PECKMAN RIVER BASIN, NEW JERSEY
Flood Risk Management Feasibility Study Geotechnical Design Considerations

May 2018

United States Army Corps of Engineers

Contents

1.0 Introduction

The objective of the study is to determine the feasibility of constructing various features proposed for the Peckman River Flood Risk Management Project. The project area under consideration is shown in Figure 1, which includes channel improvements/diversion culvert, levees, and floodwalls.

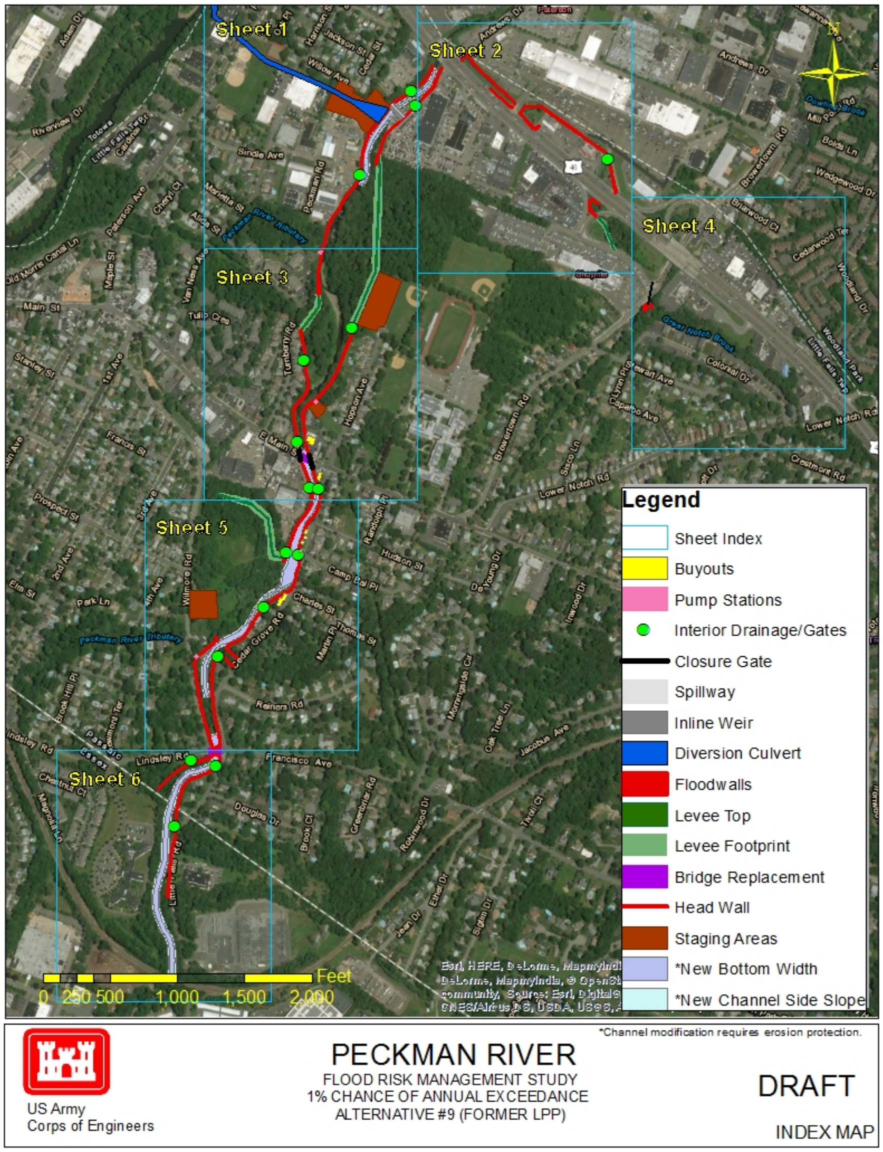
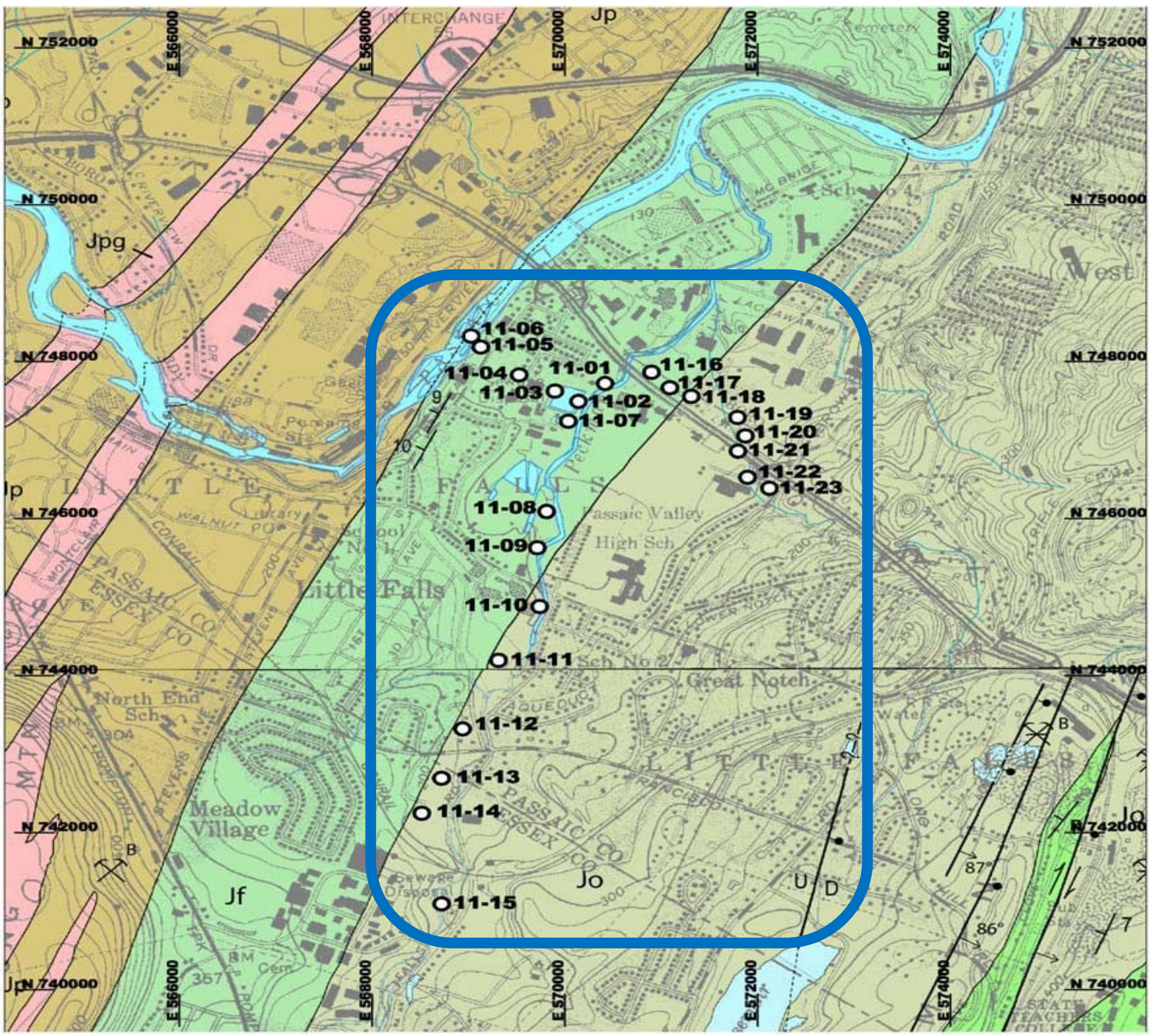


Figure 1. Google Earth view of the project area

2.0 Local Geology

The Peckman River Project area is located solely in the Paterson Quadrangle. NJGS mapping indicates Stream Terrace Deposits consisting of silt, clay,and fine sand underlying the project area. The uppermost surface (Stream Terrace Deposits) is described as moderately to well sorted, stratified; brown, yellowish-brown, reddish-brown; sand, pebble-to-cobble gravel, with minor silt. It is estimated to be as much as 20-foot thick and forms terraces with surfaces slightly above the modern floodplain along Peckman River and Preakness Brook. The lowest surface is defined as silt, clay, and/or fine sand up to 50-foot in thickness deposited on the lake bottom during the Great Notch Stage. Although the majority of the project area possesses the previous properties, the far eastern and western portions indicate two different soil types. The eastern edge is identified as Rahway Till, Yellow Phase, although it is discontinuous and generally less than 20-foot thick. This Till is described as silty sand, sandy silt, and silt with some to many subangular and subrounded pebbles and cobbles. Along the western project section the same soil properties are encountered with only the continuity changing (more continuous in western section). NJGS geologic mapping indicates Orange Mountain basalt within the western areas and Feltsville sandstone in all eastern areas. See attached Figures 2 and 3 with the project area of interest highlighted which combine the NJGS Bedrock Geologic and Surficial Geology Maps of the Paterson and Orange quadrangles, respectively.



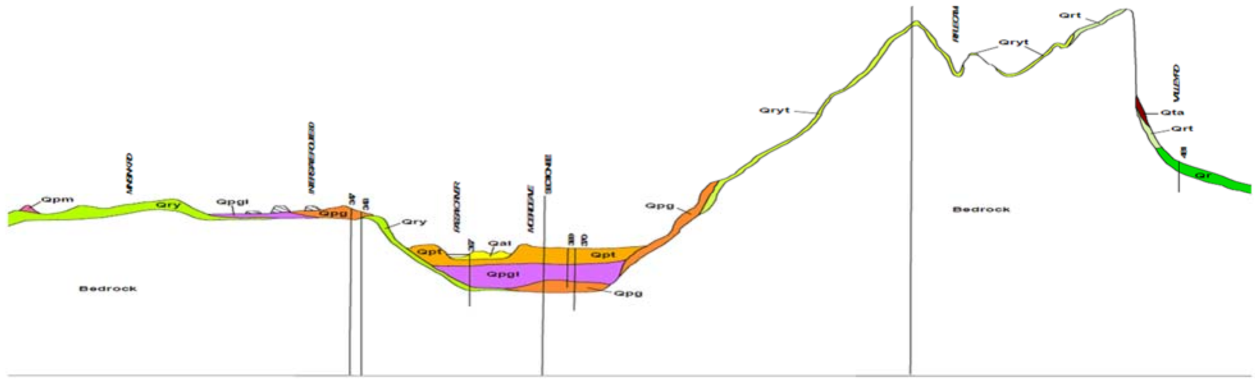


Figure 2 – NJGS geological Paterson and Orange quadrangle maps and cross section for the area of interest south of Patterson. Beige color (Jo) is Orange Mountain Basalt; Light green color (Jf) is Feltsville sandstone.

