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

May 26, 2017
File Number 14-66-5445B

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

Attention: Mr. Joseph W. Capra, P.E.

Subject: Groundwater Modeling Services for McCarty Ranch Extension Phase 1 Water Farm, City of Port St. Lucie, Florida

Dear Mr. Asrani:

Ardaman & Associates, Inc. (Ardaman) has completed the groundwater modeling services to analyze the performance of the proposed Phase I Water Farm located on the McCarty Ranch Extension property. As proposed in the scope of work, two scenarios were simulated to evaluate the effects of loading the proposed pond. The transient MODFLOW model constructed for the former Vulcan sand mine reservoir evaluation was also used for this analysis. The model was modified for this evaluation based on onsite soil investigation and testing and the farm pond construction design.

Previous Soil Investigation

A Subsurface Soil Exploration was conducted by Ardaman and detailed in the February 2017 report titled Subsurface Soil Exploration McCarty Ranch – Phase I Water Farm. The investigation was extended to include the installation of temporary monitor wells and the performance of slug tests to determine the hydraulic conductivity of the soils penetrated. The exploration included six soil borings located in Figure 1 and eight slug tests to test site conditions. Results of the slug tests show horizontal hydraulic conductivity values ranging from 0.16 to 9.93 feet/day in the upper 15 feet of sediment, and ranging from 8.11 to 20.27 feet/day from 15 to 25 feet below land surface (bls) as presented in Table 1. In the upper 15 feet of sediment, the average hydraulic conductivity was 4.67 feet/day and the geometric mean was 1.26 feet/day. In the next 10 feet of sediment, the average hydraulic conductivity was 13.29 feet/day and the geometric mean was 12.59 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 Floridana sand, Nettles sand, Pepper sand, Wabasso sand, and Winder sand, depressional, as shown in Figure 1. Depending on the soil horizon, the onsite soils permeabilities range from <0.4 feet/day to 40 feet/day. The estimated weighted average horizontal conductivity (Kh) of the upper horizons of the onsite soils is 8.7 feet/day, and the vertical conductivity (Kv) for the same horizon is 3.2 feet/day.

Groundwater Model

The transient MODFLOW model constructed for the former Vulcan sand mine reservoir evaluation 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 elevation in Layer 1 was also reduced to 15 feet below the pond bottom based on the onsite boring information, and the horizontal hydraulic conductivity value was changed to 8.7 feet/day as a worst-case condition based on the range of onsite slug tests and general onsite soil properties. The average slug test result for layer 2 of 13 feet/day was used for Kh. 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.

Layer Properties

Model Layer	Kh (ft/day)	Kv (ft/day)	Thickness (feet)
1	8.7	3.2	15
2	13	3.2	13
3	24	0.1	13

The 65-foot 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 200 feet from all sides of the pond were also entered into the model with a drain elevation of 20 feet NGVD, based on the pond construction drawings by CAPTEC. One additional change included adding the existing sand mine lake located to the east of the proposed farm pond as drain cells with a drain elevation of 20 feet NGVD, as provided on the CAPTEC drawings. The portion of the modified grid in the water farm area is shown in Figure 2.

Model Simulations

The modified model was used to for both of the proposed 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 32 feet NGVD. This scenario simulates a full water farm situation. In the model, the pond was loaded for 110 days at a rate of 0.13 feet/day (approximately 8.17 million gallons per day (MGD) to bring the elevation from the simulated groundwater elevation of approximately 23 feet NGVD to the proposed elevation of 32 feet NGVD. 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 0.12 feet/week or 0.5 feet/month, with the water level declining to ground level (28 ft NGVD) in approximately 8 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. As shown on the figure, the water level at the toe of the berm is approximately 30 feet NGVD, which is 2 feet above the surrounding land surface elevation of approximately 28 feet NGVD. Other model simulations with lower hydraulic conductivities in layer one yielded similar results with the water level above land surface outside the berm. 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 17% 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 pond was loaded in April, August, and December as a rate of 0.119 feet/day (approximately 7.47 MGD). The recharge and ET rates were also changed to monthly rates calculated using the 30-year Normal Fort Pierce NOAA data from 1981 to 2010 (Table 2). Based on this simulation, the heads fluctuated approximately 1.5 to 2.0 feet in the pond and from 1.1 feet to 1.7 feet on the outer toe of the berm. Graphs showing the cycle fluctuations for the pond, top of berm, and outer toe of the berm are provided on Figure 5. Locations of the model hydrograph monitoring points are provided on Figure 4. The four toe of berm hydrographs indicate that the simulated water levels through the load cycling of the water farm range from about 3 inches to 2 feet above land surface on the outside of the berm. The average stage in the pond is 31 feet over the period of operation in the simulation.

