.553
Point 27	-180.828	546.001
Point 28	-169.823	544.569
Point 29	-158.823	543.829

Point 30	-138.506	542.84
Point 31	-126.654	542.58
Point 32	-104.621	542.026
Point 33	-81.824	542.998
Point 34	-71.577	543.677
Point 35	-59.088	544.288
Point 36	-48.829	545.565
Point 37	-38.539	547.126
Point 38	-15.825	549.924
Point 39	-5.495	552
Point 40	17.17	556.961
Point 41	33	573.5
Point 42	51.357	580
Point 43	68.672	590
Point 44	75.878	590.5
Point 45	90.832	591
Point 46	98.217	591
Point 47	101.215	591.5
Point 48	113.744	601.5
Point 49	118.901	602
Point 50	122.3	602.5
Point 51	131.18	602.5
Point 52	141.454	604
Point 53	181.684	604
Point 54	192.082	608.1
Point 55	214.001	613.708
Point 56	220.751	614.965
Point 57	231.68	619.5
Point 58	239.825	619.5
Point 59	252.556	625.5
Point 60	267.154	628
Point 61	304.944	640.1
Point 62	328.067	656.5
Point 63	365.418	675.705
Point 64	376.199	678

Point 65	394.561	680
Point 66	592.5	681
Point 67	-220	552

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.523	(51.849, 705.635)	84.74817	(157.377, 604)	(-5.35096, 552.032)
2	22487	1.763	(51.849, 705.635)	153.606	(167.024, 604)	(15.0593, 556.499)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Co St
1	Optimized	-4.217579	552.01565	1371.8245	1430.9339	16.949362	
2	Optimized	-1.3327835	552.00235	1372.6588	1472.2352	28.553082	
3	Optimized	2.1006865	552.0073	1372.3392	1522.3046	43.001878	
4	Optimized	5.240985	552.0111	1372.0941	1568.2545	56.248086	
5	Optimized	8.157475	552.01395	1371.9226	1610.9427	68.537914	
6	Optimized	11.073965	552.01685	1371.7512	1653.631	80.827742	
7	Optimized	13.990455	552.0197	1371.5798	1696.3193	93.11757	
8	Optimized	15.9586	552.02675	1371.1646	1721.5057	100.45871	
9	Optimized	16.81925	552.03805	1370.4289	1731.3516	103.49293	
10	Optimized	18.38868	552.06325	1368.8453	1745.2285	107.92616	
11	Optimized	20.82604	552.1024	1366.425	1771.6061	116.18383	
12	Optimized	23.29328	552.14165	1363.9632	1798.4903	124.59862	
13	Optimized	25.7904	552.1809	1361.5207	1825.6382	133.08355	
14	Optimized	28.52922	552.1983	1360.4324	1864.505	144.54049	
15	Optimized	31.50974	552.1939	1360.7008	1903.8269	155.73892	
16	Optimized	33.013195	552.1917	1360.8548	309912.49	88475.759	
17	Optimized	33.663195	552.1801	1361.5728	2796.7038	411.51719	
18	Optimized	34.50158	552.16485	1365.7228	2821.2208	417.35732	
19	Optimized	36.03872	552.1369	1391.9962	2894.864	430.94041	

20	Optimized	38.75814	552.064	1439.9374	3042.2911	459.46753
21	Optimized	42.11143	552.0153	1496.4482	3178.5847	482.34487
22	Optimized	45.29355	552.01445	1547.2627	3325.9118	510.01943
23	Optimized	47.71893	552.01295	1586.0607	3437.8943	531.00472
24	Optimized	50.14431	552.0115	1624.8588	3549.8767	551.99001
25	Optimized	51.659725	552.0106	1649.0707	3628.5402	567.60374
26	Optimized	53.416895	552.00925	1677.2016	3760.1933	597.28826
27	Optimized	56.325785	552.00695	1723.7485	3977.8019	646.3394
28	Optimized	59.23468	552.00465	1770.2954	4195.4104	695.39053
29	Optimized	62.143575	552.00235	1816.8424	4413.019	744.44167
30	Optimized	65.00248	552.11145	1855.6475	4525.1904	765.47911
31	Optimized	67.53947	552.4101	1877.4644	4577.1633	774.1262
32	Optimized	70.162115	552.84635	1892.0759	4617.0717	781.37996
33	Optimized	72.708675	553.2597	1906.9003	4599.2479	772.01826
34	Optimized	74.82156	553.5907	1919.9927	4577.5053	762.02948
35	Optimized	76.49114	553.85225	1930.2534	4557.6345	753.38941
36	Optimized	77.55214	554.0104	1937.3349	4561.8437	752.56579
37	Optimized	79.27724	554.2495	1949.9384	4539.5288	742.55311
38	Optimized	81.83172	554.60355	1968.5897	4506.1813	727.64268
39	Optimized	84.760975	554.94325	1994.1265	4517.7711	723.64344
40	Optimized	88.065005	555.2685	2026.5361	4490.9639	706.66327
41	Optimized	90.27451	555.4679	2049.3876	4508.5631	705.15725
42	Optimized	92.062835	555.58595	2070.5092	4496.1018	695.52748
43	Optimized	94.5245	555.74845	2099.6536	4475.8345	681.3589
44	Optimized	96.986165	555.911	2128.7575	4455.5671	667.20194
45	Optimized	98.767845	556.02865	2149.8286	4452.6342	660.31887
46	Optimized	100.26685	556.15285	2165.9956	4442.05	652.64811
47	Optimized	102.46105	556.3562	2188.3187	4560.1127	680.10099
48	Optimized	104.7409	556.7316	2201.2577	4577.6123	681.40871
49	Optimized	106.80855	557.2514	2201.8206	4710.2131	719.26998
50	Optimized	109.2015	558.13345	2184.9632	4625.151	699.71259
51	Optimized	111.98065	559.4057	2149.9035	4724.3837	738.22032
52	Optimized	113.57235	560.208	2125.2438	4161.687	1175.741
53	Optimized	115.1852	561.6382	2061.7109	4041.0333	1142.7623
54	Optimized	117.7637	563.94725	1958.7591	3811.8559	1069.8859

55	Optimized	120.5657	566.4875	1844.9509	3586.3413	1005.3922
56	Optimized	122.2652	568.0286	1775.9076	3444.4895	963.35619
57	Optimized	123.76485	569.404	1714.0169	3306.1323	919.20825
58	Optimized	126.6946	572.091	1593.0713	3034.709	832.32991
59	Optimized	129.3163	574.479	1485.8775	2802.0806	759.91024
60	Optimized	130.82655	575.84265	1424.8527	2665.0237	716.01306
61	Optimized	131.57505	576.5185	1394.6542	2603.7865	698.0929
62	Optimized	133.70875	578.4985	1305.1504	2421.1182	644.30427
63	Optimized	135.7237	580.3951	1218.9398	2235.7523	587.05695
64	Optimized	137.5925	582.24365	1117.3336	2077.1656	554.15922
65	Optimized	140.3195	584.99655	961.51729	1820.5718	495.97536
66	Optimized	142.7138	587.48195	820.46862	1591.0709	444.90741
67	Optimized	145.15975	590.0747	672.99346	1324.2857	376.02378
68	Optimized	147.53205	592.6447	526.54633	1074.4793	316.34926
69	Optimized	149.76825	595.1014	386.33351	829.74155	256.00175
70	Optimized	151.8683	597.44485	252.41494	603.25484	202.55751
71	Optimized	154.25275	600.2279	92.726273	326.29496	134.85094
72	Optimized	156.482	602.9196	-62.174474	86.482541	49.930718

Slices of Slip Surface: 22487

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesiv Strengt (psf)
1	22487	16.11464	556.24655	1107.836	1214.5049	30.586816	0
2	22487	18.489165	555.7006	1141.8688	1317.7572	50.435191	0
3	22487	21.1275	555.1378	1177.015	1427.6515	71.868867	0
4	22487	23.765835	554.6232	1209.0992	1529.978	92.010507	0
5	22487	26.404165	554.1563	1238.255	1624.9037	110.86972	0
6	22487	29.0425	553.7366	1264.4374	1712.5416	128.49182	0
7	22487	31.680835	553.3638	1287.6802	1793.0957	144.92554	0
8	22487	33.65	553.11155	1303.4459	9332.2599	2302.2254	0
9	22487	34.50158	553.01105	1312.9225	2762.9708	415.79466	0
10	22487	35.89272	552.8639	1344.3213	2841.3143	429.25583	0
11	22487	38.27184	552.6341	1396.585	2973.9134	452.29164	0
12	22487	40.65096	552.44155	1446.5511	3100.6088	474.29341	0

13	22487	43.03008	552.2862	1494.219	3221.4585	495.27798	0
14	22487	45.4092	552.1679	1539.5515	3336.5348	515.27667	0
15	22487	47.78832	552.0865	1582.5956	3445.9113	534.29717	0
16	22487	50.16744	552.042	1623.3185	3549.6721	552.37302	0
17	22487	52.593785	552.035	1662.4353	3684.9127	579.93605	0
18	22487	55.067355	552.0669	1699.921	3850.9528	616.79844	0
19	22487	57.540925	552.13865	1734.9211	4010.4296	652.49154	0
20	22487	60.0145	552.25035	1767.4078	4163.3799	687.03392	0
21	22487	62.488075	552.4021	1797.4	4309.6947	720.38891	0
22	22487	64.961645	552.59395	1824.8763	4449.7095	752.65879	0
23	22487	67.435215	552.82605	1849.8595	4583.3241	783.80836	0
24	22487	69.873	553.0941	1872.0317	4633.4636	791.82783	0
25	22487	72.275	553.39715	1891.4193	4601.5637	777.1214	0
26	22487	74.677	553.7388	1908.4189	4564.8904	761.73092	0
27	22487	76.939	554.09495	1922.2758	4521.5743	745.33686	0
28	22487	79.2832	554.50355	1934.1804	4466.0589	726.00448	0
29	22487	81.8496	554.99205	1944.6675	4399.6535	703.95591	0
30	22487	84.416	555.52595	1952.2829	4328.4636	681.35885	0
31	22487	86.9824	556.1058	1957.0313	4251.81	658.01722	0
32	22487	89.5488	556.7322	1958.8816	4170.1638	634.07498	0
33	22487	92.062835	557.391	1957.8685	4080.1668	608.55926	0
34	22487	94.5245	558.08085	1954.1044	3982.3535	581.59108	0
35	22487	96.986165	558.8152	1947.5633	3879.556	553.99	0
36	22487	99.45385	559.5968	1938.156	3795.8677	532.69027	0
37	22487	100.95285	560.08845	1931.357	3701.1502	1021.7906	0
38	22487	102.4679	560.6142	1922.7538	3745.8865	1052.5862	0
39	22487	104.9737	561.51335	1906.602	3845.5562	1119.4557	0
40	22487	107.4795	562.462	1887.3946	3937.0474	1183.3676	0
41	22487	109.9853	563.46115	1865.0266	4020.3901	1244.3997	0
42	22487	112.4911	564.51185	1839.4385	4095.5446	1302.5635	0
43	22487	115.03325	565.63205	1810.0837	4066.2017	1302.5704	0
44	22487	117.61175	566.8247	1776.7908	3934.4828	1245.744	0
45	22487	120.6005	568.2862	1733.2838	3783.4273	1183.6509	0
46	22487	123.41	569.72135	1688.5387	3624.9933	1118.0126	0
47	22487	125.63	570.9137	1649.5471	3473.9181	1053.3011	0

48	22487	127.85	572.1536	1607.5916	3318.9164	988.03384	0
49	22487	130.07	573.4424	1562.6078	3159.8731	922.18152	0
50	22487	132.64015	575.00225	1506.2507	2991.5905	857.56136	0
51	22487	135.05015	576.51735	1450.1802	2846.8205	806.35063	0
52	22487	137.3635	578.04325	1378.0789	2702.3018	764.54045	0
53	22487	140.0905	579.91415	1277.3143	2524.1035	719.83405	0
54	22487	142.67965	581.76995	1176.6904	2330.6155	666.21897	0
55	22487	145.1309	583.6056	1076.5098	2122.878	604.12096	0
56	22487	147.58215	585.51935	971.45174	1909.2467	541.43619	0
57	22487	150.03345	587.515	861.29115	1689.5788	478.21209	0
58	22487	152.48475	589.59675	745.76566	1463.6398	414.46485	0
59	22487	154.936	591.7693	624.53465	1231.2566	350.29106	0
60	22487	157.38725	594.038	497.32708	992.22369	285.72869	0
61	22487	159.83855	596.40885	363.75937	746.31737	220.86996	0
62	22487	162.28985	598.88865	223.38288	493.26251	155.81508	0
63	22487	164.7411	601.48525	75.71954	232.7768	90.677051	0
64	22487	166.4956	603.4069	-33.911529	50.457682	29.131756	0

Alternative D – Upslope Wall Without Excavation

SLOPE/W Analysis

File Information

Created By: Lovullo, Vincent M LRB
Revision Number: 207
Last Edited By: Lovullo, Vincent M LRB
Date: 7/27/2009
Time: 10:20:19 AM
File Name: Cross-Section 2 STA. 16+00 (Option 1_D_CRITICAL_at RB st).gsz
Directory: C:\Documents and Settings\h5tddvml\My Documents\vlovullo\Projects\Cuyahoga River Technical Assistance\Slope Stability Analysis\SLOPE_W\CRITICAL FAILURE\
Last Solved Date: 7/27/2009
Last Solved Time: 10:20:22 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Spencer
Settings
- Apply Phreatic Correction: No
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Fully-Specified
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced

Number of Slices: 60
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 8000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 32
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Fill, Sand, or Silt

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay (Along probable failure)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 16 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

"Wall"

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 9e+006 psf
Phi: 0 °
Phi-B: 0 °

Pore Water Pressure
Piezometric Line: 1

Slip Surface Limits

Left Coordinate: (-400, 579.5) ft
Right Coordinate: (592.5, 681) ft

Fully Specified Slip Surfaces

Fully Specified Slip Surface 1

	X (ft)	Y (ft)
	-4	552.3272
	-0.94654	552.1999
	6.30007	552.1948
	13.54669	552.1898
	17.67425	552.1869
	21.03229	552.1429
	26.73984	552.0557
	31.29681	552.0234
	33.03815	552.0349
	33.68814	552.0343
	39.0915	552.0266
	47.62	552.0168
	54.33196	552.0114
	60.28187	552.0067
	65.86011	552.0254
	68.5677	552.0494
	72.01891	552.1441
	75.62191	552.2385
	76.939	552.2509
	80.9056	552.2884
	87.32161	552.2885
	91.50657	552.2559
	95.19907	552.2061

	99.716	552.1394
	104.74175	552.0652
	111.00625	552.3747
	116.3225	553.0767
	120.6005	553.6416
	125.2445	554.2548
	129.6845	554.7999
	133.59	555.208
	138.727	555.7449
	145.37915	556.44
	152.89985	557.0347
	160.09095	557.4037
	168.34325	557.5889
	173.4191	557.5897
	176.2191	557.5873
	179.3	557.5839
	180.5	557.5826
	181.342	557.5817
	181.692	557.5813
	185.5	557.5772
	190.49695	557.5718
	191.88795	557.5722
	195.76515	557.6059
	202.22415	557.7508
	205.5	557.884
	210.0005	558.067
	216.3354	558.3246
	219.7104	558.5157
	223.43825	558.8604
	228.81275	559.3573
	231.59	559.614
	231.82795	559.636
	232.3278	559.8248

	236.25235	561.7781
	240.49795	563.891
	244.0172	565.5112
	249.70975	568.0819
	252.664	569.4159
	256.3675	571.3248
	263.5585	575.045
	268.2943	577.4951
	273.08215	579.7618
	280.37725	583.1155
	286.4496	585.9072
	292.52955	588.7032
	299.8399	592.0657
	304.21955	594.1299
	308.97215	596.6414
	316.767	601.2781
	324.30035	606.2941
	328.0977	608.8225
	331.169	611.1214
	337.2502	615.6781
	343.33135	620.2349
	349.4766	624.6528
	355.68595	628.9321
	361.8953	633.2115
	365.04655	635.3832
	367.69655	639.1009
	371.80685	644.9195
	374.274	648.5263
	378.50635	655.0214
	385.04635	665.0848
	391.5146	675.0634
	395	680

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-400	574
	-262	574
	34.3	574
	136	600
	178.6	604
	181.7	604
	189.3	605
	231.5	617.5
	370.3	650
	395	650
	592.57566	650

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 200 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	404	681
	508	681

Point Loads

	Coordinate (ft)	Magnitude (lbs)	Direction (°)
Point Load 1	(33, 563)	57000	180
Point Load 2	(180, 578)	1.45e+005	180

Regions

	Material	Points
Region 1	Clay	6,5,8,67,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,3,69,70,4,7
Region 2	Clay (Along probable failure)	67,24,23,22,21,20,9,10,5,8
Region 3	Fill, Sand, or Silt	9,19,18,17,16,11,10
Region 4	Clay (Along probable failure)	39,40,1,68,69,3
Region 5	Clay	1,68,78,84,13,12
Region 6	Clay	71,79,85,14,15,2
Region 7	Clay (Along probable failure)	70,71,2,4
Region 8	"Wall"	79,85,75,72,84,78
Region 9	Fill, Sand, or Silt	13,12,1,41,42,43,44,45,46,47,48,49,50,51,52,53,54,74,73,55,56,57,58,59,60,61,62,
Region 10	Clay	78,68,71,79
Region 11	Clay (Along probable failure)	68,69,70,71

Points

	X (ft)	Y (ft)

Point 1	33	560
Point 2	592	560
Point 3	16	552
Point 4	592	552
Point 5	-400	552
Point 6	-400	480
Point 7	592	480
Point 8	-229	552
Point 9	-276	560
Point 10	-400	560
Point 11	-400	579.5
Point 12	78	570
Point 13	173	580
Point 14	312	586
Point 15	592.1663	586
Point 16	-322.104	579
Point 17	-306.28	577.924
Point 18	-294.333	577.662
Point 19	-284.593	574.338
Point 20	-274.834	559.087
Point 21	-258.818	556.964
Point 22	-246.827	555.288
Point 23	-236.786	554.222
Point 24	-224.823	552.673
Point 25	-213.832	550.799
Point 26	-203.748	549.553
Point 27	-180.828	546.001
Point 28	-169.823	544.569
Point 29	-158.823	543.829
Point 30	-138.506	542.84
Point 31	-126.654	542.58
Point 32	-104.621	542.026
Point 33	-81.824	542.998
Point 34	-71.577	543.677
Point 35	-59.088	544.288

Point 36	-48.829	545.565
Point 37	-38.539	547.126
Point 38	-15.825	549.924
Point 39	-5.495	552
Point 40	17.17	556.961
Point 41	33	573.5
Point 42	51.357	580
Point 43	68.672	590
Point 44	75.878	590.5
Point 45	90.832	591
Point 46	98.217	591
Point 47	101.215	591.5
Point 48	113.744	601.5
Point 49	118.901	602
Point 50	122.3	602.5
Point 51	131.18	602.5
Point 52	141.454	604
Point 53	181.684	604
Point 54	192.082	608.1
Point 55	214.001	613.708
Point 56	220.751	614.965
Point 57	231.68	619.5
Point 58	239.825	619.5
Point 59	252.556	625.5
Point 60	267.154	628
Point 61	304.944	640.1
Point 62	328.067	656.5
Point 63	365	660
Point 64	365	680
Point 65	395	680
Point 66	592.5	681
Point 67	-220	552
Point 68	180	560
Point 69	180	552
Point 70	181	552

Point 71	181	560
Point 72	180	603
Point 73	206	611.71
Point 74	205	611.46
Point 75	181	603
Point 76	200	581.1655
Point 77	201	581.2086
Point 78	180	566
Point 79	181	566
Point 80	220	582.0287
Point 81	221	582.0719
Point 82	240	582.8921
Point 83	241	582.9352
Point 84	180	580.3022
Point 85	181	580.3453

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	1	1.530	(164.86, 711.918)	206.8	(395, 680)	(-4.00001, 552.327)

Slices of Slip Surface: 1

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesiv Strengt (psf)
1	1	-2.4732735	552.26355	1356.3604	1457.2399	28.926745	0
2	1	2.676765	552.19735	1360.484	1528.9904	48.318413	0
3	1	9.92338	552.1923	1360.7996	1636.4866	79.051996	0
4	1	15.358345	552.18855	1361.0479	1717.2415	102.13686	0
5	1	17.422125	552.1871	1361.1301	1741.5763	109.09117	0
6	1	19.35327	552.1649	1362.5233	1775.1393	118.31575	0
7	1	23.886065	552.0993	1366.6091	1844.1839	136.94236	0
8	1	29.018325	552.03955	1370.328	1915.1721	156.23151	0
9	1	32.148405	552.029	1370.9858	1950.3566	166.13191	0

10	1	33.019075	552.03475	1370.6386	340674.11	97293.704	0
11	1	33.363145	552.0346	1370.6358	2818.3498	415.12528	0
12	1	33.99407	552.03385	1370.688	2833.1617	419.35757	0
13	1	34.50158	552.03315	1373.959	2848.2248	422.73891	0
14	1	36.89733	552.02975	1412.3785	2958.7484	443.41443	0
15	1	43.35575	552.0217	1515.8575	3260.0083	500.12718	0
16	1	49.4885	552.0153	1614.1553	3545.6239	553.8397	0
17	1	52.84448	552.0126	1667.8538	3745.2592	595.68641	0
18	1	57.306915	552.00905	1739.1854	4082.7495	672.00618	0
19	1	63.07099	552.01605	1830.854	4511.0752	768.54105	0
20	1	67.213905	552.0374	1895.523	4812.2093	836.34636	0
21	1	68.61985	552.05085	1917.1108	4886.941	851.58509	0
22	1	70.345455	552.0982	1941.6875	4900.5875	848.4509	0
23	1	73.82041	552.1913	1991.3235	4923.3735	840.7518	0
24	1	75.749955	552.2397	2019.0839	4961.7085	843.78404	0
25	1	76.4085	552.2459	2029.2221	4964.8131	841.76717	0
26	1	77.4695	552.2559	2045.5267	4968.6772	838.1999	0
27	1	79.4528	552.27465	2075.9671	4974.9977	831.28363	0
28	1	84.113605	552.28845	2149.4667	5008.0969	819.69902	0
29	1	89.076805	552.27485	2229.4849	5043.4454	806.8902	0
30	1	91.169285	552.25855	2263.8919	5052.9914	799.7614	0
31	1	93.35282	552.231	2300.4542	5065.4835	792.85941	0
32	1	96.708035	552.1838	2356.9217	5073.4546	778.95329	0
33	1	98.9665	552.15045	2395.0031	5093.9091	773.89884	0
34	1	100.4655	552.12835	2420.3506	5129.3288	776.78702	0
35	1	102.9784	552.09125	2462.7077	5334.0758	823.35155	0
36	1	107.874	552.21995	2532.7874	5711.128	911.37448	0
37	1	112.3751	552.55545	2583.6543	5972.4463	971.72048	0
38	1	115.03325	552.90645	2604.1541	6078.7048	996.3114	0
39	1	117.61175	553.24695	2624.0319	6066.7858	987.19379	0
40	1	119.75075	553.5294	2640.5671	6062.1157	981.11328	0
41	1	121.45025	553.7538	2653.6371	6065.0395	978.2039	0
42	1	123.77225	554.0604	2671.564	6042.3062	966.54479	0
43	1	127.4645	554.52735	2701.3397	6000.4435	946.0028	0
44	1	130.43225	554.87805	2726.7794	5988.8591	935.38629	0

45	1	132.385	555.0821	2745.2188	5985.2537	929.06508	0
46	1	134.795	555.33395	2767.9523	5997.2094	925.97456	0
47	1	137.3635	555.6024	2778.412	6010.1668	926.6908	0
48	1	140.0905	555.8874	2776.5955	6024.4062	931.29473	0
49	1	143.4166	556.23495	2774.3423	6006.0494	926.6771	0
50	1	149.1395	556.73735	2776.5789	5988.9907	921.14426	0
51	1	156.49535	557.2192	2789.6438	5979.2563	914.60669	0
52	1	164.2171	557.4963	2817.5351	5998.1503	912.02673	0
53	1	170.67165	557.58925	2849.6269	6029.0975	911.69854	0
54	1	173.20955	557.58965	2864.4715	6029.8258	907.65075	0
55	1	174.8191	557.5885	2873.9275	6031.7836	905.50064	0
56	1	177.40955	557.586	2889.2423	6032.5902	901.34049	0
57	1	178.95	557.5843	2896.2841	6032.9966	899.43783	0
58	1	179.65	557.5835	2896.4269	48472.829	13068.823	0
59	1	180.25	557.58285	2896.3983	6151.1963	933.29832	0
60	1	180.75	557.58235	2896.3983	6151.1963	933.29832	0
61	1	181.171	557.5819	2896.4895	6033.6222	899.55832	0
62	1	181.513	557.5815	2896.5188	6033.9146	899.63378	0
63	1	181.688	557.5813	2896.4982	6034.2462	899.73477	0
64	1	181.696	557.5813	2896.4982	6034.4962	899.80646	0
65	1	183.6	557.57925	2912.3669	6132.102	923.2442	0
66	1	187.4	557.57515	2943.6827	6326.8388	970.10441	0
67	1	189.8985	557.57245	2970.5477	6454.6502	999.05032	0
68	1	191.19245	557.572	2994.4644	6517.5413	1010.2261	0
69	1	191.98495	557.57305	3009.0597	6540.3363	1012.5773	0
70	1	193.9236	557.5899	3043.747	6604.4234	1021.0075	0
71	1	198.9947	557.67835	3132.0499	6732.4756	1032.4054	0
72	1	203.6121	557.80725	3209.3729	6830.0995	1038.2267	0
73	1	205.25	557.87385	3235.5262	6874.9186	1043.579	0
74	1	205.75	557.89415	3243.5196	6888.1077	1045.0688	0
75	1	208.00025	557.98565	3279.3797	6947.1398	1051.7133	0
76	1	212.00075	558.14835	3343.0691	7052.04	1063.5303	0
77	1	215.1682	558.27715	3393.6573	7125.7088	1070.1485	0
78	1	218.0229	558.42015	3437.4569	7139.6749	1061.5939	0
79	1	220.2307	558.5638	3469.3442	7096.8643	1040.1747	0

80	1	222.09465	558.73615	3493.0341	7156.3715	1050.4451	0
81	1	226.1255	559.10885	3544.2847	7317.0117	1081.8121	0
82	1	230.15635	559.4815	3595.5036	7477.6634	1113.1914	0
83	1	231.545	559.60985	3613.0436	7533.1119	1124.0615	0
84	1	231.635	559.61815	3613.8093	7536.634	1124.8519	0
85	1	231.75395	559.62915	3614.8633	7537.3029	1124.7415	0
86	1	232.07785	559.7304	3613.2055	6953.7268	957.87907	0
87	1	232.5038	559.9124	3608.0893	6725.334	893.85554	0
88	1	234.4661	560.88905	3575.9267	6470.7483	1671.3261	0
89	1	238.0387	562.6671	3516.993	6275.2075	1592.4559	0
90	1	240.1615	563.72355	3482.1976	6175.3631	1554.8998	0
91	1	242.2576	564.7011	3451.7239	6240.3595	1610.0196	0
92	1	246.8635	566.79655	3388.3603	6251.9122	1653.2725	0
93	1	251.1329	568.7245	3330.4803	6248.8533	1684.9234	0
94	1	252.61	569.3915	3310.3742	6246.0654	1694.9221	0
95	1	254.51575	570.37035	3277.0824	6049.906	1600.8904	0
96	1	259.963	573.1849	3181.0756	5834.1335	1531.7437	0
97	1	265.35625	575.9751	3085.8266	5623.5064	1465.1301	0
98	1	267.72415	577.20015	3044.0045	5539.6661	1440.8709	0
99	1	270.68825	578.62845	2998.1283	5554.9001	1476.1529	0
100	1	276.72975	581.43865	2911.051	5468.6359	1476.6223	0
101	1	282.20105	583.95395	2834.1666	5372.4122	1465.4568	0
102	1	285.2372	585.3498	2791.339	5321.2078	1460.6204	0
103	1	289.48955	587.3052	2731.4537	5253.5542	1456.1354	0
104	1	296.1847	590.38445	2637.1416	5147.2729	1449.225	0
105	1	302.02975	593.0978	2553.2249	5033.5418	1432.0116	0
106	1	304.5818	594.3213	2514.085	4898.4383	1376.607	0
107	1	306.9581	595.57705	2470.5839	4923.3891	1416.1277	0
108	1	312.8696	598.95975	2345.8439	4889.0493	1468.3203	0
109	1	320.53365	603.7861	2156.565	4817.3008	1536.1765	0
110	1	326.18365	607.5481	2004.4162	4820.1099	1625.6416	0
111	1	328.08235	608.8123	1953.2783	4820.1578	1655.1937	0
112	1	329.63335	609.97195	1903.5643	4595.215	1554.0252	0
113	1	334.2096	613.39975	1756.5513	4295.4443	1465.8306	0
114	1	340.29075	617.9565	1560.9947	3898.5388	1349.5817	0

115	1	346.40395	622.44385	1370.4199	3543.2464	1254.4819	0
116	1	352.58125	626.79245	1189.2669	3196.0787	1158.6333	0
117	1	358.7906	631.0718	1012.9591	2822.24	1044.5888	0
118	1	363.44765	634.2813	880.71752	2541.9288	959.10076	0
119	1	365.0233	635.36715	835.99945	4337.9566	2021.8559	0
120	1	366.3716	637.24205	738.69237	3279.597	1466.992	0
121	1	368.9983	640.94365	546.08684	2950.8325	1388.3805	0
122	1	371.05345	643.85295	383.58672	2698.853	1336.7196	0
123	1	373.04045	646.7229	204.49083	2410.3648	1273.5619	0
124	1	374.75415	649.26315	45.979312	2137.8481	1207.741	0
125	1	376.87035	652.5107	-156.66744	1900.4251	1097.2109	0
126	1	381.7764	660.0531	-627.31319	1377.2078	795.13129	0
127	1	388.2805	670.0741	-1252.6468	684.4736	395.18102	0
128	1	393.2573	677.5317	-1718.0166	177.31215	102.37122	0

Alternative A – Slope Cutback Without Structural Walls

SLOPE/W Analysis

File Information

Created By: Lovullo, Vincent M LRB
Revision Number: 98
Last Edited By: Lovullo, Vincent M LRB
Date: 7/28/2009
Time: 7:41:20 AM
File Name: FLATTENED SLOPE 6H1V.gsz
Directory: C:\Documents and Settings\h5tddvml\My Documents\vlovullo\Projects\Cuyahoga River Technical Assistance\Slope Stability Analysis\SLOPE_W\CRITICAL FAILURE\[1] Files for Submittal\
Last Solved Date: 7/28/2009
Last Solved Time: 7:43:05 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Spencer
Settings
- Apply Phreatic Correction: No
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 60
- Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 8000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 32
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Fill, Sand, or Silt

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay (Along probable failure)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 16 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Clay

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (-12.43981, 550.6043) ft
Left-Zone Right Coordinate: (109.42633, 572.3505) ft
Left-Zone Increment: 25
Right Projection: Range
Right-Zone Left Coordinate: (279.73034, 600.4226) ft

Right-Zone Right Coordinate: (675.27699, 665.6226) ft
Right-Zone Increment: 60
Radius Increments: 30

Slip Surface Limits

Left Coordinate: (-400, 579.5) ft
Right Coordinate: (850, 681) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-400	574
	-262	574
	34.3	574
	104	574
	187.5	587
	268	598
	582	650
	850	650

Regions

	Material	Points	Area (ft^2)
Region 1	Clay	6,5,8,40,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,3,4,7	88595.987
Region 2	Clay (Along probable failure)	40,23,22,21,20,19,9,10,5,8	1193.3773
Region 3	Fill, Sand, or Silt	9,18,17,16,15,11,10	2221.6569
Region 4	Clay (Along	38,1,2,4,3	6683.98

	probable failure)		
Region 5	Fill, Sand, or Silt	1,41,39,14,13,12	35621
Region 6	Clay	1,12,13,14,2	18602.75

Points

	X (ft)	Y (ft)
Point 1	34.5	560
Point 2	850	560
Point 3	16	552
Point 4	850	552
Point 5	-400	552
Point 6	-400	480
Point 7	850	480
Point 8	-229	552
Point 9	-276	560
Point 10	-400	560
Point 11	-400	579.5
Point 12	202.5	583
Point 13	312	586
Point 14	850	586
Point 15	-322.104	579
Point 16	-306.28	577.924
Point 17	-294.333	577.662
Point 18	-284.593	574.338
Point 19	-274.834	559.087
Point 20	-258.818	556.964
Point 21	-246.827	555.288
Point 22	-236.786	554.222
Point 23	-224.823	552.673
Point 24	-213.832	550.799
Point 25	-203.748	549.553

Point 26	-180.828	546.001
Point 27	-169.823	544.569
Point 28	-158.823	543.829
Point 29	-138.506	542.84
Point 30	-126.654	542.58
Point 31	-104.621	542.026
Point 32	-81.824	542.998
Point 33	-71.577	543.677
Point 34	-59.088	544.288
Point 35	-48.829	545.565
Point 36	-38.539	547.126
Point 37	-15.825	549.924
Point 38	-5.495	552
Point 39	850	681
Point 40	-220	552
Point 41	762.5	680

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.270	(171.83, 931.244)	130.4321	(350.37, 612.067)	(45.4992, 561.813)
2	32651	1.407	(171.83, 931.244)	379.173	(385.209, 617.809)	(70.3352, 565.907)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Coh Stre (p
1	Optimized	45.99288	561.727	765.83318	817.51462	29.838295	
2	Optimized	48.827475	561.2332	796.64617	924.33177	73.719313	
3	Optimized	53.50925	560.41755	847.54786	1102.2878	147.07416	
4	Optimized	57.91942	559.85665	882.53473	1188.4724	87.726213	
5	Optimized	63.763615	559.35985	913.53883	1326.726	118.47951	
6	Optimized	70.760575	558.66755	956.74196	1506.4756	157.63357	