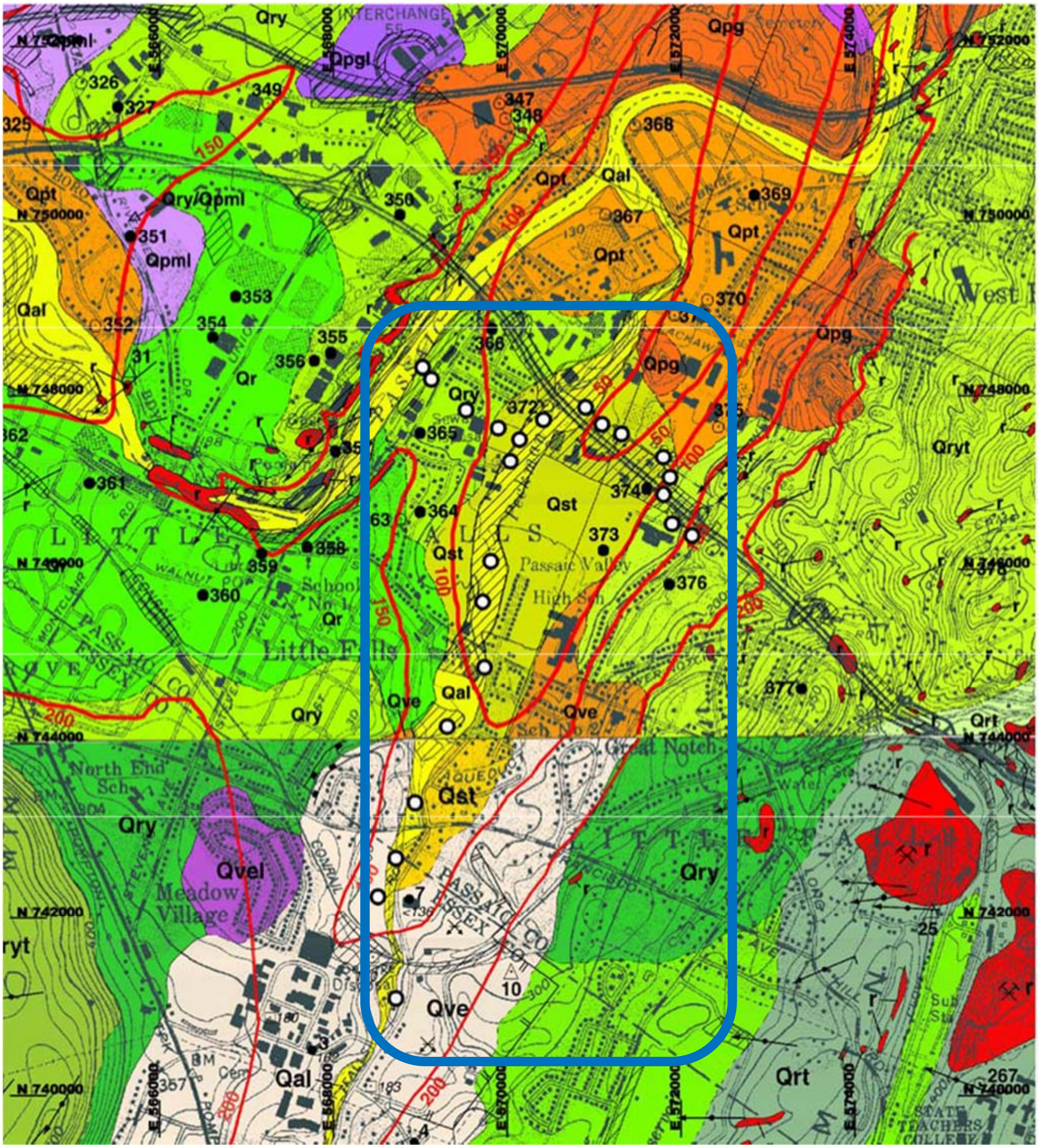


Figure 3 – NJGS surficial deposits with bedrock contours.

3.0 Subsurface Exploration

A geotechnical investigation was performed for USACE by e4sciences | Earthworks, LLC in January 2012. The work was performed under IDC#204, Contract #W912DS-09-D-0001, Task Order #0026 and included a total of twenty-three (23) geotechnical borings drilled along the Peckman River Basin in New Jersey. Twenty-one borings were completed in Little Falls, Passaic County while two borings were drilled in Cedar Grove, Essex County. Borings were drilled using the Standard Penetration Methods and Procedures. All SPT borings were drilled following ASTM standard D1586 with two modifications as follows:

-Blows per 6 inches were allowed to reach 100 blows.
-A 300 lb sampler was used upon refusal to advance the sample when it was determined that the refusal was due to cobbles.

As per Standard Penetration Methods and Procedures:

-A 140 lb hammer with a 30 inch drop was used to advance a 1 3/8 inch diameter split spoon sampler for drilling.
-When cohesive soils were present, a 3 inch diameter undisturbed piston tube was used.
-Any rocks or boulders that were encountered were cut with a NX size core.
-All soil sampling was continuous to a depth of 10 foot, then every five foot of depth thereafter.

4.0 Local Site Conditions

The borings indicate that surficial soils, fill and recent river alluvium overlie glacial deposits that are underlain by bedrock. These deposits are broken down into seven stratigraphic units as follows:

a) Organic soil and silt: The soil and silt encountered is brown organic silt/soil, with trace sand, grass and roots. Boring PRB-11-08 in the Peckman River channel did not encounter this organic layer. Boring PRB-11-10, drilled through East Main street, did not encounter this layer below the ~one-foot layer of asphalt concrete (AC). N-values for the organic layer trended near 20. The thickness of these materials ranged from 0-foot to four-foot.

b) Fill: Light brown, gray, or red in color, the fill encountered was a mix of silt, sand, and gravel with trace organic material. Fill material is native to the area and consists of reworked till, sands and gravels. Manmade materials such as glass, plastic, concrete, and asphalt are present in this unit. Fill was observed at all but two borings, PRB-11-08 and PRB-11-23. The uncorrected N-values of the fill ranged from three to 105 depending on the clast size and concentration. The thickness of fill ranged from 0-foot to 18-foot.

c) Till: Red-brown silty sand and gravel, with varying amounts of clay was encountered in the subsurface investigation. Basalt and sandstone clasts supported by the silty sand matrix include pebbles, cobbles and boulders. Till was recorded at all but three locations, PRB-11-9B, PRB-11-14, and PRB-11-18. The uncorrected N-values of the till ranged from 16 to 200 depending on the clast size, shape and concentration. The thickness of till ranged from 0-foot to >20-foot.

d) Sands and gravels: Sands and gravel units encountered were well sorted fluvial deposits. The uncorrected N-values of the materials ranged from 0 to 134. This unit was encountered at borings PRB- 11-03, PRB-11-08, PRB-11-9B, PRB-11-11, PRB-11-13, and PRB-11-14. The thickness of these materials ranged from 0-foot to 10-foot.

e) Varved sand silt and clay: Red-brown silt, clay, or very fine sand. Clay composition and cohesive strength of the varved layers varied. Uncorrected N-values ranged between 10 and 132 in these deposits. At boring PRB-11-08 sand, varved clay and silt alternates with sand layers below 13.0 feet. Varved silt and clay deposits were present in 14 of the 23 borings. In 12 of the borings, the varved deposit continued below the limit of the boring depth. The thickness of these materials ranged from 0-foot to 15.3 -foot.

f) Sandstone bedrock: The red/maroon micaceous Jurassic sandstone encountered is of the Feltville formation. Clasts of this material were encountered in the till and fill deposits. 5 foot rock core runs were advanced in Borings PRB-11-05 and PRB-11-06. The cores revealed intact Feltville sandstone. Coring rates in this formation averaged two minutes per foot. Rock Quality Designation (RQD) of the core retrieved was 33 and 14, respectively, indicating a rock quality rating of poor to very poor in the upper five feet of bedrock.

g) Basalt bedrock: Orange Mountain Basalt is a dark gray to black Jurassic basalt with Calcite filled vugs. Clasts of this material were encountered in the till and fill deposits. Contact metamorphosed surfaces indicate pillow boundaries. The five foot rock core in PRB-11-23 indicated Orange Mountain Basalt. The coring rate averaged seven minutes per foot with an RQD of 18 indicating a rock quality rating of very poor for the top feet of rock. Basalt was encountered in only one of the borings advanced in the project vicinity.

Laboratory tests included the following: grain size analysis via the hydrometer analysis, moisture content, specific gravity, Atterberg limits, triaxial testing (when plastic soils were encountered), consolidated-undrained triaxial compression tests with pore water measurements, unconfined compression strength tests, and density of rock samples. Three of the borings recovered rock cores for testing.

The results of the laboratory tests generally classified the encountered materials into the following:

Fill Materials: The fill materials include sand, gravel and rock fragments with varying amounts of silt and clay. USCS classifications include GP, GW, GM and SP. Although no transmissivity testing was conducted on the samples retrieved, grain size analyses were conducted. Samples were noted to have 5 to 25 percent passing the #200 sieve; as a result, the soil deposit is considered to be porous.

River & Till Deposits: River deposits have been identified throughout the project. These deposits are predominantly sand and silt, and have been classified as SP or SW. Most of the till deposits have fines less than 10 percent. These materials are also considered to be porous and pervious.

Varved Clay and Silt Deposits: The varved clay and silt deposits include fines (silts and clays) inter-bedded with fine sand. Due to the amount of fine-grained particles the varved clay and silt may be considered relatively impermeable and therefore be suitable for a cutoff barrier.

Bedrock: The bedrock underlying the site consists of sandstone and basalt. Bedrock was encountered at depths of 11.0, 17.5 to 18.5 feet in three borings. In the remaining 20 borings, no bedrock was encountered.

