FLOOD RISK MANAGEMENT

FEASIBILTY REPORT
&
ENVIRONMENTAL IMPACT STATEMENT

FOR
PECKMAN RIVER BASIN NEW JERSEY

APPENDIX C.3 – Geotechnical Analysis

US Army Corps of Engineers New York District

February 2020

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1.0 Introduction

The objective of the study is to determine the feasibility of constructing various features which include channel improvements, a diversion culvert, levees, and floodwalls proposed for the Peckman River Flood Risk Management Project. The overall project area evaluated in January 2012 is shown in Figure 1.

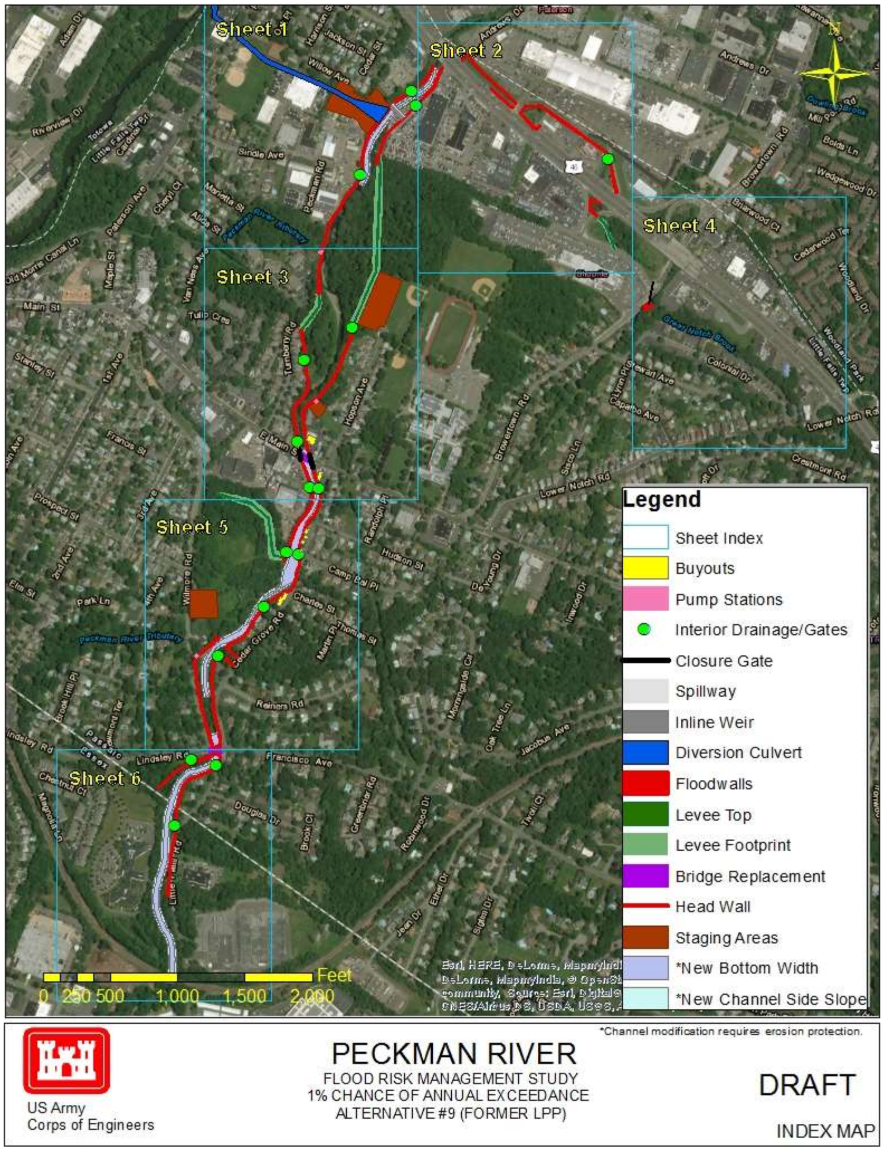

Figure 1. Google Earth view of the project area

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 3 and 4 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, below, shows the 23 soil borings that were performed in the project area.

