January 24, 2012

Mr. Thomas K. MacVicar, P.E.
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4524 Gun Club Road
Suite 201
West Palm Beach, FL 33415

Dear Tom:

RE: Seepage and Stability Analyses of Partial Cutoff Wall at L-31N
AMEC Project No. 16059.03

The Soils Section of the Geotechnical Branch, US Army Corps of Engineers (USACE), Jacksonville District has expressed concern regarding potential changes in seepage gradients that might occur at the downstream toe of the L-31N levee as a result of constructing the proposed partial cutoff wall for seepage mitigation. Following a request by the USACE, we have modeled the seepage conditions through the embankment and foundation, before and after installation of the proposed wall. As requested by the USACE, we analyzed both seepage gradients and uplift pressures at the eastern toe of L-31N, and between the toe and the proposed cutoff wall during maximum stage conditions on the west side of the levee. In addition to the seepage analysis, slope stability analyses were made to determine if there would be any loss of project integrity as a result of the proposed construction.

The results of the analyses are described herein. In summary, construction of the cutoff wall will not have a negative impact on either the seepage gradients or the stability of the L-31N levee.

Background

In the area of the proposed construction, L-31N has side slopes of 4H:1V to 3H:1V upstream and approximately 2H:1V downstream. The steepest side slopes in the reach where the wall will be constructed were selected for the typical section. The crest for the section analyzed has an elevation of 16.0 feet NGVD[1] and a width of 15.0 feet. Survey information was provided by South Florida Water Management District (SFWMD) and the United States Geological Survey (USGS).

[1] Unless otherwise noted, all elevations in this report are National Geodetic Vertical Datum 1929 (NGVD).

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The foundation soil stratigraphy for the typical section is summarized in **Table 1**. In the majority of borings, the levee appears to have been constructed directly upon naturally occurring deposits of peat/muck. The thickness of the peat/muck is generally in the range of 1-2 feet. The peat/muck in this area is underlain generally by limestone. The deeper stratigraphy of the subsurface consists of sequences of limestone and some silty to clayey sand with interbedded shell layers.

Seepage Analysis

Material Properties

For the seepage analyses, the upstream water level was taken as maximum high water stage of 9.0 feet, while the downstream canal was assumed at a minimum wet season elevation of 5.5 feet. The levee soils and foundation materials were divided into twelve strata. Hydraulic conductivity (k) properties for each stratum were determined from results of the geotechnical investigation, previous site studies, and other area references. Because k within some strata varied across the study area, average values were assigned for the levee segment**.** The following are the strata selected for the analyses:

TABLE 1

Strata Number	Model Name	Thickness (ft)	Horizontal Conductivity (ft/d)	Vertical Conductivity (ft/d)	k-Sat (ft/sec)
1	Compacted Levee Fill	Varies	0.6	0.6	6.94e-6
2	Peat/Muck	1.5	150	150	1.74e-3
3	Flow Zone 1 (Miami Limestone)	10	12,500	1,250	0.0145
4	Hard Layer 1 (Q4)	2	5	5	5.79e-5
5	Flow Zone 2 (Upper Ft. Thompson)	2	25,000	25,000	0.29
6	Flow Zone 2 (Upper Ft. Thompson)	8	25,000	25,000	0.29
7	Hard Layer 2 (Q3)	2	5	5	5.79e-5
8	Flow Zone 3 (Middle Ft. Thompson)	10	25,000	25,000	0.29
9	Hard Layer (Q2)	2	5	5	5.79e-5
10	Flow Zone 4 (lower Ft. Thompson)	10	25,000	25,000	0.29
11	Fines Deposit	2	-	-	3.24e-4
12	Slurry Wall	35	-	-	3.24e-8

Modeling Approach

The seepage analyses were performed using the SEEP/W computer program of the GeoStudio software suite. SEEP/W is a two-dimensional finite element program that performs seepage analyses for hydrogeologic models and determines seepage paths, seepage flow rates, phreatic surfaces, pore water pressures, and exit gradients for steady state and transient seepage problems.