7	Optimized	76.66737	557.9899	999.02305	1672.4264	193.0953
8	Optimized	82.03687	557.33175	1040.0975	1824.5609	224.94127
9	Optimized	87.669475	556.593	1086.2022	1998.8606	261.7006
10	Optimized	93.56519	555.77355	1137.3245	2180.1323	299.02034
11	Optimized	100.25653	554.79465	1198.418	2400.6389	344.73131
12	Optimized	104.72625	554.1151	1247.8551	2553.9066	374.50426
13	Optimized	108.67455	553.6012	1318.292	2691.8311	393.85599
14	Optimized	115.46575	552.875	1429.5347	2912.0875	425.11517
15	Optimized	121.2595	552.4436	1512.7947	3062.4502	444.35656
16	Optimized	125.70875	552.2262	1569.5899	3186.1425	463.53899
17	Optimized	130.4101	552.06955	1625.04	3282.8194	475.36059
18	Optimized	134.5516	552.02185	1668.2584	3360.123	485.13436
19	Optimized	139.3016	552.01925	1714.4858	3461.3847	500.91518
20	Optimized	145.472	552.0136	1774.774	3592.0091	521.08377
21	Optimized	150.8478	552.01075	1827.2508	3704.6625	538.33915
22	Optimized	155.42905	552.0107	1871.7583	3800.9244	553.17948
23	Optimized	160.0103	552.01065	1916.2657	3897.4045	568.08241
24	Optimized	164.59155	552.0106	1960.795	3993.6664	582.91648
25	Optimized	169.1728	552.01055	2005.3025	4090.1465	597.8194
26	Optimized	174.13615	552.0089	2053.6793	4195.2825	614.09484
27	Optimized	179.4817	552.0057	2105.6854	4308.0871	631.52853
28	Optimized	184.82725	552.0025	2157.8785	4421.0787	648.96221
29	Optimized	187.8012	552.0007	2186.6074	4483.4333	658.60422
30	Optimized	190.94405	552.06895	2209.0141	4508.9711	659.50204
31	Optimized	196.6273	552.20585	2248.9445	4602.9043	674.9871
32	Optimized	200.98445	552.34865	2277.2065	4641.2742	677.8855
33	Optimized	205.06865	552.54905	2299.601	4693.6902	686.49402
34	Optimized	210.20595	552.80115	2327.5975	4758.432	697.03059
35	Optimized	215.61955	553.12	2353.9042	4797.7631	700.76527
36	Optimized	221.3094	553.5056	2378.2779	4855.278	710.26837
37	Optimized	226.4635	553.9007	2397.6745	4877.9604	711.21055
38	Optimized	231.08195	554.3053	2411.6947	4912.6874	717.14813
39	Optimized	235.70045	554.7099	2425.9306	4947.4144	723.02386
40	Optimized	241.1704	555.2653	2437.9197	4949.8872	720.2951
41	Optimized	247.4918	555.97145	2447.667	4977.5569	725.43427

42	Optimized	251.28625	556.3953	2453.6168	4995.2129	728.79094
43	Optimized	254.5226	556.81585	2455.0451	4980.539	724.17372
44	Optimized	259.7278	557.5154	2455.6163	4997.104	728.75986
45	Optimized	265.1652	558.3218	2451.6684	4973.5138	723.12754
46	Optimized	271.9019	559.40685	2448.5264	4972.0749	723.61587
47	Optimized	278.91025	562.18855	2347.3793	4073.4208	996.5305
48	Optimized	285.37735	566.6623	2135.0562	3702.6494	905.0504
49	Optimized	292.2559	571.4051	1910.1223	3308.6778	807.45643
50	Optimized	298.872	575.9447	1695.224	2934.0979	715.26417
51	Optimized	304.47765	579.76375	1514.8945	2619.3119	637.63569
52	Optimized	309.49255	583.16725	1354.3369	2336.0137	566.7714
53	Optimized	312.7996	585.41165	1248.4562	2149.2135	520.05249
54	Optimized	315.57425	587.2827	1160.386	2001.2247	485.45845
55	Optimized	319.4904	589.91665	1036.4855	1791.8184	436.09168
56	Optimized	323.404	592.56405	911.73154	1578.0138	384.67825
57	Optimized	327.34895	595.24775	785.0352	1364.2544	334.41234
58	Optimized	332.22495	598.6082	625.73144	1091.5482	268.93945
59	Optimized	338.032	602.64535	433.81973	768.87696	193.44538
60	Optimized	343.1223	606.3797	253.4051	455.59672	116.73539
61	Optimized	347.49585	609.8113	84.467168	177.25765	53.572611
62	Optimized	350.02635	611.7968	-13.278459	19.046876	10.996719

Slices of Slip Surface: 32651

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesi Streng (psf)
1	32651	71.552405	565.5731	525.83813	597.22281	41.213967	0
2	32651	75.50994	564.51955	591.5844	800.16193	120.42229	0
3	32651	80.990535	563.1236	678.69019	1072.6146	227.43239	0
4	32651	86.471125	561.81425	760.39314	1328.5724	328.03847	0
5	32651	91.95172	560.59055	836.75575	1568.5246	422.48696	0
6	32651	97.019015	559.53165	902.82669	1715.6446	233.07177	0
7	32651	101.67301	558.6252	959.38058	1890.0013	266.85119	0
8	32651	106.6094	557.73145	1040.5058	2090.7139	301.14232	0
9	32651	111.82815	556.8576	1145.7337	2316.5934	335.73863	0

10	32651	117.0469	556.0584	1246.3005	2530.8636	368.34254	0
11	32651	122.26565	555.33335	1342.2514	2733.8957	399.04758	0
12	32651	127.4844	554.68205	1433.581	2925.5085	427.80333	0
13	32651	132.70315	554.10405	1520.3669	3106.1074	454.70378	0
14	32651	137.9219	553.59905	1602.5783	3275.7326	479.76926	0
15	32651	143.14065	553.1668	1680.2474	3434.8201	503.11562	0
16	32651	148.3594	552.80695	1753.3928	3583.0558	524.64743	0
17	32651	153.57815	552.51935	1822.0386	3720.903	544.4906	0
18	32651	158.7969	552.30385	1886.1948	3848.4548	562.66901	0
19	32651	164.01565	552.1603	1945.838	3965.6244	579.16442	0
20	32651	169.2344	552.08865	2001.0071	4072.7192	594.05387	0
21	32651	174.45315	552.08885	2051.7832	4169.6726	607.29501	0
22	32651	179.6719	552.1609	2097.9462	4256.8134	619.04523	0
23	32651	184.89065	552.30485	2139.6636	4333.9055	629.18875	0
24	32651	190	552.51475	2173.1005	4397.1424	637.73375	0
25	32651	195	552.78775	2198.8828	4446.674	644.54376	0
26	32651	200	553.12705	2220.2468	4487.3637	650.08531	0
27	32651	205.0815	553.54055	2237.7088	4518.0572	653.87937	0
28	32651	210.2445	554.0307	2251.1834	4538.7849	655.95918	0
29	32651	215.4075	554.5923	2260.1459	4550.1142	656.63783	0
30	32651	220.5705	555.2256	2264.7975	4552.2602	655.91939	0
31	32651	225.73355	555.93095	2264.7666	4545.0624	653.86429	0
32	32651	230.8966	556.70885	2260.2645	4528.7557	650.4794	0
33	32651	236.0596	557.5597	2251.1211	4503.0058	645.71754	0
34	32651	241.2226	558.484	2237.5561	4468.2572	639.64326	0
35	32651	246.3856	559.4823	2219.22	4424.1973	632.26705	0
36	32651	249.8098	560.1771	2205.0626	4348.2881	1237.3918	0
37	32651	253.54375	560.9923	2186.0505	4306.0721	1223.995	0
38	32651	259.32625	562.3161	2152.6582	4235.6532	1202.6177	0
39	32651	265.10875	563.73565	2113.3658	4153.8164	1178.0547	0
40	32651	270.75	565.2127	2074.3126	4063.6729	1148.5577	0
41	32651	276.25	566.7437	2035.5734	3965.7501	1114.388	0
42	32651	281.75	568.3645	1991.3722	3857.6312	1077.4851	0
43	32651	287.25	570.0763	1941.2795	3739.3313	1038.1057	0
44	32651	292.75	571.88045	1885.5719	3611.0545	996.20787	0

45	32651	298.25	573.77835	1824.0186	3472.5091	951.75642	0
46	32651	303.75	575.7715	1756.575	3323.7706	904.8208	0
47	32651	309.25	577.86145	1682.9054	3164.7677	855.55361	0
48	32651	314.7677	580.0573	1602.9116	2994.6562	803.52412	0
49	32651	320.3031	582.36165	1516.3113	2813.2664	748.79733	0
50	32651	325.83845	584.76975	1423.2555	2621.174	691.61854	0
51	32651	331.1437	587.17495	1327.9962	2432.4188	637.63865	0
52	32651	336.21885	589.5708	1230.93	2247.5134	586.92473	0
53	32651	341.294	592.05955	1128.0865	2053.9987	534.57567	0
54	32651	346.36915	594.6432	1019.3167	1851.363	480.38219	0
55	32651	351.44425	597.32395	904.47948	1639.6651	424.45964	0
56	32651	356.5194	600.10425	783.42591	1418.9291	366.90795	0
57	32651	361.59455	602.98655	656.02043	1188.9635	307.6948	0
58	32651	366.6697	605.9735	522.07617	949.64583	246.85746	0
59	32651	371.74485	609.0681	381.42806	700.87532	184.43296	0
60	32651	376.81995	612.2735	233.85357	442.49511	120.45925	0
61	32651	381.8951	615.59305	79.154894	174.36877	54.97176	0
62	32651	384.82105	617.5455	-12.441137	19.087203	11.020002	0

CUYAHOGA RIVER BULKHEAD TECHNICAL ASSISTANCE

APPENDIX B – STRUCTURAL DESIGN

1. GENERAL

This appendix documents the 30% level structural design of the proposed structural features of the Cuyahoga River Bulkhead Technical Assistance Study. The direction of the study was initially determined by the Project Delivery Team (PDT). The PDT determined the levels of stability to be provided and basic components of each alternative necessary to provide the required level of stability. The 30% level design presented in this appendix is a conceptual design performed and presented in only sufficient detail to size and cost estimate the various structural components of the alternatives considered. The alternatives in this study are conceptual and should only be used for planning purposes. Significantly more detailed investigation and design analyses beyond that presented in this study will be required in order to accurately determine the structural requirements and construction feasibility and costs of any stability improvements proposed for the study area.

2. DESCRIPTION OF EXISTING STUDY AREA

The existing project site consists of approximately 2500 feet of the west bank of the Cuyahoga River in Cleveland, Ohio from the Detroit/Superior Avenue Bridge to the Columbus Road Bridge. An overall plan of the study area is shown in the main section of this report.

3. PURPOSE OF STUDY

The purpose of the study is to determine possible alternatives to stabilize the west bank of the Cuyahoga River within the study area. The study involves three levels of stability as follows:

> <u>Case A</u> – Only provide acceptable stability for the west bank to assure navigation on the Cuyahoga River will not be affected by any future instability of the west bank. This case may include removal of existing soils and structures as part of the stability improvement features.
>
> <u>Case C</u> – Same as Case A, except also assures that Riverbed Road will not be affected by any future instability of the west bank. This case may include removal of existing soils and structures as part of the stability improvement features.
>
> <u>Case D</u> – Provides acceptable for the entire west bank of the Cuyahoga River within the study area from the Cuyahoga River up to and beyond the top of the existing slope along Detroit Avenue, West 25th Street and Franklin Avenue. This case provides stability improvements to the existing west bank without the removal of any existing infrastructure.

More detailed descriptions of the level of stability cases may be found in the main part of this report and the Geotechnical Appendix of this report.

4. DETERMINATION OF STABILITY COMPONENTS

The Buffalo District (LRB) Geotechnical Team performed slope stability analyses for each of the cases described above and determined the basic stability components for each case as follows:

> Case A – Components for this case includes upper and lower stability walls that provide sufficient lateral resistance to driving forces causes slope instability. Both walls are anchored near their tops. The upper stability wall is located along the approximate mid point of the existing slope. The lower stability wall is located along the Cuyahoga River, this wall is essentially a river bank bulkhead. Case A is divided into two sub-cases: with excavation along the existing slope and without excavation along the existing slope. The case with excavation also requires an anchored retaining wall at the very top of the slope. Figures 1 and 2 at the end of this appendix show details of the upper stability wall. Figure 4 at the end of this appendix shows details of the lower stability wall. Figure 5 at the end of this appendix shows details of the retaining wall at the top of the slope.
>
> Case C – Components for this case is similar to those described above for Case A and is also divided into two sub-cases: with excavation along the existing slope and without excavation along the existing slope. Details of components of Case C are shown on Figures 2, 3 and 5 at the end of this appendix.
>
> Case D - Components for this case would include upper and lower stability walls that provide sufficient lateral resistance to driving forces causes slope instability. Both walls would be anchored near their tops. The upper stability wall would be located along the approximate mid point of the existing slope. The lower stability wall would be located along the Cuyahoga River, this wall is essentially a river bank bulkhead. Figure 3 at the end of this appendix show details of the upper stability wall. Figure 4 at the end of this appendix shows details of the lower stability wall.

Overall cross sections of the entire slope with all components shown for the above cases are contained in the main part and Geotechnical Appendix of this report.

5. DESIGN PROCEDURES

5.1 Upper and Lower Stability Walls

The upper and lower stability walls were designed as anchored retaining walls using the Corps of Engineers computer program CWALSHT. This program computes penetration, bending moments, deflections, anchor forces and shear for both anchored and cantilever sheet pile walls. Both free earth and fixed earth methods are available for the analysis of anchored walls. The LRB Geotechnical Team performed slope stability analyses and determined the resultant lateral driving force and its vertical location from the existing soil mass acting about an assumed failure plane. This resultant lateral driving force was input into CWALSHT as a concentrated horizontal force at the elevation determined by the LRB Geotechnical Team. Only parameters for the soil below the failure plane were input into CWALSHT. Above the failure plane, the soil was replaced by vertical surcharges. U.S. Corps of Engineers design criteria, EM 1110-2-2504, typically requires the use of a safety factor of 1.5 to determine wall penetration and anchor forces for retaining walls and for the types of soil at the site. However, since the geotechnical analyses also included safety factors to determine the resultant lateral driving force, a safety factor of 1.2 was used in the CWALSHT analyses in order to avoid the excessive compounding of safety factors. A safety factor of 1.0 was used for the CWALSHT runs to determine the wall bending moments as recommended by EM 1110-2-2504 since safety factors are used in the calculations to size the wall members. Sample CWALSHT input and output are provided at the end of this appendix. A summary of all CWALSHT runs are presented on the Excel spreadsheet at the end of this appendix. The spreadsheet was used to size the steel members for the walls for the upper and lower stability walls and the rock anchor requirements for the upper stability walls. The very large magnitude of the anchor forces for the upper stability walls and the need to provide anchorage below the assumed failure plane required the use of rock anchors. The reinforced concrete wale for the upper stability wall was sized using the computer program GTSTRUDL. The lower stability wall is anchored to a steel sheet pile wall by a system of double channel wales and tierods. CWALSHT was used for the design of the wall members. Sizing of the double channel wales and tierods were performed using Mathcad.

5.2 Retaining Wall at Top of Slope

The steel sheet pile retaining wall at the top of the slope and its sheet pile anchor wall were designed using computer program CWALSHT. Sizing of the double channel wales and tierods were performed using Mathcad.

6. CONSTRUCTION MATERIALS

Details of construction and member sections and lengths for each of the cases are shown on the figures at the end of this appendix. All structural and sheet pile steel is ASTM A572 Grade 50 steel. Concrete has a minimum compressive strength of 4000 psi. Concrete steel reinforcement is Grade 60. Tierods are Grade 150 ksi treadbars. Rock anchors consist of 0.6” diameter Grade 270 ksi 7-wire strands with double corrosion protection. Grout for rock anchors has a minimum compressive strength of 4000 psi. Bolts for structural connections are ASTM A490 except ASTM A307 is used with double channel wales. All construction materials for the alternatives presented in this report are readily available.

7. GEOTECHNICAL PARAMETERS

The geotechnical parameters (unit weight - γ, angle of internal friction - ϕ, wall friction angle - δ, cohesion – c) used in the design of the walls were provided by the LRB Geotechnical Team and are shown in the sample CWALSHT input presented at the end of this appendix.

8. SAMPLE DESIGN CALCULATIONS

The following sample design calculations have been presented at the end of this appendix in the order shown below:

- Excel spreadsheet summary of CWALSHT results and sizing of wall members
- CWALSHT input data and results for Upper Stability Walls
- CWALSHT input data and results for Lower Stability Walls
- CWALSHT input data and results for Retaining Wall at Top of Slope
- Mathcad calculations of wale and tierod design

Since the design performed is only at the 30% level, all design calculations performed are not presented in this appendix.

9. MANUFACTURER'S LITERATURE

Manufacturer's literature is provided at the end of this appendix for the following main structural components of the stability improvement alternatives presented in this appendix:

- Steel sheet pile.
- Combi-wall systems.
- Strand Anchor System.
- Tie Back and Tie Rod Systems.

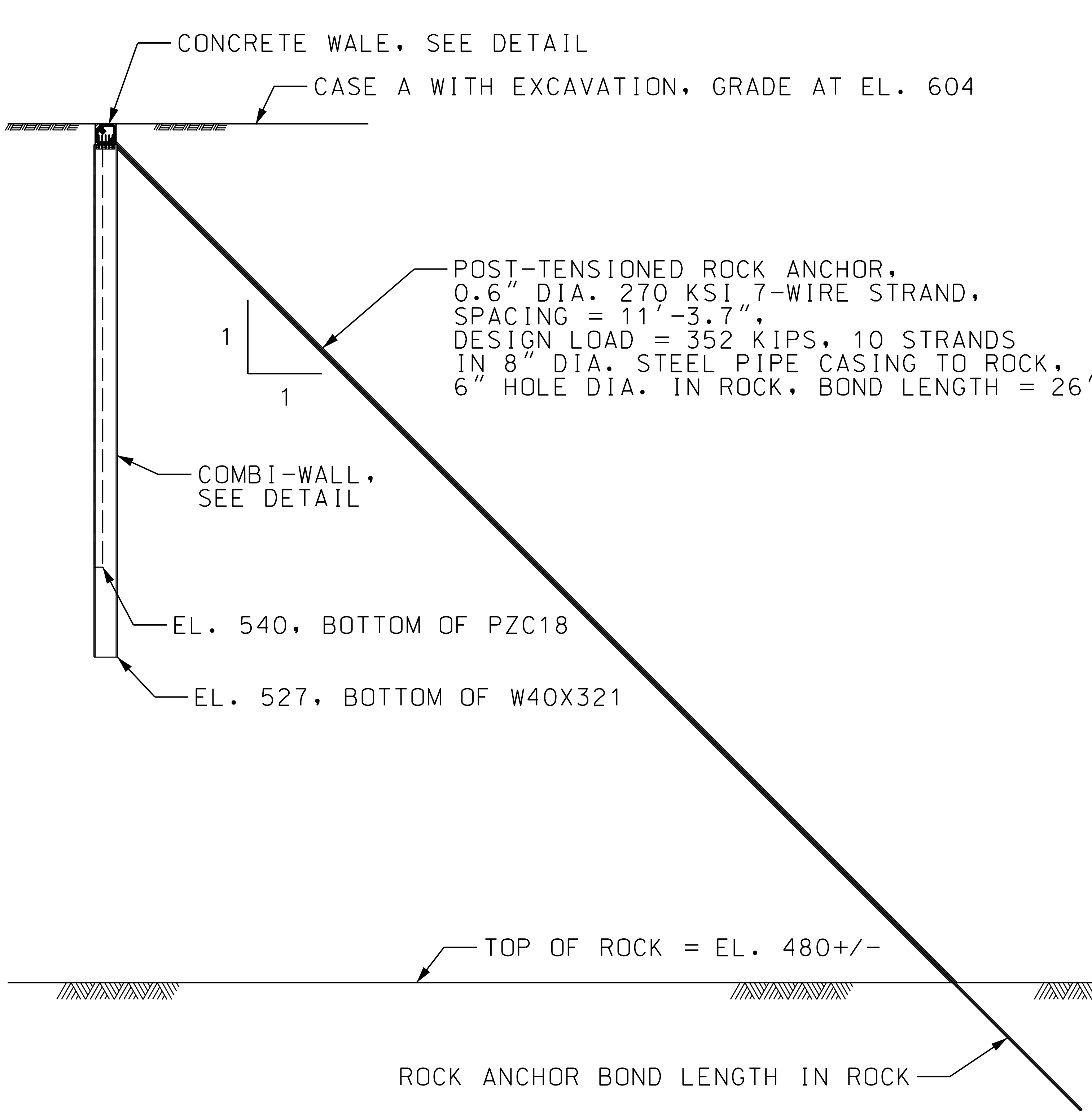
10. GREEN BULKHEAD

Figure 6 at the end of this appendix shows details of one possible version of a "Green Bulkhead" that may be included as part of the stability improvement alternatives presented in this study. The "Green Bulkhead" provides a shelf in front of the lower stability wall in the Cuyahoga River capable of supporting aquatic plant life and providing habitat for fish and other aquatic organisms. The "Green Bulkhead" was included in this study at the request of the local project partners.

11. REFERENCES

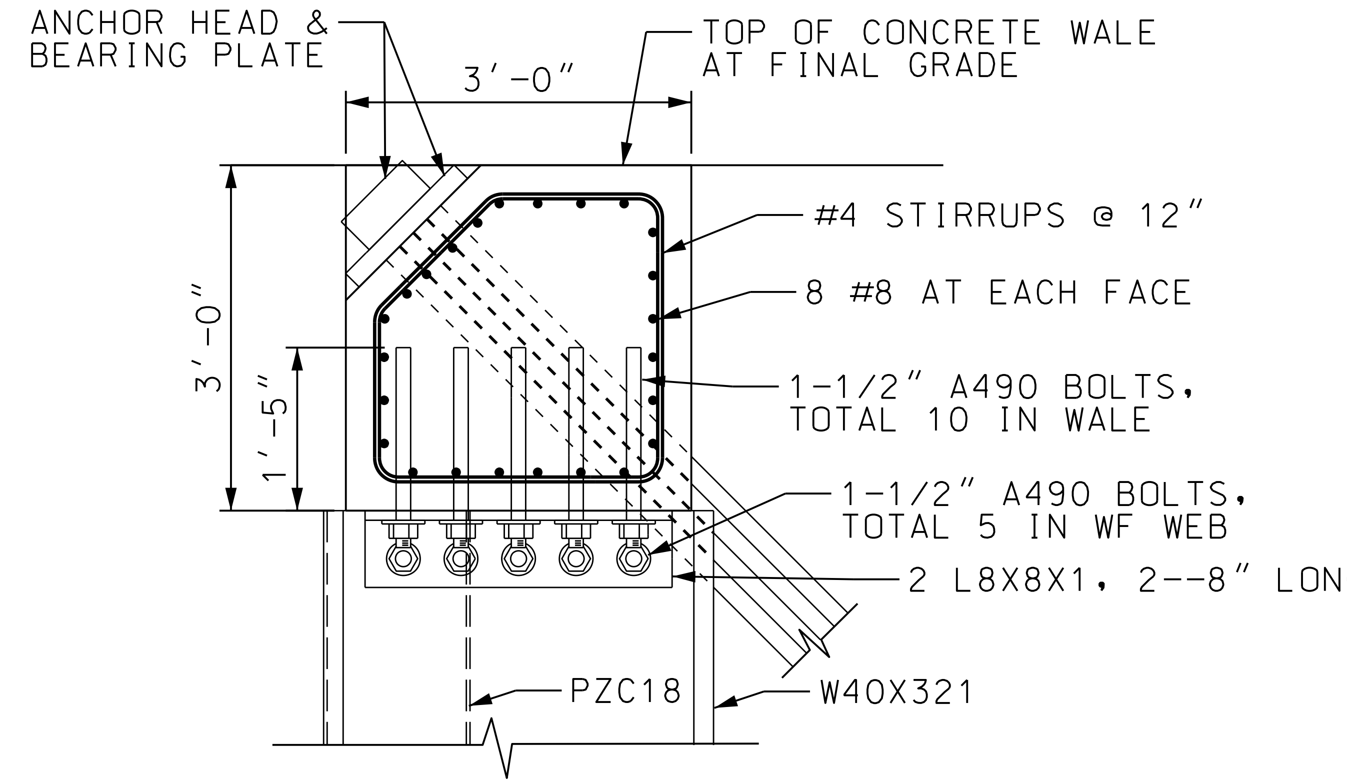
a. US Army Corps of Engineers, EM 1110-2-2104, Strength Design for Reinforced - Concrete Hydraulic Structures, 30 June 1992
b. US Army Corps of Engineers, EM 1110-2-2105, Design of Hydraulic Steel Structures, 31 May 1994
c. US Army Corps of Engineers, EM 1110-2-2504, Design of Sheet Pile Walls, 31 March 1994.
d. American Concrete Institute, Building Code Requirements for Reinforced Concrete (ACI 318-99).
e. American Institute of Steel Construction, Manual of Steel Construction, Allowable Stress Design, Ninth Edition, January 1990.
f. Post-Tensioning Institute, Recommendations for Prestressed Rock and Soil Anchors, 2004.

FIGURES



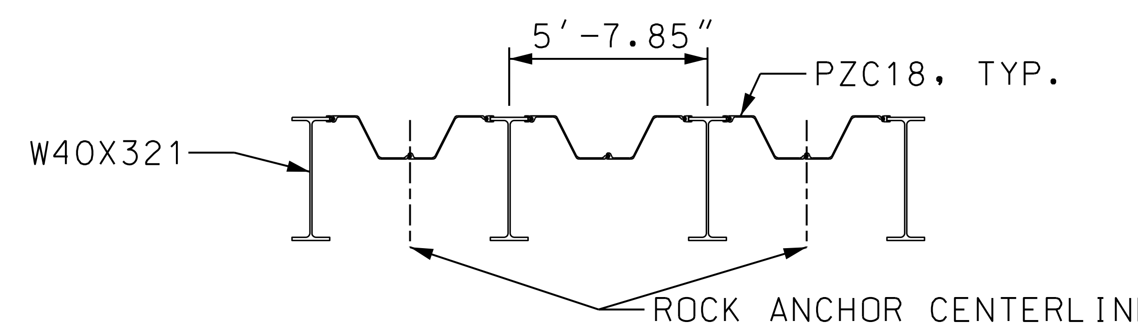
UPPER STABILITY WALL SECTION

NOT TO SCALE



CONCRETE WALE DETAIL

NOT TO SCALE



COMBI-WALL DETAIL

NOT TO SCALE

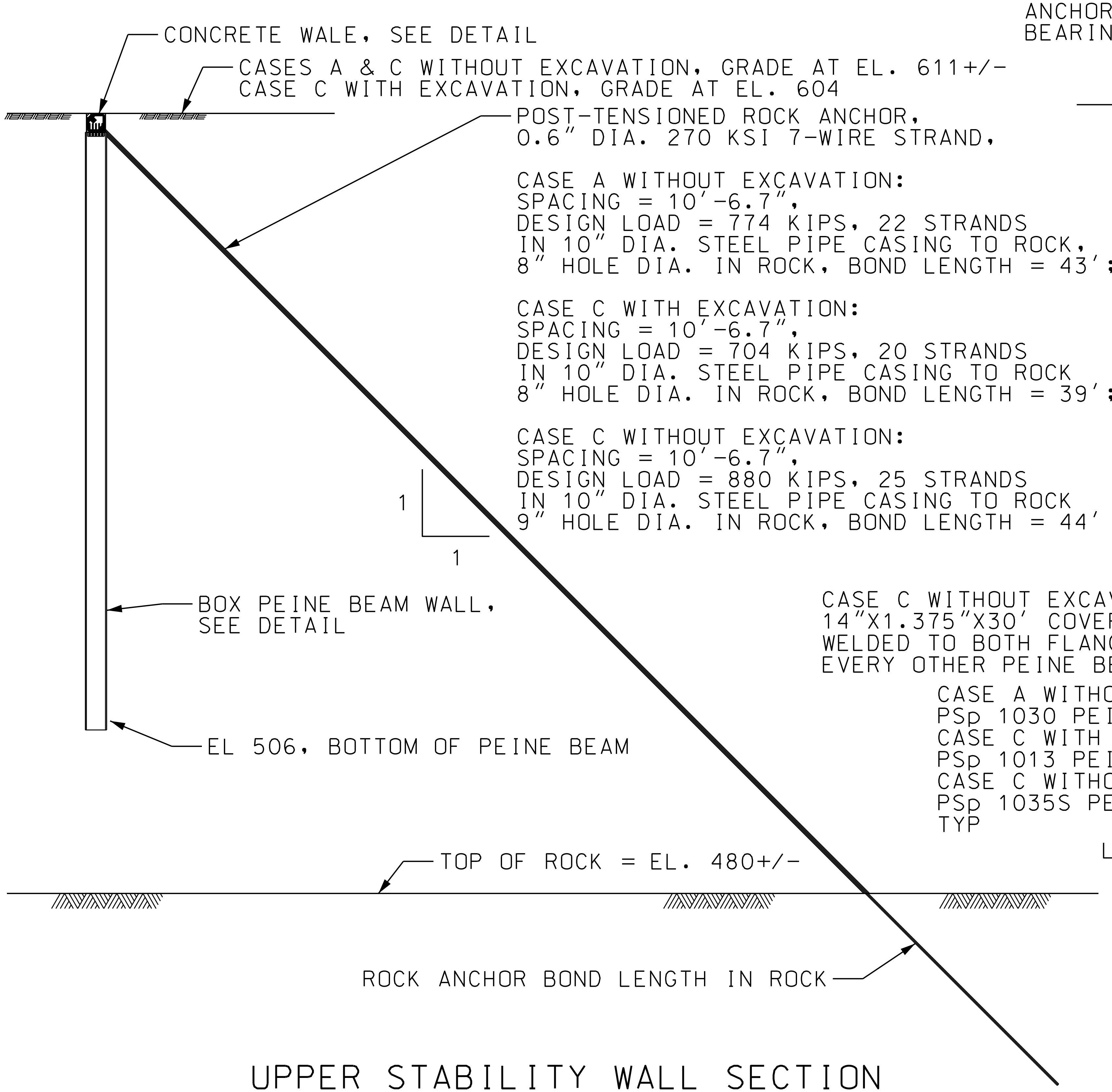
CONCEPTUAL

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

UPPER STABILITY WALL
SECTION & DETAILS
CASE A WITH EXCAVATION

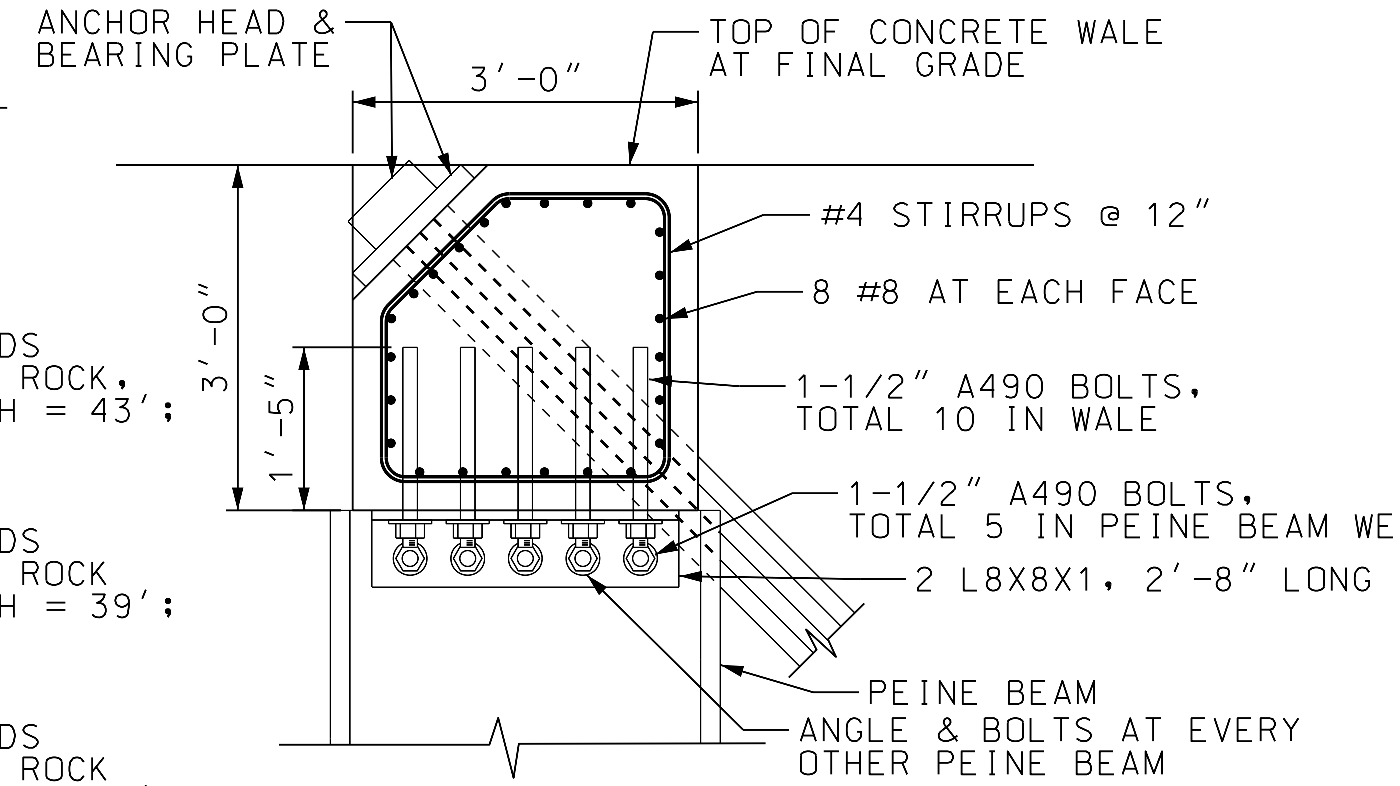
US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
JULY 2009

