Ardaman & Associates, Inc.
Geotechnical, Environmental and
Materials Consultants

October 16, 2018
File Number 18-66-5453

CAPTEC Engineering, Inc.
301 N.W. Flagler Avenue
Stuart, Florida 34994

Attention: Mr. Rhett Keene, P.E.

Subject: Groundwater Modeling Services for McCarty Ranch Extension Area 2 Water Farm, City of Port St. Lucie, Florida

Dear Mr. Keene:

Ardaman & Associates, Inc. (Ardaman) has completed the groundwater modeling services to analyze the performance of the proposed Water Farm Area 2 located on the McCarty Ranch Extension property. The transient MODFLOW model constructed for Water Farm Area 1 was modified and used for this analysis. The model was modified for this evaluation based on onsite soil investigation and testing, and the water farm pond construction design. As proposed in the scope of work, two scenarios were simulated to evaluate the effects of loading the proposed pond up to the control elevation of 4 feet above the pond bottom.

Previous Soil Investigation

A Subsurface Soil Exploration was conducted by Ardaman and detailed in the September 2018 report titled Subsurface Soil Exploration McCarty Ranch – Phase II Water Farm. The exploration included six (6) Standard Penetration Test (SPTs) borings, ten (10) auger borings, and eight (8) shallow piezometers as located in Figure 1. The piezometers were installed adjacent to the SPT boring locations to perform slug tests to determine the hydraulic conductivity of the soils penetrated. Results of the slug tests show horizontal hydraulic conductivity (k_h) values ranging from 0.075 to 30 feet/day in the upper 20 feet of sediment, ranging from 30 to 37 feet/day from 20 to 25 feet below land surface (bls) as presented in Table 1. In the upper 15 feet of sediment, the average hydraulic conductivity was 13 feet/day. In the next 10 feet of sediment, the average hydraulic conductivity was 32 feet/day.

The shallow hydraulic conductivity values are within the range of permeabilities stated in the St. Lucie County Soil Survey for the five onsite soil types. The onsite soils include Arents, Floridana sand, Kaliga muck, Nettles sand, Riviera sand, Wabasso sand, and Winder loamy sand, as shown in Figure 1. Depending on the soil horizon, the onsite soils permeabilities range from <0.4 feet/day to greater than 40 feet/day.

Groundwater Model

The transient MODFLOW model constructed for the Water Farm Area 1 was modified for this analysis. Modifications were made to the existing model based on the farm pond design and onsite testing. The first modification included grid refinement in the pond area to more accurately simulated the proposed berm, pond, and drainage canals. Cell size for the berm was reduced to 5 feet, and the pond and canal cells were reduced to 50 feet. The horizontal hydraulic conductivity value was changed to 13 feet/day in Area 2 based on the range of onsite slug tests and general onsite soil properties. The average slug test result for layer 2 of 32 feet/day was used for k_h. The properties for layer 3 were the model derived result from the previous reservoir model calibration simulation. The model layer details are provided in the below table.

Model Layer Properties – Area 2

Model Layer	k_h (ft/day)	k_v (ft/day)	Thickness (feet)
1	13	1.3	15
2	32	3.2	13
3	24	0.1	13

The berm was added to the model by increasing the land surface elevation in the appropriate cells to a maximum height of 35 ft NGVD. The proposed drainage canals located 50 feet from the north, west and south sides of the pond were also entered into the model with a drain elevation of 22 feet NGVD. The portion of the modified grid in the water farm area is shown in Figure 2. The estimated water volume available in the water farm at operating capacity (4 feet of water – 31 feet NGVD) is approximately 351 million gallons.