5.0 Geotechnical Analyses

For the geotechnical analyses, a conservative, i.e. most permeable, soil profile was considered. The seven units have been generalized into the below limits, thickness, and uncorrected n-values:

Table 1. Summary of stratigraphic unit properties.

Strata	Depth (feet)	Minimum Uncorrected N-Value (blows/foot)	Maximum Uncorrected N-Value (blows/foot)
Organic Material/Fill	6	3	105
Sands and gravels	25+	0	200

5.1 Levees

5.1.1 Seepage Analysis

Geotechnical design parameters were based on the available existing field and laboratory test data obtained from the geotechnical investigation. Embankment materials would likely be comprised of imported silty and/or clayey soil (USCS Type ML/CL) for the impervious core and silty sands (USCS Type SM) for the levee fill materials (embankment shell). The materials would be specified to ensure that they conform to the assumed properties used during design. Fill would be specified to be placed in lifts and be compacted in maximum 12-inch thick loose lifts compacted to 95 percent maximum density, in accordance with Modified Proctor test procedures ASTM D-1557. For embankment construction, it is recommended that the fill be placed two percent above its optimum moisture content.

Seepage analysis was performed assuming an eight-foot high levee with a 12-foot wide crest and three horizontal to one vertical slopes. The following is a summary of estimated permeability constants used for seepage analysis:

Table 2. Permeability Constants.

Soil Area	Permeability		Anisotropy	GeoStudio Color
	feet/sec	cm/sec	kv/kh	
Levee Fill Material	3.28×10^{-6}	1×10^{-4}	1	
Impervious Core	3.28×10^{-8}	1×10^{-6}	1	
Existing Fill	3.28×10^{-5}	1×10^{-3}	1	
Till	3.28×10^{-5}	1×10^{-3}	1	

Permeability constants were estimated from intrinsic values referenced in "Applied Hydrology", 4th ed., C.W. Fetter; Table 3.7 based on the grain size analyses obtained from the geotechnical investigation.

An impervious core with inspection trench was selected to minimize seepage with the selected typical cross section. The levee geometry is based on the required dimensions found in EM 1110-2-1913 (see sections 6-1, 6-2, 7-2f). Allowable exit gradient information is summarized in ETL 1110-2-569 (see section 6d), which recommends a maximum exit gradient of 0.5.

GeoStudio SEEP/W is a finite element program that can identify phreatic levels, exit gradients, and pore-water pressures in both a steady state cases and transient cases. Analysis was completed using the SEEP/W software. The exit gradient and total seepage rate for the steady state case are as follows:

Table 3. GeoStudio SEEP/W Steady State Case Results

Exit Gradient	Total Seepage Rate (ft^3/days)
0.49	6.97×10^{-5}

The hydraulic conductivities used in the analysis are estimated from empirical data. Additional subsurface borings including falling head permeability tests along the levee alignment should be performed in the next phase of this project in order to accurately capture the existing soil properties.

5.1.2 Slope Stability

The following soil parameters were used for analyzing the slope stability:

Table 4. Slope stability soil parameters

Soil Area	Total Unit Weight	Cohesion	Friction Angle	GeoStudio Color
	pcf	psf	degrees	
Compacted Fill Material	125	0	34	
Impervious Core	120	2000	0	
Existing Fill	120	0	32	
Till	130	0	34	

The circular failure surface was analyzed using GeoStudio SLOPE/W for three different cases; end-of-Construction, rapid drawdown, and steady-state conditions. SLOPE/W performs a two-dimensional limit equilibrium stability analysis. The analyses were run using both Janbu and Spencer's Method for this project. Pore pressure conditions for each SLOPE/W analysis were derived using the GeoStudio SEEP/W program. For the end-of-Construction case, the levee was assumed to not be hydraulically loaded and thus pore pressure only existed due to groundwater conditions. For the steady-state condition, it was assumed the levee would be loaded to its maximum height, 8 feet above the ground surface, for sufficient time such that fully saturated conditions are met. Consequently, the water level on the riverside for this analysis was also assumed to be at the top of levee height. For the rapid drawdown case, a transient analysis was performed with a full water level drop instantaneously taking place, and was performed at 30 exponentially spaced intervals for 730 days (2 years).

Factors of safety for end of construction (Case I) and steady state (Case III) conditions were 2.2 and 1.4, respectively. For rapid drawdown (Case II), the lowest factor of safety took place at the first time interval (44 min), and was calculated as 1.9.

5.1.3 Settlement

The borings indicate that the surficial soils are comprised of fill and recent river sediments over glacial deposits that overlie bedrock. The average depth of fill is approximately five-foot throughout the project area, with the exception of one boring where the fill extended to a depth of 18 feet. The fill materials consist primarily of reworked sand and till deposits with fragments of manmade materials. The fill materials include sand, gravel and rock fragments with varying amounts of silt and clay. USCS classifications include GP, GW, GM and SP. Uncorrected N-values range from 10 to 100 blows per foot and indicate that this soil deposit may be used to support the proposed embankments or flood walls providing the deposit is compacted or reworked to achieve the required design strength. In areas where the blow counts are reported to be less than 10 blows per foot, additional investigations or specialized construction activities may be warranted. As this condition is limited in area, the fill deposits are not anticipated to have a significant design or construction impact to the project. The natural deposits underlying the fill are generally medium dense to stiff inconsistency. Settlement calculations were not performed for the proposed levee geometry as part of the feasibility study as the encountered subsurface conditions are not anticipated to impact the feasibility and or cost of implementing the proposed project. However, settlement analyses will be performed during the design phase. It should be understood that localized conditions may require soil replacement, soil stabilization, or other foundation ground improvement methods.

5.2 Floodwalls

Where an earthen levee is cost prohibitive, floodwalls are used to provide flood risk management. The type of floodwall used at a particular site depends on its projection above grade, soil conditions which impact the foundation design and space limitations. Only T-walls were evaluated for preliminary cost purposes. Alternative wall options may need to be considered and evaluated due to space limitations, etc. depending on final layout.

5.2.1 Stability Analysis

The following assumptions were utilized in the wall stability analysis:

- Basic Data and Assumptions (parameters will need to be refined in the next phase using boring information available near specific floodwall locations):
    - Soil Friction Angle = 34 degrees
    - Soil Cohesion = 0
    - Soil Unit Weight (drained) = 125 pcf
    - Water Weight = 62.4 pcf
    - Surcharge, earthquake , and wind loads not considered in this phase
    - Minimum protective earth cover of 3 ft used for frost protection
- Stability Analysis
    - CTWALL-R was used to run analysis and the results of Overturning, Sliding and Bearing Capacity of each floodwall system can be found in Table 1.
    - Calculations correspond to the Design Case I2 for inland floodwalls which requires loading to top of wall. However, the minimum factors of safety shown on the CTWALL-R outputs correspond to the Design Case I1 which are more conservative.

- o Design Case I1 Factor of Safety Criteria per EM 1110-2- 2502:
  - Overturning Stability: 100% of footing base in compression
  - Sliding: Minimum Factor of Safety (FOS) of 1.5
  - Bearing Capacity: Minimum FOS of 2.0 (The actual bearing capacity will need to be checked with the allowable bearing capacity in the next phase.)
- o According to the Geotechnical Report dated January 27, 2012 for Peckman River Basin Project, the following will be required:
  - Erosion control for native and fill materials
  - Removal of organic deposits
  - Removal or rework of fill materials may be required

- Design References:
  - o EM 1110-2-2502, Retaining and Flood Walls.

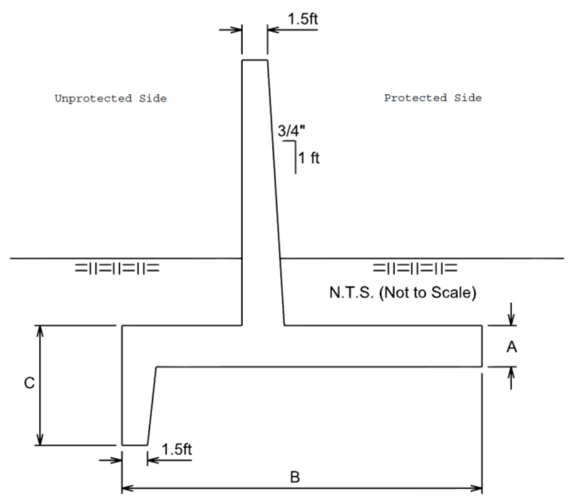


Figure 4. Typical Floodwall Detail.

Table 5. Assumed Floodwall Geometry

Exposed Wall Height (ft)	Base Thickness, A (ft)	Base Width, B (ft)	Key Thickness, C (ft)	Overturning (% base compression)	Sliding FoS	Bearing Capacity FoS
8.5	2	10	4	100	3.4	20.5
16.5	2	25	4	100	1.5	3.6
24	Assume T-walls supported on piles required.					

Notes:
(1) Soil was assumed flat on both the Protected and Unprotected sides of the floodwalls since cross sections weren't available at the time of floodwall evaluation
(2) Water level on resisting side assumed at bottom of footing level for 8.5 ft wall and at ground

surface for 16.5 ft wall.
(3) Wall types and distance from the CL of the River may vary and/or change once wall alignment has been determined in the next phase. Due to space restrictions, where T-walls cannot be accommodated, composite wall system may need to be evaluated
(4) Wall cross-sections are only a representation for preliminary cost estimation purposes.
(5) No updated site conditions and utility surveys at the time of evaluation.

5.2.2 Seepage Analysis

The exit gradients and flow quantities were analyzed for the wall geometries assumed in Table 5. The maximum exit gradients are listed below:

Table 6. Exit Gradients data.

Floodwall Water Height (ft)	Exit Gradient	Total Seepage Rate (ft^3/days)
8	0.22	1.5×10^{-4}
16	0.44	3.05×10^{-4}

Based on the preliminary results, more robust cutoff walls such as driven sheet piles embedded into the concrete T-wall sections does not appear warranted.

5.3 Retaining Walls

Retaining walls may be required where grading may take place in areas adjacent to channelization limits that will not be improved with levees or floodwalls. Only T-walls were evaluated for preliminary cost purposes.