FIGURE 1



UPPER STABILITY WALL SECTION

NOT TO SCALE



CONCRETE WALE DETAIL

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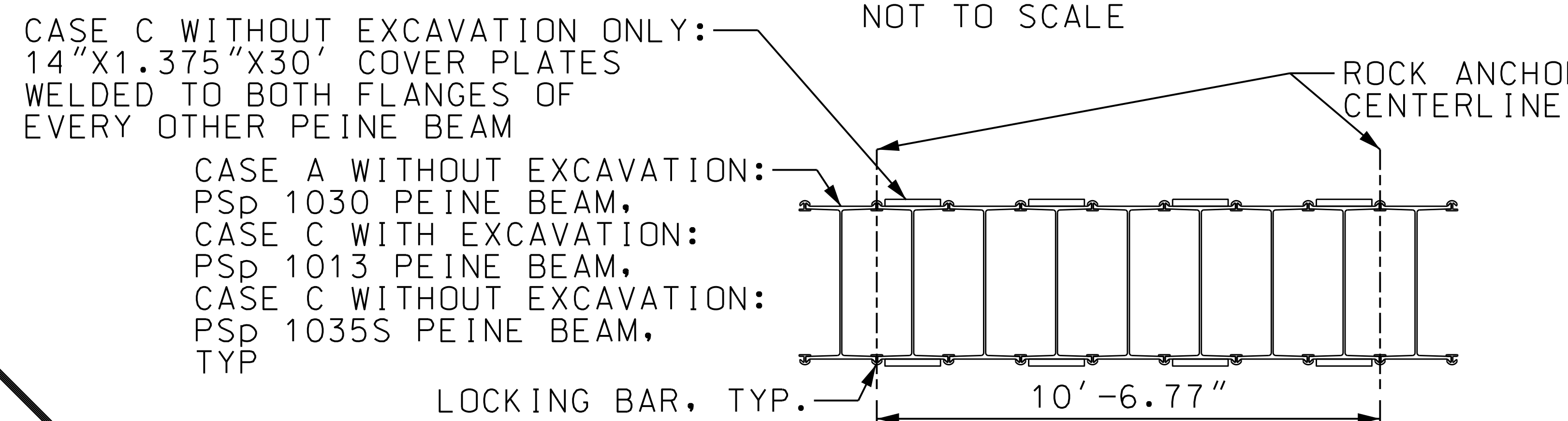


BOX PEINE BEAM WALL DETAIL

NOT TO SCALE

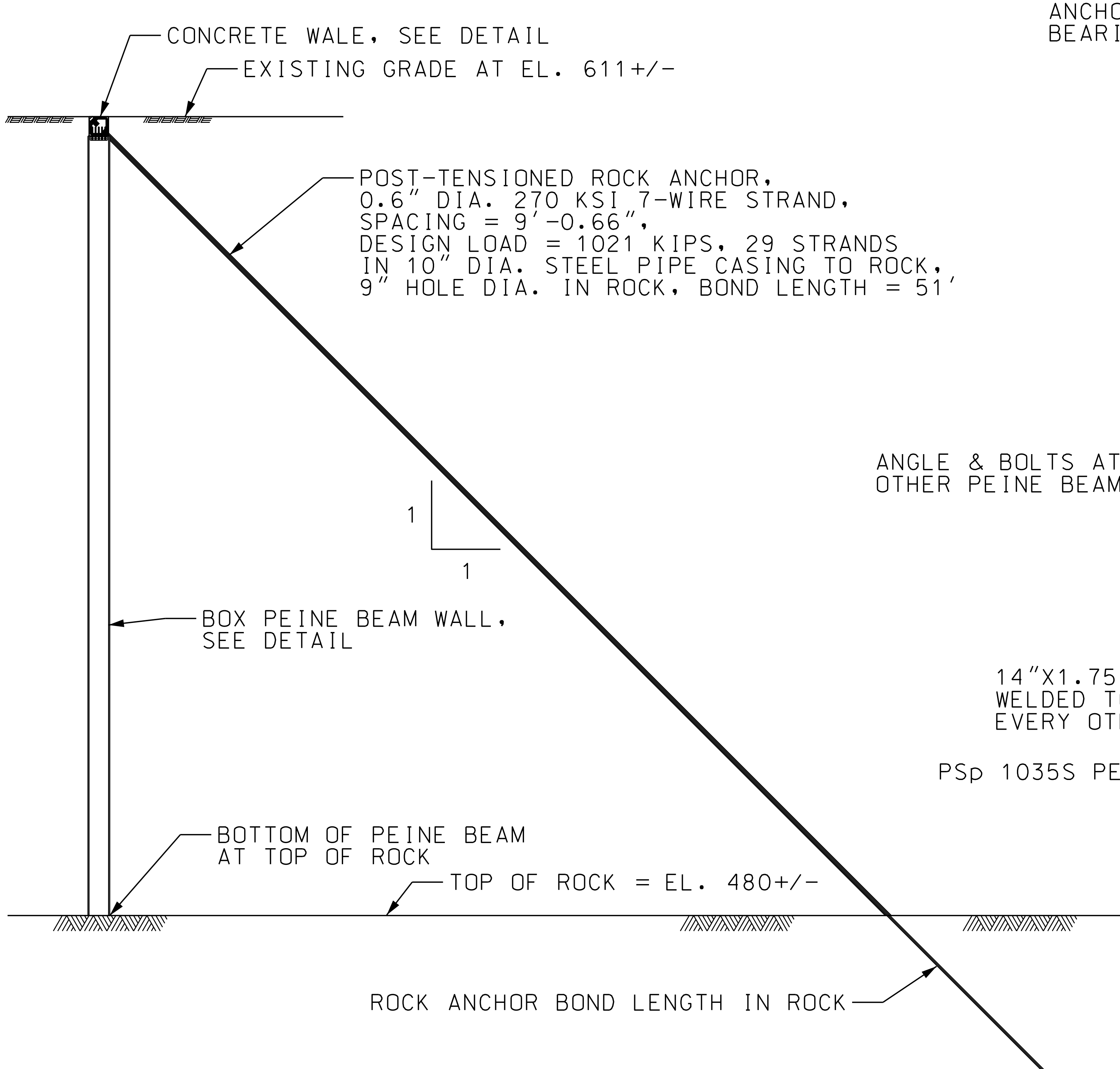
CONCEPTUAL

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

UPPER STABILITY WALL
SECTION & DETAILS
CASE A WITHOUT EXCAVATION
CASE C W/ & W/O EXCAVATION

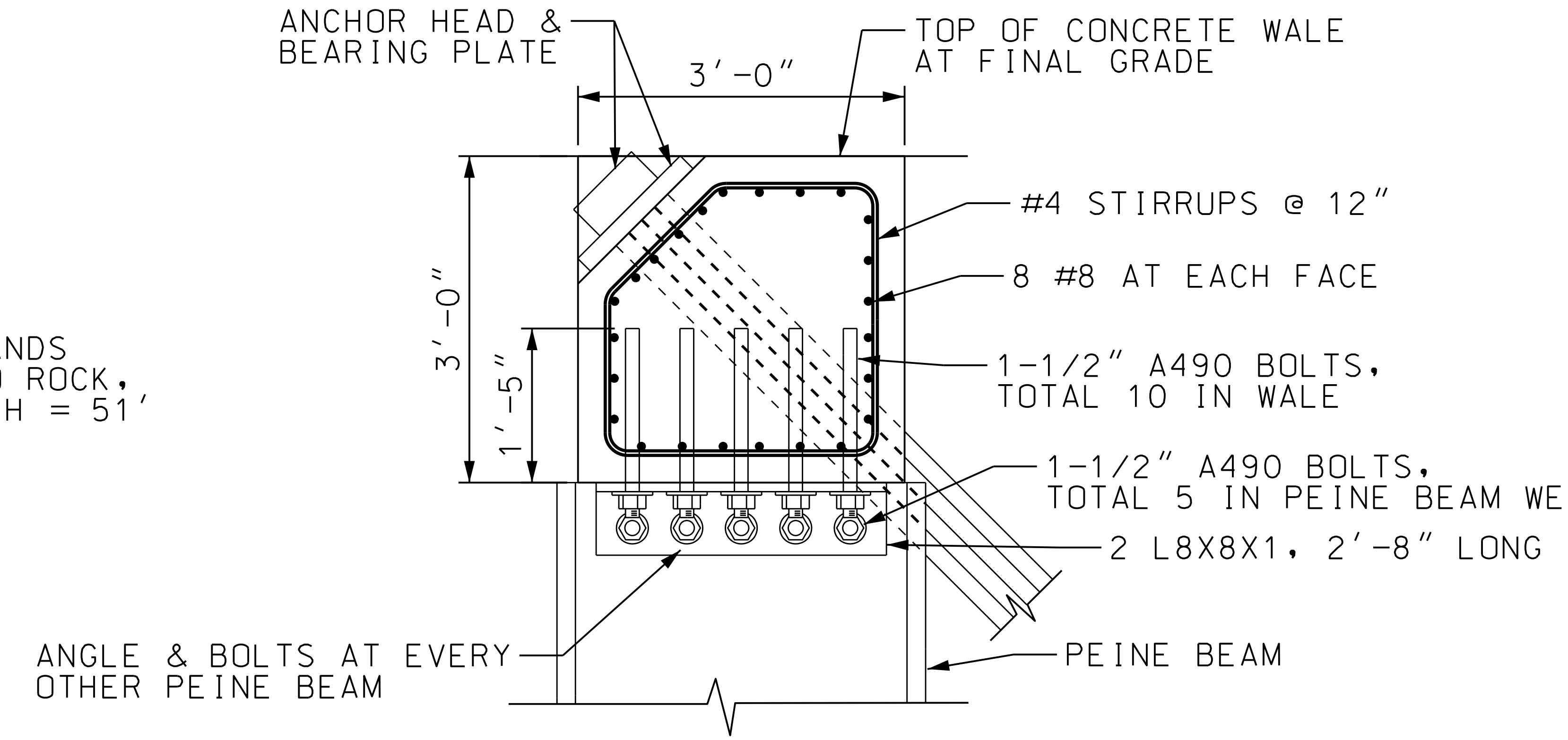
US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
JULY 2009

FIGURE 2



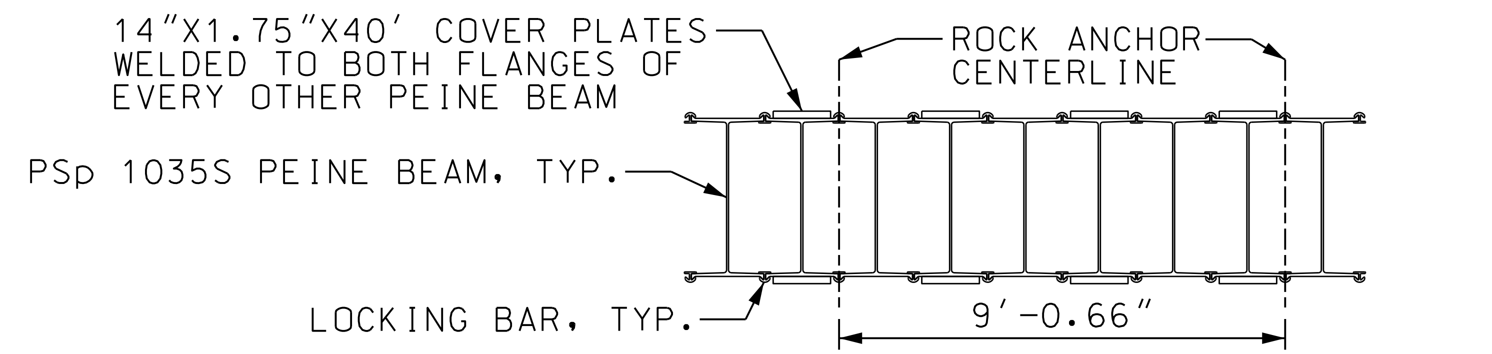
UPPER STABILITY WALL SECTION

NOT TO SCALE



CONCRETE WALE DETAIL

NOT TO SCALE



BOX PEINE BEAM WALL DETAIL

NOT TO SCALE

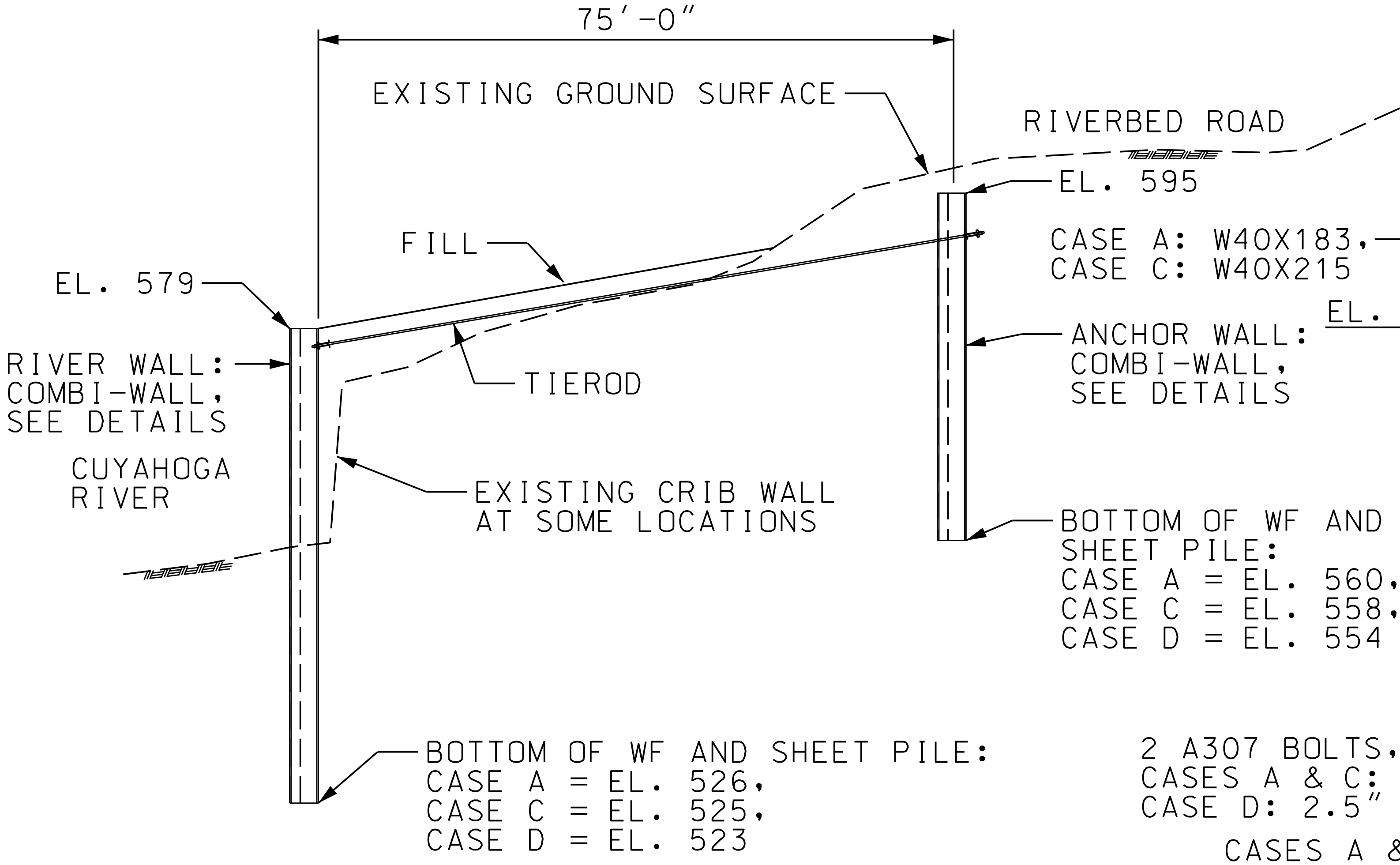
CONCEPTUAL

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

UPPER STABILITY WALL SECTION & DETAILS CASE D

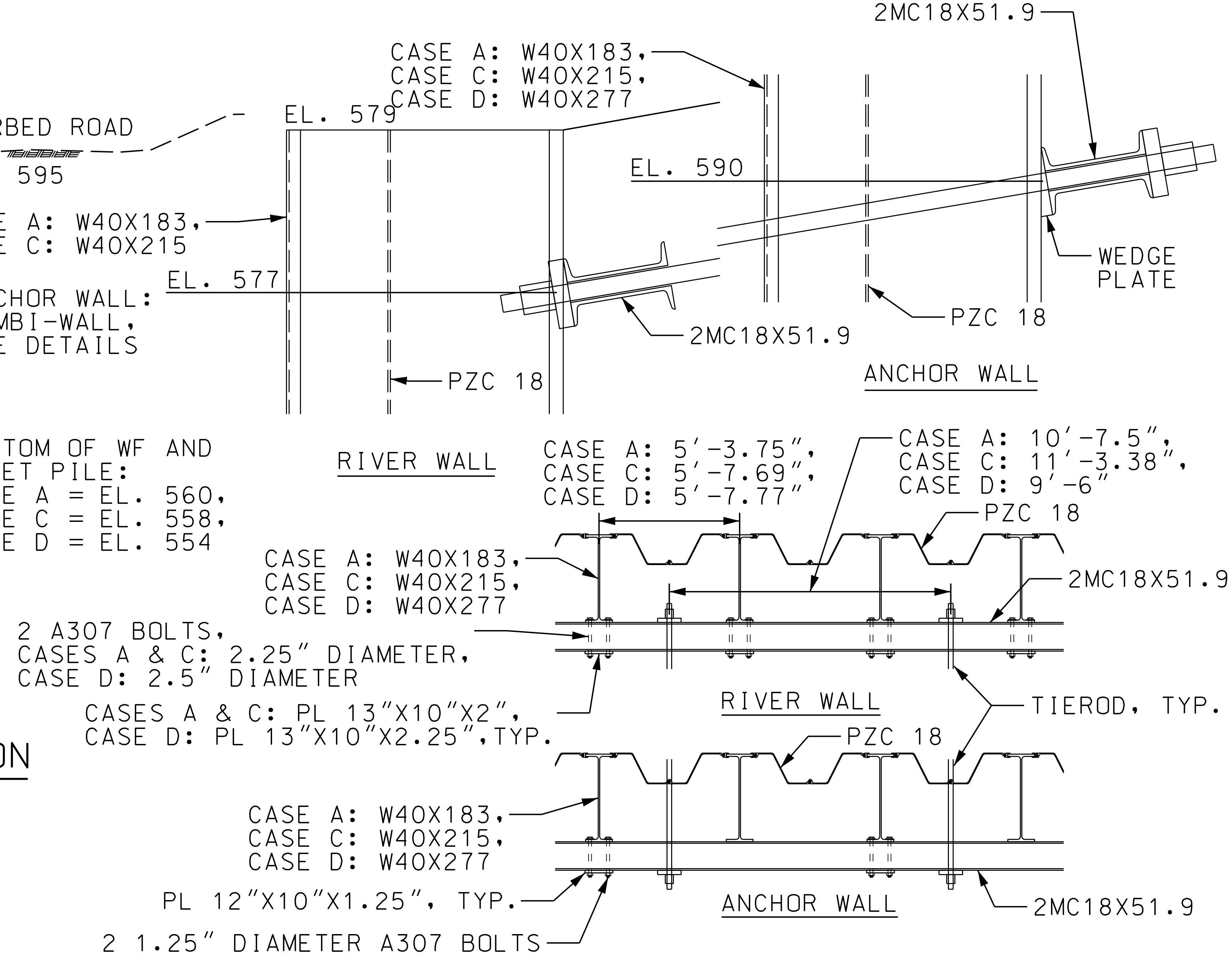
US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
JULY 2009

FIGURE 3



LOWER STABILITY WALL SECTION

NOT TO SCALE



COMBI-WALL, WALE & TIEROD DETAILS

NOT TO SCALE

NOTES:

1. ALL TIERODS ARE 3" DIAMETER GRADE 150 THREADBARS SPACED AS SHOWN WITH 13"X10"X2.5" BEARING PLATE AT EACH END.

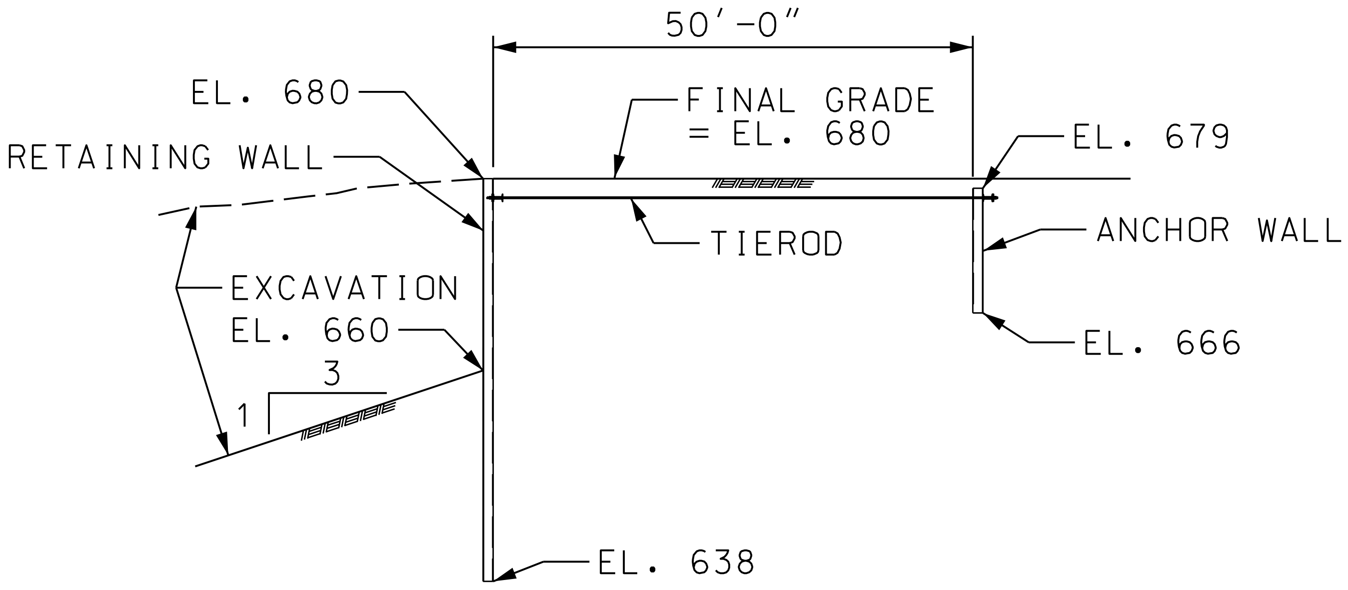
CONCEPTUAL

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

LOWER STABILITY WALL SECTION & DETAILS CASES A, C & D

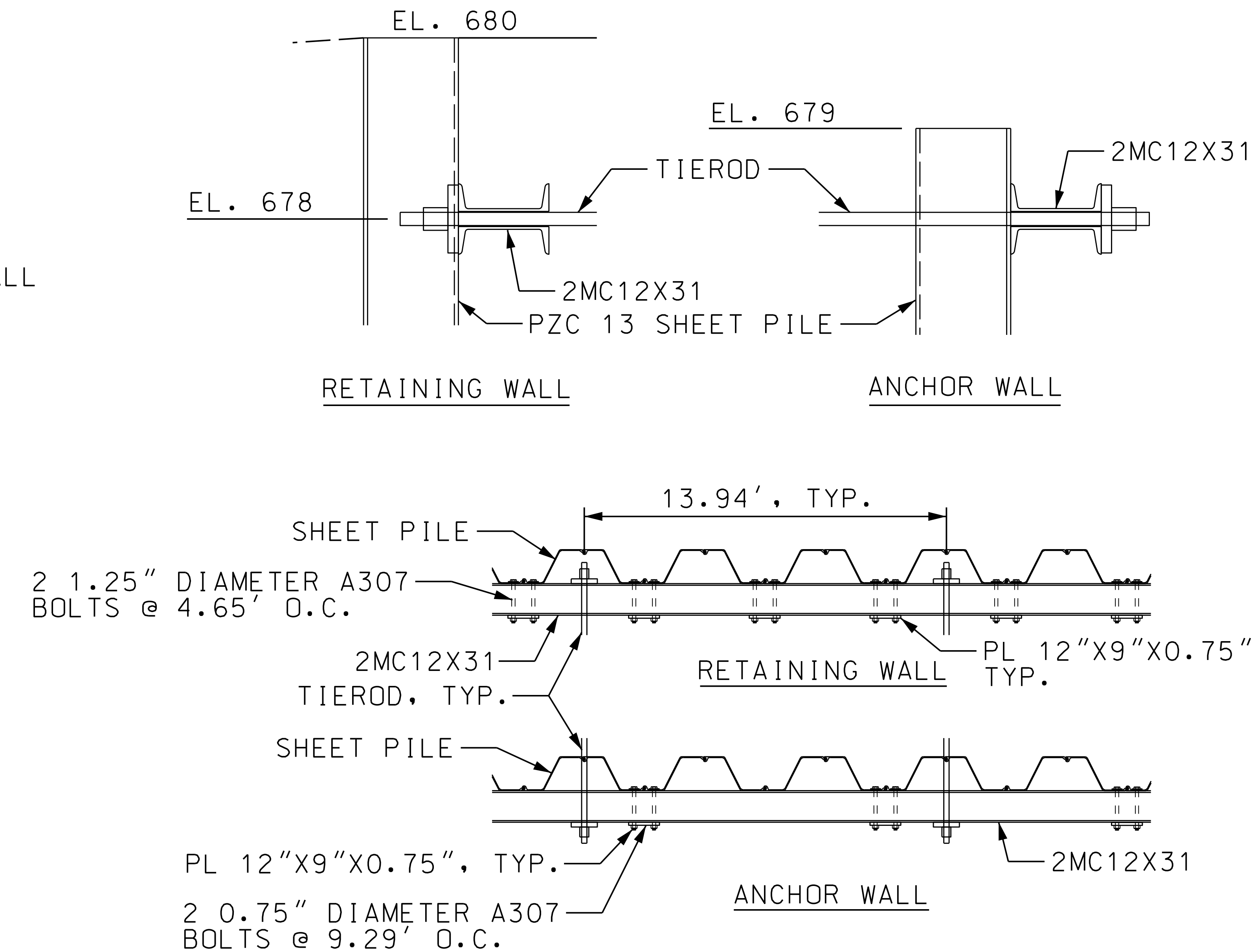
US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
JULY 2009

FIGURE 4



RETAINING WALL SECTION

NOT TO SCALE



WALE & TIEROD DETAILS

NOT TO SCALE

NOTES:

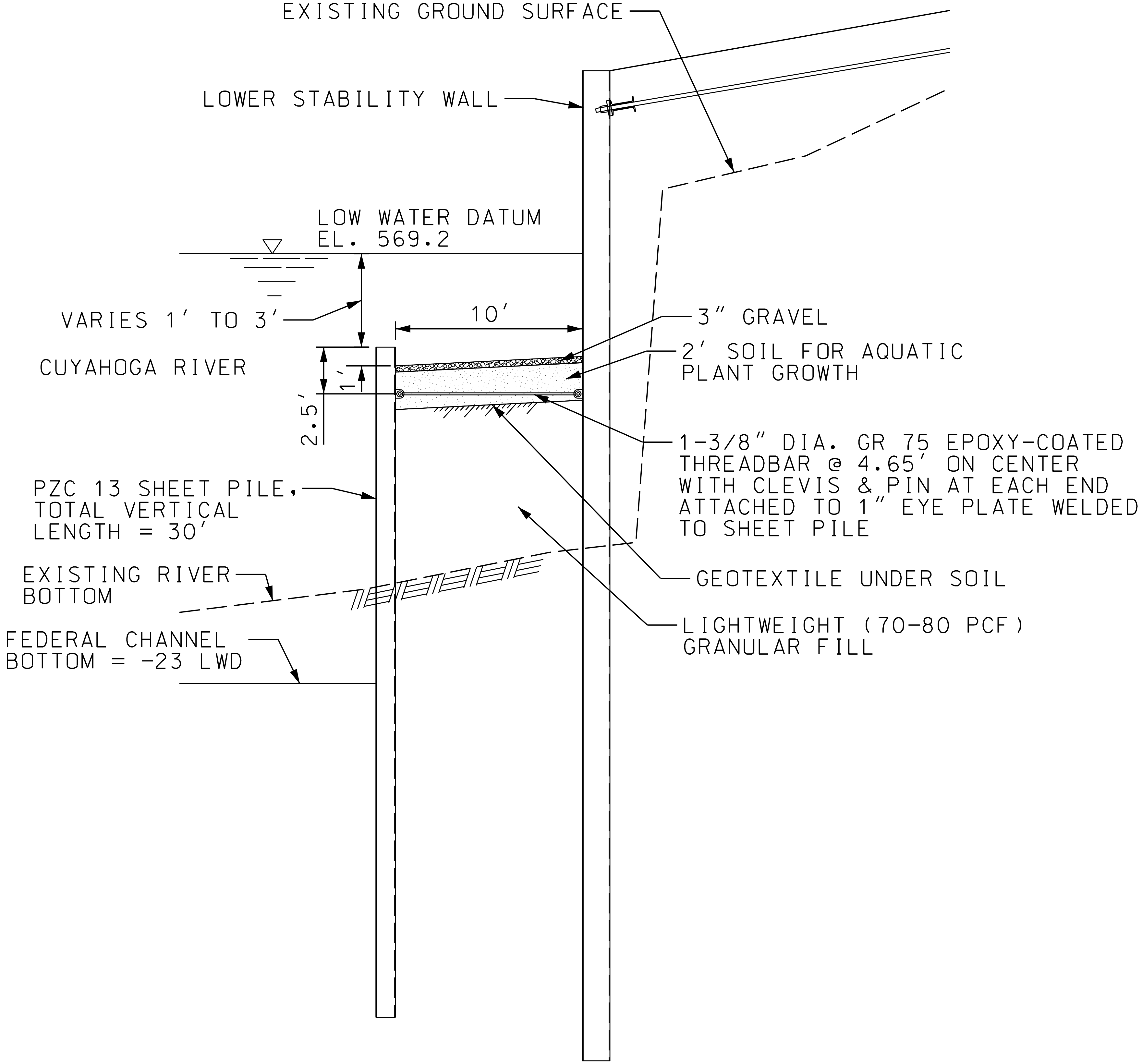
1. ALL TIERODS ARE 1.75" DIAMETER GRADE 150 THREADBARS SPACED AT 13.94' ON CENTER WITH 9"X9"X1.375" BEARING PLATE AT EACH END.
2. RETAINING WALL AT TOP SLOPE IS REQUIRED FOR CASE A WITH EXCAVATION AND CASE C WITH EXCAVATION.

CONCEPTUAL

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

RETAINING WALL AT TOP OF SLOPE SECTION & DETAILS

US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
JULY 2009



GREEN BULKHEAD SECTION

NOT TO SCALE

CONCEPTUAL

CUYAHOGA RIVER BULKHEAD
TECHNICAL ASSISTANCE
CLEVELAND, OHIO

GREEN BULKHEAD SECTION

US ARMY CORPS OF ENGINEER
BUFFALO DISTRICT
JULY 2009

FIGURE 6

SAMPLE DESIGN CALCULATIONS

CWALSHT RESULTS, SIZING OF WALL MEMBERS AND ROCK ANCHORS

UPPER STABILITY WALL

Case	Top EL feet	Free Earth Tip EL feet	Free Earth Pile Length feet	Fixed Earth Tip EL feet	Fixed Earth Pile Length feet	Steel Yield Stress psi	Free Earth Moment lb-ft	Min Reqd Sect Mod in**3	Fixed Earth Moment lb-ft	Min Reqd Sect Mod in**3	Free Earth Anch For lbs	Fixed Earth Anch For lbs	Free Earth Deflection xEI	Fixed Earth Deflection xEI	Selected Wall Member Using Fixed Earth Results	Sprovided in**3	Iprovided in**4	Deflection Inches
A1 See Note 1	611	532.03	78.97	515.08 See Note 2	95.92	50000	1538900	738.67	1309500	628.56	58139	50157	1.1009E+12	7.95E+11	Box Peine Beam System PSp 1030 w/ Locking Bars	639.5	12966	2.93
A2 See Note 1	604	539.56	64.44	527.07	76.93	50000	543080	260.68	452340	217.12	23956	20221	2.64E+11	1.84E+11	CombiWall w/ BBS conn W40x321&PZC18	234.7	4917	1.85
C1 See Note 1	604	530.73	73.27	513.12 See Note 2	90.88	50000	1795200	861.70	1536700	737.62	67854	58866	1.32E+12	9.60E+11	See Note 4	785.5	17086	2.66
C2 See Note 1	604	534.48	69.52	519.25 See Note 2	84.75	50000	1194200	573.22	1025200	492.10	52817	45914	6.55E+11	4.77E+11	Box Peine Beam System PSp 1013 w/ Locking Bars	506.29	10006	2.26
D	611	528.05	82.95	509.14 See Note 6	101.86	50000	2401500	1152.72	2078000	997.44	90837	79618	1.86E+12	1.37E+12	See Note 5	1000	22139	2.89

Notes: 1. Cases A1 and C1 are without excavation, Cases A2 and C2 are with excavation. 2. Pile tip elevation for Cases A1, C1 and C2 will be 506 instead of elevations shown since skin friction/end bearing required to resist rock anchor vertical force component governs pile depths for these cases. 3. Fixed earth results have been used for design. 4. Box Peine Beam System consisting of PSp 1035S with Locking Bars and 14"x1.375" cover plates (30' long) on both flanges of every other PSp 1035S
5. Box Peine Beam System consisting of PSp 1035S with Locking Bars and 14"x1.75" cover plates (40' long) on both flanges of every other PSp 1035S
6. Pile tip elevation will at top of rock, EL 480 +/-, since skin friction and end bearing in soil layers is insufficient to resist rock anchor vertical force component.