<u>Nutrient Uptake</u>

When the water farm is loaded with water, the potential for mass pollutant removal will be similar to wet detention ponds. The pollutant removal occurs by solids settling, algal and vegetative uptake, and absorption primarily within the permanent pool. The Florida Department of Environmental Protection TMDL Protocol indicates that the typical mass removal efficiency for total phosphorus would range between 40% and 60%, for TKN would range between 20% and 30%, and for nitrite and nitrate would range between 30% and 40%. These removal efficiencies could be improved by adding wetland vegetation to the water farm or by incorporating floating treatment wetlands.

<u>Conclusions</u>

Ardaman has completed the groundwater modeling services to analyze the performance of the proposed Phase I Water Farm 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 0.12 feet/week or 0.5 feet/month, with the water level declining to ground level (28 ft NGVD) in approximately 8 months.

- The water level at the toe of the berm is approximately 30 feet NGVD, which is 2 feet above the surrounding land surface elevation of approximately 28 feet NGVD.
- Other model simulations with lower hydraulic conductivities in layer one yielded similar results with the water level above land surface outside the berm.
- The groundwater flow modeling shows that the loading of the water farm at 4 feet above existing grade with the current design has water daylighting outside the berm.
- 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 17% 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 1.5 to 2.0 feet in the pond and from 1.1 feet to 1.7 feet on the outer toe of the berm.
- The four toe of berm hydrographs indicate that the simulated water levels through the load cycling of the water farm range from about 3 inches to 2 feet above land surface on the outside of the berm.
- The average stage in the pond is 31 feet over the period of operation in the simulation, or 3 feet above grade.
- When the water farm is loaded with water, the potential for mass pollutant removal will be similar to wet detention ponds. The typical mass removal efficiency for total phosphorus would range between 40% and 60%, for TKN would range between 20% and 30%, and for nitrite and nitrate would range between 30% and 40%.
- These nutrient removal efficiencies could be improved by adding wetland vegetation to the water farm or by incorporating floating treatment wetlands.

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.