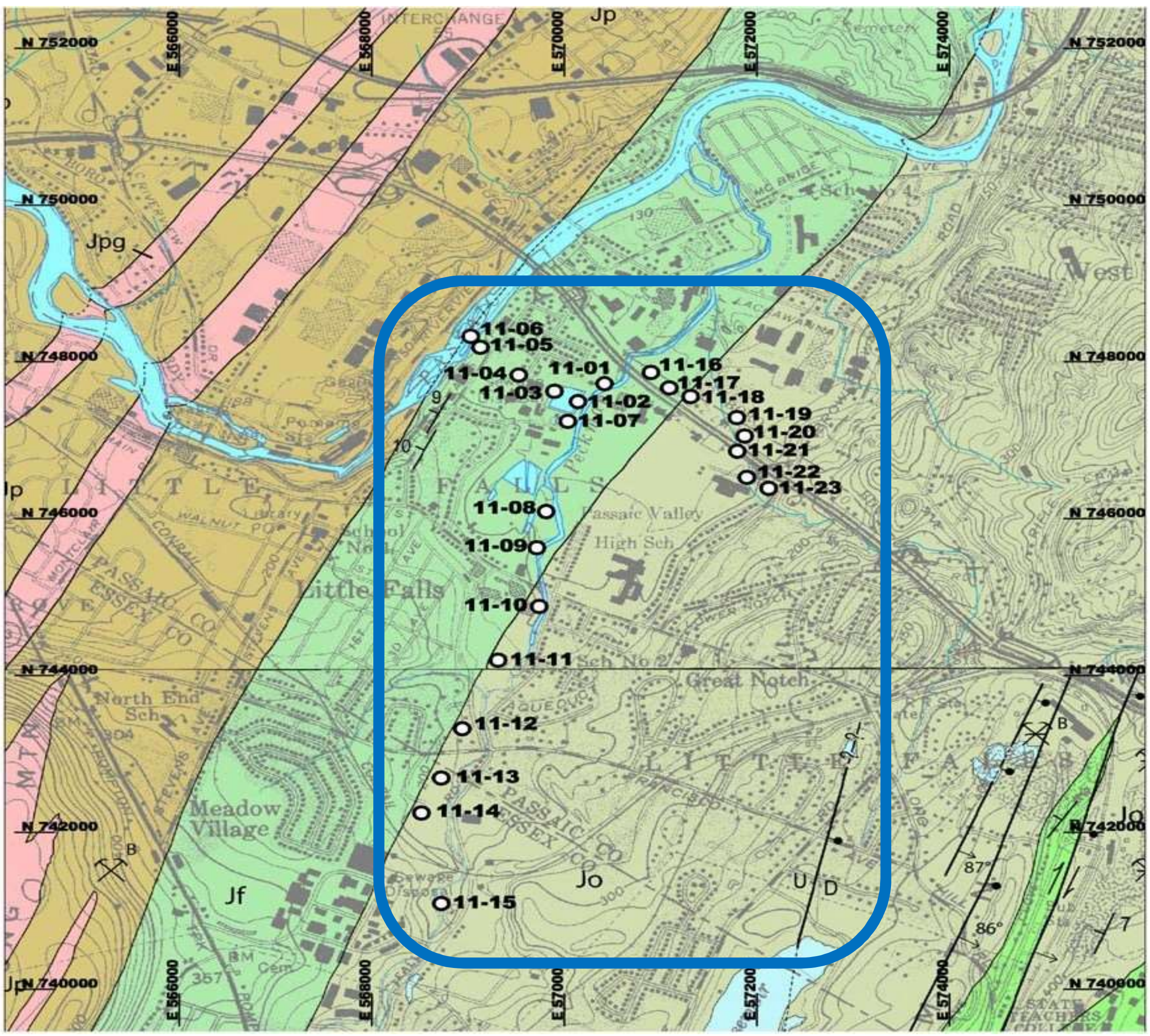

Figure 2. Map of Soil Borings Performed

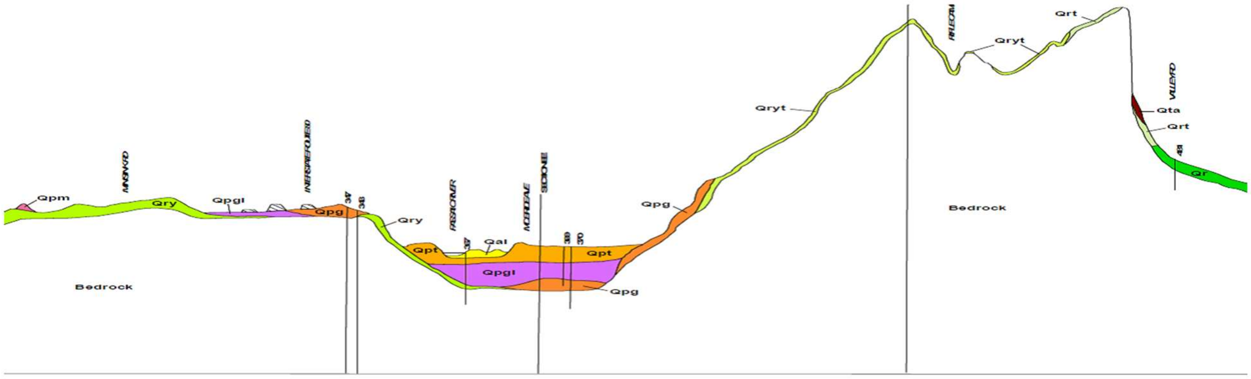

Figure 3 – NJGS geological Paterson and Orange quadrangle maps and cross section for the area of interest south of Patterson. Beige color (Jo) is Orange Mountain Basalt; Light green color (Jf) is Feltsville sandstone.