UPPER STABILITY WALL

Case	Rock Anchor spacing feet	Rock Anchor Force lbs	Number of Strands	Rock Anchor Design Load lbs	Hole Diameter inches	All. Bond Stress psi	Bond Length feet
A1	10.56	749	22	774	8	60	42.77
A2	11.31	323	10	352	6	60	25.94
C1	10.56	879	25	880	9	60	43.23
C2	10.56	686	20	704	8	60	38.90
D	9.05	1019	29	1021	9	60	50.15

Note: Rock anchors designed using fixed earth anchor force.

CALCULATION EQUATIONS

Min. Reqd Sect Mod = (CWALSHT Max Moment x12) / (0.5xSteel Yield Stress) per EM 1110-2-2504

Rock Anchor Bond Length = [(Rock Anchor Design Load x 1000) / (PI * Hole Diameter * Allowable Bond Stress)] / 12 per PTI Recommendations

LOWER STABILITY WALL

Case	Top EL feet	Free Earth Tip EL feet	Free Earth Pile Length feet	Fixed Earth Tip EL feet	Fixed Earth Pile Length feet	Steel Yield Stress psi	Free Earth Moment lb-ft	Min Reqd Sect Mod in**3	Fixed Earth Moment lb-ft	Min Reqd Sect Mod in**3	Free Earth Anch For lbs	Fixed Earth Anch For lbs	Free Earth Deflection xEI	Fixed Earth Deflection xEI	Selected Wall Member Using Fixed Earth Results	Sprovided in**3	Iprovided in**4	Deflection Inches
A	579	536.96	42.04	526.53	52.47	50000	319550	153.38	278420	133.64	24073	21308	5.56E+10	4.28E+10	CombiWall w/ BBS conn W40x183&PZC18	142.5	2993	0.64
C	579	536.13	42.87	525.38	53.62	50000	363250	174.36	318070	152.67	27343	24303	6.56E+10	5.07E+10	CombiWall w/ BBS conn W40x215&PZC18	164.7	3425	0.66
D	579	534.5	44.5	523.13	55.87	50000	461150	221.35	407340	195.52	34650	31028	8.93E+10	6.94E+10	CombiWall w/ BBS conn W40x277&PZC18	208.4	4351	0.71

Note: Fixed earth results have been used for design.

ANCHOR WALL FOR LOWER STABILITY WALL

Case	Top EL feet	Tip EL feet	Pile Length feet	Steel Yield Stress psi	Moment lb-ft	Min Reqd Sect Mod in**3	Deflection xEI	Selected Wall Member	Sprovided in**3	Iprovided in**4	Deflection Inches
A	595	560.08	34.92	50000	195580	93.88	7.25E+10	CombiWall w/ BBS conn W40x183&PZC18	142.5	2993	0.84
C	595	558.32	36.68	50000	232430	111.57	9.47E+10	CombiWall w/ BBS conn W40x215&PZC18	164.7	3425	0.95
D	595	554.54	40.46	50000	322290	154.70	1.58E+11	CombiWall w/ BBS conn W40x277&PZC18	208.4	4351	1.25

Note: Anchor wall has been designed using main wall fixed earth results.

RETAINING WALL AT TOP OF SLOPE

Top EL feet	Free Earth Tip EL feet	Free Earth Pile Length feet	Fixed Earth Tip EL feet	Fixed Earth Pile Length feet	Steel Yield Stress psi	Free Earth Moment lb-ft	Min Reqd Sect Mod in**3	Fixed Earth Moment lb-ft	Min Reqd Sect Mod in**3	Free Earth Anch For lbs	Fixed Earth Anch For lbs	Free Earth Deflection xEI	Fixed Earth Deflection xEI	Selected Wall Member Using Free Earth Results	Sprovided in**3	Iprovided in**4	Deflection Inches
680	638.24	41.76	628.4	51.6	50000	43727	20.99	35571	17.07	7182	6448	6.51E+09	4.90E+09	PZC 13	24.3	152	1.48

Note: Free earth results have been used for design.

ANCHOR WALL FOR RETAINING WALL

Top EL feet	Tip EL feet	Pile Length feet	Steel Yield Stress psi	Moment lb-ft	Min Reqd Sect Mod in**3	Deflection xEI	Selected Wall Member	Sprovided in**3	Iprovided in**4	Deflection Inches
679	666.47	12.53	50000	24760	11.88	1.82E+09	PZC 13	24.3	152	0.41

CWALSHT INPUT/OUTPUT FOR UPPER STABILITY WALL

CASE A WITHOUT EXCAVATION – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
  DATE: 29-JUNE-2009                                          TIME: 13:56:18

                              ****************
                              *  INPUT DATA  *
                              ****************


        I.--HEADING
       'CUYAHOGA WEST BANK STABILIZATION
       'UPPER STABILIZATION WALL - CASE A1

       II.--CONTROL
          ANCHORED WALL DESIGN
          FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
          FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.20

      III.--WALL DATA
          ELEVATION AT TOP OF WALL    = 611.00 FT.
          ELEVATION AT ANCHOR         = 608.00 FT.

       IV.--SURFACE POINT DATA

            IV.A.--RIGHTSIDE
               DIST. FROM     ELEVATION
               WALL (FT)        (FT)
                    0.00        552.00

            IV.B.--LEFTSIDE
               DIST. FROM     ELEVATION
               WALL (FT)        (FT)
                    0.00        552.00

        V.--SOIL LAYER DATA

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

                 ANGLE OF         ANGLE OF                        <-SAFETY->
   SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
  WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
  (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
 130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

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

                 ANGLE OF         ANGLE OF                        <-SAFETY->
   SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
  WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
  (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
 130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF
```

```
 VI.--WATER DATA
    UNIT WEIGHT         = 62.40 (PCF)
    RIGHTSIDE ELEVATION = 552.00 (FT)
    LEFTSIDE ELEVATION  = 552.00 (FT)
    NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

    VII.A.--VERTICAL LINE LOADS
         NONE

    VII.B.--VERTICAL UNIFORM LOADS
              NONE

    VII.C.--VERTICAL STRIP LOADS
         NONE

    VII.D.--VERTICAL RAMP LOADS
         NONE

    VII.E.--VERTICAL TRIANGULAR LOADS
         NONE

    VII.F.--VERTICAL VARIABLE LOADS

         VII.F.1.--RIGHTSIDE
         DIST. FROM      VARIABLE
         WALL (FT)      LOAD (PSF)
            0.00         3650.00
          100.00         6150.00

         VII.F.2.--LEFTSIDE
         DIST. FROM      VARIABLE
         WALL (FT)      LOAD (PSF)
            0.00         3650.00
          100.00         2450.00

VIII.--HORIZONTAL LOADS

    VIII.A.--HORIZONTAL LINE LOADS
         ELEVATION     LINE LOAD
            (FT)         (PLF)
          581.00      95000.00

    VIII.B.--HORIZONTAL DISTRIBUTED LOADS
         NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
  DATE: 29-JUNE-2009                                          TIME: 13:56:22

                         ****************************
                         *  SUMMARY OF RESULTS FOR  *
                         *   ANCHORED WALL DESIGN   *
                         ****************************

      I.--HEADING
       'CUYAHOGA WEST BANK STABILIZATION
       'UPPER STABILIZATION WALL - CASE A1
```

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

METHOD	:	FREE EARTH	FIXED EARTH
WALL BOTTOM ELEVATION (FT)	:	532.03	515.08
PENETRATION (FT)	:	19.97	36.92
MAXIMUM BENDING MOMENT (LB-FT)	:	-1.5698E+06	-1.3542E+06
AT ELEVATION (FT)	:	581.00	581.00
MAXIMUM SCALED DEFLECTION (LB-IN^3)	:	1.2024E+12	8.8370E+11
AT ELEVATION (FT)	:	574.00	576.00
ANCHOR FORCE (LB)	:	5.8139E+04	5.0157E+04

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

<u>CASE A WITHOUT EXCAVATION</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

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

DATE: 5-JUNE-2009 TIME: 6:34:25

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

I.--HEADING
'CUYAHOGA WEST BANK STABILIZATION
'UPPER STABILIZATION WALL - CASE A1 WITHOUT FS

II.--CONTROL
ANCHORED 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 = 611.00 FT.
ELEVATION AT ANCHOR = 608.00 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00

IV.B.--LEFTSIDE

DIST. FROM ELEVATION

WALL (FT)	(FT)
0.00	552.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 552.00 (FT)
LEFTSIDE ELEVATION = 552.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS

NONE

VII.B.--VERTICAL UNIFORM LOADS

NONE

VII.C.--VERTICAL STRIP LOADS

NONE

VII.D.--VERTICAL RAMP LOADS

NONE

VII.E.--VERTICAL TRIANGULAR LOADS

NONE

VII.F.--VERTICAL VARIABLE LOADS

VII.F.1.--RIGHTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3650.00
100.00	6150.00

VII.F.2.--LEFTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3650.00
100.00	2450.00

```
VIII.--HORIZONTAL LOADS

     VIII.A.--HORIZONTAL LINE LOADS
          ELEVATION     LINE LOAD
             (FT)         (PLF)
           581.00      95000.00

     VIII.B.--HORIZONTAL DISTRIBUTED LOADS
          NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
  DATE: 5-JUNE-2009                                           TIME: 6:34:28

                         ****************************
                         *  SUMMARY OF RESULTS FOR  *
                         *   ANCHORED WALL DESIGN   *
                         ****************************

     I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'UPPER STABILIZATION WALL - CASE A1 WITHOUT FS

    II.--SUMMARY

         RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
         AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

         LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
         AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

    METHOD                            :    FREE EARTH         FIXED EARTH

    WALL BOTTOM ELEVATION (FT)        :        535.01              519.46
          PENETRATION (FT)             :        16.99               32.54

    MAXIMUM BENDING MOMENT (LB-FT)    :   -1.5389E+06         -1.3095E+06
          AT ELEVATION (FT)           :        581.00              581.00

    MAXIMUM SCALED DEFLECTION (LB-IN^3):    1.1009E+12          7.9549E+11
          AT ELEVATION (FT)           :        575.00              577.00

    ANCHOR FORCE (LB)                 :    5.6995E+04          4.8502E+04

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

<u>CASE A WITH EXCAVATION</u> – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
  PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
  DATE: 5-JUNE-2009                                           TIME: 6:36:47

                              ****************
                              *  INPUT DATA  *
                              ****************
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```
 I.--HEADING
'CUYAHOGA WEST BANK STABILIZATION
'UPPER STABILIZATION WALL - CASE A2

II.--CONTROL
   ANCHORED WALL DESIGN
   FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
   FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.20

III.--WALL DATA
    ELEVATION AT TOP OF WALL    = 604.00 FT.
    ELEVATION AT ANCHOR         = 601.00 FT.

 IV.--SURFACE POINT DATA

      IV.A.--RIGHTSIDE
         DIST. FROM     ELEVATION
         WALL (FT)        (FT)
              0.00        552.00

      IV.B.--LEFTSIDE
         DIST. FROM     ELEVATION
         WALL (FT)        (FT)
              0.00        552.00

  V.--SOIL LAYER DATA

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

                ANGLE OF         ANGLE OF                        <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

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

                ANGLE OF         ANGLE OF                        <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

 VI.--WATER DATA
    UNIT WEIGHT         = 62.40 (PCF)
    RIGHTSIDE ELEVATION = 552.00 (FT)
    LEFTSIDE ELEVATION  = 552.00 (FT)
    NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

    VII.A.--VERTICAL LINE LOADS
         NONE

    VII.B.--VERTICAL UNIFORM LOADS
              NONE
```

VII.C.--VERTICAL STRIP LOADS
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS

VII.F.1.--RIGHTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3000.00
100.00	3650.00

VII.F.2.--LEFTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3000.00
100.00	2450.00

VIII.--HORIZONTAL LOADS

VIII.A.--HORIZONTAL LINE LOADS

ELEVATION (FT)	LINE LOAD (PLF)
578.00	40000.00

VIII.B.--HORIZONTAL DISTRIBUTED LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 5-JUNE-2009 TIME: 6:36:50

****
* SUMMARY OF RESULTS FOR *
* ANCHORED WALL DESIGN *
****

I.--HEADING
'CUYAHOGA WEST BANK STABILIZATION
'UPPER STABILIZATION WALL - CASE A2

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

METHOD	:	FREE EARTH	FIXED EARTH
WALL BOTTOM ELEVATION (FT)	:	539.56	527.07
PENETRATION (FT)	:	12.44	24.93
MAXIMUM BENDING MOMENT (LB-FT)	:	-5.5100E+05	-4.6508E+05
AT ELEVATION (FT)	:	578.00	578.00

```
   MAXIMUM SCALED DEFLECTION (LB-IN^3):    2.8144E+11          2.0039E+11
         AT ELEVATION (FT)            :        573.00              575.00

   ANCHOR FORCE (LB)                  :    2.3956E+04          2.0221E+04

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

<u>CASE A WITH EXCAVATION</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

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 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
 DATE: 5-JUNE-2009                                              TIME: 6:35:59

                             ****************
                             *  INPUT DATA  *
                             ****************

       I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'UPPER STABILIZATION WALL - CASE A2 WITHOUT FS

      II.--CONTROL
         ANCHORED 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    = 604.00 FT.
         ELEVATION AT ANCHOR         = 601.00 FT.

      IV.--SURFACE POINT DATA

           IV.A.--RIGHTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)         (FT)
                   0.00        552.00

           IV.B.--LEFTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)         (FT)
                   0.00        552.00

       V.--SOIL LAYER DATA

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

                ANGLE OF          ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF   DEF
```

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 552.00 (FT)
LEFTSIDE ELEVATION = 552.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS

NONE

VII.B.--VERTICAL UNIFORM LOADS

NONE

VII.C.--VERTICAL STRIP LOADS

NONE

VII.D.--VERTICAL RAMP LOADS

NONE

VII.E.--VERTICAL TRIANGULAR LOADS

NONE

VII.F.--VERTICAL VARIABLE LOADS

VII.F.1.--RIGHTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3000.00
100.00	3650.00

VII.F.2.--LEFTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3000.00
100.00	2450.00

VIII.--HORIZONTAL LOADS

VIII.A.--HORIZONTAL LINE LOADS

ELEVATION (FT)	LINE LOAD (PLF)
578.00	40000.00

VIII.B.--HORIZONTAL DISTRIBUTED LOADS

NONE

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

   I.--HEADING
    'CUYAHOGA WEST BANK STABILIZATION
    'UPPER STABILIZATION WALL - CASE A2 WITHOUT FS

  II.--SUMMARY

       RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
       AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

       LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
       AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

  METHOD                            :    FREE EARTH         FIXED EARTH

  WALL BOTTOM ELEVATION (FT)        :        541.34              529.86
        PENETRATION (FT)             :        10.66               22.14

  MAXIMUM BENDING MOMENT (LB-FT)    :   -5.4308E+05         -4.5234E+05
        AT ELEVATION (FT)           :        578.00              578.00

  MAXIMUM SCALED DEFLECTION (LB-IN^3):    2.6382E+11          1.8441E+11
        AT ELEVATION (FT)           :        574.00              575.00

  ANCHOR FORCE (LB)                 :    2.3612E+04          1.9667E+04

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

<u>CASE C WITHOUT EXCAVATION</u> – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
 DATE: 27-JULY-2009                                          TIME: 10:43:12

                             ****************
                             *  INPUT DATA  *
                             ****************

     I.--HEADING
    'CUYAHOGA WEST BANK STABILIZATION
    'UPPER STABILIZATION WALL - CASE C WITHOUT EXCAVATION

    II.--CONTROL
       ANCHORED WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.20

   III.--WALL DATA
       ELEVATION AT TOP OF WALL    = 611.00 FT.
       ELEVATION AT ANCHOR         = 608.00 FT.
```

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 552.00 (FT)
LEFTSIDE ELEVATION = 552.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS
NONE

VII.B.--VERTICAL UNIFORM LOADS
NONE

VII.C.--VERTICAL STRIP LOADS
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS

VII.F.1.--RIGHTSIDE
DIST. FROM VARIABLE

```
            WALL (FT)      LOAD (PSF)
               0.00         3650.00
             100.00         6150.00

            VII.F.2.--LEFTSIDE
            DIST. FROM      VARIABLE
            WALL (FT)      LOAD (PSF)
               0.00         3650.00
             100.00         2450.00

   VIII.--HORIZONTAL LOADS

        VIII.A.--HORIZONTAL LINE LOADS
             ELEVATION     LINE LOAD
                (FT)         (PLF)
              581.00     110000.00

        VIII.B.--HORIZONTAL DISTRIBUTED LOADS
             NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-JULY-2009                                          TIME: 10:43:15

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *   ANCHORED WALL DESIGN   *
                       ****************************

    I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'UPPER STABILIZATION WALL - CASE C WITHOUT EXCAVATION

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
        AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

        LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
        AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

   METHOD                            :    FREE EARTH          FIXED EARTH

   WALL BOTTOM ELEVATION (FT)        :        530.73               513.12
         PENETRATION (FT)             :        21.27                38.88

   MAXIMUM BENDING MOMENT (LB-FT)    :   -1.8321E+06          -1.5894E+06
         AT ELEVATION (FT)           :        581.00               581.00

   MAXIMUM SCALED DEFLECTION (LB-IN^3):    1.4440E+12           1.0690E+12
         AT ELEVATION (FT)           :        573.00               576.00

   ANCHOR FORCE (LB)                 :    6.7854E+04           5.8866E+04

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

<u>CASE C WITHOUT EXCAVATION</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

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 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
 DATE: 27-JULY-2009                                          TIME: 10:42:21

                            ****************
                            *  INPUT DATA  *
                            ****************

       I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'UPPER STABILIZATION WALL - CASE C WITHOUT EXCAVATION

      II.--CONTROL
         ANCHORED 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    = 611.00 FT.
         ELEVATION AT ANCHOR         = 608.00 FT.

      IV.--SURFACE POINT DATA

           IV.A.--RIGHTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)         (FT)
                   0.00        552.00

           IV.B.--LEFTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)         (FT)
                   0.00        552.00

       V.--SOIL LAYER DATA

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

                ANGLE OF         ANGLE OF                        <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

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

                ANGLE OF         ANGLE OF                        <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

      VI.--WATER DATA
         UNIT WEIGHT         = 62.40 (PCF)
```

```
        RIGHTSIDE ELEVATION = 552.00 (FT)
        LEFTSIDE ELEVATION  = 552.00 (FT)
        NO SEEPAGE

    VII.--VERTICAL SURCHARGE LOADS

        VII.A.--VERTICAL LINE LOADS
             NONE

        VII.B.--VERTICAL UNIFORM LOADS
                  NONE

        VII.C.--VERTICAL STRIP LOADS
             NONE

        VII.D.--VERTICAL RAMP LOADS
             NONE

        VII.E.--VERTICAL TRIANGULAR LOADS
             NONE

        VII.F.--VERTICAL VARIABLE LOADS

             VII.F.1.--RIGHTSIDE
             DIST. FROM      VARIABLE
             WALL (FT)      LOAD (PSF)
                0.00         3650.00
              100.00         6150.00

             VII.F.2.--LEFTSIDE
             DIST. FROM      VARIABLE
             WALL (FT)      LOAD (PSF)
                0.00         3650.00
              100.00         2450.00

   VIII.--HORIZONTAL LOADS

        VIII.A.--HORIZONTAL LINE LOADS
             ELEVATION     LINE LOAD
                (FT)         (PLF)
              581.00     110000.00

        VIII.B.--HORIZONTAL DISTRIBUTED LOADS
             NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-JULY-2009                                          TIME: 10:42:24

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *   ANCHORED WALL DESIGN   *
                       ****************************

    I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'UPPER STABILIZATION WALL - CASE C WITHOUT EXCAVATION

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
```

```
    AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

    LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
    AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

METHOD                               :    FREE EARTH         FIXED EARTH

WALL BOTTOM ELEVATION (FT)           :        533.87              517.72
      PENETRATION (FT)                :        18.13               34.28

MAXIMUM BENDING MOMENT (LB-FT)       :   -1.7952E+06         -1.5367E+06
      AT ELEVATION (FT)              :        581.00              581.00

MAXIMUM SCALED DEFLECTION (LB-IN^3):    1.3181E+12          9.5993E+11
      AT ELEVATION (FT)              :        574.00              577.00

ANCHOR FORCE (LB)                    :    6.6490E+04          5.6914E+04

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

<u>CASE C WITH EXCAVATION</u> – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
  PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
  DATE: 5-JUNE-2009                                             TIME: 6:40:45

                              ****************
                              *  INPUT DATA  *
                              ****************

      I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'UPPER STABILIZATION WALL - CASE C

     II.--CONTROL
        ANCHORED WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.20

    III.--WALL DATA
        ELEVATION AT TOP OF WALL    = 604.00 FT.
        ELEVATION AT ANCHOR         = 601.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       552.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       552.00
```

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 552.00 (FT)
LEFTSIDE ELEVATION = 552.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS

NONE

VII.B.--VERTICAL UNIFORM LOADS

NONE

VII.C.--VERTICAL STRIP LOADS

NONE

VII.D.--VERTICAL RAMP LOADS

NONE

VII.E.--VERTICAL TRIANGULAR LOADS

NONE

VII.F.--VERTICAL VARIABLE LOADS

VII.F.1.--RIGHTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3000.00
100.00	3650.00

VII.F.2.--LEFTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3000.00
100.00	2450.00

VIII.--HORIZONTAL LOADS

VIII.A.--HORIZONTAL LINE LOADS

```
            ELEVATION     LINE LOAD
              (FT)          (PLF)
             578.00      85000.00

       VIII.B.--HORIZONTAL DISTRIBUTED LOADS
            NONE


 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
 DATE: 5-JUNE-2009                                        TIME: 6:40:49

                        ****************************
                        *  SUMMARY OF RESULTS FOR  *
                        *   ANCHORED WALL DESIGN   *
                        ****************************

     I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'UPPER STABILIZATION WALL - CASE C

    II.--SUMMARY

         RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
         AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

         LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
         AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

    METHOD                            :    FREE EARTH        FIXED EARTH

    WALL BOTTOM ELEVATION (FT)        :        534.48             519.25
          PENETRATION (FT)             :        17.52              32.75

    MAXIMUM BENDING MOMENT (LB-FT)    :   -1.2148E+06        -1.0560E+06
          AT ELEVATION (FT)           :        578.00             578.00

    MAXIMUM SCALED DEFLECTION (LB-IN^3):    7.0906E+11         5.2574E+11
          AT ELEVATION (FT)           :        571.00             573.00

    ANCHOR FORCE (LB)                 :    5.2817E+04         4.5914E+04

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

<u>CASE C WITH EXCAVATION</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
 DATE: 5-JUNE-2009                                        TIME: 6:40:13

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

```
  I.--HEADING
 'CUYAHOGA WEST BANK STABILIZATION
 'UPPER STABILIZATION WALL - CASE C WITHOUT FS

 II.--CONTROL
    ANCHORED 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    = 604.00 FT.
    ELEVATION AT ANCHOR         = 601.00 FT.

 IV.--SURFACE POINT DATA

      IV.A.--RIGHTSIDE
         DIST. FROM     ELEVATION
         WALL (FT)         (FT)
              0.00        552.00

      IV.B.--LEFTSIDE
         DIST. FROM     ELEVATION
         WALL (FT)         (FT)
              0.00        552.00

  V.--SOIL LAYER DATA

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

               ANGLE OF          ANGLE OF                        <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

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

               ANGLE OF          ANGLE OF                        <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

 VI.--WATER DATA
    UNIT WEIGHT         = 62.40 (PCF)
    RIGHTSIDE ELEVATION = 552.00 (FT)
    LEFTSIDE ELEVATION  = 552.00 (FT)
    NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

    VII.A.--VERTICAL LINE LOADS
         NONE

    VII.B.--VERTICAL UNIFORM LOADS
              NONE

    VII.C.--VERTICAL STRIP LOADS
```

```
          NONE

     VII.D.--VERTICAL RAMP LOADS
          NONE

     VII.E.--VERTICAL TRIANGULAR LOADS
          NONE

     VII.F.--VERTICAL VARIABLE LOADS

          VII.F.1.--RIGHTSIDE
          DIST. FROM      VARIABLE
          WALL (FT)      LOAD (PSF)
             0.00         3000.00
           100.00         3650.00

          VII.F.2.--LEFTSIDE
          DIST. FROM      VARIABLE
          WALL (FT)      LOAD (PSF)
             0.00         3000.00
           100.00         2450.00

  VIII.--HORIZONTAL LOADS

     VIII.A.--HORIZONTAL LINE LOADS
          ELEVATION     LINE LOAD
             (FT)         (PLF)
           578.00      85000.00

     VIII.B.--HORIZONTAL DISTRIBUTED LOADS
          NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 5-JUNE-2009                                           TIME: 6:40:16

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *   ANCHORED WALL DESIGN   *
                       ****************************

   I.--HEADING
    'CUYAHOGA WEST BANK STABILIZATION
    'UPPER STABILIZATION WALL - CASE C WITHOUT FS

  II.--SUMMARY

     RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

     LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

  METHOD                             :    FREE EARTH         FIXED EARTH

  WALL BOTTOM ELEVATION (FT)         :        536.92              522.92
        PENETRATION (FT)              :        15.08               29.08

  MAXIMUM BENDING MOMENT (LB-FT)     :   -1.1942E+06         -1.0252E+06
        AT ELEVATION (FT)            :        578.00              578.00
```

```
MAXIMUM SCALED DEFLECTION (LB-IN^3):    6.5468E+11          4.7745E+11
      AT ELEVATION (FT)            :        572.00              574.00

ANCHOR FORCE (LB)                  :    5.1920E+04          4.4574E+04

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

<u>CASE D</u> – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
  PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
  DATE: 17-JUNE-2009                                         TIME: 9:59:20

                            ****************
                            *  INPUT DATA  *
                            ****************

        I.--HEADING
       'CUYAHOGA WEST BANK STABILIZATION
       'UPPER STABILIZATION WALL - CASE D

       II.--CONTROL
          ANCHORED WALL DESIGN
          FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
          FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.20

      III.--WALL DATA
          ELEVATION AT TOP OF WALL    = 611.00 FT.
          ELEVATION AT ANCHOR         = 608.00 FT.

       IV.--SURFACE POINT DATA

            IV.A.--RIGHTSIDE
               DIST. FROM     ELEVATION
               WALL (FT)         (FT)
                    0.00       552.00

            IV.B.--LEFTSIDE
               DIST. FROM     ELEVATION
               WALL (FT)         (FT)
                    0.00       552.00

        V.--SOIL LAYER DATA

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

                 ANGLE OF         ANGLE OF                         <-SAFETY->
  SAT.    MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.    WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)    (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00     30.00    0.00    15.00    0.00                  DEF  DEF

           V.B.--LEFTSIDE
               LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
```

LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	<-SAFETY-> <-FACTOR-> PASS.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 552.00 (FT)
LEFTSIDE ELEVATION = 552.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS
NONE

VII.B.--VERTICAL UNIFORM LOADS
NONE

VII.C.--VERTICAL STRIP LOADS
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS

VII.F.1.--RIGHTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3650.00
100.00	6150.00

VII.F.2.--LEFTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3650.00
100.00	2450.00

VIII.--HORIZONTAL LOADS

VIII.A.--HORIZONTAL LINE LOADS

ELEVATION (FT)	LINE LOAD (PLF)
581.00	145000.00

VIII.B.--HORIZONTAL DISTRIBUTED LOADS
NONE

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

DATE: 17-JUNE-2009 TIME: 9:59:26

****
* SUMMARY OF RESULTS FOR *

```
                    *   ANCHORED WALL DESIGN   *
                    ****************************

   I.--HEADING
    'CUYAHOGA WEST BANK STABILIZATION
    'UPPER STABILIZATION WALL - CASE D

  II.--SUMMARY

       RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
       AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

       LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
       AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

  METHOD                            :    FREE EARTH         FIXED EARTH

  WALL BOTTOM ELEVATION (FT)        :        528.05              509.14
        PENETRATION (FT)             :        23.95               42.86

  MAXIMUM BENDING MOMENT (LB-FT)    :   -2.4526E+06         -2.1497E+06
        AT ELEVATION (FT)           :        581.00              581.00

  MAXIMUM SCALED DEFLECTION (LB-IN^3):    2.0469E+12          1.5358E+12
        AT ELEVATION (FT)           :        572.00              575.00

  ANCHOR FORCE (LB)                 :    9.0837E+04          7.9618E+04

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

<u>CASE D</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
DATE: 17-JUNE-2009                                         TIME: 9:58:46

                            ****************
                            *  INPUT DATA  *
                            ****************

     I.--HEADING
    'CUYAHOGA WEST BANK STABILIZATION
    'UPPER STABILIZATION WALL - CASE D WITHOUT FS

    II.--CONTROL
       ANCHORED 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    = 611.00 FT.
       ELEVATION AT ANCHOR         = 608.00 FT.

    IV.--SURFACE POINT DATA
```

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 552.00 (FT)
LEFTSIDE ELEVATION = 552.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS
NONE

VII.B.--VERTICAL UNIFORM LOADS
NONE

VII.C.--VERTICAL STRIP LOADS
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS

VII.F.1.--RIGHTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3650.00
100.00	6150.00

VII.F.2.--LEFTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	3650.00
100.00	2450.00

VIII.--HORIZONTAL LOADS

VIII.A.--HORIZONTAL LINE LOADS

ELEVATION (FT)	LINE LOAD (PLF)
581.00	145000.00

VIII.B.--HORIZONTAL DISTRIBUTED LOADS

NONE

CWALSHT INPUT/OUTPUT FOR LOWER STABILITY WALL

CASE A FRONT WALL DESIGN – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

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 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
 DATE: 5-JUNE-2009                                          TIME: 12:35:17

                            ****************
                            *  INPUT DATA  *
                            ****************

       I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'LOWER STABILIZATION WALL - CASE A

      II.--CONTROL
         ANCHORED WALL DESIGN
         FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
         FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.20

     III.--WALL DATA
         ELEVATION AT TOP OF WALL    = 579.00 FT.
         ELEVATION AT ANCHOR         = 577.00 FT.

      IV.--SURFACE POINT DATA

           IV.A.--RIGHTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)         (FT)
                   0.00        552.00

           IV.B.--LEFTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)         (FT)
                   0.00        552.00
                  30.00        552.00
                 100.00        542.00

       V.--SOIL LAYER DATA

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

                ANGLE OF         ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                   DEF  DEF

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

                ANGLE OF         ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
```

```
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                    DEF  DEF

      VI.--WATER DATA
         UNIT WEIGHT         = 62.40 (PCF)
         RIGHTSIDE ELEVATION = 552.00 (FT)
         LEFTSIDE ELEVATION  = 552.00 (FT)
         NO SEEPAGE

     VII.--VERTICAL SURCHARGE LOADS

         VII.A.--VERTICAL LINE LOADS
              NONE

         VII.B.--VERTICAL UNIFORM LOADS
                   NONE

         VII.C.--VERTICAL STRIP LOADS
              NONE

         VII.D.--VERTICAL RAMP LOADS
              NONE

         VII.E.--VERTICAL TRIANGULAR LOADS
              NONE

         VII.F.--VERTICAL VARIABLE LOADS

              VII.F.1.--RIGHTSIDE
              DIST. FROM      VARIABLE
              WALL (FT)      LOAD (PSF)
                 0.00         2000.00
               100.00         4100.00

              VII.F.2.--LEFTSIDE
              DIST. FROM      VARIABLE
              WALL (FT)      LOAD (PSF)
                 0.00          500.00
                30.00            0.00

    VIII.--HORIZONTAL LOADS

         VIII.A.--HORIZONTAL LINE LOADS
              ELEVATION     LINE LOAD
                 (FT)         (PLF)
               563.00      41000.00

         VIII.B.--HORIZONTAL DISTRIBUTED LOADS
              NONE


 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
 DATE: 5-JUNE-2009                                          TIME: 12:35:22

                         ****************************
                         *  SUMMARY OF RESULTS FOR  *
                         *   ANCHORED WALL DESIGN   *
                         ****************************

     I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
```

```
  'LOWER STABILIZATION WALL - CASE A

II.--SUMMARY

     RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

     LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

METHOD                           :    FREE EARTH         FIXED EARTH

WALL BOTTOM ELEVATION (FT)       :        536.96              526.53
      PENETRATION (FT)            :        15.04               25.47

MAXIMUM BENDING MOMENT (LB-FT)   :   -3.3702E+05         -2.9831E+05
      AT ELEVATION (FT)          :        563.00              563.00

MAXIMUM SCALED DEFLECTION (LB-IN^3):  6.7970E+10          5.2658E+10
      AT ELEVATION (FT)          :        559.00              560.00

ANCHOR FORCE (LB)                :    2.4073E+04          2.1308E+04

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

<u>CASE A FRONT WALL DESIGN</u> – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 5-JUNE-2009                                         TIME: 12:34:34

                            ****************
                            *  INPUT DATA  *
                            ****************

     I.--HEADING
    'CUYAHOGA WEST BANK STABILIZATION
    'LOWER STABILIZATION WALL - CASE A WITHOUT FS

    II.--CONTROL
       ANCHORED 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    = 579.00 FT.
       ELEVATION AT ANCHOR         = 577.00 FT.

    IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)         (FT)
                 0.00        552.00

         IV.B.--LEFTSIDE
```

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00
30.00	552.00
100.00	542.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 552.00 (FT)
LEFTSIDE ELEVATION = 552.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS
NONE

VII.B.--VERTICAL UNIFORM LOADS
NONE

VII.C.--VERTICAL STRIP LOADS
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS

VII.F.1.--RIGHTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	2000.00
100.00	4100.00

VII.F.2.--LEFTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)

```
             0.00          500.00
            30.00            0.00

   VIII.--HORIZONTAL LOADS

        VIII.A.--HORIZONTAL LINE LOADS
             ELEVATION     LINE LOAD
                (FT)         (PLF)
              563.00      41000.00

        VIII.B.--HORIZONTAL DISTRIBUTED LOADS
             NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 5-JUNE-2009                                           TIME: 12:34:38

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *   ANCHORED WALL DESIGN   *
                       ****************************

    I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE A WITHOUT FS

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
        AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   METHOD                            :    FREE EARTH         FIXED EARTH

   WALL BOTTOM ELEVATION (FT)        :        540.13              530.54
         PENETRATION (FT)             :        11.87               21.46

   MAXIMUM BENDING MOMENT (LB-FT)    :   -3.1955E+05         -2.7842E+05
         AT ELEVATION (FT)           :        563.00              563.00

   MAXIMUM SCALED DEFLECTION (LB-IN^3):    5.5630E+10          4.2820E+10
         AT ELEVATION (FT)           :        560.00              561.00

   ANCHOR FORCE (LB)                 :    2.2825E+04          1.9887E+04

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

<u>CASE A BACK WALL DESIGN</u> – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 22-JUNE-2009                                          TIME: 9:55:52
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```
****************
*  INPUT DATA  *
****************
```