6.0 Conclusions

The information provided in this report is for conceptual purposes only and details and assumptions provided are subject to change. Further evaluation/analysis and information (including, but not limited to, additional borings, field tests, laboratory tests, surveys) will be required in future phases in order to refine feature designs, layout and cost estimates.

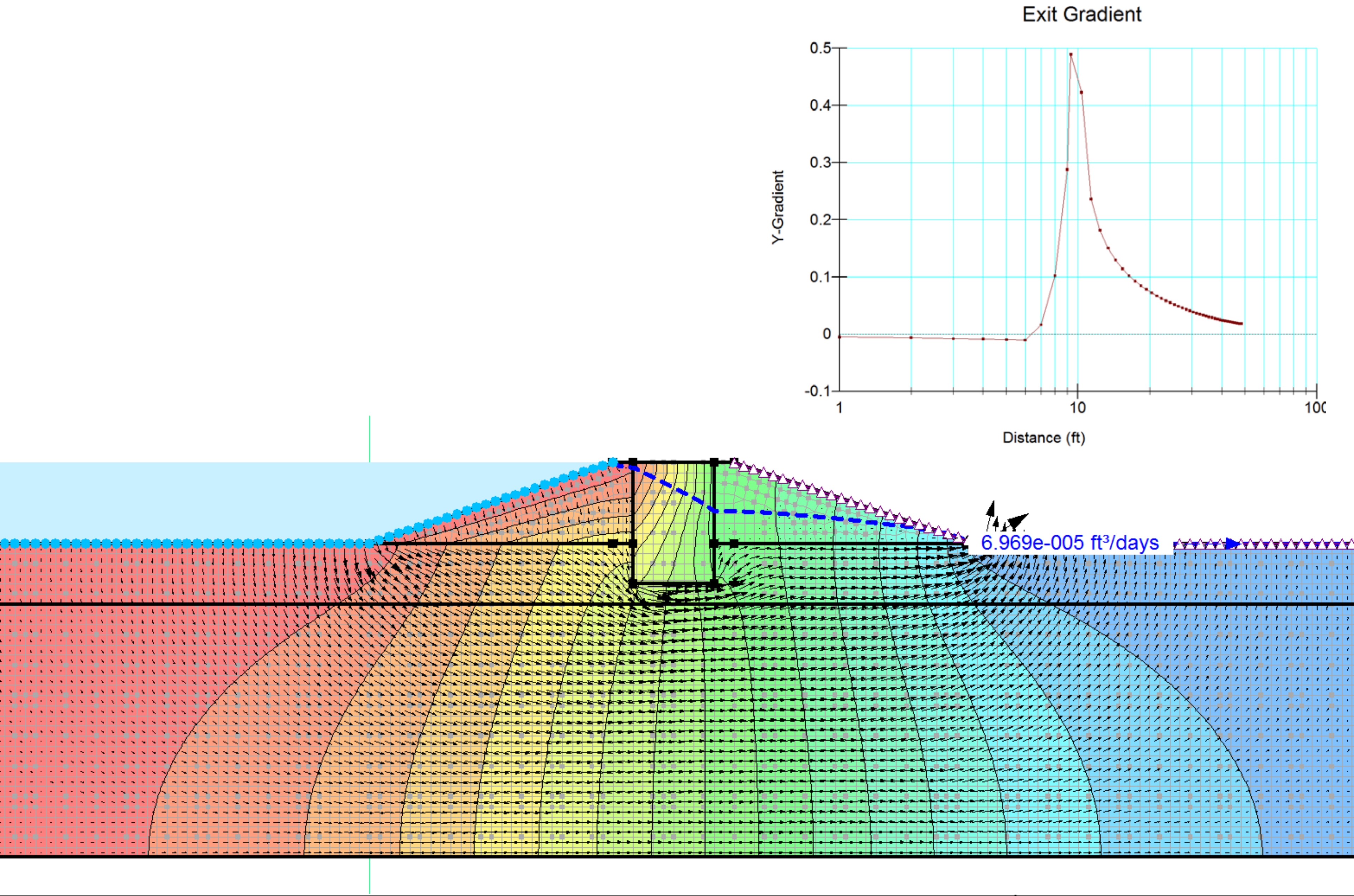
7.0 Attachments:

Geotechnical Calculations

- **GeoStudio Figures**
  - **Figure 1 - Levee Seepage – Case III: Steady State**
  - **Figure 2 - Slope Stability – Case I: End of Construction**
  - **Figure 3 - Slope Stability – Case II: Rapid Drawdown**
  - **Figure 4 - Slope Stability – Case III: Steady State**
  - **Figure 5 - 8 ft Floodwall Seepage – Case III: Steady State**
  - **Figure 6 - 16 ft Floodwall Seepage – Case III: Steady State**
- **Flood Wall Stability Calculation**
  - **CTWALL-R Output – Eight-foot Floodwall**
  - **CTWALL-R Output – 16-foot Floodwall**

Geotechnical and HTRW Investigations for Peckman River Basin Project, New Jersey, dated January 27, 2012.