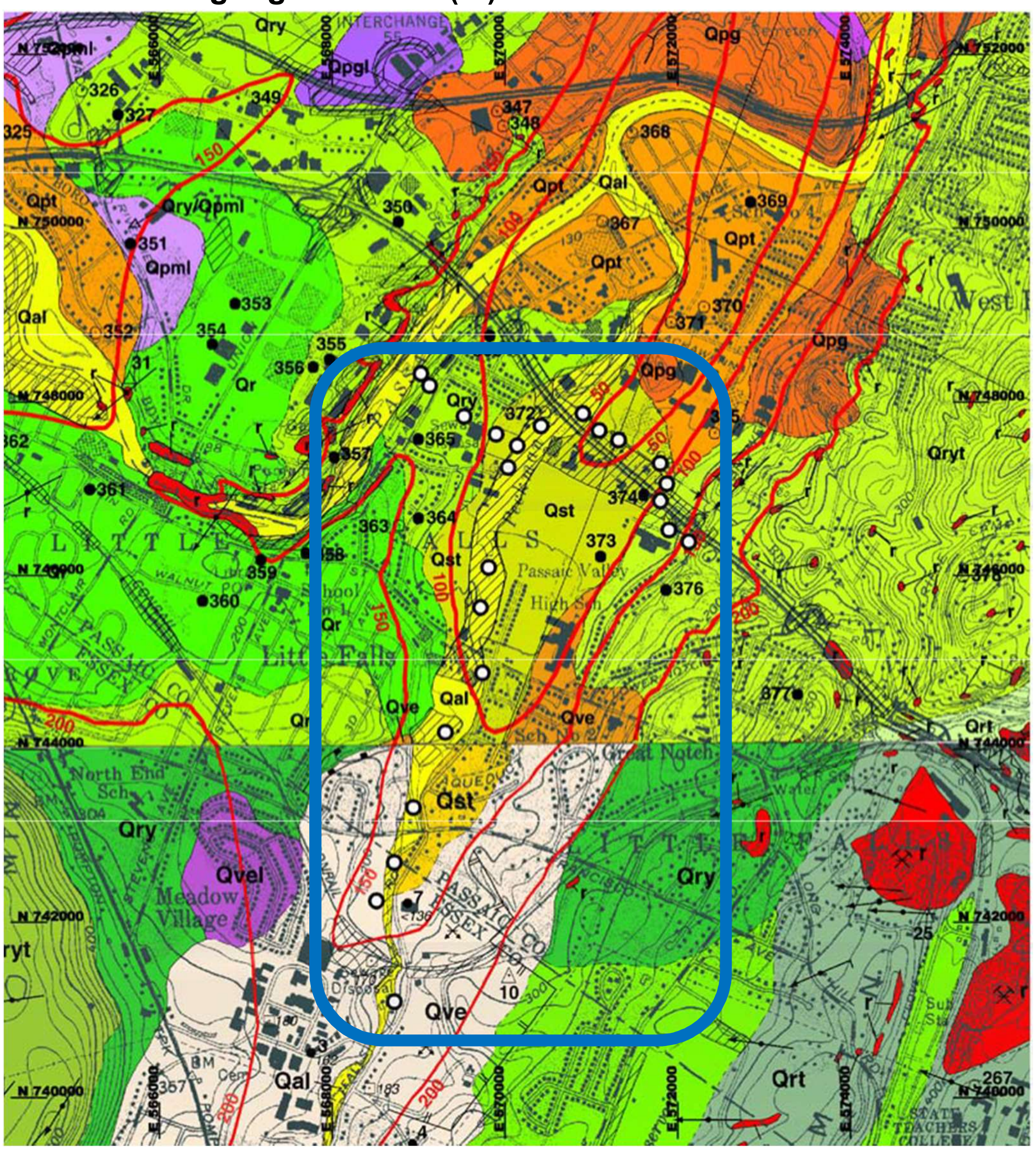

Figure 4 – NJGS surficial deposits with bedrock contours.

3.0 Subsurface Exploration

A geotechnical investigation was performed for USACE by e4sciences | Earthworks, LLC in January 2012. The e4sciences | Earthworks, LLC geotechnical report is provided in Attachment 9. 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. The original scope of the project included levees, floodwalls channel improvements, and a diversion culvert from the Peckman River crossing under New Jersey Route 46 in in Passaic County to Little Falls Road near Old Bridge Road in Essex County. The

The current project scope has been revised to be centrally localized and includes floodwalls and levees, with a diversion culvert and channel improvements proposed from the Peckman River south of New Jersey Route 46, north of Passaic Valley High School. The borings performed in the area of this updated project scope include borings PRB-11-01 through PRB-11-08. PRB-11-01, PRB-11-02, and PRB-11-07 were performed near the diversion culvert entrance retaining walls. PRB-11-08 was performed approximately 500 feet southwest of proposed levee section 2. Borings PRB-11-03 to PRB-11-06 were performed in the area of the proposed diversion culvert. However, explorations were not advanced in the immediate area of portions of the currently proposed levee and floodwall alignment. Consequently, additional explorations must be performed in the areas of the proposed levees and floodwalls pertaining to the current project scope so that subsurface conditions at these locations can be evaluated and confirmed in respect to this preliminary geotechnical assessment. 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 Subsurface 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 approximately 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 4-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 3 to 105, with an average of 31 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 two locations, PRB-11-9B, and PRB-11-14. The uncorrected N-values of the till ranged from 16 to 200, with an average of 94 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, with an average of 29. 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, with an average of 26 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 Designations (RQD) of the cores retrieved were 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.

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 18.1 feet in three borings. In the remaining 20 borings, no bedrock was encountered.

5.0 Geotechnical Analyses

For the geotechnical analyses a generalized profile was created using subsurface information obtained in the borings performed within the most recent project scope limits. These borings include PRB-11-01 to PRB-11-08 which are shown on Figure 5.