I.--HEADING

'CUYAHOGA WEST BANK STABILIZATION

'LOWER STABILIZATION WALL - CASE A

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   = 595.00 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	595.00
1.00	600.00
50.00	605.00
100.00	620.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	590.00
75.00	579.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT

LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	<-SAFETY-> <-FACTOR-> PASS.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT

LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	<-SAFETY-> <-FACTOR-> PASS.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT   = 62.40 (PCF)

RIGHTSIDE ELEVATION = 568.00 (FT)

LEFTSIDE ELEVATION = 568.00 (FT)

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

NONE

```
VIII.--HORIZONTAL LOADS

     VIII.A.--HORIZONTAL LINE LOADS
          ELEVATION     LINE LOAD
             (FT)          (PLF)
           590.00      21308.00

     VIII.B.--HORIZONTAL DISTRIBUTED LOADS
          NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 22-JUNE-2009                                           TIME: 9:55:56

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

    I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE A

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      560.08
         PENETRATION (FT)     :       29.92

   MAX. BEND. MOMENT (LB-FT)  :  2.7063E+05
         AT ELEVATION (FT)    :      573.67

   MAX. SCALED DEFL. (LB-IN^3):  1.7134E+11
         AT ELEVATION (FT)    :      595.00

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

<u>CASE A BACK WALL DESIGN</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 22-JUNE-2009                                           TIME: 9:56:25

                            ****************
                            *  INPUT DATA  *
                            ****************

      I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE A  NO SF
```

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   = 595.00 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	595.00
1.00	600.00
50.00	605.00
100.00	620.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	590.00
75.00	579.00

V.--SOIL LAYER DATA

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

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

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

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT   = 62.40 (PCF)
RIGHTSIDE ELEVATION = 568.00 (FT)
LEFTSIDE ELEVATION = 568.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS

VIII.A.--HORIZONTAL LINE LOADS

ELEVATION (FT)	LINE LOAD (PLF)
590.00	21308.00

```
        VIII.B.--HORIZONTAL DISTRIBUTED LOADS
             NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 22-JUNE-2009                                              TIME: 9:56:29

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

    I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE A  NO SF

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      568.44
         PENETRATION (FT)     :       21.56

   MAX. BEND. MOMENT (LB-FT)  :  1.9558E+05
         AT ELEVATION (FT)    :      578.04

   MAX. SCALED DEFL. (LB-IN^3):  7.2532E+10
         AT ELEVATION (FT)    :      595.00

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

<u>CASE C FRONT WALL DESIGN</u> – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 5-JUNE-2009                                               TIME: 12:39:58

                            ****************
                            *  INPUT DATA  *
                            ****************

      I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE C

     II.--CONTROL
        ANCHORED WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.20

    III.--WALL DATA
```

ELEVATION AT TOP OF WALL = 579.00 FT.
ELEVATION AT ANCHOR = 577.00 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00
30.00	552.00
100.00	542.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 552.00 (FT)
LEFTSIDE ELEVATION = 552.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS
NONE

VII.B.--VERTICAL UNIFORM LOADS
NONE

VII.C.--VERTICAL STRIP LOADS
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

```
      VII.F.--VERTICAL VARIABLE LOADS

           VII.F.1.--RIGHTSIDE
           DIST. FROM      VARIABLE
           WALL (FT)      LOAD (PSF)
              0.00         2000.00
            100.00         4100.00

           VII.F.2.--LEFTSIDE
           DIST. FROM      VARIABLE
           WALL (FT)      LOAD (PSF)
              0.00          500.00
             30.00            0.00

   VIII.--HORIZONTAL LOADS

      VIII.A.--HORIZONTAL LINE LOADS
           ELEVATION     LINE LOAD
              (FT)         (PLF)
            563.00      46000.00

      VIII.B.--HORIZONTAL DISTRIBUTED LOADS
           NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 5-JUNE-2009                                            TIME: 12:40:03

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *   ANCHORED WALL DESIGN   *
                       ****************************

    I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE C

   II.--SUMMARY

      RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
      AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

      LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   METHOD                           :    FREE EARTH         FIXED EARTH

   WALL BOTTOM ELEVATION (FT)       :        536.13              525.38
         PENETRATION (FT)            :        15.87               26.62

   MAXIMUM BENDING MOMENT (LB-FT)   :   -3.8280E+05         -3.4024E+05
         AT ELEVATION (FT)          :        563.00              563.00

   MAXIMUM SCALED DEFLECTION (LB-IN^3):    8.0104E+10          6.2284E+10
         AT ELEVATION (FT)          :        559.00              560.00

   ANCHOR FORCE (LB)                :    2.7343E+04          2.4303E+04

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

<u>CASE C FRONT WALL DESIGN</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 5-JUNE-2009                                         TIME: 12:39:22

                            ****************
                            *  INPUT DATA  *
                            ****************

      I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE C WITHOUT FS

     II.--CONTROL
        ANCHORED 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    = 579.00 FT.
        ELEVATION AT ANCHOR         = 577.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)         (FT)
                  0.00       552.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)         (FT)
                  0.00       552.00
                 30.00       552.00
                100.00       542.00

      V.--SOIL LAYER DATA

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

               ANGLE OF          ANGLE OF                        <-SAFETY->
 SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->  <-FACTOR->
WGHT.   WGHT.  FRICTION  ESION  FRICTION   ESION   ELEV.  SLOPE  ACT. PASS.
(PCF)   (PCF)    (DEG)   (PSF)    (DEG)    (PSF)   (FT)  (FT/FT)
130.00  130.00   30.00    0.00    15.00     0.00                  DEF  DEF

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

               ANGLE OF          ANGLE OF                        <-SAFETY->
 SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->  <-FACTOR->
WGHT.   WGHT.  FRICTION  ESION  FRICTION   ESION   ELEV.  SLOPE  ACT. PASS.
(PCF)   (PCF)    (DEG)   (PSF)    (DEG)    (PSF)   (FT)  (FT/FT)
130.00  130.00   30.00    0.00    15.00     0.00                  DEF  DEF
```

```
 VI.--WATER DATA
    UNIT WEIGHT          = 62.40 (PCF)
    RIGHTSIDE ELEVATION = 552.00 (FT)
    LEFTSIDE ELEVATION  = 552.00 (FT)
    NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

    VII.A.--VERTICAL LINE LOADS
         NONE

    VII.B.--VERTICAL UNIFORM LOADS
              NONE

    VII.C.--VERTICAL STRIP LOADS
         NONE

    VII.D.--VERTICAL RAMP LOADS
         NONE

    VII.E.--VERTICAL TRIANGULAR LOADS
         NONE

    VII.F.--VERTICAL VARIABLE LOADS

         VII.F.1.--RIGHTSIDE
         DIST. FROM      VARIABLE
         WALL (FT)      LOAD (PSF)
            0.00         2000.00
          100.00         4100.00

         VII.F.2.--LEFTSIDE
         DIST. FROM      VARIABLE
         WALL (FT)      LOAD (PSF)
            0.00          500.00
           30.00            0.00

VIII.--HORIZONTAL LOADS

    VIII.A.--HORIZONTAL LINE LOADS
         ELEVATION     LINE LOAD
            (FT)         (PLF)
          563.00      46000.00

    VIII.B.--HORIZONTAL DISTRIBUTED LOADS
         NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 5-JUNE-2009                                            TIME: 12:39:26

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *   ANCHORED WALL DESIGN   *
                       ****************************

   I.--HEADING
    'CUYAHOGA WEST BANK STABILIZATION
    'LOWER STABILIZATION WALL - CASE C WITHOUT FS

  II.--SUMMARY
```

```
     RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

     LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

METHOD                              :    FREE EARTH         FIXED EARTH

WALL BOTTOM ELEVATION (FT)          :        539.35              529.48
      PENETRATION (FT)               :        12.65               22.52

MAXIMUM BENDING MOMENT (LB-FT)      :   -3.6325E+05         -3.1807E+05
      AT ELEVATION (FT)             :        563.00              563.00

MAXIMUM SCALED DEFLECTION (LB-IN^3):    6.5640E+10          5.0700E+10
      AT ELEVATION (FT)             :        560.00              561.00

ANCHOR FORCE (LB)                   :    2.5947E+04          2.2719E+04

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

<u>CASE C BACK WALL DESIGN</u> – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
  PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
  DATE: 22-JUNE-2009                                          TIME: 9:57:06

                              ****************
                              *  INPUT DATA  *
                              ****************

       I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'LOWER STABILIZATION WALL - CASE C

      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    = 595.00 FT.

      IV.--SURFACE POINT DATA

           IV.A.--RIGHTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)         (FT)
                   0.00        595.00
                   1.00        600.00
                  50.00        605.00
                 100.00        620.00

           IV.B.--LEFTSIDE
              DIST. FROM     ELEVATION
```

```
            WALL (FT)         (FT)
                 0.00        590.00
                75.00        579.00

       V.--SOIL LAYER DATA

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

                ANGLE OF         ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                   DEF  DEF

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

                ANGLE OF         ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                   DEF  DEF

      VI.--WATER DATA
         UNIT WEIGHT         = 62.40 (PCF)
         RIGHTSIDE ELEVATION = 568.00 (FT)
         LEFTSIDE ELEVATION  = 568.00 (FT)
         NO SEEPAGE

     VII.--VERTICAL SURCHARGE LOADS
         NONE

    VIII.--HORIZONTAL LOADS

         VIII.A.--HORIZONTAL LINE LOADS
              ELEVATION     LINE LOAD
                 (FT)         (PLF)
               590.00      24303.00

         VIII.B.--HORIZONTAL DISTRIBUTED LOADS
              NONE
 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
 DATE: 22-JUNE-2009                                          TIME: 9:57:10

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

     I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'LOWER STABILIZATION WALL - CASE C

    II.--SUMMARY

         RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

         LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.
```

```
WALL BOTTOM ELEV. (FT)     :      558.32
      PENETRATION (FT)     :       31.68

MAX. BEND. MOMENT (LB-FT)  :  3.2091E+05
      AT ELEVATION (FT)    :      572.76

MAX. SCALED DEFL. (LB-IN^3):  2.2420E+11
      AT ELEVATION (FT)    :      595.00

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

<u>CASE C BACK WALL DESIGN</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 22-JUNE-2009                                          TIME: 9:57:33

                            ****************
                            *  INPUT DATA  *
                            ****************

      I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE C   NO SF

     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    = 595.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00        595.00
                  1.00        600.00
                 50.00        605.00
                100.00        620.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00        590.00
                 75.00        579.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

```
               ANGLE OF         ANGLE OF                             <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

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

               ANGLE OF         ANGLE OF                             <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

     VI.--WATER DATA
        UNIT WEIGHT         = 62.40 (PCF)
        RIGHTSIDE ELEVATION = 568.00 (FT)
        LEFTSIDE ELEVATION  = 568.00 (FT)
        NO SEEPAGE

    VII.--VERTICAL SURCHARGE LOADS
        NONE

   VIII.--HORIZONTAL LOADS

        VIII.A.--HORIZONTAL LINE LOADS
             ELEVATION     LINE LOAD
                (FT)         (PLF)
              590.00      24303.00

        VIII.B.--HORIZONTAL DISTRIBUTED LOADS
             NONE


 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
 DATE: 22-JUNE-2009                                          TIME: 9:57:38

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

    I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE C   NO SF

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      567.19
         PENETRATION (FT)     :       22.81

   MAX. BEND. MOMENT (LB-FT)  :  2.3243E+05
         AT ELEVATION (FT)    :      577.36
```

MAX. SCALED DEFL. (LB-IN^3): 9.4743E+10
AT ELEVATION (FT) : 595.00

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

CASE D FRONT WALL DESIGN – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 17-JUNE-2009 TIME: 9:57:33

****
* INPUT DATA *
****

I.--HEADING
'CUYAHOGA WEST BANK STABILIZATION
'LOWER STABILIZATION WALL - CASE D

II.--CONTROL
ANCHORED WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.20

III.--WALL DATA
ELEVATION AT TOP OF WALL = 579.00 FT.
ELEVATION AT ANCHOR = 577.00 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00
30.00	552.00
100.00	542.00

V.--SOIL LAYER DATA

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

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 552.00 (FT)
LEFTSIDE ELEVATION = 552.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS
NONE

VII.B.--VERTICAL UNIFORM LOADS
NONE

VII.C.--VERTICAL STRIP LOADS
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS

VII.F.1.--RIGHTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	2000.00
100.00	4100.00

VII.F.2.--LEFTSIDE

DIST. FROM WALL (FT)	VARIABLE LOAD (PSF)
0.00	500.00
30.00	0.00

VIII.--HORIZONTAL LOADS

VIII.A.--HORIZONTAL LINE LOADS

ELEVATION (FT)	LINE LOAD (PLF)
563.00	57000.00

VIII.B.--HORIZONTAL DISTRIBUTED LOADS
NONE

****

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

     I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'LOWER STABILIZATION WALL - CASE D

    II.--SUMMARY

         RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
         AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

         LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

    METHOD                             :    FREE EARTH         FIXED EARTH

    WALL BOTTOM ELEVATION (FT)         :        534.50              523.13
          PENETRATION (FT)              :        17.50               28.87

    MAXIMUM BENDING MOMENT (LB-FT)     :   -4.8509E+05         -4.3439E+05
          AT ELEVATION (FT)            :        563.00              563.00

    MAXIMUM SCALED DEFLECTION (LB-IN^3):    1.0869E+11          8.5074E+10
          AT ELEVATION (FT)            :        559.00              560.00

    ANCHOR FORCE (LB)                  :    3.4650E+04          3.1028E+04

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

<u>CASE D FRONT WALL DESIGN</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
  PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
  DATE: 17-JUNE-2009                                       TIME: 9:56:56

                         ****************
                         *  INPUT DATA  *
                         ****************

       I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'LOWER STABILIZATION WALL - CASE D WITHOUT FS

      II.--CONTROL
         ANCHORED 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     = 579.00 FT.
         ELEVATION AT ANCHOR          = 577.00 FT.

      IV.--SURFACE POINT DATA
```

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	552.00
30.00	552.00
100.00	542.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
130.00	130.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 552.00 (FT)
LEFTSIDE ELEVATION = 552.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS
NONE

VII.B.--VERTICAL UNIFORM LOADS
NONE

VII.C.--VERTICAL STRIP LOADS
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS

VII.F.1.--RIGHTSIDE

DIST. FROM WALL (FT) VARIABLE LOAD (PSF)

```
            0.00          2000.00
          100.00          4100.00

           VII.F.2.--LEFTSIDE
           DIST. FROM      VARIABLE
           WALL (FT)      LOAD (PSF)
             0.00          500.00
            30.00            0.00

   VIII.--HORIZONTAL LOADS

      VIII.A.--HORIZONTAL LINE LOADS
           ELEVATION     LINE LOAD
              (FT)         (PLF)
            563.00      57000.00

      VIII.B.--HORIZONTAL DISTRIBUTED LOADS
           NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 17-JUNE-2009                                        TIME: 9:57:01

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *   ANCHORED WALL DESIGN   *
                       ****************************

    I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE D WITHOUT FS

   II.--SUMMARY

      RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
      AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

      LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   METHOD                            :    FREE EARTH         FIXED EARTH

   WALL BOTTOM ELEVATION (FT)        :        537.82              527.40
         PENETRATION (FT)             :        14.18               24.60

   MAXIMUM BENDING MOMENT (LB-FT)    :   -4.6115E+05         -4.0734E+05
         AT ELEVATION (FT)           :        563.00              563.00

   MAXIMUM SCALED DEFLECTION (LB-IN^3):    8.9298E+10          6.9412E+10
         AT ELEVATION (FT)           :        560.00              561.00

   ANCHOR FORCE (LB)                 :    3.2939E+04          2.9096E+04

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

<u>CASE D BACK WALL DESIGN</u> – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

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  PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
  DATE: 22-JUNE-2009                                          TIME: 9:58:08

                            ****************
                            *  INPUT DATA  *
                            ****************

       I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'LOWER STABILIZATION WALL - CASE D

      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    = 595.00 FT.

      IV.--SURFACE POINT DATA

           IV.A.--RIGHTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)        (FT)
                   0.00       595.00
                   1.00       600.00
                  50.00       605.00
                 100.00       620.00

           IV.B.--LEFTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)        (FT)
                   0.00       590.00
                  75.00       579.00

       V.--SOIL LAYER DATA

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

                ANGLE OF         ANGLE OF                        <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

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

                ANGLE OF         ANGLE OF                        <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF
```

```
     VI.--WATER DATA
        UNIT WEIGHT         = 62.40 (PCF)
        RIGHTSIDE ELEVATION = 568.00 (FT)
        LEFTSIDE ELEVATION  = 568.00 (FT)
        NO SEEPAGE

    VII.--VERTICAL SURCHARGE LOADS
        NONE

   VIII.--HORIZONTAL LOADS

        VIII.A.--HORIZONTAL LINE LOADS
             ELEVATION     LINE LOAD
                (FT)         (PLF)
              590.00      31028.00

        VIII.B.--HORIZONTAL DISTRIBUTED LOADS
             NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 22-JUNE-2009                                            TIME: 9:58:11

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

    I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'LOWER STABILIZATION WALL - CASE A

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      554.54
         PENETRATION (FT)     :       35.46

   MAX. BEND. MOMENT (LB-FT)  :  4.4322E+05
         AT ELEVATION (FT)    :      570.90

   MAX. SCALED DEFL. (LB-IN^3):  3.7592E+11
         AT ELEVATION (FT)    :      595.00

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

<u>CASE D BACK WALL DESIGN</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
 DATE: 22-JUNE-2009                                          TIME: 9:58:38

                            ****************
                            *  INPUT DATA  *
                            ****************

       I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'LOWER STABILIZATION WALL - CASE D  NO SF

      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    = 595.00 FT.

      IV.--SURFACE POINT DATA

           IV.A.--RIGHTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)        (FT)
                   0.00       595.00
                   1.00       600.00
                  50.00       605.00
                 100.00       620.00

           IV.B.--LEFTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)        (FT)
                   0.00       590.00
                  75.00       579.00

       V.--SOIL LAYER DATA

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

                ANGLE OF         ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF

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

                ANGLE OF         ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00  130.00    30.00    0.00    15.00    0.00                  DEF  DEF
```

```
      VI.--WATER DATA
         UNIT WEIGHT         = 62.40 (PCF)
         RIGHTSIDE ELEVATION = 568.00 (FT)
         LEFTSIDE ELEVATION  = 568.00 (FT)
         NO SEEPAGE

     VII.--VERTICAL SURCHARGE LOADS
         NONE

    VIII.--HORIZONTAL LOADS

         VIII.A.--HORIZONTAL LINE LOADS
              ELEVATION     LINE LOAD
                 (FT)         (PLF)
               590.00      31028.00

         VIII.B.--HORIZONTAL DISTRIBUTED LOADS
              NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 22-JUNE-2009                                              TIME: 9:58:43

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

     I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'LOWER STABILIZATION WALL - CASE D  NO SF

    II.--SUMMARY

         RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

         LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

    WALL BOTTOM ELEV. (FT)     :      564.59
          PENETRATION (FT)     :       25.41

    MAX. BEND. MOMENT (LB-FT)  :  3.2229E+05
          AT ELEVATION (FT)    :      575.95

    MAX. SCALED DEFL. (LB-IN^3):  1.5752E+11
          AT ELEVATION (FT)    :      595.00

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

CWALSHT INPUT/OUTPUT FOR RETAINING WALL AT TOP OF SLOPE

FRONT WALL DESIGN – RUN TO DETERMINE PILE TIP ELEVATION AND ANCHOR FORCE, SAFETY FACTORS APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
  PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
  DATE: 23-JUNE-2009                                          TIME: 7:45:44

                              ****************
                              *  INPUT DATA  *
                              ****************

        I.--HEADING
       'CUYAHOGA WEST BANK STABILIZATION
       'RETAINING WALL AT TOP OF SLOPE

       II.--CONTROL
          ANCHORED 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    = 680.00 FT.
          ELEVATION AT ANCHOR         = 678.00 FT.

       IV.--SURFACE POINT DATA

            IV.A.--RIGHTSIDE
               DIST. FROM     ELEVATION
               WALL (FT)         (FT)
                    0.00        680.00

            IV.B.--LEFTSIDE
               DIST. FROM     ELEVATION
               WALL (FT)         (FT)
                    0.00        660.00
                  168.00        604.00
                  250.00        604.00

        V.--SOIL LAYER DATA

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

                 ANGLE OF          ANGLE OF                           <-SAFETY->
   SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->  <-FACTOR->
  WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
  (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
 125.00  125.00    30.00    0.00    15.00    0.00                  DEF  DEF

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

                 ANGLE OF          ANGLE OF                           <-SAFETY->
   SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->  <-FACTOR->
```

```
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
125.00  125.00    30.00    0.00    15.00    0.00                  DEF  DEF

      VI.--WATER DATA
         UNIT WEIGHT         = 62.40 (PCF)
         RIGHTSIDE ELEVATION = 650.00 (FT)
         LEFTSIDE ELEVATION  = 650.00 (FT)
         NO SEEPAGE

     VII.--VERTICAL SURCHARGE LOADS

         VII.A.--VERTICAL LINE LOADS
              NONE

         VII.B.--VERTICAL UNIFORM LOADS
                   LEFTSIDE     RIGHTSIDE
                     (PSF)        (PSF)
                      0.00        250.00

         VII.C.--VERTICAL STRIP LOADS
              NONE

         VII.D.--VERTICAL RAMP LOADS
              NONE

         VII.E.--VERTICAL TRIANGULAR LOADS
              NONE

         VII.F.--VERTICAL VARIABLE LOADS
              NONE

    VIII.--HORIZONTAL LOADS
         NONE


 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
 DATE: 23-JUNE-2009                                          TIME: 7:45:49

                        ****************************
                        *  SUMMARY OF RESULTS FOR  *
                        *   ANCHORED WALL DESIGN   *
                        ****************************

     I.--HEADING
      'CUYAHOGA WEST BANK STABILIZATION
      'RETAINING WALL AT TOP OF SLOPE

    II.--SUMMARY

         RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
         AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

         LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

         *****WARNING:  STANDARD WEDGE SOLUTION DOES NOT EXIST
                        AT ALL ELEVATIONS.  SEE COMPLETE OUTPUT.

    METHOD                            :    FREE EARTH        FIXED EARTH

    WALL BOTTOM ELEVATION (FT)        :        638.24             628.40
```

```
      PENETRATION (FT)              :        21.76               31.60

   MAXIMUM BENDING MOMENT (LB-FT)   :   -6.7760E+04         -5.6408E+04
      AT ELEVATION (FT)             :        662.03              663.07

   MAXIMUM SCALED DEFLECTION (LB-IN^3):    1.6478E+10          1.2343E+10
      AT ELEVATION (FT)             :        660.00              661.00

   ANCHOR FORCE (LB)                :    7.1828E+03          6.4483E+03

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

<u>FRONT WALL DESIGN</u> – RUN TO DETERMINE MAXIMUM SHEET PILE BENDING MOMENT AND DEFLECTION, SAFETY FACTORS NOT APPLIED TO SOIL PARAMETERS IN PASSIVE ZONE

```
 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
 DATE: 23-JUNE-2009                                         TIME: 7:49:06

                            ****************
                            *  INPUT DATA  *
                            ****************

      I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'RETAINING WALL AT TOP OF SLOPE WITHOUT SF

     II.--CONTROL
        ANCHORED 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    = 680.00 FT.
        ELEVATION AT ANCHOR         = 678.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       680.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       660.00
                168.00       604.00
                250.00       604.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

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.
125.00	125.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
125.00	125.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT   = 62.40 (PCF)
RIGHTSIDE ELEVATION = 650.00 (FT)
LEFTSIDE ELEVATION = 650.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS

NONE

VII.B.--VERTICAL UNIFORM LOADS

LEFTSIDE (PSF)	RIGHTSIDE (PSF)
0.00	250.00

VII.C.--VERTICAL STRIP LOADS

NONE

VII.D.--VERTICAL RAMP LOADS

NONE

VII.E.--VERTICAL TRIANGULAR LOADS

NONE

VII.F.--VERTICAL VARIABLE LOADS

NONE

VIII.--HORIZONTAL LOADS

NONE

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

DATE: 23-JUNE-2009 TIME: 7:49:13

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

I.--HEADING

'CUYAHOGA WEST BANK STABILIZATION
'RETAINING WALL AT TOP OF SLOPE WITHOUT SF

II.--SUMMARY

```
RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELLASTICITY EQUATIONS FOR SURCHARGE LOADS.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

*****WARNING:  STANDARD WEDGE SOLUTION DOES NOT EXIST
               AT ALL ELEVATIONS.  SEE COMPLETE OUTPUT.

METHOD                              :    FREE EARTH         FIXED EARTH

WALL BOTTOM ELEVATION (FT)          :        647.29              639.51
      PENETRATION (FT)               :        12.71               20.49

MAXIMUM BENDING MOMENT (LB-FT)      :   -4.3727E+04         -3.5571E+04
      AT ELEVATION (FT)             :        664.41              665.41

MAXIMUM SCALED DEFLECTION (LB-IN^3):    6.5105E+09          4.8996E+09
      AT ELEVATION (FT)             :        664.00              664.00

ANCHOR FORCE (LB)                   :    5.5597E+03          4.9369E+03

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

BACK WALL DESIGN

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 23-JUNE-2009                                          TIME: 9:33:55

                            ****************
                            *  INPUT DATA  *
                            ****************

     I.--HEADING
    'CUYAHOGA WEST BANK STABILIZATION
    'ANCHOR WALL FOR RETAINING WALL AT TOP OF SLOPE

    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    = 679.00 FT.

    IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00       679.00
                 1.00       680.00

         IV.B.--LEFTSIDE
            DIST. FROM     ELEVATION
```

WALL (FT)	(FT)
0.00	678.00
1.00	680.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
125.00	125.00	30.00	0.00	15.00	0.00			DEF	DEF

V.B.--LEFTSIDE

LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

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.
125.00	125.00	30.00	0.00	15.00	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 650.00 (FT)
LEFTSIDE ELEVATION = 650.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS
NONE

VII.B.--VERTICAL UNIFORM LOADS

LEFTSIDE (PSF)	RIGHTSIDE (PSF)
0.00	250.00

VII.C.--VERTICAL STRIP LOADS
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS
NONE