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TABLES

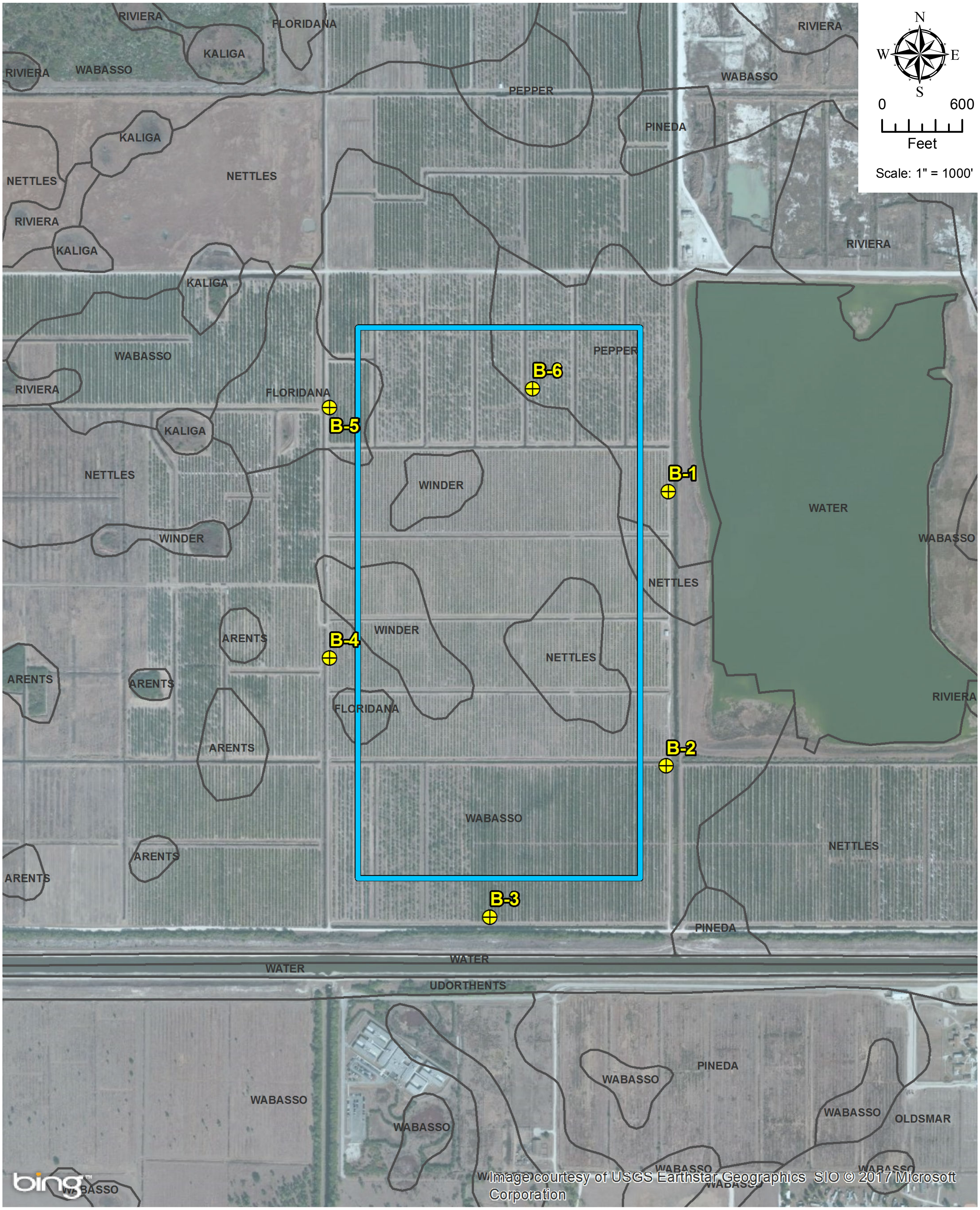
TABLE 1
McCARTY RANCH EXTENSION PHASE I WATER FARM
SLUG TEST RESULTS

Well No.	Soil Description	Screened Interval (feet bls)	Depth to Water Table (feet bls)	Hydraulic Conductivity (ft/day)	Hydraulic Conductivity Average (ft/day)	Hydraulic Conductivity Geometric Mean (ft/day)
MW1a near B1	Silty fine SAND	5 to 9	8.42	0.19	4.67	1.26
MW4 near B4	Fine SAND (mostly shell) and Silty fine SAND	10 to 15	8.65	9.93		
MW5a near B5	Fine SAND and Clayey fine SAND	4 to 8	5.73	8.41		
MW6 near B6	Clayey fine SAND	5 to 9	8.6	0.16		
MW1 near B1	Fine SAND with shell and cemented sand	19 to 24	9.36	20.27	13.29	12.59
MW2 near B2	Fine SAND and SHELL	15 to 20	10.67	8.11		
MW3 near B3	Fine SAND mostly SHELL	13 to 18	10.68	13.28		
MW5 near B5	Cemented SAND and SHELL	20 to 25	5.6	11.5		