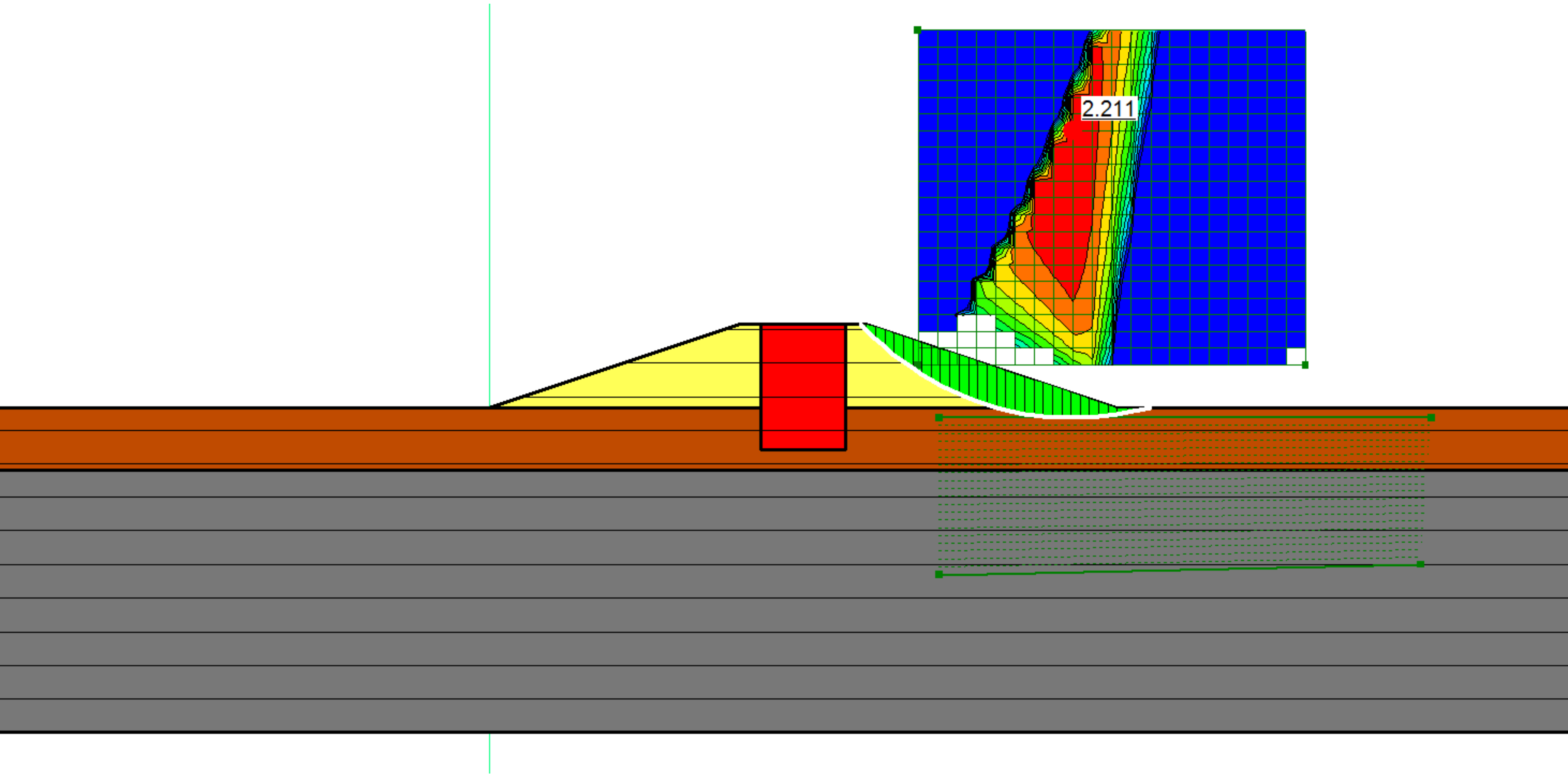
GeoStudio Figures



Levee Seepage – Case III: Steady State

Figure 1

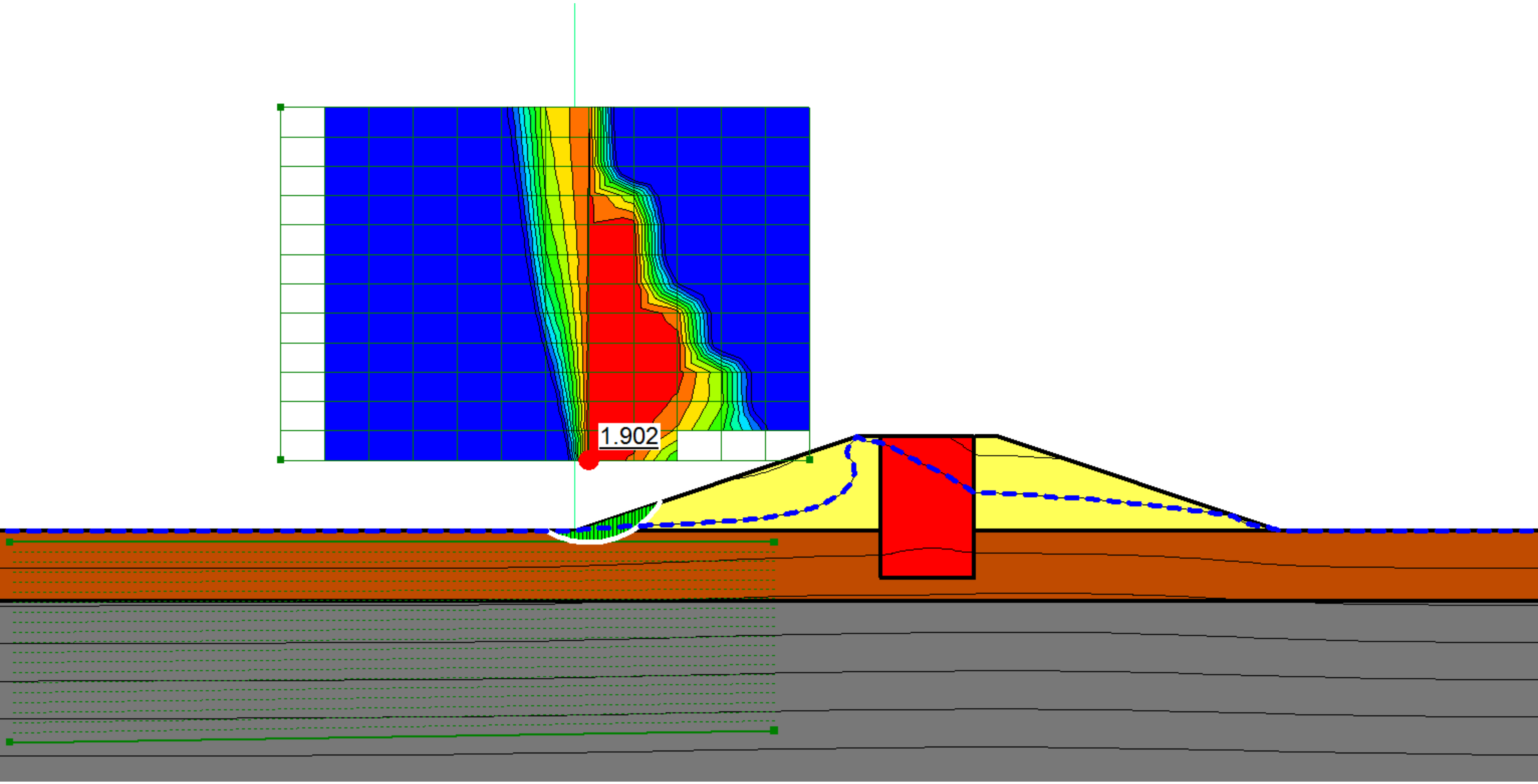
December 2017



Slope Stability – Case I: End of Construction

Figure 2

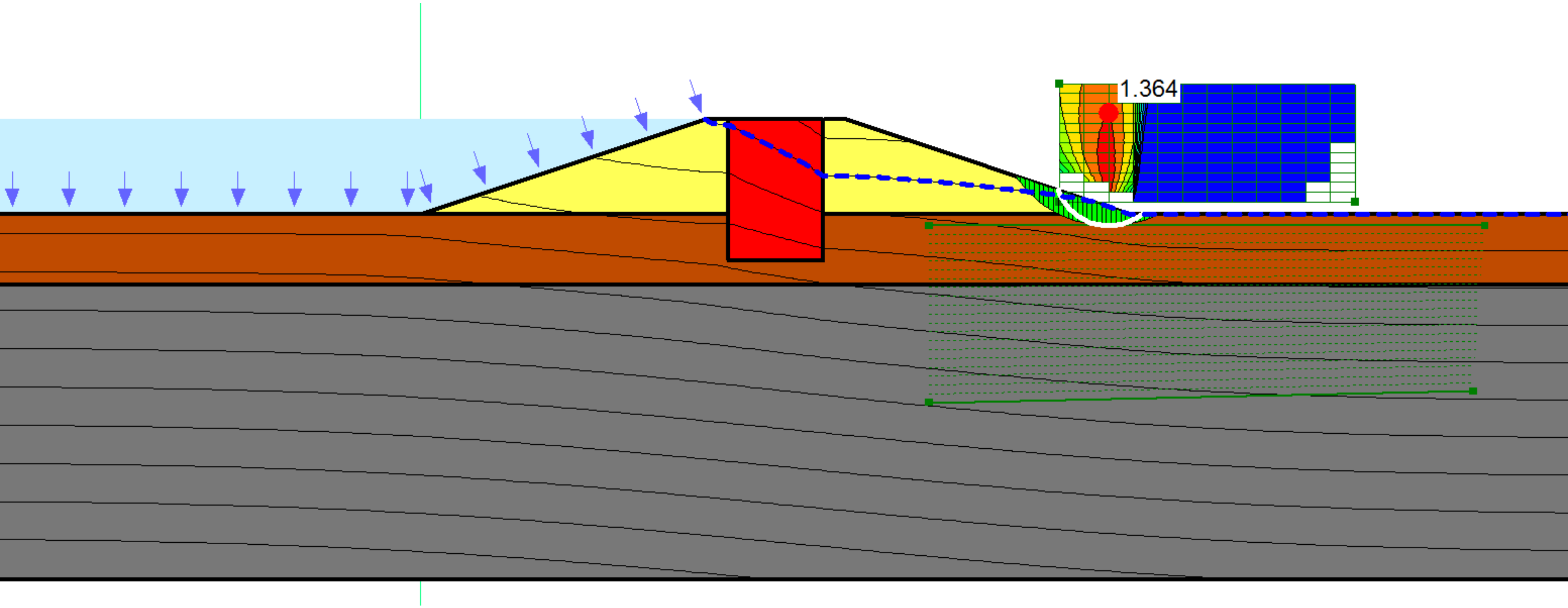
December 2017



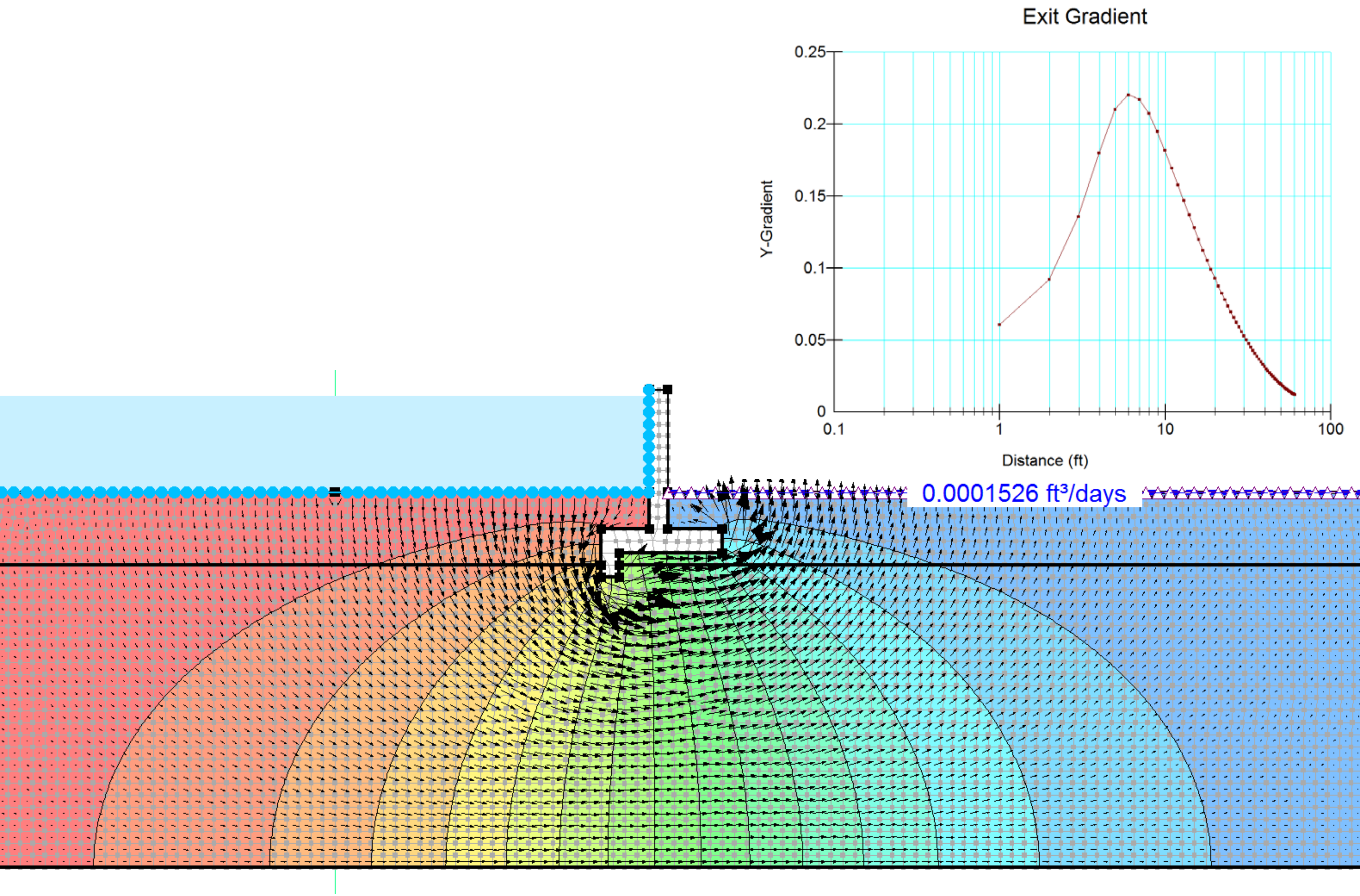
Slope Stability – Case II: Rapid Drawdown