Model Simulations

The modified model was used for all of the modeled scenarios. The purpose of the first scenario was to determine the rate of water level decline from aquifer infiltration and evapotranspiration (ET), assuming the farm pond was loaded four feet above land surface to a height of 31 feet NGVD. This scenario simulates a full water farm situation. In the model, the pond was loaded for 100 days at a rate of 0.1135 feet/day to bring the elevation from the simulated groundwater elevation of approximately 22.5 feet NGVD to the proposed elevation of 31 feet NGVD. The total volume of water required was approximately 943 million gallons. Following the loading period, only average annual recharge from rainfall was added to the pond area for a period of one year to record to the rate of water level decline. Based on this simulation, the estimated rate of pond level decline is approximately 0.127 feet/week or 0.55 feet/month, with the water level declining to ground level (27 ft NGVD) in approximately seven (7) months. A hydrograph showing the simulated water levels in the pond is provided in Figure 3. The hydrograph location and resulting groundwater contours for the full pond are provided in Figure 4. The potential impact of the water table mound on surrounding properties is small due to the presence of the perimeter ditches surrounding the water farm, which helps lower the

water table and keeps the mound on the water farm site as shown in Figure 4. The amount of water that flows through the aquifer directly back to the C-23 canal is estimated at approximately 3% through the loading cycles.

The second scenario was constructed to cycle the pond and determine the fluctuation throughout the years and the average stage over the period of operation. The resulting heads from the first scenario, when the water table elevation was at land surface, was used as the starting heads for the second scenario. The model was modified to run at monthly time steps for 10 years with three loading cycles per year. In this simulation the Area 2 pond was loaded in April, August, and December at rates of 0.0925 feet/day (approximately 7.68 MGD), 0.12225 feet/day (approximately 10.16 MGD), and 0.0870 feet/day (approximately 7.22 MGD), respectively. The rates were adjusted to load the pond level up to 31 feet at the end of each cycle based on the recharge and ET rates during the cycle month. The recharge and ET rates were varied monthly based on the 30-year Normal Fort Pierce NOAA data from 1981 to 2010 (Table 2). Based on this simulation, the heads fluctuated approximately 1.75 to 2.5 feet in the pond. The total volume of water required to maintain the water level for the year was approximately 770 million gallons. A graph showing the cycle fluctuations for the pond is provided on Figure 5. Locations of the model hydrograph monitoring points are provided on Figure 4.

To estimate the effects of loading Area 2 while Area 1 is fully loaded, an additional 10-year simulation was run with Area 1 held at an elevation of 32 feet. The loading rates were reduced in Area 2, so the water level did not exceed 31 feet. In this simulation the Area 2 pond was loaded in April, August, and December at rates of 0.0792 feet/day (approximately 6.58 MGD), 0.1030 feet/day (approximately 8.56 MGD), and 0.0720 feet/day (approximately 5.98 MGD), respectively. The rates were reduced from the previous simulation of approximately 1.10 MGD in April, 1.6 MGD in August, and 1.25 MGD in December. Based on this simulation, the heads fluctuated approximately 1.3 to 2.0 feet in the pond. The total volume of water required to maintain the water level for the year was approximately 648 million gallons. A graph showing the cycle fluctuations for the pond is provided on Figure 5. A summary of volumes of water required to fill and then maintain the pond for various scenarios are provided in the following table:

Volume Summary

Condition	Volume (Million Gallons)
Available at Operating Level	351
Required to Initially Fill Pond to Operating Level	943
Required to Maintain Pond for One Year (No Area 1)	770
Required to Maintain Pond for One Year (With Area 1)	648

Conclusions

Ardaman has completed the groundwater modeling services to analyze the performance of the proposed Water Farm Area 2 located on the McCarty Ranch Extension property and has concluded the following:

- Based on the full pond loading simulation, the estimated rate of pond level decline is approximately 0.127 feet/week or 0.55 feet/month, with the water level declining to ground level (27 ft NGVD) in approximately 7 months.
- The potential impact of the water table mound on surrounding properties is small due to the presence of the perimeter ditches surrounding the water farm, which helps lower the water table and keeps the mound on the water farm site.
- The amount of water that flows through the aquifer directly back to the C-23 canal is estimated at approximately 3% through the loading cycles.
- The modeling results of the 10-year cycle testing with three loading cycles per year indicate that the heads fluctuated approximately 1.3 to 2.0 feet in the pond
- The average stage in the pond is 30 feet over the period of operation in the simulation, or 3 feet above grade in the three cycles per year simulation.
- The estimated annual volume of water required to maintain Water Farm 2 without Water Farm 1 loaded is 770 MG.
- The estimated annual volume of water required to maintain Water Farm 2 with Water Farm 1 fully loaded is 648 MG.