VIII.--HORIZONTAL LOADS

VIII.A.--HORIZONTAL LINE LOADS

ELEVATION (FT)	LINE LOAD (PLF)
678.00	7182.00

VIII.B.--HORIZONTAL DISTRIBUTED LOADS

```
          NONE


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 23-JUNE-2009                                          TIME: 9:34:00

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

    I.--HEADING
     'CUYAHOGA WEST BANK STABILIZATION
     'ANCHOR WALL FOR RETAINING WALL AT TOP OF SLOPE

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      666.47
         PENETRATION (FT)     :       11.53

   MAX. BEND. MOMENT (LB-FT)  :  2.4760E+04
         AT ELEVATION (FT)    :      672.54

   MAX. SCALED DEFL. (LB-IN^3):  1.8240E+09
         AT ELEVATION (FT)    :      679.00

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

DESIGN OF ANCHORAGE COMPONENTS FOR CASE A & C LOWER STABILITY WALL

Per EM 1110-2-2504, anchorage components must be determined using design results with safety factors applied to the strength parameters of soil in passive resistance zone.

Tension Anchor Force from Cwalsht Fixed Earth Analysis:
(use Case C force for design of Case A also)

$$T_{anc} := 24303 \cdot \frac{lb}{ft}$$

SIZE WALES USING CWALSHT RESULTS

$s := 11.28 \cdot ft$ Tierod Spacing

$E := 29000000 \cdot \frac{lb}{in^2}$ Modulus of Elasticity

$F_y := 50000 \cdot \frac{lb}{in^2}$ Wale Yield Stress
A50 Steel

$M_x := \frac{T_{anc} \cdot s^2}{10}$ $M_x = 309227\, lb\, ft$

Maximum Wale Bending Moment per EM 1110-2-2504, equation for three span continuous beam

Try 2 MC18x51.9 Channel Sections

MC18x51.9 Properties:

$h := 18 \cdot in$ Channel Web Depth $t_w := 0.6 \cdot in$ Channel Web Thickness

$t_f := 0.625 \cdot in$ Channel Flange Thickness

$S_x := 69.7 \cdot in^3$ $I_x := 627 \cdot in^4$

$f_{bx} := \frac{M_x}{2S_x}$ $f_{bx} = 26619 \frac{lb}{in^2}$ Bending stress about x-axis

$F_b := 0.66 \cdot F_y$

$F_y = 50000 \frac{lb}{in^2}$ $F_{bx} := \frac{5}{6} \cdot 0.66 \cdot F_y$ Allowable bending stress about x-axis using factors from EM 1110-2-2105

$F_{bx} = 27500 \frac{lb}{in^2}$ > $f_{bx} = 26619 \frac{lb}{in^2}$ OK

CHECK SHEAR ON 2 MC18x51.9

$F_v := \frac{5}{6} \cdot 0.4 \cdot F_y$ $\quad F_v = 16667 \frac{lb}{in^2}$ Allowable Shear Stress

$V := \frac{T_{anc} \cdot s}{2}$ $\quad V = 137069\,lb$ Maximum Shear in Wale

$A_v := 2 \cdot h \cdot t_w$ $\quad A_v = 21.6\,in^2$ Web Area Resisting Shear

$f_v := \frac{V}{A_v}$ $\quad f_v = 6346 \frac{lb}{in^2}$ Wale Shear Stress $<$ $F_v = 16667 \frac{lb}{in^2}$ OK

Check Maximum Wale Deflection (Equation for 3-span continous beam)

$D := \frac{0.0069 \cdot T_{anc} \cdot s^4}{E \cdot 2 I_x}$ $\quad D = 0.129\,in$ OK

USE 2 MC18x51.9 Grade 50 Channel Sections

SIZE TIERROD USING CWALSHT RESULTS

$s = 11.28\,ft$ Tierod Spacing

$T_{anc} = 24303 \frac{lb}{ft}$ Anchor Force from CWALSHT results

$T_t := T_{anc} \cdot s$ $\quad T_t = 274138\,lb$ Tensile Force per Tierod

Use all-thread bar tierods

$P_y := 775000 \cdot lb$ Yield Strength for 3 inch diameter Grade 150 thread bar $\quad F_y := 150000 \cdot \frac{lb}{in^2}$

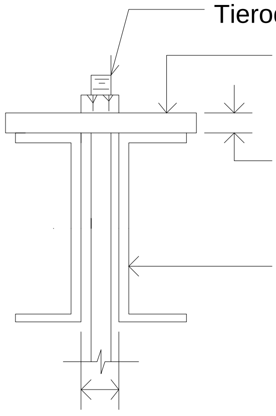
Reduce yield strengths by 0.4 per EM 1110-2-2504 to get allowable tensile strength

$P_a := 0.4 \cdot P_y$ Allowable Strength for 3 inch diameter Grade 150 thread bar

$P_a = 310000\,lb$ $>$ $T_t = 274138\,lb$ OK

Use 3" diameter Grade 150 threadbars at 11.28' on center

SIZE TIEROD PLATE WASHER



$T_t = 274138\,lb$ Tensile Force per Tierod

$d_h := 3.25 \cdot in$ Hole Diameter in Plate for Tierod

$b := 13 \cdot in$ Plate Length

$t := 2.5 \cdot in$ Trial Plate Thickness

$S := \frac{(b - d_h) \cdot t^2}{6}$ $S = 10.16\,in^3$ Plate Section Modulus

$d_c := 3.5 \cdot in$ Distance Between Channels

$F_y := 50000 \cdot \frac{lb}{in^2}$ Yield Stress $F_b := \frac{5}{6} \cdot 0.6 \cdot F_y$ $F_b = 25000\,\frac{lb}{in^2}$ Allowable Bending Stress per EM 1110-2-2105

$M := \frac{T_t \cdot d_c}{4}$ $M = 239871\,lb \cdot in$ Plate Bending Moment

$f_b := \frac{M}{S}$ $f_b = 23618\,\frac{lb}{in^2}$ Plate Bending Stress < $F_b = 25000\,\frac{lb}{in^2}$ OK

USE 13" x 10" x 2.5" GRADE A50 TIEROD PLATE WASHER

SIZE BOLTS FOR WALES TO KING PILE CONNECTION

$T := \frac{T_{anc} \cdot 67.69 \cdot in}{2}$ $T = 68545\,lb$ Maximum applied tensile force per bolt (2 bolts at 67.69" on center)

Use A307 bolts, Tensile Strength for 2.25" bolt = 195000 lb (from ASTM A307)

Allowable Tension = $0.4 \cdot 195000 \cdot lb = 78000\,lb$ > $T = 68545\,lb$ OK,

Use two 2-1/4" diameter A307 bolts at 67.69" on center

SIZE BOLT PLATE WASHER

Single plate washer will be used for each pair of bolts

$T := \frac{T_{anc} \cdot 67.69 \cdot in}{2}$ $T = 68545\,lb$ Tensile Force per Bolt

$d_h := 2.5 \cdot in$ Hole Diameter for Bolts (2.25" bolts)

$b := 13 \cdot in$ Plate Length $t := 2 \cdot in$ Trial Plate Thickness

$S := \frac{(b - 2 \cdot d_h) \cdot t^2}{6}$ $S = 5.33\,in^3$ Plate Section Modulus

$d_c = 3.5\,in$ Distance Between Channels

$F_y := 50000 \cdot \frac{lb}{in^2}$ Yield Stress $F_b := 0.83 \cdot 0.6 \cdot F_y$ $F_b = 24900\,\frac{lb}{in^2}$ Allowable Bending Stress per EM 1110-2-2105

$M := \frac{2 \cdot T \cdot d_c}{4}$ $M = 119953\,lb \cdot in$ Plate Bending Moment

$f_b := \frac{M}{S}$ $f_b = 22491\,\frac{lb}{in^2}$ Plate Bending Stress < $F_b = 24900\,\frac{lb}{in^2}$ OK

USE 13" x 10" x 2" BOLT PLATE WASHER PER PAIR OF BOLTS

DESIGN OF ANCHORAGE COMPONENTS FOR CASE D LOWER STABILITY WALL

Per EM 1110-2-2504, anchorage components must be determined using design results with safety factors applied to the strength parameters of soil in passive resistance zone.

Tension Anchor Force from Cwalsht Fixed Earth Analysis: $T_{anc} := 31028 \cdot \frac{lb}{ft}$

SIZE WALES USING CWALSHT RESULTS

$s := 9.5 \cdot ft$ Tierod Spacing

$E := 29000000 \cdot \frac{lb}{in^2}$ Modulus of Elasticity

$F_y := 50000 \cdot \frac{lb}{in^2}$ Wale Yield Stress
Grade 50 Steel

$M_x := \frac{T_{anc} \cdot s^2}{10}$ $M_x = 280028\,lb\,ft$ Maximum Wale Bending Moment per EM 1110-2-2504, equation for three span continuous beam

Try 2 MC18x51.9 Channel Sections

MC18x51.9 Properties:

$h := 18 \cdot in$ Channel Web Depth $t_w := 0.6 \cdot in$ Channel Web Thickness

$t_f := 0.625 \cdot in$ Channel Flange Thickness

$S_x := 69.7 \cdot in^3$ $I_x := 627 \cdot in^4$

$f_{bx} := \frac{M_x}{2S_x}$ $f_{bx} = 24106 \frac{lb}{in^2}$ Bending stress about x-axis

$F_b := 0.66 \cdot F_y$

$F_y = 50000 \frac{lb}{in^2}$ $F_{bx} := \frac{5}{6} \cdot 0.66 \cdot F_y$ Allowable bending stress about x-axis using factors from EM 1110-2-2105

$F_{bx} = 27500 \frac{lb}{in^2}$ > $f_{bx} = 24106 \frac{lb}{in^2}$ OK

CHECK SHEAR ON 2 MC18x51.9

$F_v := \frac{5}{6} \cdot 0.4 \cdot F_y \quad F_v = 16667 \frac{lb}{in^2}$ Allowable Shear Stress

$V := \frac{T_{anc} \cdot s}{2} \quad V = 147383\, lb$ Maximum Shear in Wale

$A_v := 2 \cdot h \cdot t_w \quad A_v = 21.6\, in^2$ Web Area Resisting Shear

$f_v := \frac{V}{A_v} \quad f_v = 6823 \frac{lb}{in^2}$ Wale Shear Stress $<$ $F_v = 16667 \frac{lb}{in^2}$ OK

Check Maximum Wale Deflection (Equation for 3-span continous beam)

$D := \frac{0.0069 \cdot T_{anc} \cdot s^4}{E \cdot 2 I_x} \quad D = 0.083\, in$ OK

USE 2 MC18x51.9 Grade 50 Channel Sections

SIZE TIEROD USING CWALSHT RESULTS

$s = 9.5\, ft$ Tierod Spacing

$T_{anc} = 31028 \frac{lb}{ft}$ Anchor Force from CWALSHT results

$T_t := T_{anc} \cdot s \quad T_t = 294766\, lb$ Tensile Force per Tierod

Use all-thread bar tierods

$P_y := 775000 \cdot lb$ Yield Strength for 3 inch diameter Grade 150 thread bar $F_y := 150000 \cdot \frac{lb}{in^2}$

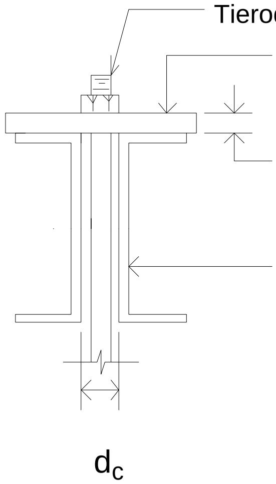
Reduce yield strengths by 0.4 per EM 1110-2-2504 to get allowable tensile strength

$P_a := 0.4 \cdot P_y$ Allowable Strength for 3 inch diameter Grade 150 thread bar

$P_a = 310000\, lb$ $>$ $T_t = 294766\, lb$ OK

Use 3" diameter Grade 150 threadbars at 9.5' on center

SIZE TIEROD PLATE WASHER



$T_t = 294766\,lb$ Tensile Force per Tierod

$d_h := 3.25 \cdot in$ Hole Diameter in Plate for Tierod

$b := 13 \cdot in$ Plate Length

$t := 2.5 \cdot in$ Trial Plate Thickness

$S := \frac{(b - d_h) \cdot t^2}{6}$ $S = 10.16\,in^3$ Plate Section Modulus

$d_c := 3.5 \cdot in$ Distance Between Channels

$F_y := 50000 \cdot \frac{lb}{in^2}$ Yield Stress

$F_b := \frac{5}{6} \cdot 0.6 \cdot F_y$ $F_b = 25000 \frac{lb}{in^2}$ Allowable Bending Stress per EM 1110-2-2105

$M := \frac{T_t \cdot d_c}{4}$ $M = 257920\,lb \cdot in$ Plate Bending Moment

$f_b := \frac{M}{S}$ $f_b = 25395 \frac{lb}{in^2}$ Plate Bending Stress ~ $F_b = 25000 \frac{lb}{in^2}$ OK

USE 13" x 10" x 2.5" GRADE A50 TIEROD PLATE WASHER

SIZE BOLTS FOR WALES TO KING PILE CONNECTION

$T := \frac{T_{anc} \cdot 67.77 \cdot in}{2}$ $T = 87615\,lb$ Maximum applied tensile force per bolt (2 bolts at 67.77" on center)

Use A307 bolts, Tensile Strength for 2.5" bolt = 240000 lb (from ASTM A307)

Allowable Tension = $0.4 \cdot 240000 \cdot lb = 96000\,lb$ > $T = 87615\,lb$ OK,

Use two 2-1/2" diameter A307 bolts at 67.77" on center

SIZE BOLT PLATE WASHER

Single plate washer will be used for each pair of bolts

$T := \frac{T_{anc} \cdot 67.77 \cdot in}{2}$ $T = 87615\,lb$ Tensile Force per Bolt

$d_h := 2.75 \cdot in$ Hole Diameter for Bolts (2.5" bolts)

$b := 13 \cdot in$ Plate Length $t := 2.25 \cdot in$ Trial Plate Thickness

$S := \frac{(b - 2 \cdot d_h) \cdot t^2}{6}$ $S = 6.33\,in^3$ Plate Section Modulus

$d_c = 3.5\,in$ Distance Between Channels

$F_y := 50000 \cdot \frac{lb}{in^2}$ Yield Stress $F_b := \frac{5}{6} \cdot 0.6 \cdot F_y$ $F_b = 25000\,\frac{lb}{in^2}$ Allowable Bending Stress per EM 1110-2-2105

$M := \frac{2 \cdot T \cdot d_c}{4}$ $M = 153327\,lb \cdot in$ Plate Bending Moment

$f_b := \frac{M}{S}$ $f_b = 24229\,\frac{lb}{in^2}$ Plate Bending Stress < $F_b = 25000\,\frac{lb}{in^2}$ OK

USE 13" x 10" x 2.25" BOLT PLATE WASHER PER PAIR OF BOLTS

DESIGN OF ANCHORAGE COMPONENTS FOR RETAINING WALL AT TOP OF SLOPE

Per EM 1110-2-2504, anchorage components must be determined using design results with safety factors applied to the strength parameters of soil in passive resistance zone.

Tension Anchor Force from Cwalsht Free Earth Analysis: $T_{anc} := 7182 \cdot \frac{lb}{ft}$

SIZE WALES USING CWALSHT RESULTS

$s := 13.94 \cdot ft$ Tierod Spacing

$E := 29000000 \cdot \frac{lb}{in^2}$ Modulus of Elasticity

$F_y := 50000 \cdot \frac{lb}{in^2}$ Wale Yield Stress
A50 Steel

$M_x := \frac{T_{anc} \cdot s^2}{10}$ $M_x = 139563\, lb\, ft$ Maximum Wale Bending Moment per EM 1110-2-2504, equation for three span continuous beam

Try 2 MC12x31 Channel Sections

MC12x31 Properties:

$h := 12 \cdot in$ Channel Web Depth $t_w := 0.37 \cdot in$ Channel Web Thickness

$t_f := 0.7 \cdot in$ Channel Flange Thickness

$S_x := 33.8 \cdot in^3$ $I_x := 203 \cdot in^4$

$f_{bx} := \frac{M_x}{2 S_x}$ $f_{bx} = 24775 \frac{lb}{in^2}$ Bending stress about x-axis

$F_b := 0.66 \cdot F_y$

$F_y = 50000 \frac{lb}{in^2}$ $F_{bx} := \frac{5}{6} \cdot 0.66 \cdot F_y$ Allowable bending stress about x-axis using factors from EM 1110-2-2105

$F_{bx} = 27500 \frac{lb}{in^2}$ > $f_{bx} = 24775 \frac{lb}{in^2}$ OK

CHECK SHEAR ON 2 MC12x31

$F_v := \frac{5}{6} \cdot 0.4 \cdot F_y$ $F_v = 16667 \frac{lb}{in^2}$ Allowable Shear Stress

$V := \frac{T_{anc} \cdot s}{2}$ $V = 50059\,lb$ Maximum Shear in Wale

$A_v := 2 \cdot h \cdot t_w$ $A_v = 8.88\,in^2$ Web Area Resisting Shear

$f_v := \frac{V}{A_v}$ $f_v = 5637 \frac{lb}{in^2}$ Wale Shear Stress < $F_v = 16667 \frac{lb}{in^2}$ OK

Check Maximum Wale Deflection (Equation for 3-span continous beam)

$D := \frac{0.0069 \cdot T_{anc} \cdot s^4}{E \cdot 2 I_x}$ $D = 0.275\,in$ OK

USE 2 MC12x31 Grade 50 Channel Sections

SIZE TIEROD USING CWALSHT RESULTS

$s = 13.94\,ft$ Tierod Spacing

$T_{anc} = 7182 \frac{lb}{ft}$ Anchor Force from CWALSHT results

$T_t := T_{anc} \cdot s$ $T_t = 100117\,lb$ Tensile Force per Tierod

Use all-thread bar tierods

$P_y := 320000 \cdot lb$ Yield Strength for 1-3/4 inch diameter Grade 150 thread bar $F_y := 150000 \cdot \frac{lb}{in^2}$

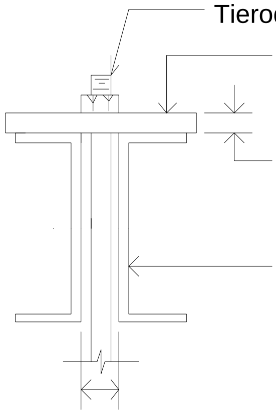
Reduce yield strengths by 0.4 per EM 1110-2-2504 to get allowable tensile strength

$P_a := 0.4 \cdot P_y$ Allowable Strength for 1-3/4 inch diameter Grade 150 thread bar

$P_a = 128000\,lb$ > $T_t = 100117\,lb$ OK

Use 1-3/4" diameter Grade 150 threadbars at 13.94' on center

SIZE TIEROD PLATE WASHER



$T_t = 100117\,lb$ Tensile Force per Tierod

$d_h := 2 \cdot in$ Hole Diameter in Plate for Tierod

$b := 9 \cdot in$ Plate Length

$t := 1.375 \cdot in$ Trial Plate Thickness

$S := \frac{(b - d_h) \cdot t^2}{6}$ $S = 2.21\,in^3$ Plate Section Modulus

$d_c := 2 \cdot in$ Distance Between Channels

$F_y := 50000 \cdot \frac{lb}{in^2}$ Yield Stress $F_b := \frac{5}{6} \cdot 0.6 \cdot F_y$ $F_b = 25000\,\frac{lb}{in^2}$ Allowable Bending Stress per EM 1110-2-2105

$M := \frac{T_t \cdot d_c}{4}$ $M = 50059\,lb \cdot in$ Plate Bending Moment

$f_b := \frac{M}{S}$ $f_b = 22695\,\frac{lb}{in^2}$ Plate Bending Stress < $F_b = 25000\,\frac{lb}{in^2}$ OK

USE 9" x 9" x 1.375" GRADE A50 TIEROD PLATE WASHER

SIZE BOLTS FOR WALES TO SHEET PILE CONNECTION

$T := \frac{T_{anc} \cdot 55.76 \cdot in}{2}$ $T = 16686\,lb$ Maximum applied tensile force per bolt (2 bolts at 55.76" on center)

Use A307 bolts, Tensile Strength for 1-1/4" bolt = 58150 lb (from ASTM A307)

Allowable Tension = $0.4 \cdot 58150 \cdot lb = 23260\,lb$ > $T = 16686\,lb$ OK

Use two 1-1/4" diameter A307 bolts at 55.76" on center

SIZE BOLT PLATE WASHER

Single plate washer will be used for each pair of bolts in adjacent pile flanges

$T := \frac{T_{anc} \cdot 55.76 \cdot in}{2}$ $T = 16686\,lb$ Tensile Force per Bolt

$d_h := 1.5 \cdot in$ Hole Diameter for Bolts (1-1/4" bolts)

$b := 12 \cdot in$ Plate Length $t := 0.75 \cdot in$ Trial Plate Thickness

$S := \frac{(b - 2 \cdot d_h) \cdot t^2}{6}$ $S = 0.84\,in^3$ Plate Section Modulus

$d_c = 2\,in$ Distance Between Channels

$F_y := 50000 \cdot \frac{lb}{in^2}$ Yield Stress $F_b := 0.83 \cdot 0.6 \cdot F_y$ $F_b = 24900\,\frac{lb}{in^2}$ Allowable Bending Stress per EM 1110-2-2105

$M := \frac{2 \cdot T \cdot d_c}{4}$ $M = 16686\,lb \cdot in$ Plate Bending Moment

$f_b := \frac{M}{S}$ $f_b = 19776\,\frac{lb}{in^2}$ Plate Bending Stress < $F_b = 24900\,\frac{lb}{in^2}$ OK

USE 12" x 9" x 3/4" BOLT PLATE WASHER PER PAIR OF BOLTS

MANUFACTURER’S LITERATURE

LBFoster Piling

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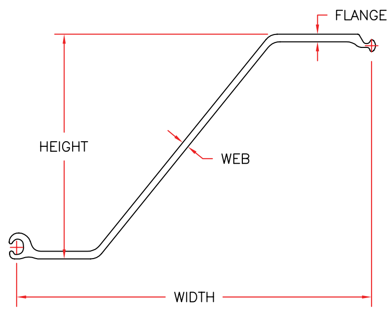
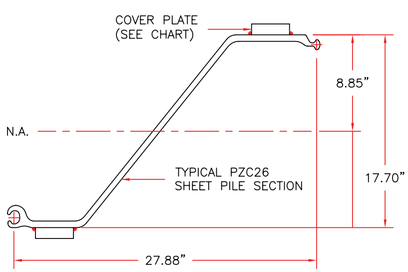
Z PILE PROFILE



Section	Width	Height	Web Thick-ness	Flange Thick-ness	Weight		Moment of Inertia		Section Modulus		Nominal Coating Area
	in.	in.	in.	in.	lb / lft	lb / ft^2	in^4	in^4 / wft	in^3	in^3 / wft	ft^2 / lft
	mm	mm	mm	mm	kg / lm	kg / m^2	cm^4	cm^4 / wm	cm^3	cm^3 / wm	m^2 / lm
PZC 13	**27.88**	**12.56**	**0.375**	**0.375**	**50.4**	**21.7**	**353.0**	**152.0**	**56.2**	**24.2**	**5.60**
	708	**319**	**9.5**	**9.5**	**75.1**	**106.0**	**14,695**	**20,755**	**920**	**1,300**	**1.71**
PZC 14	27.88	12.60	0.420	0.420	55.0	23.7	381.6	164.3	60.5	26.0	5.60
	708	320	10.7	10.7	81.8	115.5	15,890	22,445	990	1,400	1.71
PZC 18	**25.00**	**15.25**	**0.375**	**0.375**	**50.4**	**24.2**	**532.2**	**255.5**	**69.8**	**33.5**	**5.60**
	635	**387**	**9.5**	**9.5**	**75.1**	**118.2**	**22,155**	**34,890**	**1,145**	**1,800**	**1.71**
PZC 19	25.00	15.30	0.420	0.420	55.0	26.4	576.3	276.6	75.3	36.1	5.60
	635	388	10.7	10.7	81.8	128.8	23,990	37,780	1,235	1,945	1.71
PZC 25	27.88	17.66	0.485	0.560	69.4	29.9	938.7	404.1	106.3	45.7	6.15
	708	449	12.3	14.2	103.3	145.9	39,075	55,190	1,740	2,455	1.87
PZC 26	**27.88**	**17.70**	**0.525**	**0.600**	**73.9**	**31.8**	**994.3**	**428.1**	**112.4**	**48.4**	**6.15**
	708	**450**	**13.3**	**15.2**	**110.0**	**155.4**	**41,390**	**58,460**	**1,840**	**2,600**	**1.87**
PZC 28	27.88	17.75	0.570	0.645	79.0	34.0	1,057.1	455.1	119.1	51.3	6.15
	708	451	14.5	16.4	117.6	166.1	44,000	62,145	1,950	2,755	1.87

Available Grades: ASTM A572 Gr. 50 and 60, and A690

COVER PLATED Z PROFILES



Section	Normal Width	Plate Size	Per Single Section				Per Unit of Wall			
			Area	Weight	Total Surface Area	Nominal Coating Area*	Weight: Plates Full Length	Weight: Plates Half Length	Moment of Inertia	Section Modulus
	in.	in.	in.^{2}	lbs / ft	ft^2 / ft	ft^2 / ft	lbs / ft^2	lbs / ft^2	in.^{4} / ft	in.^{3} / ft
	mm	mm	cm^2	kg / m	m^2 / m	m^2 / m	kg / m^2	kg / m^2	cm^4 / m	cm^3 / m
PZC 37-CP	**27.88**	**3.5 x 0.9375**	**28.28**	**96.2**	**6.96**	**6.46**	**41.4**	**36.6**	**673.3**	**68.8**
(PZC26)	**708**	**89 x 24**	**182.5**	**143.1**	**2.12**	**1.97**	**202.2**	**178.7**	**91,900**	**3,700**
PZC 39-CP	27.88	3.5 x 1.125	29.60	100.6	7.03	6.53	43.3	37.6	728.3	73.0
(PZC26)	708	89 x 29	190.9	149.7	2.14	1.99	211.6	183.4	99,500	3,930
PZC 41-CP	**27.88**	**3.5 x 1.25**	**30.47**	**103.6**	**7.07**	**6.57**	**44.6**	**38.2**	**766.1**	**75.8**
(PZC26)	**708**	**89 x 32**	**196.6**	**154.2**	**2.15**	**2.00**	**217.8**	**186.6**	**104,600**	**4,080**

*Excludes socket interior and ball interlock.

°Filet weld should be sized to adequately resist design loads and should be continuous and all around.

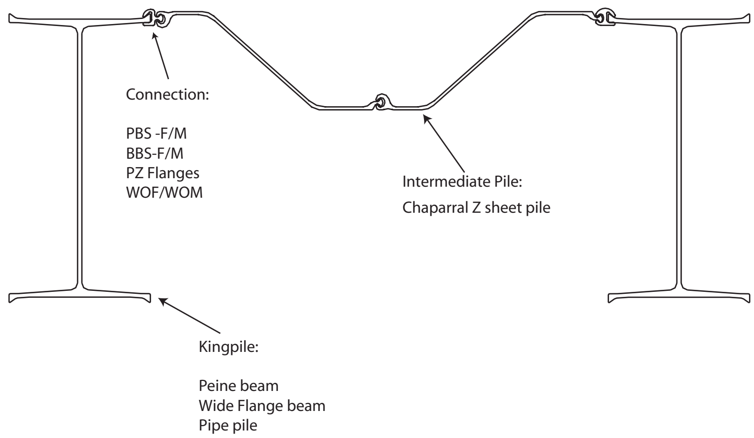
°Cover plate length depends upon moment curve. Best economy is obtained when plate length is limited to area of high moment.

Available Grades: ASTM A572 Gr. 50

Combi-wall Systems

LBFoster Piling

L.B. Foster is dedicated to offering the most efficient combi-wall system for your needs through utilizing a variety of systems. Using specialized beams from Peine or domestic wide flange beams, extruded connectors from Pile Pro, and PZC sheet pile from Chaparral, L.B. Foster is able to put together the right package. Systems using the Wide Flange Beams and PZC sheet pile are 100% melted and manufactured in U.S.A.



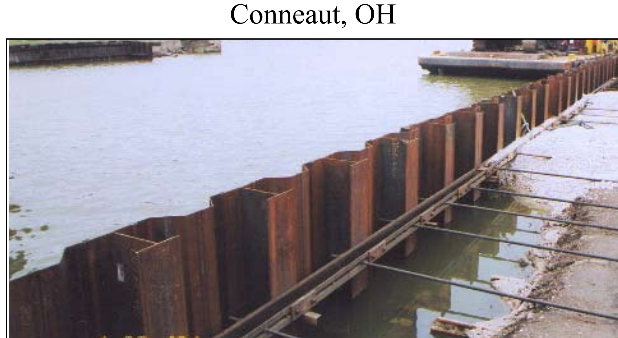
The systems shown represent only a portion of the variations possible. Intermediate sheet pile function as earth retention and for load transfer. The sheet pile is only required to resist active earth pressures down to the zero earth pressure level and may extend below this level as a safety measure. Shortening the lengths of the intermediate sheet pile will reduce the cost of the job and facilitate installation.

Peine system properties shown are with the connectors being supplied loose. Moment of inertia and section modulus can be improved if the connectors are welded on to the beams. This is possible in a variety of combinations. The wide flange beams will have either the connectors or flanges welded on with a full length fillet weld as standard. Please contact us with your project requirements so we can offer a custom solution.

Port of Oakland, Phase 1

Port of Oakland, Phase 2

Conneaut, OH



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Combi-walls are piling walls that are comprised of high modulus structural components interspaced by lighter sheet piles. The high modulus components - known as king piles - can be tubular, box, bearing or other types of fabricated piles.