Figure 3

December 2017



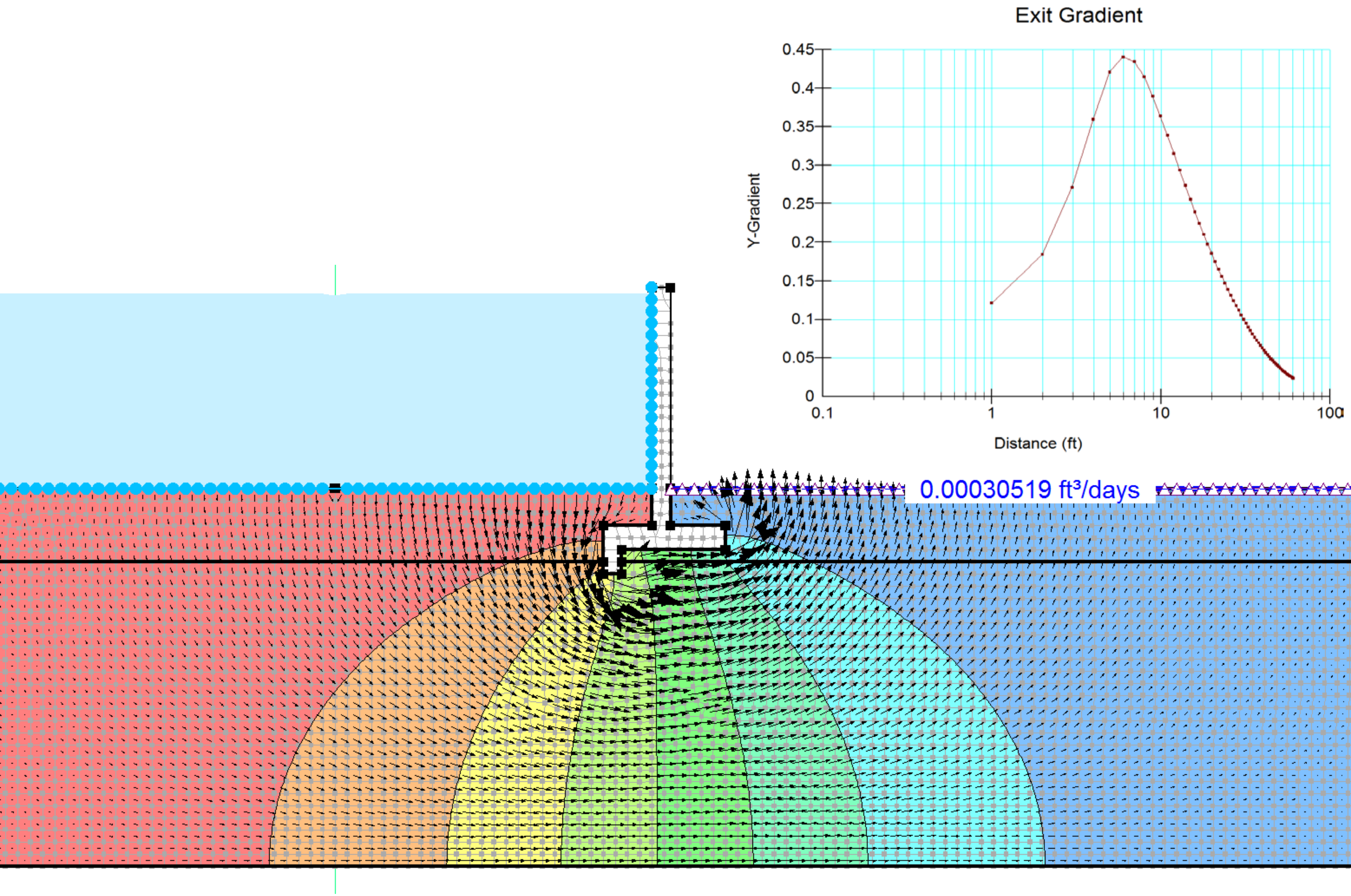
	Slope Stability – Case III: Steady State	Figure 4
		December 2017



Seepage – 8 ft Floodwall

Figure 5

December 2017



	Seepage – 16 ft Floodwall	Figure 6
		December 2017

Floodwall Stability Calculations

Peckman T-Wall - 8 foot

***************** Echoprint of Input Data *****************

Date: 2017/12/ 4 Time: 17.48.55

Structural geometry data:
Elevation of top of stem (ELTS) = 148.50 ft
Height of stem (HTS) = 11.50 ft
Thickness top of stem (TTS) = 1.50 ft
Thickness bottom of stem (TBS) = 1.50 ft
Dist. of batter at bot. of stem (TBSR)= 0.00 ft
Depth of heel (THEEL) = 4.00 ft
Distance of batter for heel (BTRH) = 0.00 ft
Depth of toe (TTOE) = 2.00 ft
Width of toe (TWIDTH) = 4.50 ft
Distance of batter for toe (BTRT) = 0.00 ft
Width of base (BWIDTH) = 10.00 ft
Depth of key (HK) = 2.00 ft
Width of bottom of key (TK) = 1.50 ft
Dist. of batter at bot. of key (BTRK) = 0.00 ft

Structure coordinates:

x (ft)	y (ft)
0.00	133.00
0.00	137.00
4.00	137.00
4.00	148.50
5.50	148.50
5.50	137.00
10.00	137.00
10.00	135.00
1.50	135.00
1.50	133.00

NOTE: X=0 is located at the left-hand side
of the structure. The Y values correspond
to the actual elevation used.

Structural property data:
Unit weight of concrete = 0.150 kcf

Driving side soil property data:

Phi (deg)	c (ksf)	Moist Unit wt. (kcf)	Saturated unit wt. (kcf)	Delta (deg)	Elev. soil (ft)

34.00 0.000 0.125 0.130 0.00 140.00

Driving side soil geometry:

Soil point	Batter (in:1ft)	Distance (ft)
1	0.00	500.00
2	0.00	0.00
3	0.00	500.00

Driving side soil profile:

Soil point	x (ft)	y (ft)
1	-1496.00	140.00
2	4.00	140.00

Resisting side soil property data:

Phi (deg)	c (ksf)	Moist Unit wt. (kcf)	Saturated unit wt. (kcf)	Elev. soil (ft)	Batter (in:1ft)
34.00	0.000	0.125	0.130	140.00	0.00

Resisting side soil profile:

Soil point	x (ft)	y (ft)
1	5.50	140.00
2	505.50	140.00

Foundation property data:
phi for soil-structure interface = 30.00 (deg)
c for soil-structure interface = 0.000 (ksf)
phi for soil-soil interface = 34.00 (deg)
c for soil-soil interface = 0.000 (ksf)

Water data:
Driving side elevation = 148.00 ft
Resisting side elevation = 135.00 ft
Unit weight of water = 0.0624 kcf
Seepage pressures computed by Line of Creep method.

Minimum required factors of safety:
Sliding FS = 1.50
Overturning = 100.00% base in compression

Crack options:
o Crack depth is to be calculated
o Computed cracks *will* be filled with water

Strength mobilization factor =   0.6667

At-rest pressures on the resisting side *are used*
in the overturning analysis.

Forces on the resisting side *are used* in the sliding analysis.

Do iterate in overturning analysis.

***** Summary of Results *****

```
***************    *** Satisfied ***
* Overturning *    Required base in comp. = 100.00 %
***************    Actual base in comp.   = 100.00 %
                   Overturning ratio      = 105.43
```

Xr (measured from toe) =   5.70 ft
Resultant ratio   = 0.5702
Stem ratio   = 0.4500
Base pressure at heel =   1.6033 ksf
Base pressure at toe =   0.6531 ksf

```
***********    *** Satisfied ***
* Sliding *    Min. Required =   1.50
***********    Actual FS     =   3.42
```

```
***********
* Bearing *
***********
```

Net ultimate bearing pressure =   19.8876 (ksf)
Factor of safety =   20.474

********************* Output Results *********************

Date: 2017/12/ 4   Time: 17.48.55

```
**************************
**  Overturning Results  **
**************************
```

Solution converged in 1 iterations.

SMF used to calculate K's =   0.6667
Alpha for the SMF   = -57.1474
Calculated earth pressure coefficients:

Driving side at rest K = 0.4183
Driving side at rest Kc = 0.6468
Resisting side at rest K = 0.4408
Resisting side at rest Kc = 0.6639
At-rest K's for resisting side calculated.

Depth of cracking = 0.00 ft

** Driving side pressures **

Earth pressures:

Elevation (ft)	Pressure (ksf)
140.00	0.0000
133.00	0.5373

** Resisting side pressures **

Earth pressures:

Elevation (ft)	Pressure (ksf)
140.00	0.0000
135.00	0.2755

Balancing earth pressures:

Elevation (ft)	Pressure (ksf)
135.00	0.5959
133.00	0.5959

** Uplift pressures **

Water pressures:

x-coord. (ft)	Pressure (ksf)
0.00	0.1248
1.50	0.1248
1.50	0.0000
10.00	0.0000

** Forces and moments **

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight..........	6.038		-5.42	-32.75
Structure, driving side:				
Moist soil................	0.000		0.00	0.00

Saturated soil............ 1.560 -8.00 -12.48
Water above structure...... 0.000 0.00 0.00
Water above soil........... 1.997 -8.00 -15.97
External vertical loads.... 0.000 0.00 0.00
Ext. horz. pressure loads.. 0.000 0.00 0.00
Ext. horz. line loads...... 0.000 0.00 0.00
Structure, resisting side:
Moist soil................ 1.688 -2.25 -3.80
Saturated soil............ 0.000 0.00 0.00
Water above structure...... 0.000 0.00 0.00
Water above soil........... 0.000 0.00 0.00
Driving side:
Effective earth loads...... 1.881 0.33 0.63
Shear (due to delta)....... 0.000 0.00 0.00
Horiz. surcharge effects... 0.000 0.00 0.00
Water loads............... 0.000 -135.00 0.00
Resisting side:
Effective earth loads...... -0.689 1.67 -1.15
Balancing earth load....... -1.192 -1.00 1.19
Water loads............... 0.000 0.00 0.00
Foundation:
Vertical force on base..... -11.282 -5.70 64.33
Uplift.................... 0.000 0.00 0.00
===
** Statics Check ** SUMS = 0.000 0.000 0.00

Angle of base = 11.31 degrees
Normal force on base = 11.296 kips
Shear force on base = -1.044 kips
Max. available shear force = 8.221 kips

Base pressure at heel = 1.6033 ksf
Base pressure at toe = 0.6531 ksf

Xr (measured from toe) = 5.70 ft
Resultant ratio = 0.5702
Stem ratio = 0.4500
Base in compression = 100.00 %
Overturning ratio = 105.43

Volume of concrete = 1.49 cubic yds/ft of wall

NOTE: The engineer shall verify that the computed bearing pressures below the wall do not exceed the allowable foundation bearing pressure, or, perform a bearing capacity analysis using the program CBEAR. Also, the engineer shall verify that the base pressures do not result in excessive differential settlement of the wall foundation.