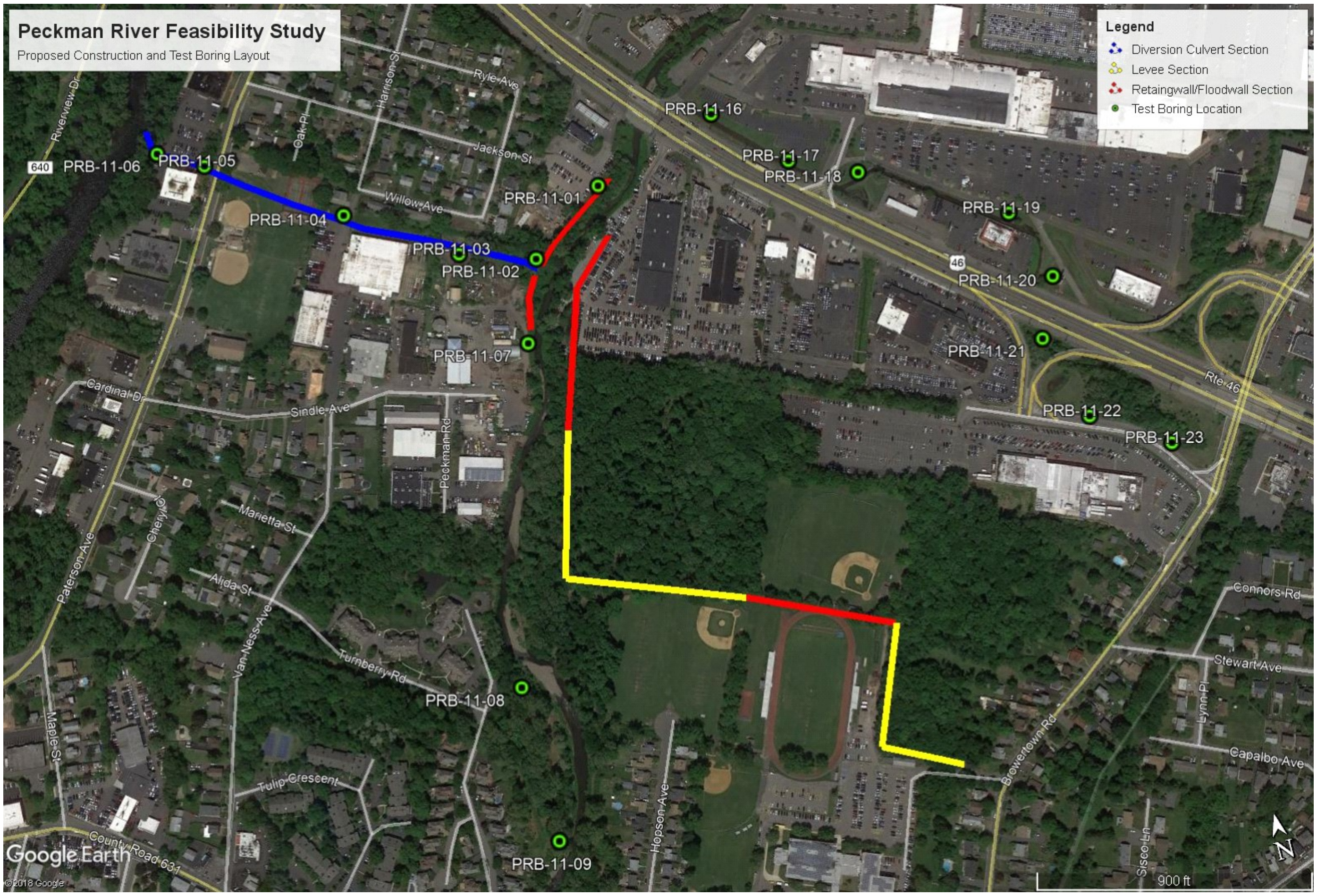

Figure 5 – Google Earth aerial of project site and soil boring locations.

The subsurface conditions anticipated to be encountered within the limits of the revised project area can be generalized into the 5 stratum shown in the table below. Depths and average uncorrected N values shown were used to formulate geotechnical design parameters.

Table 1. Summary of stratigraphic unit properties.

Strata	Depth (feet)	Average Uncorrected N-value/RQD
Organic Silt (OH)	0-3	20
FILL Sand and Gravel	3-8	31
Sand and Gravel Till (GM)	8-18	94
Varved Silt and Clay (ML/CL)	18-25	26
Sandstone Bedrock	5-7	14-33

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. Based on the current project limits, soil borings PRB-11-01 to PRB-11-08 were selectively chosen to develop the soil strength parameters. Embankment materials would likely be comprised of imported silt and/or clay soil (USCS Type ML/CL) for the impervious core and imported silty sands (USCS Type SM) or on-site material from the diversion culvert excavation (USCS Type GM/SM) for the remainder of the levee fill materials (embankment shell). The project specifications would be written to ensure that they conform to the assumed properties used during design. Fill would be specified to be placed in lifts and be placed 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 approximately two percent above its optimum moisture content.