We appreciate the opportunity to provide these hydrogeological services to CAPTEC and the City of Port St. Lucie, and we look forward to the next phase of the project. Please do not hesitate to call us should you have any questions or need additional information.

Very truly yours,

ARDAMAN & ASSOCIATES, INC.

Douglas P. Dufresne, P.G.
Project Director/Senior Hydrogeologist
Florida License No. 1527

Valerie Davis, P.G.
Project Hydrogeologist III

DPD:vcd

TABLES

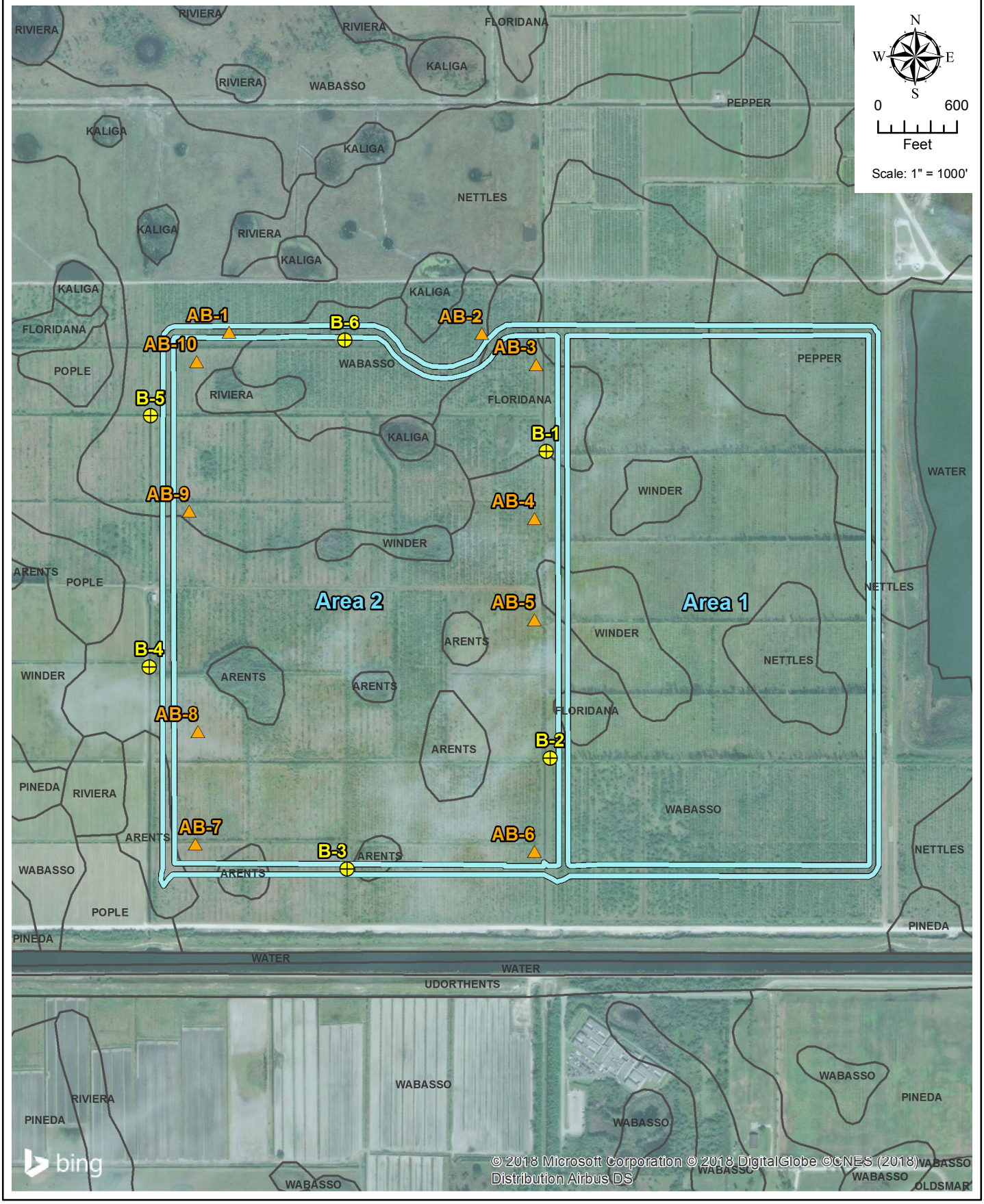
TABLE 1
McCARTY RANCH EXTENSION WATER FARM AREA 2
SLUG TEST RESULTS

Well No.	Soil Description	Screened Interval (feet bls)	Depth to Water Table (feet bls)	Hydraulic Conductivity (ft/day)	Hydraulic Conductivity Average (ft/day)
B-1	Fine sand with clay	5 to 10	8	0.075	13
B-2	Fine sand and shell	12 to 17	8.6	30	
B-3	Clayey fine sand to shelly fine sand	10 to 15	7	10	
B-4	Clayey fine sand with limestone fragments	4 to 9	6.8	0.03	
B-6	Shelly fine sand	13 to 18	6.0	24	
B-5	Fine sand and shell	15 to 20	7.25	30	32
B-1	Fine sand with shell	20 to 25	7.7	30	
B-4	Shelly fine sand	19 to 24	6.8	37	

TABLE 2
PRECIPITATION DISTRIBUTION AND
THORNTHWAITE POTENTIAL ET CALCULATION
CLIMATE DATA FROM FORT PIERCE NOAA STATION (1981-2010)