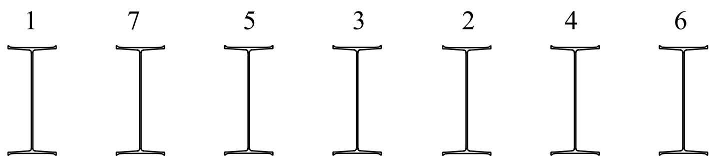
It is essential that a stable, heavy, adequately rigid and straight pile-driving template frame, adapted to suit the length and weight of the pilings, be provided.

The king piles are fixed into position within the template using welded bracket guides which take into account width tolerances.

Driving of the king piles must be carried out with extreme care in order to ensure that they are embedded straight and vertical, or at a prescribed batter, thereby guaranteeing that they are parallel to each other and at the required spacing.

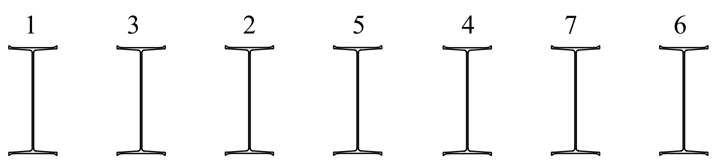
The driving sequence of the king piles must ensure that the pile toe encounters soil uniformly on its total circumference and not just on one side.

This is achieved by driving in the following sequence



(large driving step)

At least, however, the following sequence should be observed:



(small driving step)

In general, all of the king piles should be driven in sequence to full penetration without interruption. Following successful completion of this, the intermediate light piling sections can be set and driven. During the setting and driving operations of the king piles, a constant check (using theodolites) should be made of their alignment in relation to the wall.

When the guide frames have been removed, a final survey should be made to ensure that the deviations in the distance between the king piles are within the acceptable tolerances in order to allow the proper installation of the sheet pile. However, if the deviations are outside the specified or practical tolerances, then either the intermediate piles have to be adjusted or the king piles must be extracted and re-driven.

To overcome difficult driving conditions, it may be possible to use: jetting; excavating inside the king piles; or any other the ground pre-treatment methods normally adopted for sheet piling.

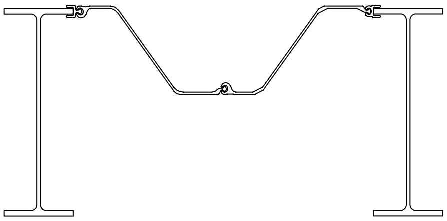
Above text taken from the “NASSPA Best Practices Sheet Piling Installation Guide”

Combi-wall Solution Variations

L.B. Foster is dedicated to offering the most efficient combi-wall system for your needs through utilizing our vast array of systems

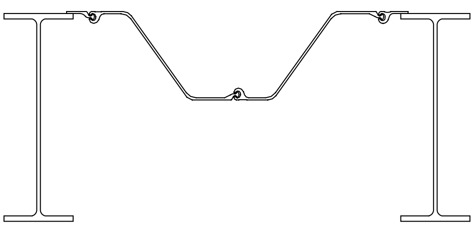
100% Domestic Solutions:

Wide Flange with Extruded Connectors



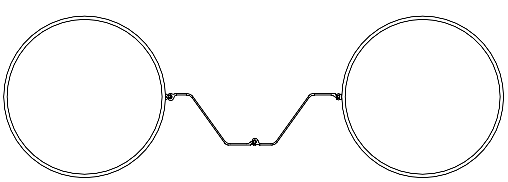
Width Range: 48” - 74”
Section Modulus Range (in^3 / ft): 40-335
Moment of Inertia Range (in^4 / ft): 700-7070

Wide Flange with Z-Profile Flanges



Width Range: 50” - 80”
Section Modulus Range (in^3 / ft): 40-320
Moment of Inertia Range (in^4 / ft): 700-6800

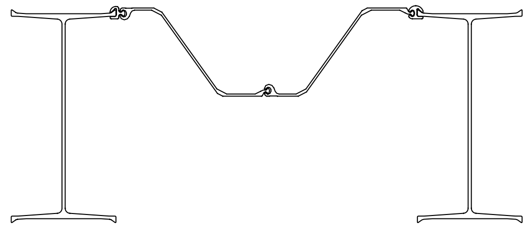
Pipe Pile with Extruded Connectors



The properties are only limited to jobsite and manufacturing restrictions.

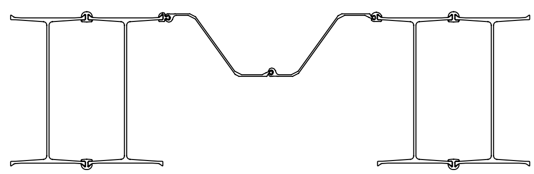
Foreign Solutions:

Single Peine Beam System



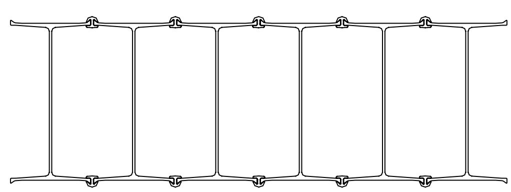
Width Range: 54” - 77”
Section Modulus Range (in^3 / ft): 30-280
Moment of Inertia Range (in^4 / ft): 500 - 6200

Double Peine Beam System



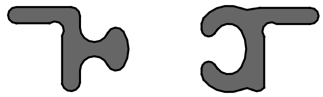
Width Range: 70” - 95”
Section Modulus Range (in^3 / ft): 40 - 435
Moment of Inertia Range (in^4 / ft): 500 - 8800

Box Peine Beam System



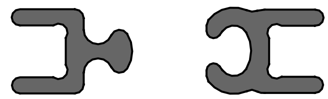
Width Range: 16” - 19”
Section Modulus Range (in^3 / ft): 130 - 700
Moment of Inertia Range (in^4 / ft): 1000 - 14600

L.B. Foster Combi-wall systems can be supplied with a range of connections. Each connector series offers distinct advantages to assure you have the best system for your project.



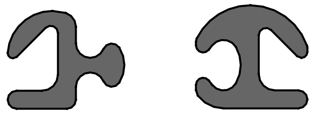
One Leg BBS Connectors:

Universal & in stock - ready for quick orders
Field or shop weld full length to beam



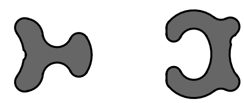
BBS Connectors:

Produced to your job requirements
Field or shop weld full length to beam



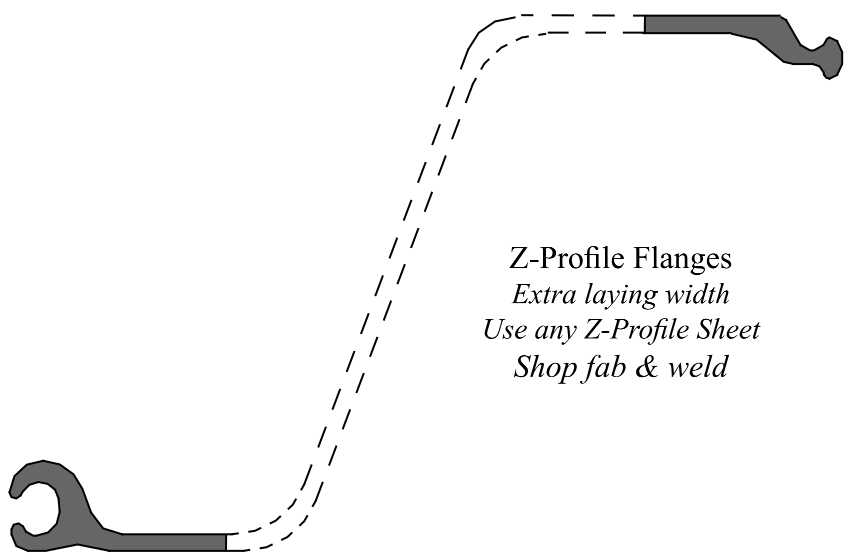
PBS Connectors:

Most flexible system on the market
Simply tack weld to sheet pile in field

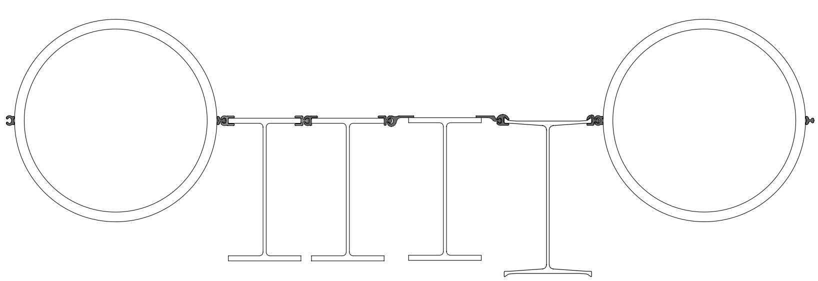


WOM / WOF Connectors:

Used in weight efficient pipe combi-walls
Field or shop weld full length to pipe



Z-Profile Flanges
Extra laying width
Use any Z-Profile Sheet
Shop fab & weld



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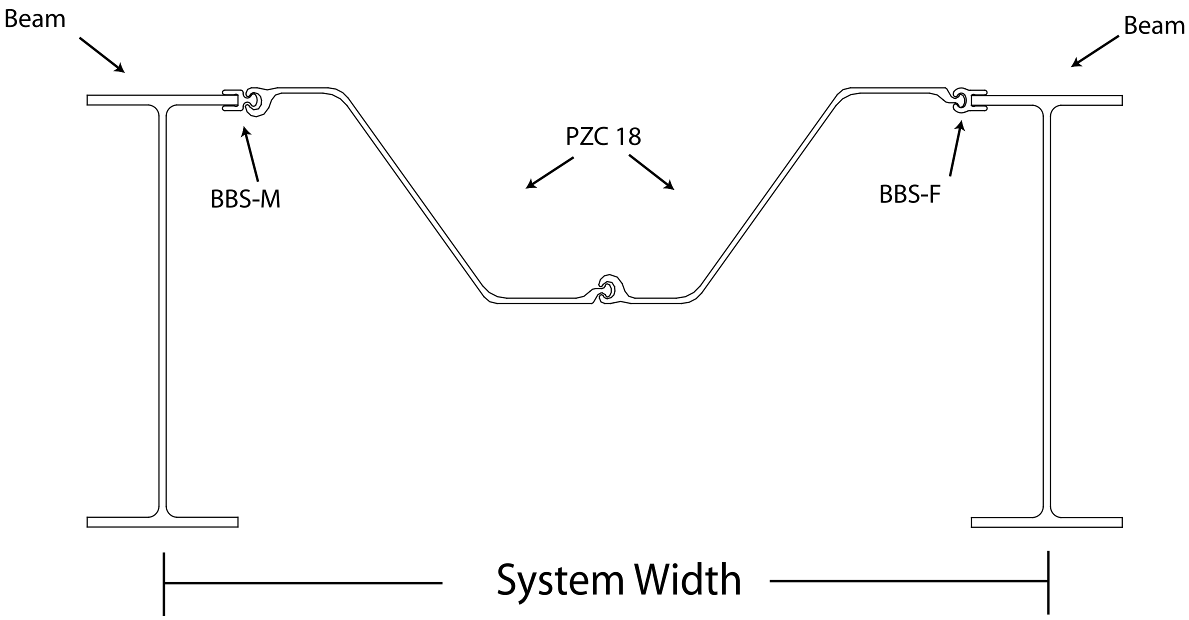
PZC™ 18 Combi-wall Solution



Dimensions and Properties

Beam	System Width	Section Modulus	Moment of Inertia	Weight in Pounds lb / ft²		
	in.	in³ / ft	in⁴ / ft	100%	80%	60%
W33 x 118	63.42	82.8	1519	44.4	40.0	35.6
W33 x 130	63.45	91.5	1675	46.7	42.3	37.8
W36 x 135	63.89	97.0	1902	47.3	42.9	38.5
W40 x 149	63.75	110.9	2319	50.0	45.6	41.2
W40 x 167	63.75	127.5	2668	53.4	49.0	44.6
W40 x 183	63.75	142.5	2993	46.4	52.0	47.6
W40 x 199	67.69	149.6	3102	56.0	51.8	47.7
W40 x 215	67.69	164.7	3425	58.8	54.7	50.5
W40 x 249	67.69	188.5	3927	64.8	60.7	56.6
W40 x 277	67.77	208.4	4351	69.7	65.6	61.5
W40 x 297	67.77	219.4	4584	73.3	69.1	65.0
W40 x 321	67.85	234.7	4917	77.4	73.3	69.2
W40 x 372	68.00	270.3	5706	86.3	82.1	78.0

% of sheet pile length to beam length

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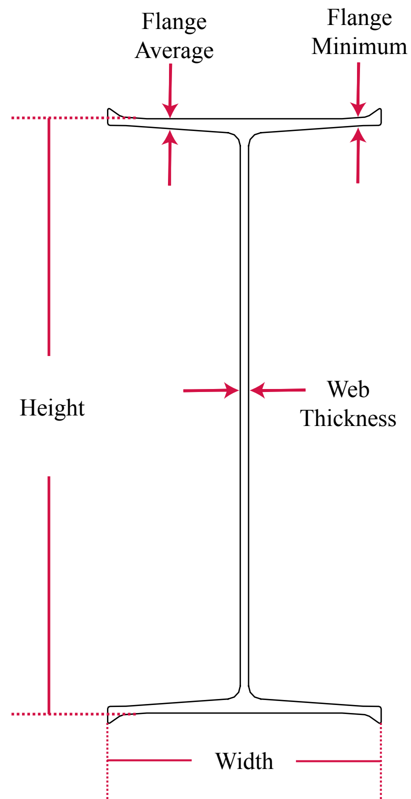
Peine Beam



Section	Weight	Width	Height	Web Thickness	Flange Thickness		Moment of Inertia	Section Modulus
					Average	Minimum		
	lb / lft	in.	in.	in.	in.	in.	in^4	in^3
PSp 600	126.33	18.11	23.62	0.551	0.610	0.551	3801	321.84
PSp 606	137.08	18.11	23.86	0.551	0.728	0.551	4257	356.81
PSp 700	133.72	18.11	27.56	0.551	0.610	0.551	5342	387.68
PSp 706	144.47	18.11	27.80	0.551	0.728	0.551	8960	428.87
PSp 800	148.51	18.11	31.50	0.551	0.673	0.551	7669	486.97
PSp 806	159.26	18.11	31.73	0.551	0.791	0.551	8476	534.20
PSp 900	155.90	18.11	35.43	0.551	0.673	0.551	9969	562.70
PSp 906	166.65	18.11	35.67	0.551	0.791	0.551	10990	616.22
PSp 1000	163.29	18.11	39.37	0.551	0.673	0.551	12624	641.30
PSp 1006	174.04	18.11	39.61	0.551	0.791	0.551	13883	701.10
PSp 1001	179.42	18.11	39.37	0.551	0.815	0.551	14309	726.91
PSp 1013	186.14	18.11	39.53	0.551	0.894	0.551	15101	764.08
PSp 1016	190.17	18.11	39.61	0.551	0.933	0.551	15568	786.11
PSp 1016 S	201.59	18.11	39.84	0.551	1.151	0.551	16863	846.52
PSp 1017	211.00	18.11	40.04	0.551	1.150	0.551	17964	897.35
PSp 1030	235.86	18.11	40.55	0.709	1.165	0.551	19568	965.09
PSp 1035S	245.27	18.11	40.75	0.709	1.264	0.551	20708	1016.41

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WILLIAMS FORM ENGINEERING CORP.

Strand Anchor System

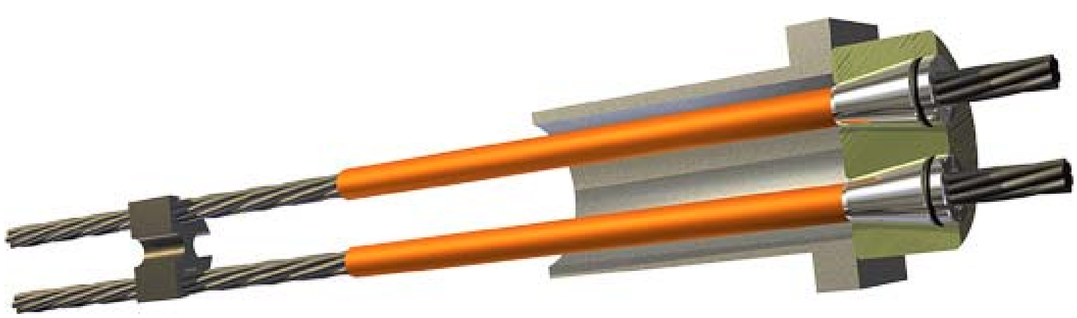
Williams has added strand anchor systems to an already fine line of ground engineering products. Williams has made a commitment to the ground engineering industry to supply well engineered, quality products and back those products with technical support and timely material delivery. The same commitment has been made with the Williams strand anchor line.

Williams Strand Anchors utilize a high density extruded polyethylene sheath over corrosion inhibiting compound in the unbonded zone. Williams has the most technologically advanced extrusion equipment for the manufacture of permanent and temporary anchors. The state of the art equipment allows for precise extruded lengths in the unbonded zone and high quality manufacturing.

Williams Strand Anchors are produced from 0.6” diameter, 7 wire strand (fpu = 270 ksi, 1862 N/mm2) meeting ASTM A-416 and are manufactured in accordance with the Post-Tensioning Institute’s Recommendations for Prestressed Rock and Soil Anchors.

Advantages of Williams Grout Bonded Strand Anchors

- High capacity - Anchors utilize a 0.6” dia. 270 KSI (ultimate stress) strand. The number of strands per anchor dictate the load carrying capacity of the anchor.
- Lightweight - For a Class I protected anchor, the corrugated duct is grouted in the field, greatly reducing the weight of the anchor. There is more load carrying capacity per pound of 7-wire 270 KSI strand than solid bar.
- Anchors arrive to the jobsite fully fabricated and packaged in coils to allow for installation in areas where there are clearance issues or bench width constraints.
- Unlike bar systems, strand can be produced in any length.
- All Williams strand anchors utilize a small diameter greased filled extruded high density polyethylene sheathing, allowing for a greater number of individual strands to be contained in a given drill hole size. Manual greasing and sheathing of individual strands require a larger free stressing sheath.
- Stringent quality control of manufacturing is maintained because Williams’ engineering department provides shop drawings for each production order showing customer preference details and specific contract requirements.



Applications

- Dam Tie-Downs
- Temporary Excavation Support
- Landslide Mitigation
- Permanent Tieback Systems
- Slope Surface Stabilization
- Foundations

Corrosion Protection

The anchor system can be produced to meet the Post-Tensioning Institute's Recommendations for Prestressed Rock and Soil Anchors. Williams Strand Anchors are supplied with the following classes of Corrosion Protection:

Class I - Encapsulated Tendon:
Anchorage: Anchor Head, Bearing Plate w/ Trumpet and End Cap.
Free Stressing Length: Corrosion inhibiting compound filled HDPE sheath encased in grout.
Bond Length: Grout Filled encapsulated corrugated sheathing.

Class II - Encapsulated Tendon:
Anchorage: Anchor Head, Bearing Plate w/ optional Trumpet and optional End Cap.
Free Stressing Length: Corrosion inhibiting compound filled HDPE sheath encased in grout.
Bond Length: Externally grouted.

Design and Construction Support

Williams is committed to assisting designers and foundation engineers with prebid design information, budget pricing and anchor details. Williams' technical staff will work with designers to ensure that the specified strand anchor system is economical and appropriate for the application.

Williams is also committed to assisting the contractor with project pricing, bearing plate calculations, quantity take-offs, anchor submittals and shop drawings. Williams' manufacturing personnel will work with the technical staff to ensure the anchors are delivered to the jobsite, ready to install and on time. Williams also offers on-site technical assistance to the contractor.

Number of Strands	Cross-Sectional Area (Aps)	Ultimate Load (fpu*Aps)	Maximum Jacking Load (0.8*fpu*Aps)	Maximum Design Load (0.6*fpu*Aps)	HDPE Tubing	Anchor Heads
1	0.217 in^2 (140 mm^2)	58.6 kips (261 kN)	46.9 kips (209 kN)	35.2 kips (157 kN)		
2	0.434 in^2 (280 mm^2)	117 kips (522 kN)	93.8 kips (418 kN)	70.4 kips (314 kN)		C 4.6
3	0.651 in^2 (420 mm^2)	176 kips (783 kN)	141 kips (627 kN)	106 kips (471 kN)	3" nom. (3-1/2" O.D.)	
4	0.868 in^2 (560 mm^2)	234 kips (1044 kN)	188 kips (836 kN)	141 kips (628 kN)		
5	1.09 in^2 (700 mm^2)	293 kips (1305 kN)	235 kips (1045 kN)	176 kips (785 kN)		

6	1.30 in^2 (840 mm^2)	352 kips (1566 kN)	281 kips (1254 kN)	211 kips (942 kN)		C 7.6*
7	1.52 in^2 (980 mm^2)	410 kips (1827 kN)	328 kips (1463 kN)	246 kips (1099 kN)		
8	1.74 in^2 (1120 mm^2)	469 kips (2088 kN)	375 kips (1672 kN)	282 kips (1256 kN)		
9	1.95 in^2 (1260 mm^2)	527 kips (2349 kN)	422 kips (1881 kN)	317 kips (1413 kN)		
10	2.17 in^2 (1400 mm^2)	586 kips (2610 kN)	469 kips (2090 kN)	352 kips (1570 kN)		C 12.6
11	2.39 in^2 (1540 mm^2)	645 kips (2871 kN)	516 kips (2299 kN)	387 kips (1727 kN)	4” nom. (4.6” O.D.)	
12	2.60 in^2 (1680 mm^2)	703 kips (3132 kN)	563 kips (2508 kN)	422 kips (1884 kN)		
13	2.82 in^2 (1820 mm^2)	762 kips (3393 kN)	610 kips (2717 kN)	458 kips (2041 kN)		
14	3.04 in^2 (1960 mm^2)	820 kips (3654 kN)	657 kips (2926 kN)	493 kips (2198 kN)		
15	3.26 in^2 (2100 mm^2)	879 kips (3915 kN)	704 kips (3135 kN)	528 kips (2355 kN)		
16	3.47 in^2 (2240 mm^2)	938 kips (4176 kN)	750 kips (3344 kN)	563 kips (2515 kN)		C 19.6
17	3.69 in^2 (2380 mm^2)	996 kips (4437 kN)	797 kips (3553 kN)	598 kips (2669 kN)	5” nom. (5.6” O.D.)	
18	3.91 in^2 (2520 mm^2)	1055 kips (4698 kN)	844 kips (3762 kN)	634 kips (2826 kN)		
19	4.12 in^2 (2660 mm^2)	1113 kips (4959 kN)	891 kips (3971 kN)	669 kips (2983 kN)		
20	4.34 in^2 (2800 mm^2)	1172 kips (5220 kN)	938 kips (4180 kN)	704 kips (3140 kN)		
21	4.56 in^2 (2940 mm^2)	1231 kips (5481 kN)	985 kips (4389 kN)	739 kips (3297 kN)		C 22.6
22	4.77 in^2 (3080 mm^2)	1289 kips (5742 kN)	1032 kips (4598 kN)	774 kips (3454 kN)		
23	4.99 in^2 (3220 mm^2)	1348 kips (6003 kN)	1079 kips (4807 kN)	810 kips (3611 kN)		
24	5.21 in^2 (3360 mm^2)	1406 kips (6264 kN)	1126 kips (5016 kN)	845 kips (3768 kN)		
25	5.43 in^2 (3500 mm^2)	1465 kips (6525 kN)	1173 kips (5225 kN)	880 kips (3925 kN)	6” nom. (6.6” O.D.)	C 27.6
26	5.64 in^2 (3640 mm^2)	1524 kips (6786 kN)	1219 kips (5434 kN)	915 kips (4082 kN)		
27	5.86 in^2 (3780 mm^2)	1582 kips (7047 kN)	1266 kips (5643 kN)	950 kips (4239 kN)		
28	6.08 in^2 (3920 mm^2)	1640 kips (7308 kN)	1313 kips (5852 kN)	986 kips (4396 kN)		
29	6.29 in^2 (4060 mm^2)	1699 kips (7569 kN)	1360 kips (6061 kN)	1021 kips (4553 kN)		C 31.6
30	6.51 in^2	1758 kips	1407 kips	1056 kips		

	(4200 mm^2)	(7820 kN)	(6270 kN)	(4710 kN)		
31	6.73 in^2 (4340 mm^2)	1816 kips (8091 kN)	1454 kips (6479 kN)	1091 kips (4867 kN)		

* Use a C4.6 Anchor Head for Class II protection on a four strand anchor.
1) Mill certification provided upon request to indicate the actual tensile strength of the 7-wire strand with each shipment of Williams strand anchors.
2) Larger diameter anchors available upon request.

Design and Construction Support

Williams is committed to assisting designers and foundation engineers with prebid design information, budget pricing and anchor details. Williams' technical staff will work with designers to ensure that the specified strand anchor system is economical and appropriate for the application.

Williams is also committed to assisting the contractor with project pricing, bearing plate calculations, quantity take-offs, anchor submittals and shop drawings. Williams' manufacturing personnel will work with the technical staff to ensure the anchors are delivered to the jobsite, ready to install and on time. Williams also offers on-site technical assistance to the contractor.

Corrosion Protection

Optional coatings for steel end caps, bearing plates with trumpet and anchor heads are available for additional corrosion protection as required by the designer. Coating specifications are as follows:
Electro Zinc Plating: ASTM B-633 (anchor heads)
Hot Dip Galvanizing: ASTM A-153 (bearing plates/trumpets and steel end caps)
Epoxy Coating: ASTM A-755 (bearing plates/trumpets and steel end caps)

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WILLIAMS FORM ENGINEERING CORP.

Ground Anchor Systems

Concrete Anchor Systems

Post Tensioning Systems

Threaded Bars with Fasteners

Tie Rods Tie Backs

Micro Piles

Concrete Forming Hardware Systems

WILLIAMS CONCRETE ACCESSORIES DIVISION

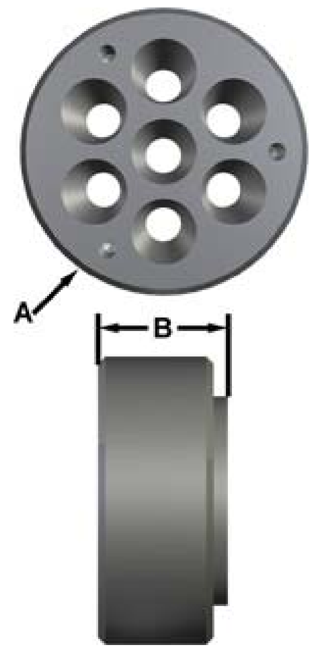
Strand Anchor Accessories

Strand Anchors | Strand Accessories | Installation Equipment | Case Histories

Wedge Plates (Anchor Heads)
Bearing Plates
PVC Centralizer
Heat Shrink Tubing & Canusa
Anchor Head Wedges
Spacers
Corrugated Duct
Steel End Cap

Anchor Heads (Wedge Plates)

Williams Wedge Plates are full strength permanent components. They are available galvanized.



Type	A Diameter	B Thickness	Part Number
C 4.6	5" (127 mm)	2" (51 mm)	RSAH04W
C 7.6	5" (127 mm)	2" (51 mm)	RSAH07W
C 12.6	7-3/8" (187 mm)	3-3/8" (86 mm)	RSAH12S
C 19.6	8-1/4" (210 mm)	4" (102 mm)	RSAH19S
C 22.6	9" (229 mm)	4-1/8" (105 mm)	RSAH22
C 27.6	10" (254 mm)	4-1/2" (114 mm)	RSAH27
C 31.6	10-3/4" (273 mm)	4-7/8" (122 mm)	RSAH31

Anchor Head Wedges

All wedges are equipped with a ring to keep the wedge attached to the tendon during elongation and/or tensioning operations.

3-Piece Wedges - RSWG03
The 3-Piece anchor wedges are PTI recommended for use on permanent anchors and/or anchors requiring incerემental loading. They uniformly engage the strand with less relaxation at low loads. They are manufactured from quality steels and are case hardened for durability.

2-Piece Wedges - RSWG02
The 2-Piece anchor wedges are useful in higher stress applications where the anchor is loaded and simply locked off, typical to temporary applications. They are manufactured from quality steels and are case hardened for durability.

Stressing Head Wedges - RSXSHW

Stressing head wedges are necessary for prestressing all classes of strand anchors. The stressing wedges are heat treated, chrome plated and designed for multiple uses.

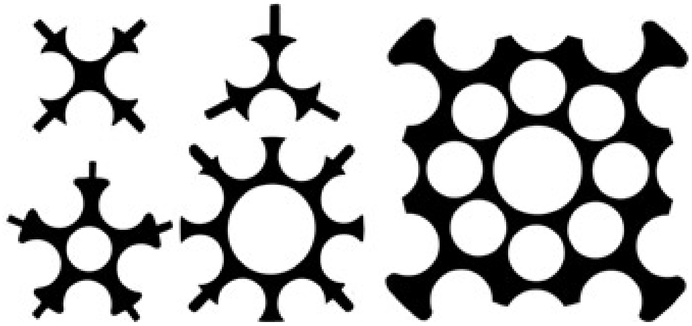
Bearing Plates - S1K

Williams Bearing Plates are available in sizes as required per anchor, and are designed in accordance with PTI specifications. Plate stock can be provided in Grade 36 or Grade 50.

Anchor Head Class 1 & 2	Trumpet Class 1		Bearing Plate Center Hole Head Clearance Class 1 & 2
	O.D.	I.D.	
C 4.6	4-1/2" (114 mm)	4" (102 mm)	3-1/2" (89 mm)
C 7.6			3-3/4" (95 mm)
C 12.6	6-5/8" (168 mm)	6" (152 mm)	5-1/4" (133 mm)
C 19.6	7-5/8" (194 mm)	7-1/8" (181 mm)	6-1/2" (165 mm)
C 22.6	8-5/8" (219 mm)	7-7/8" (200 mm)	7-1/2" (191 mm)
C 27.6			8" (203 mm)
C 31.6	10-3/4" (273 mm)	10" (254 mm)	8-1/2" (216 mm)

Spacers - RSPS

Strand spacers are provided in the anchor bond zone to separate the strand and provide for the minimum required grout cover around each strand for corrosion protection and bond strength development. The strand spacers are normally located 1-2 feet above the bottom of the anchor and at the top of the bond zone. The intermediate strand spacers are typically placed at a distance of 8-10 feet, center to center along the bond zone between the top and bottom spacer.

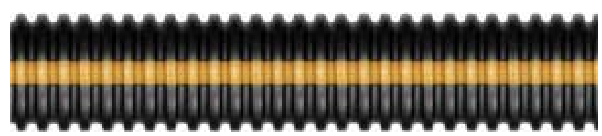


PVC Centralizer - CEN

Centralizers are placed over the strand anchor assembly to maintain the minimum required 0.5” distance between the assembled anchor bundle and the drill hole wall. Depending on the anchor type and orientation, there are a wide variety of centralizers available for every application. State drill hole size for ordering.

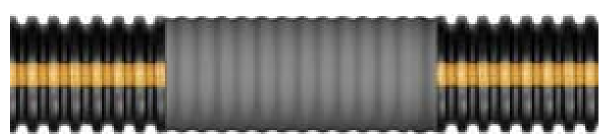
Corrugated Duct - R75

Williams utilizes corrugated duct that complies with the required wall thickness (0.060” nominal) as specified by the Post-Tensioning Institute’s Recommendations for Prestressed Rock and Soil Anchors.



Heat Shrink Tubing and Canusa

Provides a corrosion protected seal when connecting smooth or corrugated segments.



Steel End Caps

Williams offers a bolt on steel end cap to provide corrosion protection for exposed anchor ends. Caps are provided with a closed cell neoprene seal. Most often the caps are packed with corrosion inhibiting wax or grease.

Type	Width	Height
C 4.6	8” (203 mm)	4-5/8” (117 mm)
C 7.6		

C 12.6	10" (254 mm)	5-3/8" (133 mm)
C 19.6	12" (194 mm)	6" (152 mm)
C 22.6		
C 27.6	14" (356 mm)	7-7/8" (200 mm)
C 31.6		

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Tie Back and Tie Rod Systems

Advantages