Seepage analyses were performed using the computer program SEEP/W, which is part of the GeoStudio suite of programs. The levee geometry is eight-foot high with a 12-foot wide crest and three horizontal to one vertical slopes. An impervious core and inspection trench was selected to minimize seepage through the levee. The proposed levee geometry satisfies the required dimensions required in EM 1110-2-1913 (see sections 6-1, 6-2, 7-2f). The following summarizes the 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 x 10	1×10^{-7}	0.5	
Organic Silt	3.28×10^{-6}	1×10^{-4}	0.5	
FILL Sand and Gravel	3.28×10^{-5}	1×10^{-3}	1	
Sand and Gravel (Till)	3.28×10^{-5}	1×10^{-3}	1	
Varved Silt and Clay	3.28×10^{-9}	1×10^{-7}	0.5	

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

During steady-state seepage analysis, it was determined that excessive uplift pressures are present on the impervious organic silt soil layer. It was determined that the factor of safety against uplift, or heave was approximately 0.7 at the toe of the levee. Excessive seepage (piping potential) though the shell of the embankment was also determined to be an issue. The determined horizontal factor of safety for piping at the toe of the levee was 2.5, which is less than the recommended value of 3 put forth in Jacksonville District’s “Herbert Hoover Dike Loadings and Factors of Safety for Use in Seepage and Stability Analysis.” To mitigate these excessive uplift pressures on the organic silt soil layer and piping through the levee shell, a one-foot diameter toe drain was placed five feet below the landside toe of the levee, in the sand and gravel fill layer. This design element reduced uplift pressures at the toe of the levee eliminating the potential for heave and resulted in factors of safety for piping above 3. It is noted that the toe drain should be designed with appropriate surrounding filter media to prevent clogging of the drain and will be done during the design phase of the project. The GeoStudio results and calculations are attached.

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	
Levee Shell	130	0	32	yellow
Impervious Core	120	1500	0	black
Organic Silt (OH)	110	200	0	dark orange
FILL Sand and Gravel	125	0	32	gray
Sand and Gravel Till (GM)	135	0	34	brown
Varved Silt and Clay (ML/CL)	120	2500	0	red

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 Spencer's Method. Pore pressure conditions for each SLOPE/W analysis were derived using the GeoStudio SEEP/W program except for the rapid drawdown case in which the "staged undrained strength" approach was used. This method follows that developed by Duncan, Wright and Wong (1990) as outlined in EM 1110-2-1902, Section G-3.

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. For the rapid drawdown case, calculations are done in two stages. The first stage involves the conditions before drawdown (maximum water height), and is considered an effective stress analysis before drawdown. The second stage uses R envelope parameters which consist of the effective strength parameters for the freely drained materials, and the undrained shear strengths determined from the result of Stage 1 are used for materials that do not drain freely.

Factors of safety for the levee design with toe drain end of construction (Case I) and steady state (Case III) conditions was 1.6 for both cases. For rapid drawdown (Case II), the factor of safety was computed to be 1.3. These factors of safety meet required minimum factors of safety established in EM 110-2-1913, Table 6-1b.

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 thickness of fill is approximately one to nine feet throughout the project area. 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 for the natural site soils include GP, GW, GM and SP. Uncorrected N-values for the fill layer range from 10 to 100 blows per foot, with an average uncorrected N-value of 31, 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. Uncorrected N-values for the natural Till and sand and gravel ranged from 16 to 200 blows per foot, with an average value of 94 for the Till and 29 for the sand and gravel material. The Till and sand and gravel materials are suitable to support the proposed construction. In areas where loose or soft materials may be locally encountered beneath the levees or floodwalls, specialized ground improvement may be warranted, especially in areas where organic soils was encountered. As this condition is limited in area, the fill and organic soil deposits are not anticipated to have a significant design or construction impact to the project. Settlement calculations were not performed for the proposed levee as part of the feasibility study as significant settlement is not anticipated to occur based on the encountered subsurface conditions. As such, any minor settlement will not 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 Diversion Culvert