MONTH	Precipitation (in)	Precipitation (ft)	80% Precipitation (ft/day)	DAILY AVG. TEMP.(F)	DAILY AVG. TEMP.(C)	HEAT INDEX Im	Unadj. Potential ETmonth (in)	30 degree Latitude Daylight Factor	Adjusted Potential ETmonth (in)	Adjusted Potential ET Day (ft/day)
January	2.35	0.19583	0.00505	62.00	16.67	6.19	1.52	0.90	1.37	0.00368
February	3.09	0.25750	0.00736	64.10	17.83	6.86	1.83	0.87	1.59	0.00473
March	3.68	0.30667	0.00791	67.20	19.56	7.88	2.35	1.03	2.42	0.00651
April	2.87	0.23917	0.00638	71.20	21.78	9.28	3.16	1.08	3.41	0.00947
May	3.78	0.31500	0.00813	76.80	24.89	11.36	4.55	1.18	5.37	0.01443
June	5.72	0.47667	0.01271	80.50	26.94	12.81	5.65	1.17	6.61	0.01837
July	6.04	0.50333	0.01299	81.90	27.72	13.37	6.11	1.20	7.33	0.01971
August	7.49	0.62417	0.01611	81.90	27.72	13.37	6.11	1.14	6.96	0.01872
September	7.69	0.64083	0.01709	80.90	27.17	12.97	5.78	1.03	5.95	0.01654
October	5.42	0.45167	0.01166	76.70	24.83	11.32	4.52	0.98	4.43	0.01191
November	3.58	0.29833	0.00796	70.10	21.17	8.89	2.92	0.89	2.60	0.00722
December	2.13	0.17750	0.00458	64.70	18.17	7.05	1.92	0.88	1.69	0.00455
TOTALS	**53.84**		**0.00983**						**49.74**	**0.01136**

FIGURES



▲ Auger Boring Locations ⊕ SPT and Piezometer Locations Water Farm Soil Boundary

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

BORING AND SOIL LOCATION MAP
McCARTY RANCH EXTENSION
WATER FARM AREA 2
CITY OF PORT ST. LUCIE

FIGURE 1

W:\Projects\2018\18-66-5453 - PSL McCarty Ranch- Area 2\ArcGIS\ArcLayouts\Borings&Soil.mxd