****

** Sliding Results **
****

Solution converged. Summation of forces = 0.

Wedge Number	Horizontal Loads (kips)	Vertical Loads (kips)
1	0.000	2.869
2	1.997	1.997
3	0.000	0.000

Water pressures on wedges:

Wedge number	Top press. (ksf)	Bottom press. (ksf)	x-coord. (ft)	press. (ksf)
1	0.4992	0.1248		
2			0.0000	0.1248
2			10.0000	0.0000
3	0.0000	0.0000		

Points of sliding plane:
Point 1 (left), x = 0.00 ft, y = 133.00 ft
Point 2 (right), x = 10.00 ft, y = 135.00 ft

Depth of cracking = 0.00 ft

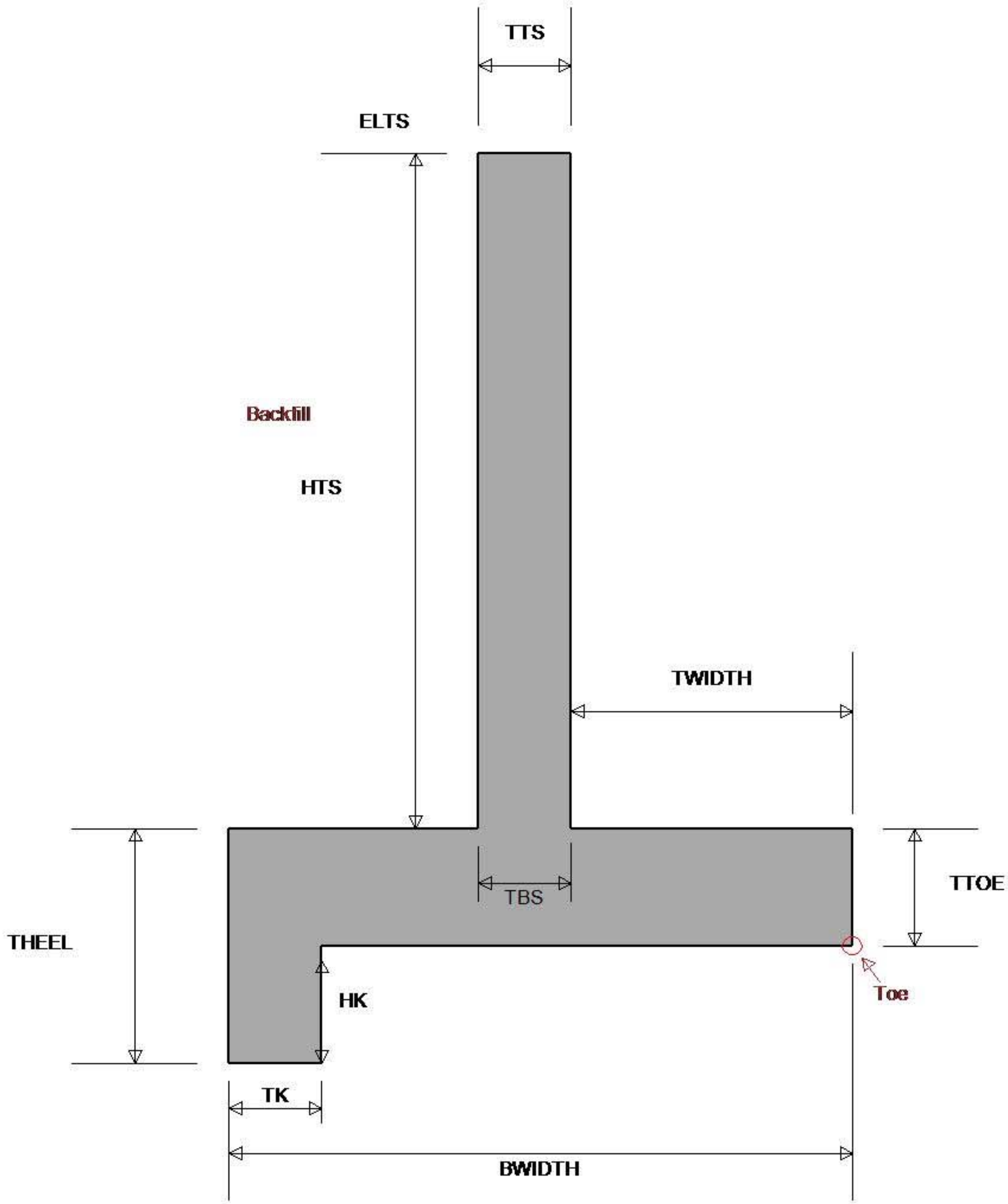
Wedge number	Failure angle (deg)	Total length (ft)	Weight of wedge (kips)	Submerged length (ft)	Uplift force (kips)
1	-50.609	9.058	2.615	9.058	2.826
2	11.310	10.198	10.195	0.000	0.636
3	39.504	7.860	1.895	0.000	0.000

Wedge number	Net force (kips)
1	-5.222
2	2.911
3	2.312
SUM =	0.000

```
+-----------------------------+
| Factor of safety =    3.421 |
+-----------------------------+
```

```
**********************
**  Bearing Results  **
**********************

          Base width =     10.198 (ft)
                  Xr =      5.702 (ft)
Effective base width =     11.630 (ft)
 (measured along slope)
          Base slope =    11.3099 (deg)

                 phi =     34.000 (deg)
                   c =      0.000 (ksf)
     Effective gamma =     0.0676 (kcf)

         Normal load =     11.296 (kips)
    Load inclination =      5.280 (deg)
   Load eccentricity =     -0.716 (ft)

           Surcharge =     0.6250 (ksf)
           Embedment =      5.000 (ft)
        Ground slope =     0.0000 (deg)


        Bearing Capacity Factors
===========================================
                  C        Q        G
===========================================
Bearing         42.1637  29.4398  31.1456
Embedment        1.1617   1.0809   1.0809
Inclination      0.8861   0.8861   0.7135
Base Tilt        0.7427   0.7514   0.7514
Ground Slope     1.0000   1.0000   1.0000

Net ultimate bearing pressure =    19.8876 (ksf)

+------------------------------+
| Factor of safety =     20.474 |
+------------------------------+
```

Peckman T-Wall - 8 foot



BTRH=	0.00
BTRK=	0.00
BTRT=	0.00
BWIDTH=	10.00
ELTS=	148.50
HK=	2.00
HTS=	11.50
TBS=	1.50
TBSR=	0.00
THEEL=	4.00
TK=	1.50
TTOE=	2.00
TTS=	1.50
TWIDTH=	4.50

NOTE: All units in feet

Peckman T- Wall - 16 foot

***************** Echoprint of Input Data *****************

Date: 2017/12/ 6 Time: 18.53.26

Structural geometry data:

Elevation of top of stem (ELTS)	=	148.50 ft
Height of stem (HTS)	=	19.50 ft
Thickness top of stem (TTS)	=	1.50 ft
Thickness bottom of stem (TBS)	=	1.50 ft
Dist. of batter at bot. of stem (TBSR)	=	0.00 ft
Depth of heel (THEEL)	=	8.50 ft
Distance of batter for heel (BTRH)	=	0.00 ft
Depth of toe (TTOE)	=	2.00 ft
Width of toe (TWIDTH)	=	12.50 ft
Distance of batter for toe (BTRT)	=	0.00 ft
Width of base (BWIDTH)	=	25.00 ft
Depth of key (HK)	=	2.00 ft
Width of bottom of key (TK)	=	1.50 ft
Dist. of batter at bot. of key (BTRK)	=	0.00 ft

Structure coordinates:

x (ft)	y (ft)
0.00	120.50
0.00	129.00
11.00	129.00
11.00	148.50
12.50	148.50
12.50	129.00
25.00	129.00
25.00	127.00
1.50	122.50
1.50	120.50

NOTE: X=0 is located at the left-hand side
of the structure. The Y values correspond
to the actual elevation used.

Structural property data:
Unit weight of concrete = 0.150 kcf

Driving side soil property data:

Phi (deg)	c (ksf)	Moist Unit wt. (kcf)	Saturated unit wt. (kcf)	Delta (deg)	Elev. soil (ft)

34.00	0.000	0.125	0.130	0.00	132.00

Driving side soil geometry:

Soil point	Batter (in:1ft)	Distance (ft)
1	0.00	500.00
2	0.00	0.00
3	0.00	500.00

Driving side soil profile:

Soil point	x (ft)	y (ft)
1	-1489.00	132.00
2	11.00	132.00

Resisting side soil property data:

Phi (deg)	c (ksf)	Moist Unit wt. (kcf)	Saturated unit wt. (kcf)	Elev. soil (ft)	Batter (in:1ft)
34.00	0.000	0.125	0.130	132.00	0.00

Resisting side soil profile:

Soil point	x (ft)	y (ft)
1	12.50	132.00
2	512.50	132.00

Foundation property data:
phi for soil-structure interface = 30.00 (deg)
c for soil-structure interface = 0.000 (ksf)
phi for soil-soil interface = 34.00 (deg)
c for soil-soil interface = 0.000 (ksf)

Water data:
Driving side elevation = 148.00 ft
Resisting side elevation = 132.00 ft
Unit weight of water = 0.0624 kcf
Seepage pressures computed by Line of Creep method.

Minimum required factors of safety:
Sliding FS = 1.50
Overturning = 100.00% base in compression

Crack options:
o Crack depth is to be calculated
o Computed cracks *will* be filled with water

Strength mobilization factor = 0.6667

At-rest pressures on the resisting side *are used*
in the overturning analysis.

Forces on the resisting side *are used* in the sliding analysis.

Do iterate in overturning analysis.

***** Summary of Results *****

```
***************    *** Satisfied ***
* Overturning *    Required base in comp. = 100.00 %
***************    Actual base in comp.   = 100.00 %
                   Overturning ratio      =   1.57
```

Xr (measured from toe) = 9.27 ft
Resultant ratio = 0.3706
Stem ratio = 0.5000
Base pressure at heel = 0.1757 ksf
Base pressure at toe = 1.3954 ksf

```
***********    *** Satisfied ***
* Sliding *    Min. Required =   1.50
***********    Actual FS     =   1.53
```

```
***********
* Bearing *
***********
```

Net ultimate bearing pressure = 4.4072 (ksf)
Factor of safety = 3.639

********************* Output Results *********************

Date: 2017/12/ 6 Time: 18.53.26

```
**************************
**  Overturning Results  **
**************************
```

Solution converged in 1 iterations.