An approximately 1,700 foot diversion culvert is proposed approximately 800 feet south of New Jersey Route 46 intersection with Andrews Drive. The culvert runs east to west, with the exit of the culvert discharging into the Passaic River. The reinforced concrete culvert is proposed to consist of a wide mouth entrance with a weir, transitioning to a double box design. The discharging end of the culvert will consist of a stilling basin before emptying to the Passaic River. The diversion culvert entrance and exits are proposed to include retaining walls on each side. Soil borings PRB-11-01, PRB-11-02, and PRB-11-07 were performed in the vicinity of the proposed culvert entrance retaining walls which are proposed to be approximately 100 feet in length. Additionally, in soil borings PRB-11-05 and PRB-11-06, bedrock was observed. This bedrock included sandstone of the Feltville Formation. Due to the proposed bearing elevations of the culvert near the discharging end, bedrock excavation may be necessary and require special equipment or construction techniques.

5.2.1 Bearing Capacity

Analysis was conducted using the subsurface conditions observed in soil borings PRB-11-02 to PRB-11-06 to evaluate bearing conditions of the culvert on the soil. The stratigraphy along the culvert alignment revealed that a majority of the culvert excavation would consist of sand and gravel till material with a small amount of sand and gravel fill material near the surface of the excavation. The range of excavation for the culvert construction was between 16 and 24 feet below the existing ground surface. Analyzing stratigraphy in each of the five borings along the culvert alignment and the proposed loading conditions of the culvert and associated roadway above, it was determined that the culvert would have a fully compensated foundation. A fully compensated foundation case means that the bearing soil at the bottom of the culvert was subjected to higher stresses due to the excavated soil above, than from the full load of the culvert and backfill. The analysis is included in the Attachments section. The presumptive allowable bearing capacity for glacial till soils from the 2015 International Building Code, Table 1806.2 is 3,000 psf.

5.2.3 Settlement

As illustrated in section 5.2.1 and in the attached analysis, the culvert is determined to have a fully compensated foundation case where the bearing soil beneath the culvert was previously loaded to a higher magnitude than they load imposed after culvert construction. Due to this case, settlement of the culvert structure is would be negligible, if at all.

5.3 Floodwall and Retaining Wall Stability Analysis

Where an earthen levee is cost prohibitive, floodwalls are proposed to provide flood risk management. Global stability analyses for both the proposed floodwalls and retaining walls are included in the Structural section of this appendix.

5.4 Floodwall Seepage

Seepage below the proposed floodwalls was analyzed using SEEP/W software. The stratigraphic conditions used were the same as those used for the levee seepage analysis. Floodwall dimensions were taken from the proposed floodwall feasibility design drawings. Due to the impervious soil materials, it was determined that piping will not be considered as the impervious material is subject to uplift/heave. It was determined through the seepage analysis that excessive uplift pressures on the organic silt layer near the surface to approximately 40 feet beyond the end of the wall foundation exist, resulting in a factor of safety less than one against uplift. A one-foot diameter toe drain was implemented five feet below the surface in the sand and gravel fill layer, to relieve uplift pressures and lower exit gradients on the landside of the floodwall. When the toe drain was implemented, the analysis showed uplift pressures with a factor of safety greater than one. The floodwall seepage analysis is included in the Attachments section.

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

- **Attachments**
    - **Attachment 1 - Engineering Soil Parameters**
    - **Attachment 2 - Culvert Bearing and Settlement Calculations**
    - **Attachment 3 – GeoStudio Seepage – No Toe Drain**
    - **Attachment 4 – GeoStudio Seepage – Toe Drain**
    - **Attachment 5 - GeoStudio Slope Stability - No Toe Drain**
    - **Attachment 6 - GeoStudio Slope Stability – Toe Drain**
    - **Attachment 7 - Piping Factor of Safety Calculations**
    - **Attachment 8 - SAJ Herbert Hoover Dike Loadings and Factors of Safety for Use in Seepage and Stability Analysis**
    - **Attachment 9 - e4sciences | Earthworks, LLC Geotechnical Report**

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