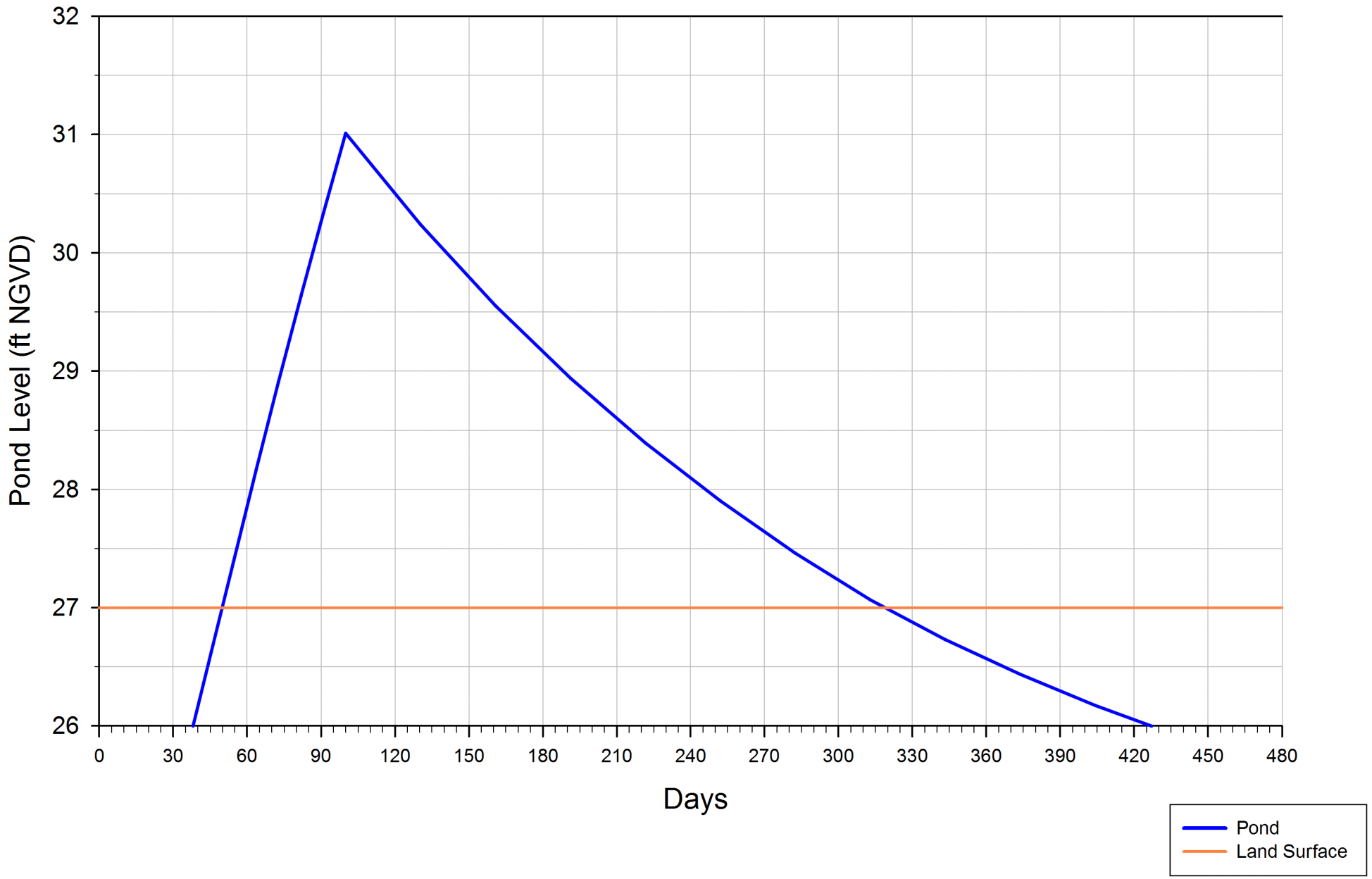
grid2 PropBound

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

WATER FARM AREA MODEL GRID
McCARTY RANCH EXTENSION
WATER FARM AREA 2
CITY OF PORT ST. LUCIE

FIGURE 2

W:\Projects\2018\18-66-5453 - PSL McCarty Ranch- Area 2\ArcGIS\ArcLayouts\Grid.mxd