The SEEP/W model requires the user to input the geologic strata, soil/water physical properties, water levels, topography, and boundary conditions. It then solves the flow equations iteratively by satisfying Laplace's equation for fluid flow, generating what is termed a flow net. The flow net is a pictorial presentation that shows the total head and flow within the 2-D finite element mesh used to depict the cross-section being analysed. Because the flow lines and equipotential (head) lines cross at right angles, the solution has the appearance of a net.

Modelling Results

The seepage model results for the pre-construction condition (without cutoff wall) are shown in **Figure 1**. The results with the cutoff wall are shown in **Figure 2**. The cutoff wall raises the phreatic line through the embankment on the order of 1.5 feet, resulting in a seepage breakout near the downstream toe. This results in a maximum gradient at the toe of 0.25, which provides a factor of safety (FS) of approximately 4 against piping or seepage failure. Uplift pressures are low relative to the weight of overlying soil and rock—the minimum FS against uplift at shallow depths near the toe is approximately 2 and the FS increases with depth to approximately 30 beneath the bottom of the cutoff wall.

Based on these seepage analyses, construction of the slurry wall will have no significant detrimental impact on seepage gradients or uplift pressures in the downstream area of the L-31N levee.

Stability Analysis

Material Properties

For the stability analyses, the unit weights, cohesion, and friction angle properties for the soil and foundation materials were determined from results of the geotechnical investigation, previous site studies, and other area references. Because k within some strata varied across the study area, average values were assigned for the levee segment. The following **TABLE 2** summarizes the strata properties selected for the analyses:

TABLE 2

Model Number	Layer	Thickness (ft)	Unit Weight (pcf)	Cohesion (psf)	Phi (º)
1	Compacted Levee Fill	Varies	125	0	38
2	Peat/Muck	1.5	70	200	25
3	Flow Zone 1 (Miami Limestone)	10	135	500	45
4	Hard Layer 1 (Q4)	2	130	5000	38
5	Flow Zone 2 (Upper Ft. Thompson)	2	125	1000	38
6	Flow Zone 2 (Upper Ft. Thompson)	8	125	1000	38
7	Hard Layer 2 (Q3)	2	130	5000	38
8	Flow Zone 3 (Middle Ft. Thompson)	10	125	1000	38
9	Hard Layer (Q2)	2	130	5000	38
10	Flow Zone 4 (Lower Ft. Thompson)	10	125	1000	38
11	Fines Deposit	2	100	200	0
12	Slurry Wall	35	130	250	15

The slope stability analyses were completed using the SLOPE/W software package in GeoStudio. SLOPE/W performs a 2-dimensional finite difference limit-equilibrium analysis using a method-of-slices search routine to look for the critical failure surface with the minimum factor of safety. The failure surface used in the search routine includes both circular and wedge-shapes.

For this report, the phreatic surface and pore pressures used as input to SLOPE/W were generated in the SEEP/W analyses. The circular failure surface search routine used several methods, including Bishop, Janbu, Spencer, and Morgenstern-Price to find the minimum factor of safety for the embankments. The results of the analyses are shown in **Figure 3** for the pre-construction condition, and **Figure 4** for the installed partial cutoff wall.

The minimum calculated FS was 2.7 without the cutoff wall and 2.6 with the cutoff wall. These values are significantly above the USACE minimum acceptable factor of safety of 1.4 for levees. The analysis also indicates that construction of the partial cutoff wall will not impact the integrity of the levee.

Conclusions

The results of the seepage and stability analyses indicate that installation of the proposed partial cutoff wall at the downstream toe of the L-31N levee will not have a significant impact on the seepage gradients or uplift pressures, or on the calculated FS against downstream slope failure. We conclude that the proposed construction will not result in any loss of project integrity.

We appreciate the opportunity to provide these analyses for the project. Please contact us if there are any questions or if additional discussion is needed regarding this matter.

Sincerely,

Leslie G Bromwell

Les Bromwell, P.E.
Principal Engineer

Michael Kelley

Michael P. Kelley, P.E.
Geotechnical Services Manager

lgb:mpk/dl
attachments Figures 1-4