SMF used to calculate K's = 0.6667
Alpha for the SMF = -57.1298
Calculated earth pressure coefficients:

Driving side at rest K = 0.4183
Driving side at rest Kc = 0.6468
Resisting side at rest K = 0.4408
Resisting side at rest Kc = 0.6639
At-rest K's for resisting side calculated.

Depth of cracking = 0.00 ft

** Driving side pressures **

Water pressures:

Elevation (ft)	Pressure (ksf)
148.00	0.0000
132.00	0.9984
120.50	1.4448

Earth pressures:

Elevation (ft)	Pressure (ksf)
132.00	0.0000
120.50	0.4387

** Resisting side pressures **

Water pressures:

Elevation (ft)	Pressure (ksf)
132.00	0.0000
127.00	0.4299
122.50	1.2422
122.50	1.4114
120.50	1.4448

Earth pressures:

Elevation (ft)	Pressure (ksf)
132.00	0.0000
127.00	0.0970

Balancing earth pressures:

Elevation (ft)	Pressure (ksf)
127.00	2.5572
120.50	2.5572

** Uplift pressures **

Water pressures:

x-coord. (ft)	Pressure (ksf)
0.00	1.4448
1.50	1.4114
1.50	1.2422
25.00	0.4299

** Forces and moments **

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight...........	21.281		-14.64	-311.61
Structure, driving side:				
Moist soil.................	0.000		0.00	0.00
Saturated soil.............	4.290		-19.50	-83.65
Water above structure......	0.000		0.00	0.00
Water above soil...........	10.982		-19.50	-214.16
External vertical loads....	0.000		0.00	0.00
Ext. horz. pressure loads..		0.000	0.00	0.00
Ext. horz. line loads......		0.000	0.00	0.00
Structure, resisting side:				
Moist soil.................	0.000		0.00	0.00
Saturated soil.............	4.875		-6.25	-30.47
Water above structure......	0.000		0.00	0.00
Water above soil...........	0.000		0.00	0.00
Driving side:				
Effective earth loads......		2.522	-2.67	-6.73
Shear (due to delta).......	0.000		0.00	0.00
Horiz. surcharge effects...		0.000	0.00	0.00
Water loads................		22.035	3.04	67.08
Resisting side:				
Effective earth loads......		-0.243	1.67	-0.40
Balancing earth load.......		-16.622	-3.25	54.02
Water loads................		-7.693	-3.09	23.76
Foundation:				
Vertical force on base.....	-19.639		-9.27	181.96
Uplift.....................	-21.790		-14.69	320.20
** Statics Check ** SUMS =	0.000	0.000		0.00

Angle of base = 14.57 degrees
Normal force on base = 23.189 kips
Shear force on base = 11.145 kips
Max. available shear force = 17.222 kips

Base pressure at heel = 0.1757 ksf
Base pressure at toe = 1.3954 ksf

Xr (measured from toe) = 9.27 ft
Resultant ratio = 0.3706

Stem ratio = 0.5000
Base in compression = 100.00 %
Overturning ratio = 1.57

Volume of concrete = 5.25 cubic yds/ft of wall

NOTE: The engineer shall verify that the computed bearing pressures below the wall do not exceed the allowable foundation bearing pressure, or, perform a bearing capacity analysis using the program CBEAR. Also, the engineer shall verify that the base pressures do not result in excessive differential settlement of the wall foundation.

****
** Sliding Results **
****

Solution converged. Summation of forces = 0.

Wedge Number	Horizontal Loads (kips)	Vertical Loads (kips)
1	0.000	7.477
2	7.987	10.982
3	0.000	0.000

Water pressures on wedges:

Wedge number	Top press. (ksf)	Bottom press. (ksf)	x-coord. (ft)	press. (ksf)
1	0.9984	1.4448		
2			0.0000	1.4448
2			25.0000	0.4299
3	0.0000	0.4299		

Points of sliding plane:
Point 1 (left), x = 0.00 ft, y = 120.50 ft
Point 2 (right), x = 25.00 ft, y = 127.00 ft

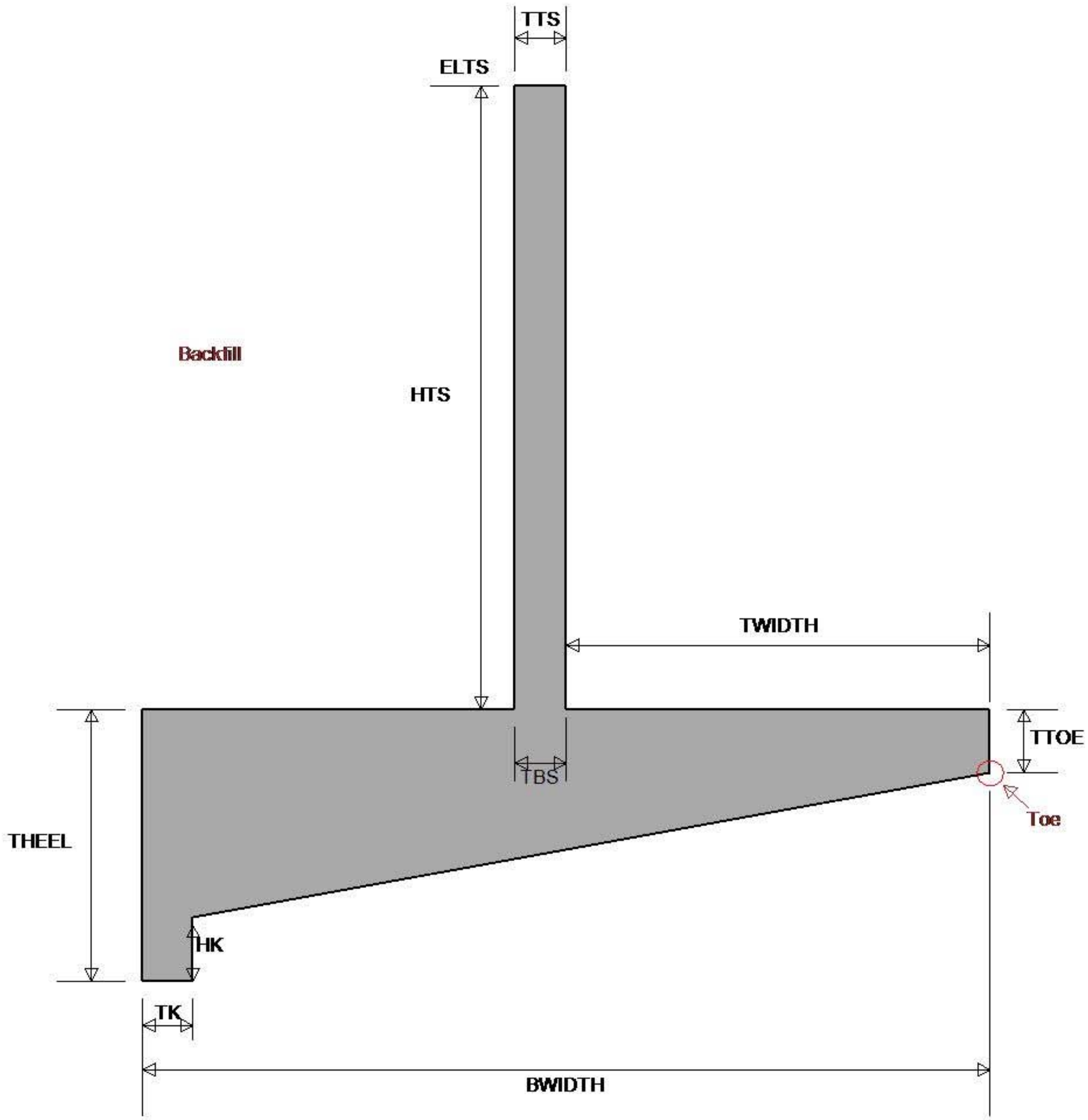
Depth of cracking = 0.00 ft

Wedge number	Failure angle (deg)	Total length (ft)	Weight of wedge (kips)	Submerged length (ft)	Uplift force (kips)
1	-56.926	13.724	5.598	13.724	16.765
2	14.574	25.831	32.868	25.831	24.213

```
    3   33.130     9.148      2.490    9.148      1.967

  Wedge     Net force
  number     (kips)
  ===================
     1      -16.615
     2       14.247
     3        2.367
  ===================
     SUM =    0.000

+----------------------------+
| Factor of safety =    1.532 |
+----------------------------+




**********************
**  Bearing Results  **
**********************

          Base width =     25.831 (ft)
                 Xr =      9.265 (ft)
  Effective base width =     19.147 (ft)
   (measured along slope)
          Base slope =    14.5742 (deg)

                phi =     34.000 (deg)
                  c =      0.000 (ksf)
       Effective gamma =     0.0676 (kcf)

         Normal load =     23.189 (kips)
     Load inclination =     25.670 (deg)
    Load eccentricity =      3.342 (ft)

           Surcharge =     0.3380 (ksf)
           Embedment =      5.000 (ft)
        Ground slope =     0.0000 (deg)


        Bearing Capacity Factors
============================================
                C         Q         G
============================================
Bearing        42.1637   29.4398   31.1456
Embedment        1.0982    1.0491    1.0491
Inclination     0.5109    0.5109    0.0600
Base Tilt       0.6753    0.6863    0.6863
Ground Slope     1.0000    1.0000    1.0000

Net ultimate bearing pressure =     4.4072 (ksf)

+------------------------------+
```

| Factor of safety =   3.639 |
+--------------------------------+

Peckman T-Wall - 16 foot



BTRH=	0.00
BTRK=	0.00
BTRT=	0.00
BWIDTH=	25.00
ELTS=	148.50
HK=	2.00
HTS=	19.50
TBS=	1.50
TBSR=	0.00
THEEL=	8.50
TK=	1.50
TTOE=	2.00
TTS=	1.50
TWIDTH=	12.50

NOTE: All units in feet