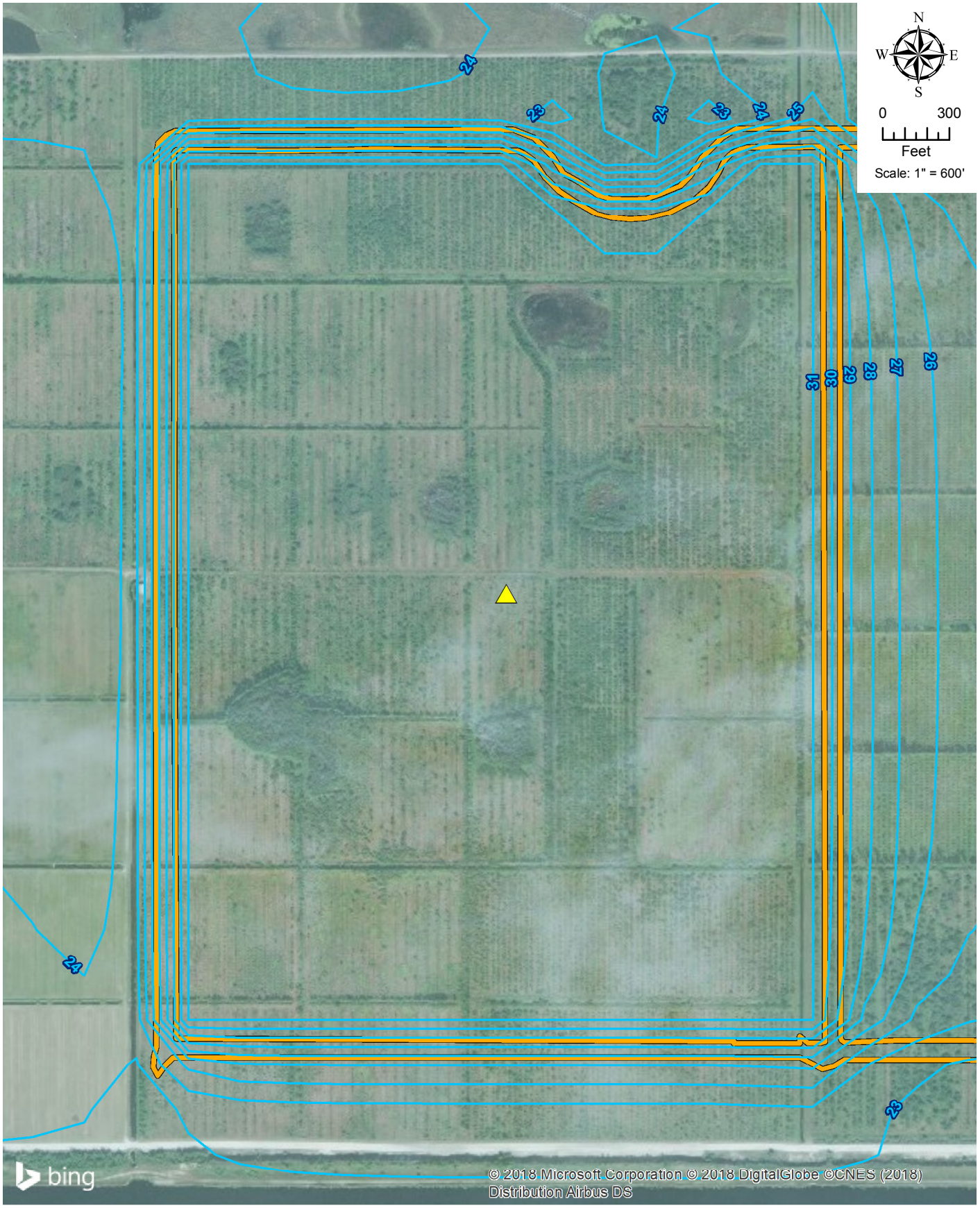


Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

POND LEVEL RECESSION FROM 31 FT NGVD - BERM 50 FEET
McCARTY RANCH EXTENSION WATER FARM AREA 2
CITY OF PORT ST. LUCIE, FLORIDA

Figure 3

W:\Projects\2018\18-66-5453 - PSL McCarty Ranch- Area 2\SigmaPlot\PondMoundRecess-Berm50ft.JNB