- Lighter weights with higher strengths and lower costs
- Continuously threaded for maximum versatility or threaded on ends only
- Durable threads and components capable of developing the full capacity of the bar
- Right and left hand capability for use with sleeve nuts and turnbuckles
- Up to 50 foot stock lengths
- Several options of corrosion protection from simple to multiple protection for aggressive environments

Williams Grade 150 KSI All-Thread-Bar

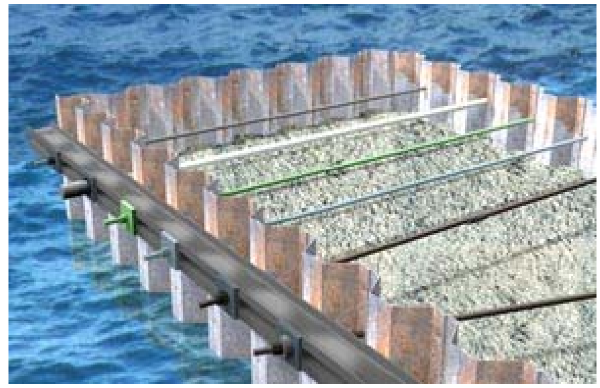
consist of high tensile steel available in five diameters from 1"(26 mm) to 2-1/2"(65 mm) with guaranteed tensile strengths to 778 kips (3460 kN). Lengths of up to 50 feet are available on smaller diameters and lengths of up to 40 feet are available on the 1 3/4" and 2 1/2" diameters. Bars are provided with cold rolled threads over all or a portion of the bar's length and all tension components for the systems are designed to develop 100% of the bars published ultimate strength. Bars are produced to ASTM A-722-98 physical standards. Williams All-Thread 150 KSI Bar must never be welded, subjected to the high heat of a torch, or used as a ground. Field cutting should be done with an abrasive wheel or band saw. All components of the systems are designed and manufactured in the United States and have been field proven around the world.

Williams Grade 75 All-Thread Rebar

is a continuously threaded bar specially designed to be used for fasteners, concrete forming tie rods and anchors. All-Thread Rebar is available in 9 diameters from #6 (20 mm) through #20 (64) with ultimate tensile strengths up to 491,000 lbs (2184 kN) and lengths up to 50 feet. The bars are provided with a special thread designed to meet the requirements of ASTM A615 and Canadian Rebar Specifications CSA-G30.18-M92.
Threads are cold rolled on the bar over all or a portion of the length as desired. Because of the full 360 degrees concentric thread, Williams All-Thread Rebar should only be bent under special provisions. All tension components are designed to develop 100% of the bars published ultimate strength. All components for the system are manufactured in North America.

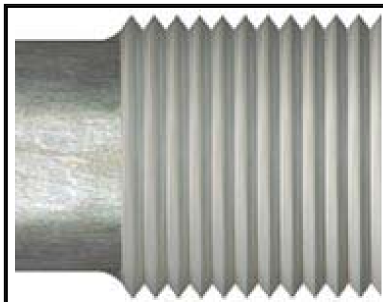
Tie Thru Rod System Specifications

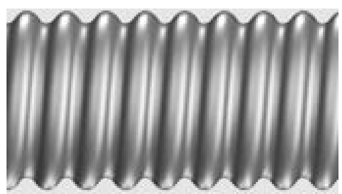
For a detailed breakdown of the parts and components involved in tie backs and tie rod systems, click on the image to the right.

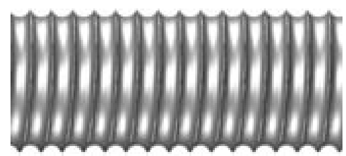


Conversion Chart - Compare for Yourself!

Williams All-Thread-Bars are more economical than heavier ASTM A-36 or upset threaded rods. All-Thread bars are usually on the the order of 10-30% less expensive than A-36 tie rods when bar comparison is based on equivalent ultimate strengths. Not only are the bars less expensive but since the bars are smaller, additional savings may result with the connectors and material freight. In addition,since smaller diameter bars have smaller surface areas than larger bars, corrosion protection may be more economical. It is not uncommon to see cost savings up to 30% when comparing the Williams All-Thread tie rod systems to upset threaded or A-36 rod systems. Bars shown actual size.







Old Style A36 Tie Rods				Grade 75 All-Thread Rebar					150 KSI All-Thread-Bar				
Actual Tie Rod Dia.	Heavy Upset Thread Dia.	Weight per Linear Foot (Meters)	Min. Ultimate Strength of Bar	Bar Desig. & Nominal Dia.	Approx. Thread Major Dia. & Threads per Inch	Weight per Linear Foot (Meters)	Min. Yield Strength of Rebar	Min. Ultimate Strength of Rebar	Bar Dia.	Approx. Thread Major Dia. & Threads per Inch	Weight per Linear Foot (Meters)	Min. Yield Strength of Bar	Min. Ultimate Strength of Bar
1-1/4" (32 mm)	1-1/2" (38 mm)	4.17 lbs. (1.9 KG)	71.2 kips (317 kN)	#8 - 1" (25 mm)	1-1/8" - 3-1/2 (28.6 mm)	2.7 lbs. (3.94 Kg)	59.3 kips (264 kN)	79 kips (351 kN)	1" (26 mm)	1-1/8" - 4 (28.6 mm)	3.09 lbs. (4.6 Kg)	102 kips (454 kN)	128 kips (567 kN)
1-3/8" (35 mm)	1-3/4" (44 mm)	5.05 lbs. (2.3 KG)	86.2 kips (383 kN)	#9 - 1-1/8" (28 mm)	1-1/4" - 3-1/2 (31.8 mm)	3.4 lbs. (5.06 Kg)	75 kips (334 kN)	100 kips (445 kN)					
1-1/2" (38 mm)	2" (51 mm)	6.01 lbs. (2.7 KG)	103 kips (456 kN)	#10 - 1-1/4" (32 mm)	1-3/8" - 3 (34.9 mm)	4.3 lbs. (5.50 Kg)	95.3 kips (424 kN)	127 kips (565 kN)					
1-5/8" (41 mm)	2" (51 mm)	7.05 lbs. (3.2 KG)	120 kips (535 kN)										
1-3/4" (44 mm)	2-1/4" (57 mm)	8.18 lbs. (3.7 KG)	140 kips (620 kN)	#11 - 1-3/8" (35 mm)	1-1/2" - 3 (38.1 mm)	5.3 lbs. (7.85 Kg)	117 kips (521 kN)	156 kips (694 kN)	1-1/4" (32 mm)	1-7/16" - 4 (36.5 mm)	4.51 lbs. (6.71 Kg)	150 kips (667 kN)	188 kips (834 kN)
1-7/8" (48 mm)	2-1/4" (57 mm)	9.39 lbs. (4.3 KG)	160 kips (712 kN)	#14 - 1-3/4" (45 mm)	1-7/8" - 3 (47.6 mm)	7.65 lbs. (11.8 Kg)	168.7 kips (750 kN)	225 kips (1001 kN)					
2" (51 mm)	2-1/2" (64 mm)	10.7 lbs. (4.8 KG)	182 kips (810 kN)										
2-1/8" (54 mm)	2-1/2" (64 mm)	12.1 lbs. (5.5 KG)	206 kips (915 kN)						1-3/8" (36 mm)	1-9/16" - 4 (39.7 mm)	5.71 lbs. (8.50 Kg)	190 kips (843 kN)	237 kips (1054 kN)
2-1/4" (57 mm)	2-3/4" (70 mm)	13.5 lbs. (6.1 KG)	231 kips (1026 kN)										

2-3/8" (60 mm)	2-3/4" (70 mm)	15.1 lbs. (6.8 KG)	257 kips (1143 kN)	#18 - 2-1/4" (55 mm)	2-7/16" - 3 (61.9 mm)	13.6 lbs. (19.6 Kg)	300 kips (1335 kN)	400 kips (1779 kN)	1-3/4" (45 mm)	2" - 3-1/2 (50.8 mm)	9.06 lbs. (13.5 Kg)	320 kips (1423 kN)	400 kips (1779 kN)
2-1/2" (64 mm)	3-1/4" (83 mm)	16.7 lbs. (7.6 KG)	285 kips (1266 kN)										
2-5/8" (67 mm)	3-1/4" (83 mm)	18.4 lbs. (8.3 KG)	314 kips (1396 kN)										
2-3/4" (70 mm)	3-1/2" (89 mm)	20.2 lbs. (9.2 KG)	346 kips (1532 kN)										
2-7/8" (73 mm)	3-1/2" (89 mm)	22.1 lbs. (10.0 KG)	376 kips (1675 kN)										
3" (76 mm)	3-3/4" (95 mm)	24.0 lbs. (10.9 KG)	410 kips (1823 kN)	#20 - 2-1/2" (64 mm)	2-3/4" - 2-3/4 (69.9 mm)	16.7 lbs. (24.8 Kg)	368 kips (1637 kN)	491 kips (2184 kN)	2-1/2" (65 mm) & 3" (75 mm)	2-3/4" - 3 (69.9 mm) & 3-3/64" (78.2 mm)	18.2 lbs. (27.1 Kg) & 22.3 lbs./ft. (32.7 Kg/M)	622 kips (2766 kN) & 775 kips (3448 kN)	778 kips (3457 kN) & 969 kips (4311 kN)
3-1/8" (80 mm)	3-3/4" (95 mm)	26.1 lbs. (11.8 KG)	445 kips (1979 kN)										
3-1/4" (83 mm)	4" (102 mm)	28.2 lbs. (12.8 KG)	481 kips (2141 kN)										
3-3/8" (86 mm)	4" (102 mm)	30.4 lbs. (13.8 KG)	519 kips (2309 kN)	#28 - 3-1/2" (89 mm)	3-3/4" - 2-3/4 (95.0 mm)	32.7 lbs. (48.6 Kg)	720 kips (3206 kN)	960 kips (4274 kN)					
3-1/2" (89 mm)	4-1/4" (108 mm)	32.7 lbs. (14.8 KG)	558 kips (2482 kN)										
3-5/8" (92 mm)	4-1/4" (108 mm)	35.1 lbs. (15.9 KG)	599 kips (2663 kN)										
3-3/4" (95 mm)	4-1/2" (114 mm)	37.6 lbs. (17.0 KG)	641 kips (2851 kN)										
4" (102 mm)	4-1/2" (114 mm)	42.7 lbs. (19.4 KG)	729 kips (3242 kN)										

Also available: Williams 3" (75 mm) 150 KSI All-Thread-Bar

Cuyahoga River Bulkhead
Technical Assistance
Cleveland, OH

Appendix C: Cost Estimates

1. GENERAL

This appendix documents the 30% level cost estimates of the proposed structural features of the Cuyahoga River Bulkhead Technical Assistance Study. The estimates follow the 30% design level design presented in Appendix B. The overall study length is approximately 2500 lineal feet. A single cross section with the various structural components for each alternative was given. Limited existing layout and existing conditions was given. These estimates should only be used for planning purposes. Significantly more detailed investigation and design beyond what is presented in Appendix B will be required in order to accurately determine the structural requirements, construction feasibility and costs.

2. Description of Existing Study Area

The existing project site consists of approximately 2500 feet of the west bank of the Cuyahoga River in Cleveland, Ohio from the Detroit/Superior Avenue Bridge to the Columbus Road Bridge.

3. Alternatives

See Appendix B – Structural Design for a list of alternatives and cross section for each alternative.

4. Cost Estimates

Each type of wall – Upper Stability Walls with and without excavation, Lower Stability Walls with and without excavation and the Retaining and Green Bulkhead alternatives were estimated separately and presented in a summary sheet showing costs per Lineal foot as requested by the Project Manager. Estimates were completed using MII software with appropriate databases. Line items were developed where items did not exist within the Cost Book

Each estimate uses the same basic assumptions and line items to build the costs. Due to lack of detailed designs, assumptions as to clearing and grubbing, excavation requirements, type of soils that may be encountered, have been made. Existing bulkhead/shoreline excavation is not known and is not a part of these estimates.

Price quotes for the different steel wall sections were obtained from L.B. Foster Company. It is assumed that all alternatives will be able to be constructed using land plant. Pricing for wales and tie rods are from Conneaut Pier Repair.

Anchor costs per foot are from Cazenovia Creek flood control project with research from Buffalo Inner Harbor and Conneaut Pier Repair projects as backup.

Contingences are set at 20% at this stage of study.

Cuyahoga River Bulkhead
Technial Assistance
Cleveland, OH

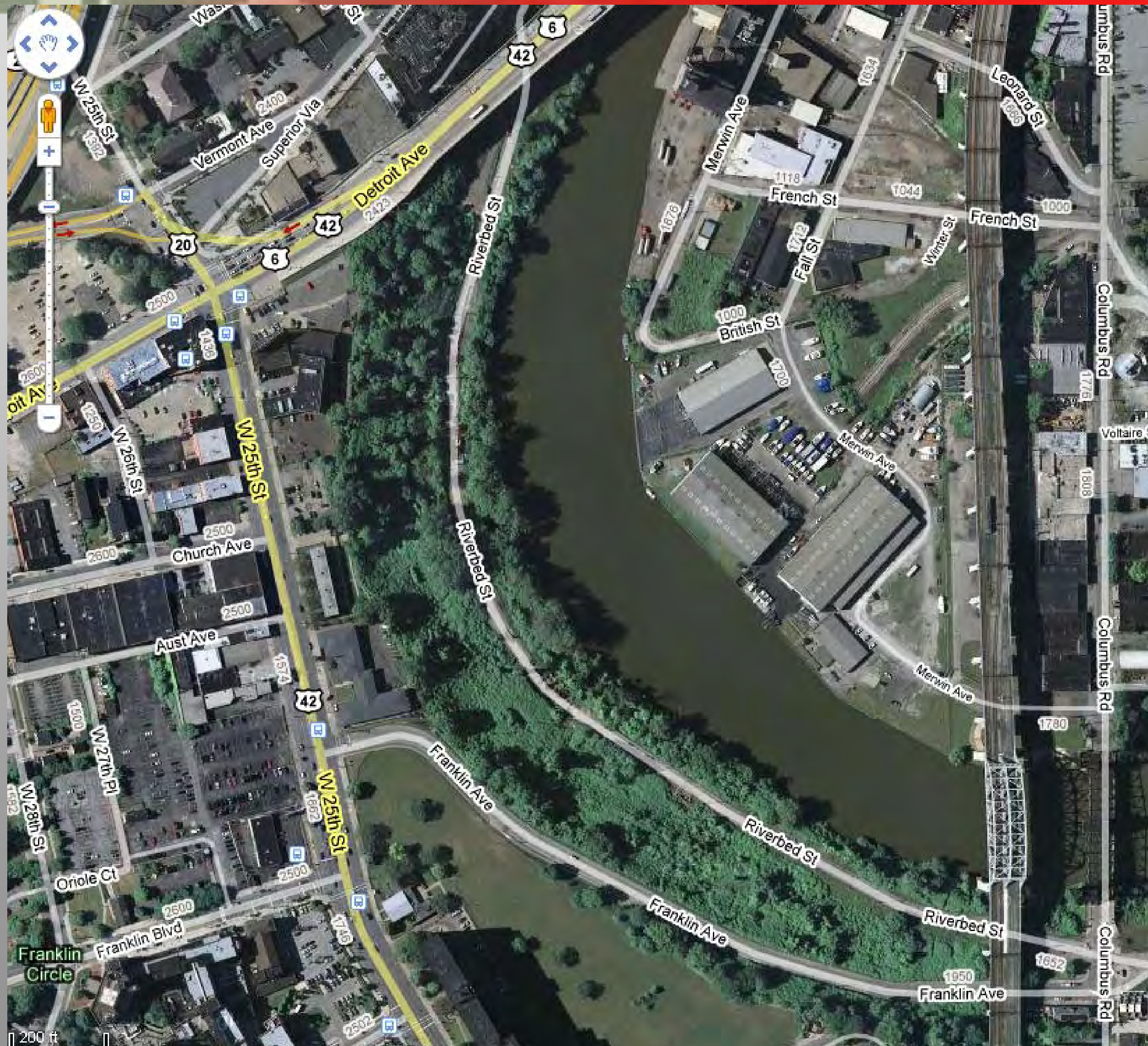
		Unit Price W/O contingencies	Contract Price	Contingencies @ 20%-25%	Contract Price + Contingencies	Unit Price with Contingencies (Rounded)	Total Cost with Contingencies
Upper Stability Wall Combi-Wall - CASE A With Excavation	**2,500.00 LF**	*14,825.84*	**37,064,600**	**7,412,921**	**44,477,521**	*17,800.00*	**44,500,000**
Upper Stability Wall Box Peine Beam - CASE A Without Excavation	**2,500.00 LF**	*46,631.03*	**116,577,575**	**23,315,517**	**139,893,092**	*56,000.00*	**140,000,000**
Upper Stability Wall Box Peine Beam - CASE C With Excavation	**2,500.00 LF**	*39,182.55*	**97,956,375**	**19,591,276**	**117,547,651**	*47,000.00*	**117,500,000**
Upper Stability Wall Box Peine Beam - CASE C Without Excavation	**2,500.00 LF**	*50,702.45*	**126,756,125**	**25,351,327**	**152,107,452**	*60,800.00*	**152,000,000**
Upper Stability Wall Box Peine Beam CASE D	**2,500.00 LF**	*61,672.84*	**154,182,100**	**30,836,418**	**185,018,518**	*74,000.00*	**185,000,000**
Lower Stability Wall Combi-Wall - CASE A	**2,500.00 LF**	*8,839.80*	**22,099,500**	**4,419,901**	**26,519,401**	*10,600.00*	**26,500,000**
Lower Stability Wall Combi-Wall - CASE C	**2,500.00 LF**	*8,899.39*	**22,248,475**	**4,449,693**	**26,698,168**	*10,700.00*	**26,750,000**
Lower Stability Wall Combi-Wall - CASE D	**2,500.00 LF**	*11,330.96*	**28,327,400**	**5,665,482**	**33,992,882**	*13,600.00*	**34,000,000**
Retaining Wall @ Top of Slope	**2,500.00 LF**	*3,049.06*	**7,622,650**	**1,524,531**	**9,147,181**	*3,700.00*	**9,250,000**
Green Bulkhead Section	**2,500.00 LF**	*997.37*	**2,493,425**	**623,354**	**3,116,779**	*1,300.00*	**3,250,000**
MOB/DEMOB	**1 LS**		**168,291**	**42,073**	**210,364**		**215,000**

Upper Stability Wall Combi-Wall - CASE A With Excavation	44,500,000
Lower Stability Wall Combi-Wall - CASE A	26,500,000
Retaining Wall @ Top of Slope	9,250,000
MOB/DEMOB	215,000
Alternative A with excavation TOTAL	**80,465,000**
Upper Stability Wall Box Peine Beam - CASE A Without Excavation	140,000,000
Lower Stability Wall Combi-Wall - CASE A	26,500,000
MOB/DEMOB	215,000
Alternative A without excavation TOTAL	**166,715,000**
Upper Stability Wall Box Peine Beam - CASE C With Excavation	117,500,000
Lower Stability Wall Combi-Wall - CASE C	26,750,000
Retaining Wall @ Top of Slope	9,250,000
MOB/DEMOB	215,000
Alternative C with excavation TOTAL	**153,715,000**
Upper Stability Wall Box Peine Beam - CASE C Without Excavation	152,000,000
Lower Stability Wall Combi-Wall - CASE C	26,750,000
MOB/DEMOB	215,000
Alternative C without excavation TOTAL	**178,965,000**
Upper Stability Wall Box Peine Beam CASE D	185,000,000
Lower Stability Wall Combi-Wall - CASE D	34,000,000
MOB/DEMOB	215,000
Alternative D TOTAL	**219,215,000**
Green Bulkhead add-on to each of above	**3,250,000**

Cuyahoga River
Riverbed St. and Vicinity
Bulkheads and Slope Stability

Objectives

- Describe the Problem
- Summarize Past Studies
- Discuss Causative Factors
- Determine Stakeholder Interests
- Discuss Potential Remediation Alternatives and Decision-Making


W 25th St
Vermont Ave
Superior Via
Detroit Ave
Riverbed St
Merwin Ave
French St
Leonard St
Columbus Rd
Fall St
Winter St
British St
Voltaire St
W 26th St
Church Ave
Aust Ave
W 27th Pl
W 28th St
Franklin Ave
Oriole Ct
Franklin Blvd
Franklin Circle
200 ft


20 ft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Traffic
More...
Map
Satellite
Terrain
Riverbed St
20 ft
10 m
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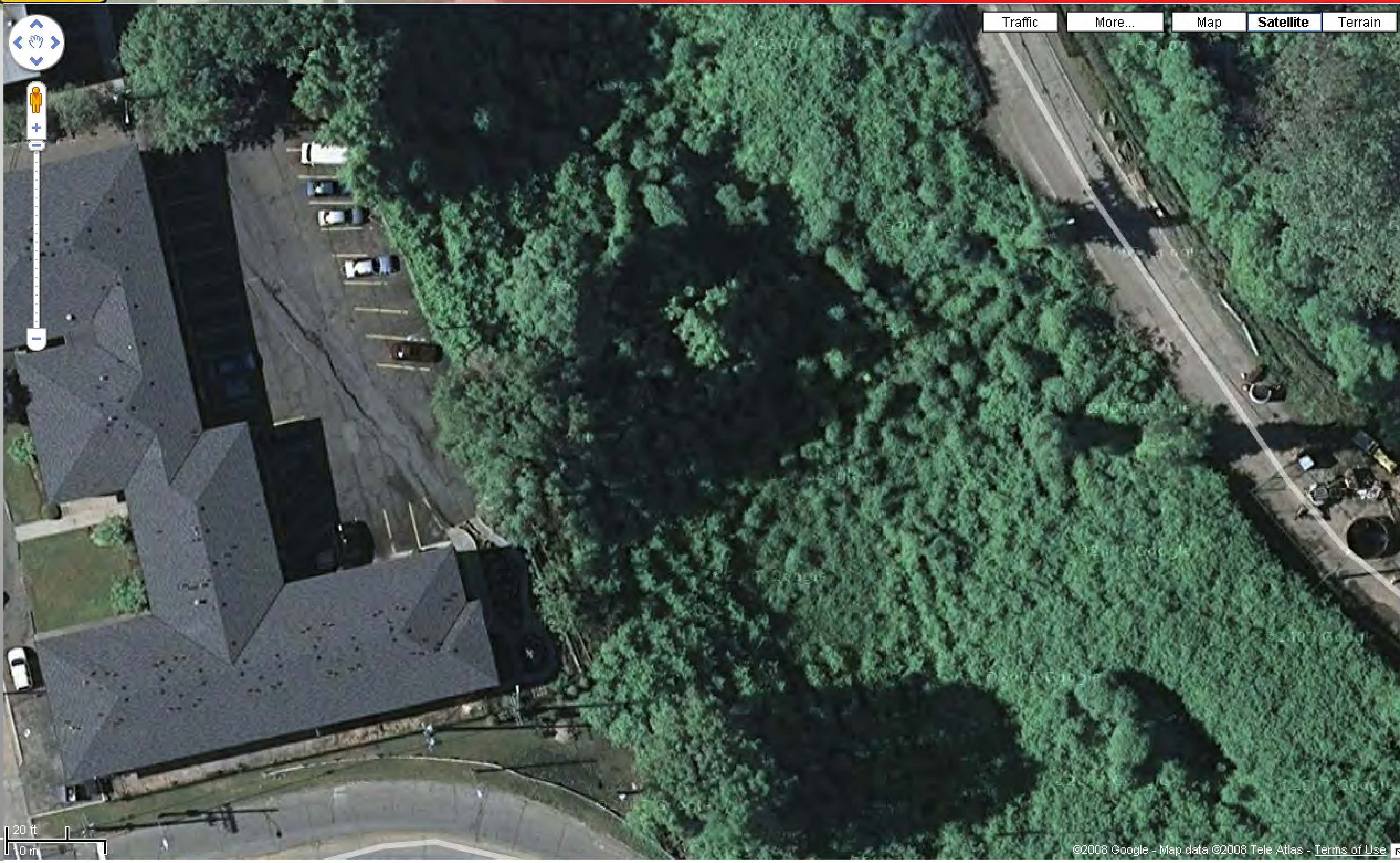

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Geologic History (Peck)

- Cuyahoga River initially cut through bedrock to about sea level
- Glacial advances shoved material into the channel and filled it with glacial till.
- Glacial retreats resulted in raised lake levels that covered the area and allowed filling of the valley with lake deposits
- End of glacial period produced high runoff into a higher Lake Erie, so sand and gravel was deposited over the lake deposits in a deltaic formation to El. 812.
- Lake Erie began dropping, so river started downcutting through the deltaic deposits into the lake deposits and glacial tills.
- These cuts left oversteepened slopes that have failed
- These failures have softened these soils, so they now continue to creep with fluctuations in loading and groundwater levels.

Figure 2 Geological Cross-Section for Present Cuyahoga River Valley
(after Peck 1954)

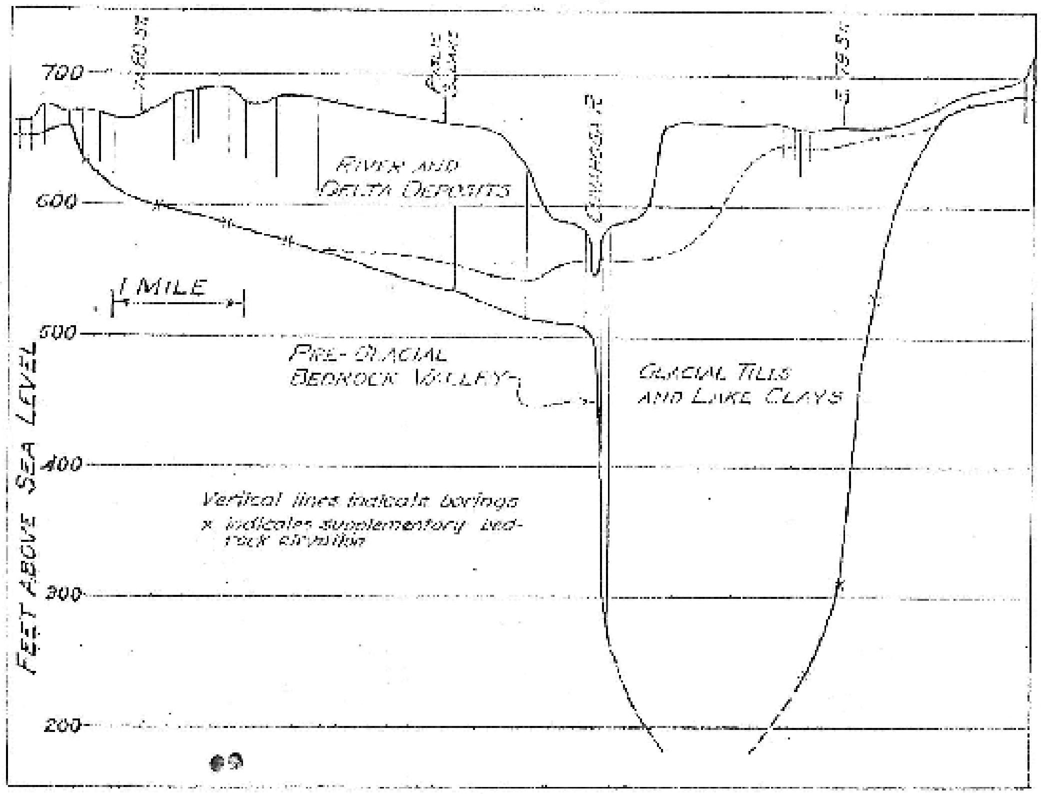

FIG. 2. EAST-WEST SECTION THROUGH VALLEY

Past Investigations

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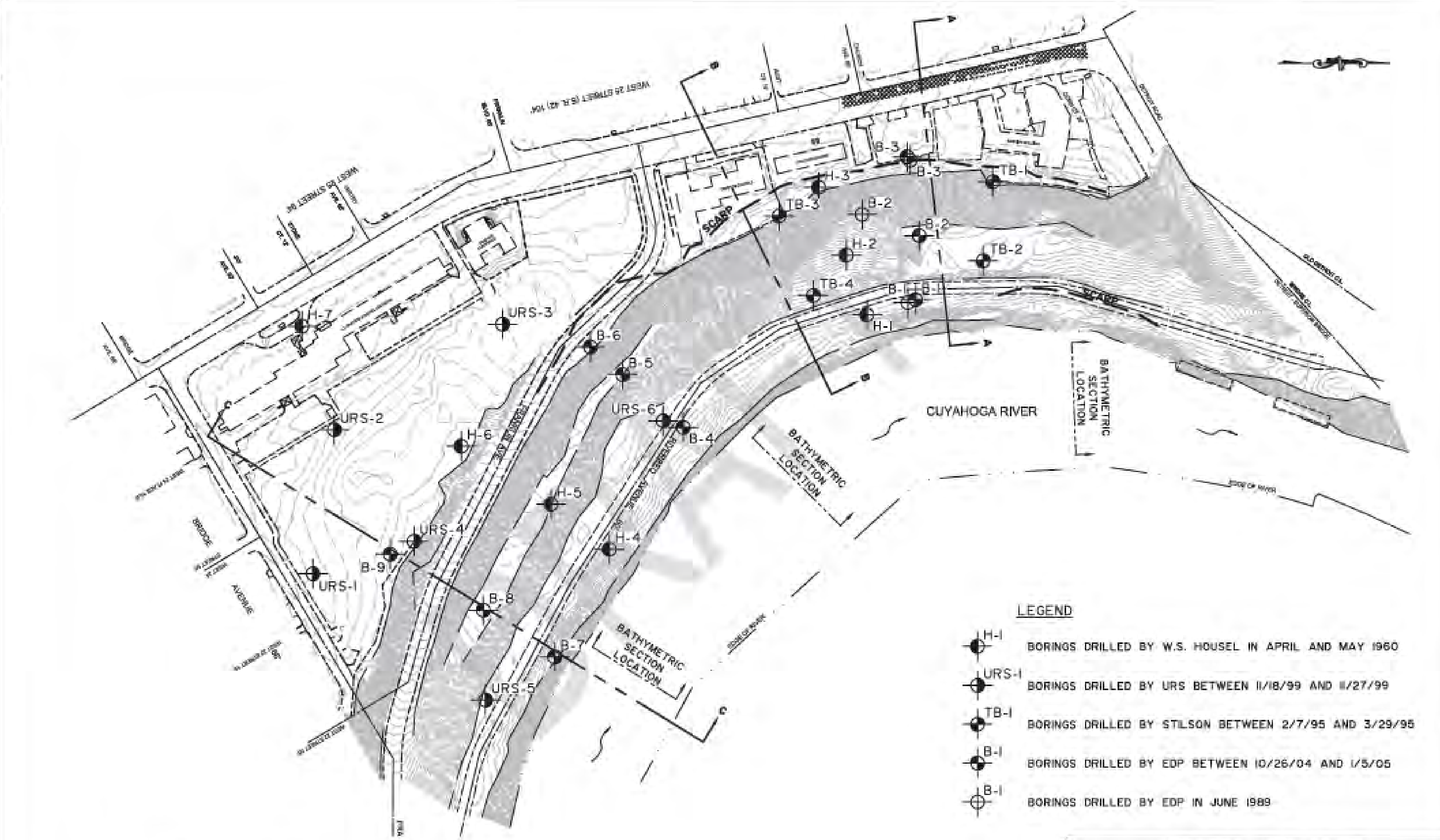

OVERALL SITE PLAN

Conceptual Stabilization Alternatives
Cuyahoga River Valley Intermodal Connector
Cleveland, Ohio

Project: 012-00720-302	Drawn By: AJS
Drawing Date: 1/25/06	Approved By: MGR
Revision Date:	Scale: 1" = 200'

BBCM

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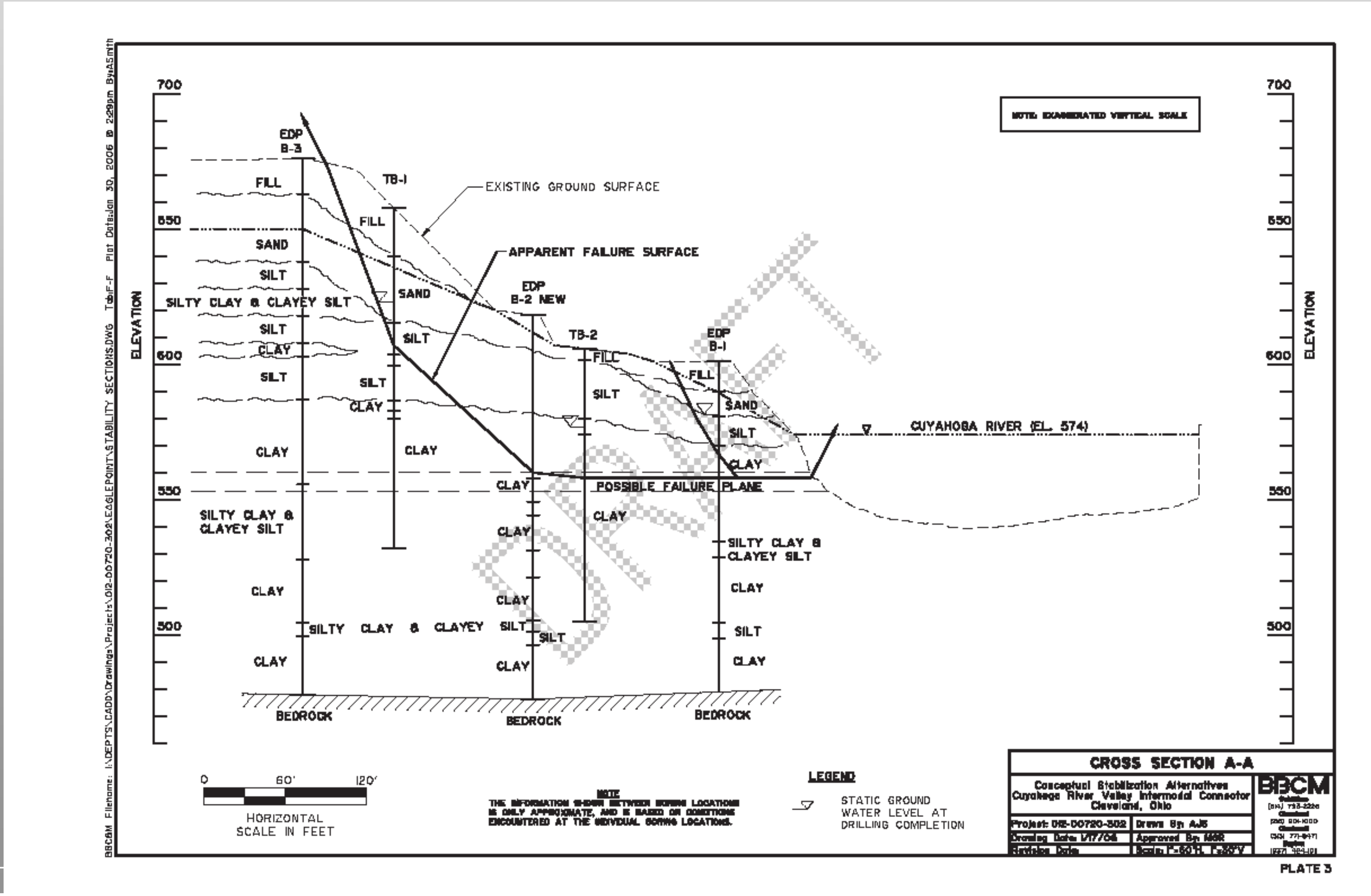
Cross section A-A



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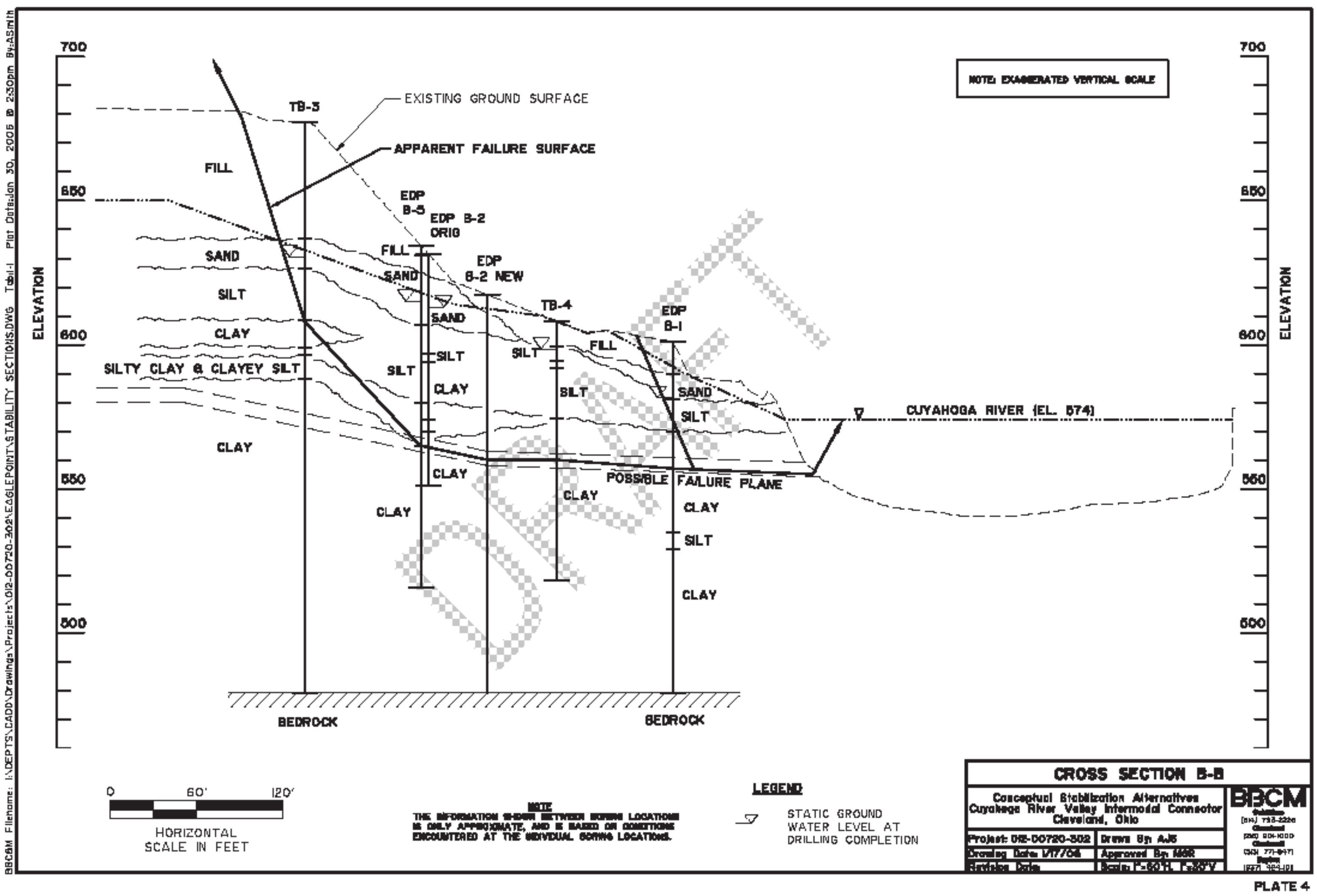
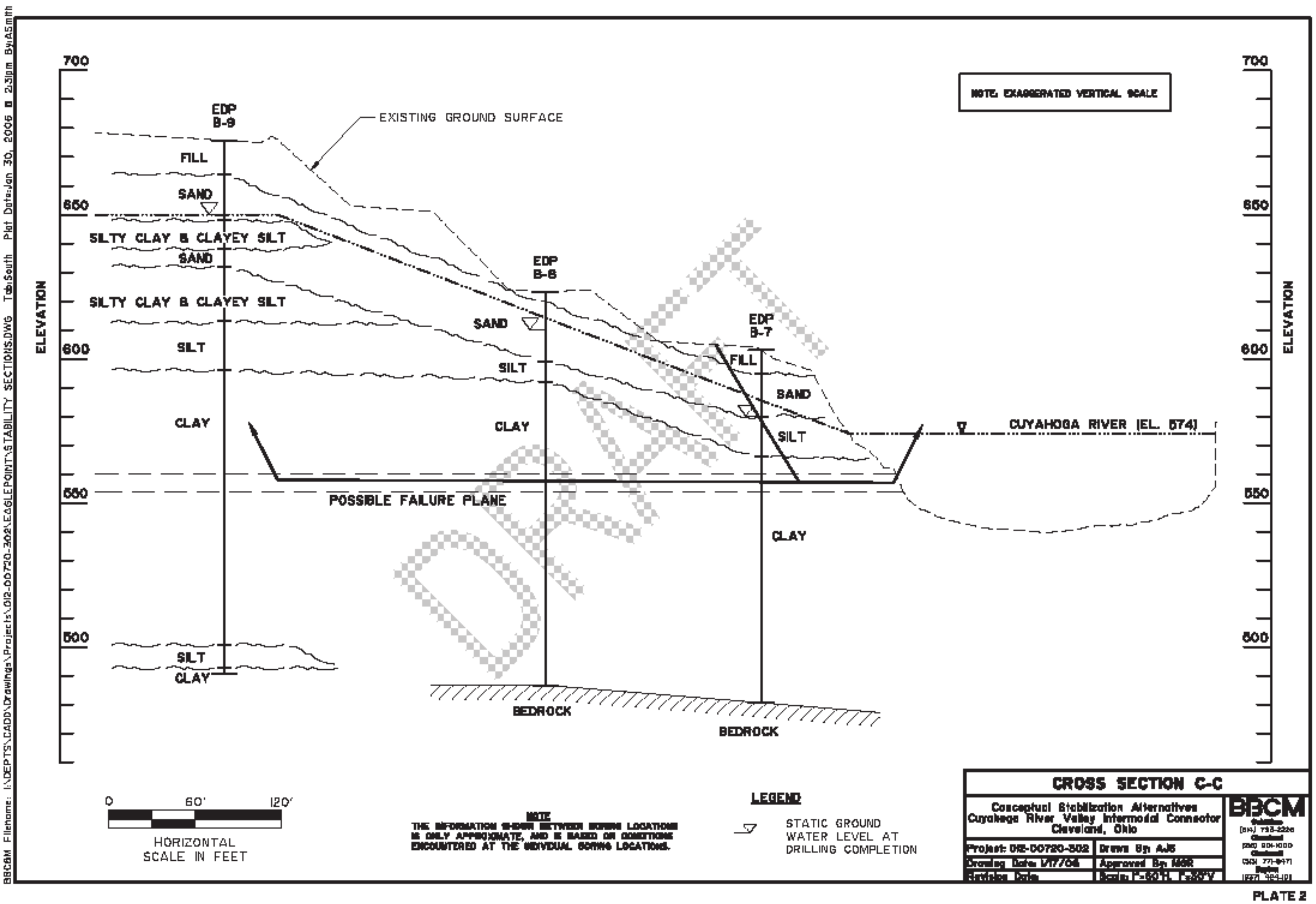
Cross section B-B



Cross section C-C



Past Studies & Recommendations

- Cleveland Union Terminal (1923)
  - Drilling discovered very soft clay layer at El. 490-495
  - No recommendations
- University of Michigan (1960) (CMHA)
  - Drilling, testing, no instrumentation
  - Calculated “load ratios”
  - Recommended no structures at midslope without deep foundations
- HNTB (1966)
  - Undrained slope stability analysis
- Neff &Associates (1989-1992) (Transitional Housing)
- PSI (1989-1992) (Superior Bridge Area)
  - Inclinometer data showing potential failure plane
- Lewin Corp. (1992) (CMHA)
  - Drilling, testing, and Inclinometer data
  - Discovered soft layer at El. 570-580
- Stilson Assoc. (1995) (CMHA)
  - Drilling, testing, and Inclinometer data
  - Back-calculated residual shear strength angle along potential failure plane
  - Recommended stone columns for remediation

Past Studies & Recommendations (cont'd)

- Bradley Thesis (CSU)
  - Described an ancient river valley about 125 ft deeper than current river level.
- URS Greiner (2000) (CMHA)
  - Addressed southern end of reach
  - Recommended caution with construction and further review on case-by case basis.
- BBCM (2003) (West Bank Connector)
  - Geologic history of site
  - Suggested regrading, riverbank armoring, and retaining structures
- EDP (2005) (Transitional Housing)
  - Drilling, testing, instrumentation
  - Residual shear strength data
  - Suggested anchoring system for slope instability remediation
- BBCM (2006) (for ODOT – Intermodal Connector)
  - Discussion of deeper failure surfaces
  - Costs for rehabilitating slopes
  - Recommended regrading, drainage improvements, & retaining walls
- NTH (2006) (NE Ohio Regional Sewer District)
  - Analyzed slope failures in downstream portion of reach
  - Concluded that sewer did not likely cause slope instability

Stakeholders

- City of Cleveland
  - Public trust
  - Loss of Revenue from Industry?
- Cuyahoga Metropolitan Housing Authority
  - Structural damage to Housing Units
  - Potential Safety Issues for Tenants
- ODOT
  - Potential loss of Bridge Approach
  - Maintenance costs for Riverbed Street
  - Safety Issues for Traffic along Riverbed Street
- Cleveland Cuyahoga Port Authority and Flats-Oxbow Association
  - Loss of business due to River Impingement
- NE Ohio Regional Sewer District
  - Loss of service due to line breaks
  - Environmental impacts (spills into Cuyahoga River)
- Public
  - Environmental Impacts

Factors Affecting Slope Stability

- Loading along the failure surface
  - Overbank fill placement
  - Ponded surface water saturating soils
  - Seasonal groundwater fluctuations
- Loss of resisting soil at the toe of slope
  - Dredging or natural erosion processes
  - Structural failure of Aging Retention Systems
- Soil shear strength along the failure plane
  - Reduced strength due to previous movement

Uncertainties

- Exact Location of Failure Plane(s)
  - Not plainly evident from borings.
  - One large slide or 2 smaller slides?
  - Movement at midslope?
  - Movement of Retaining Wall
- Potential Deeper (larger global) Failure Plane(s)
- Groundwater levels & fluctuations
- Shear Strength(s) along the Failure Plane(s)

Dealing with Uncertainties

The Standard

- Remediation concepts must reduce risk to tolerable levels.
- Tolerable levels are different for economic loss vs. life loss.

The Problem

- Uncertainties increase the probability of poor performance

The Impacts

- One large slide or 2 smaller slides
  - Selected alternative at mid slope or lower slope may not stop upper slope movement
- Potential Deeper Failure Plane
  - Entire slope, including remedial work, may continue moving
- Groundwater levels and soil properties
  - Remedial concept must be conservatively designed, and therefore more costly

The Solutions to Reduce Risk and Maximize Efficiency

- Reduce or remove uncertainty (More studies)
- Increase Conservativeness (Over design)
- Reduce Consequences (move people or structures)

Remediation Concepts

- Reduce Driving Forces
  - Excavate upper slope to shallower geometry
- Increase Resisting Forces
  - Place fill at toe of slope(s)
  - Anchored Retaining Structure
- Increase Shear Strength along Failure Plane
  - Soil Improvement methods
    - Stone Columns
    - Vibroflotation
    - Deep Soil Mixing
    - Jet Grouting
- Lower Groundwater Levels
  - Dewatering wells
  - Horizontal Drains

Remediation Selection Factors

- Project Cost
- Construction Duration
- Performance
  - Subsequent movement after remediation
  - Must be compatible with planned use
- Impacts during and after Construction
  - Environmental
  - Economic
  - Engineering
- Others?

Questions?