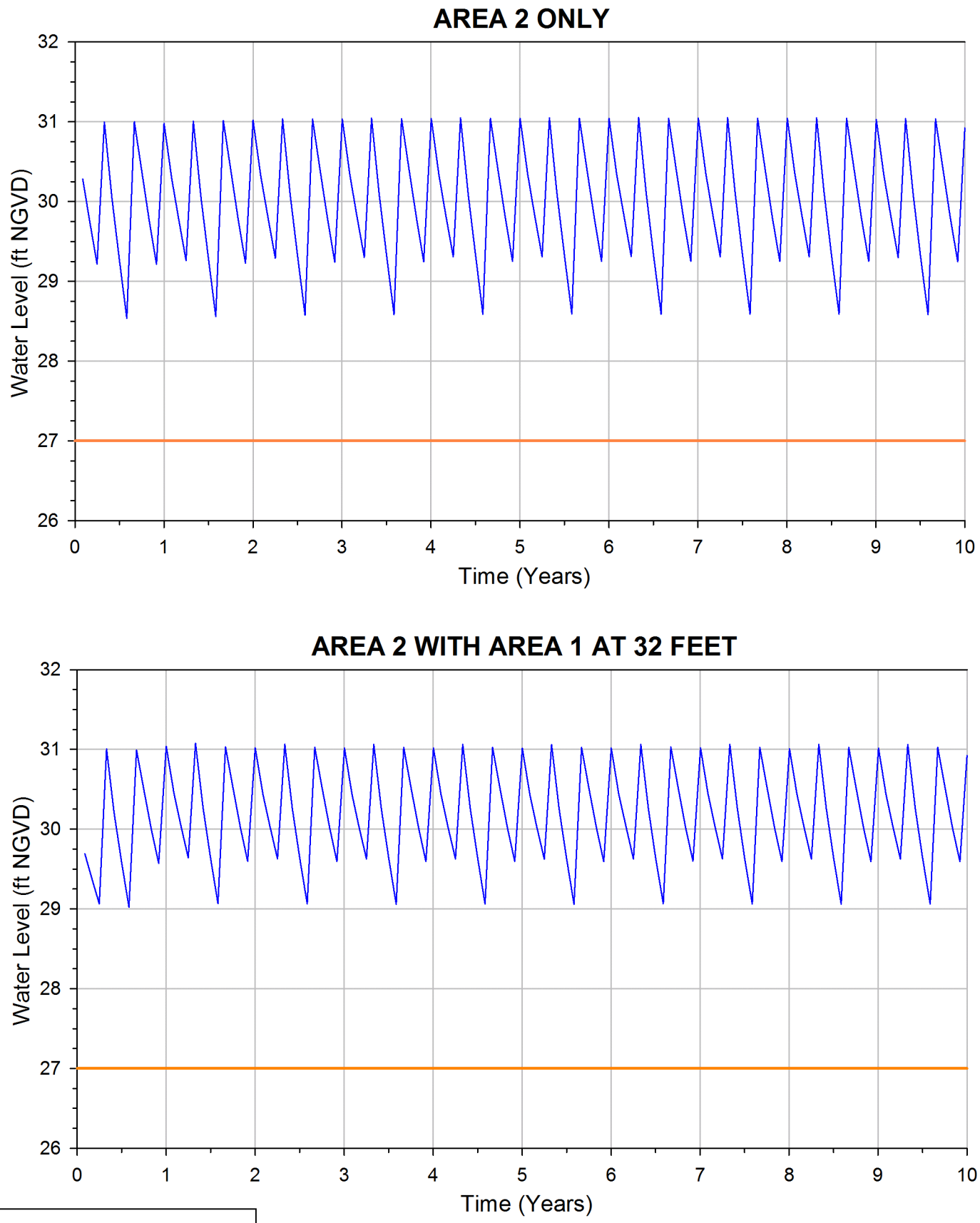
△ Hydrograph Location — Water Table Contour (Interval = 1 ft NGVD) ▢ Water Farm

W:\Projects\2018\18-66-5453 - PSL McCarty Ranch- Area 2\ArcGIS\ArcLayouts\FullPondContours-Berm50.mxd

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

FULL POND WATER TABLE CONTOURS
McCARTY RANCH EXTENSION
WATER FARM AREA 2
CITY OF PORT ST. LUCIE

FIGURE 4



Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

10 YEAR SIMULATED WATER LEVELS
McCARTY RANCH EXTENSION WATER FARM AREA 2
CITY OF PORT ST. LUCIE, FLORIDA

FIGURE 5

W:\Projects\2018\18-66-5453 - PSL McCarty Ranch- Area 2\SigmaPlot\10yr-WL-graphs-Berm50ft..JNB