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



Previous Soil Boring Water Farm Soil Boundary

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

FIGURE 1

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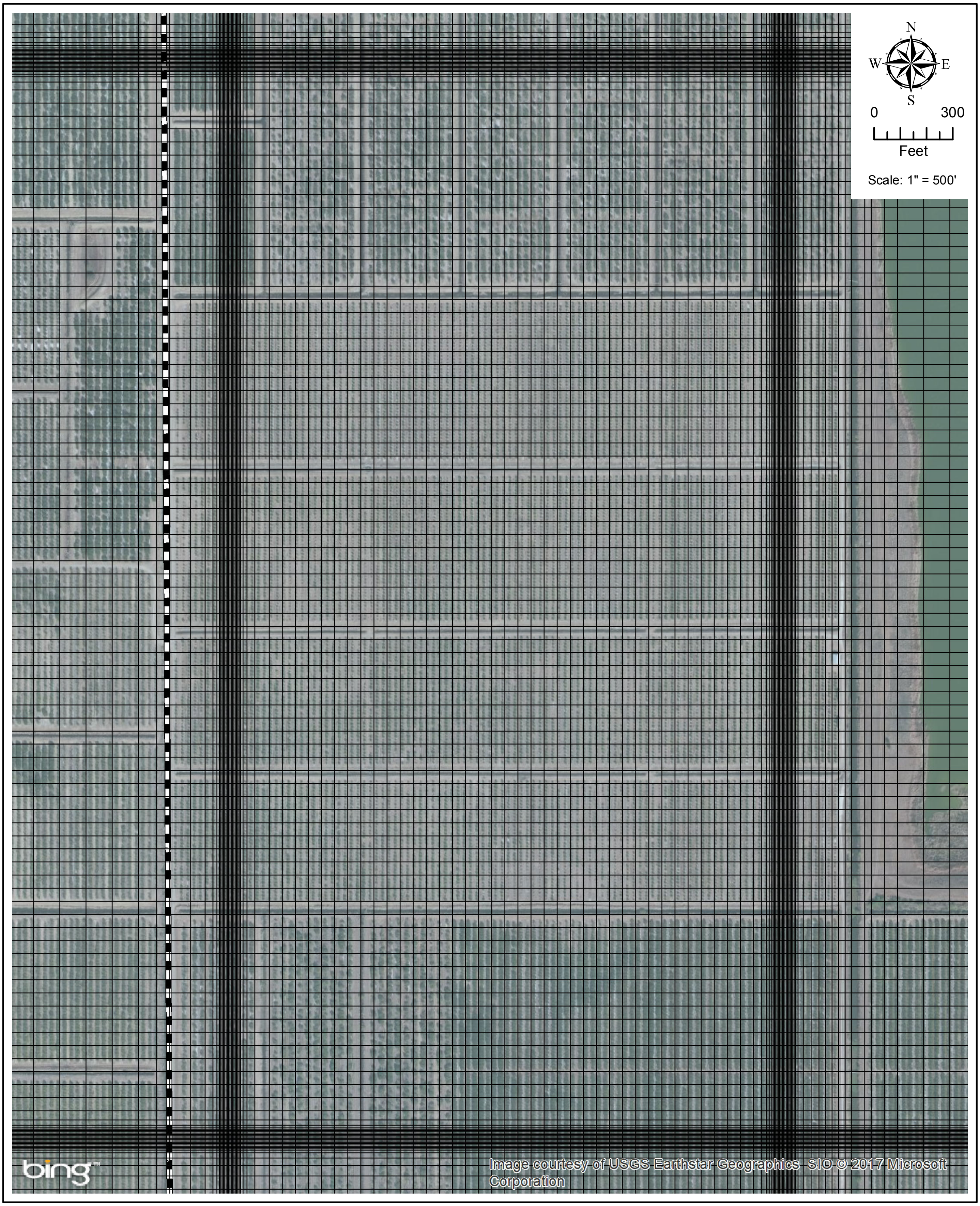

Grid Line
PropBound

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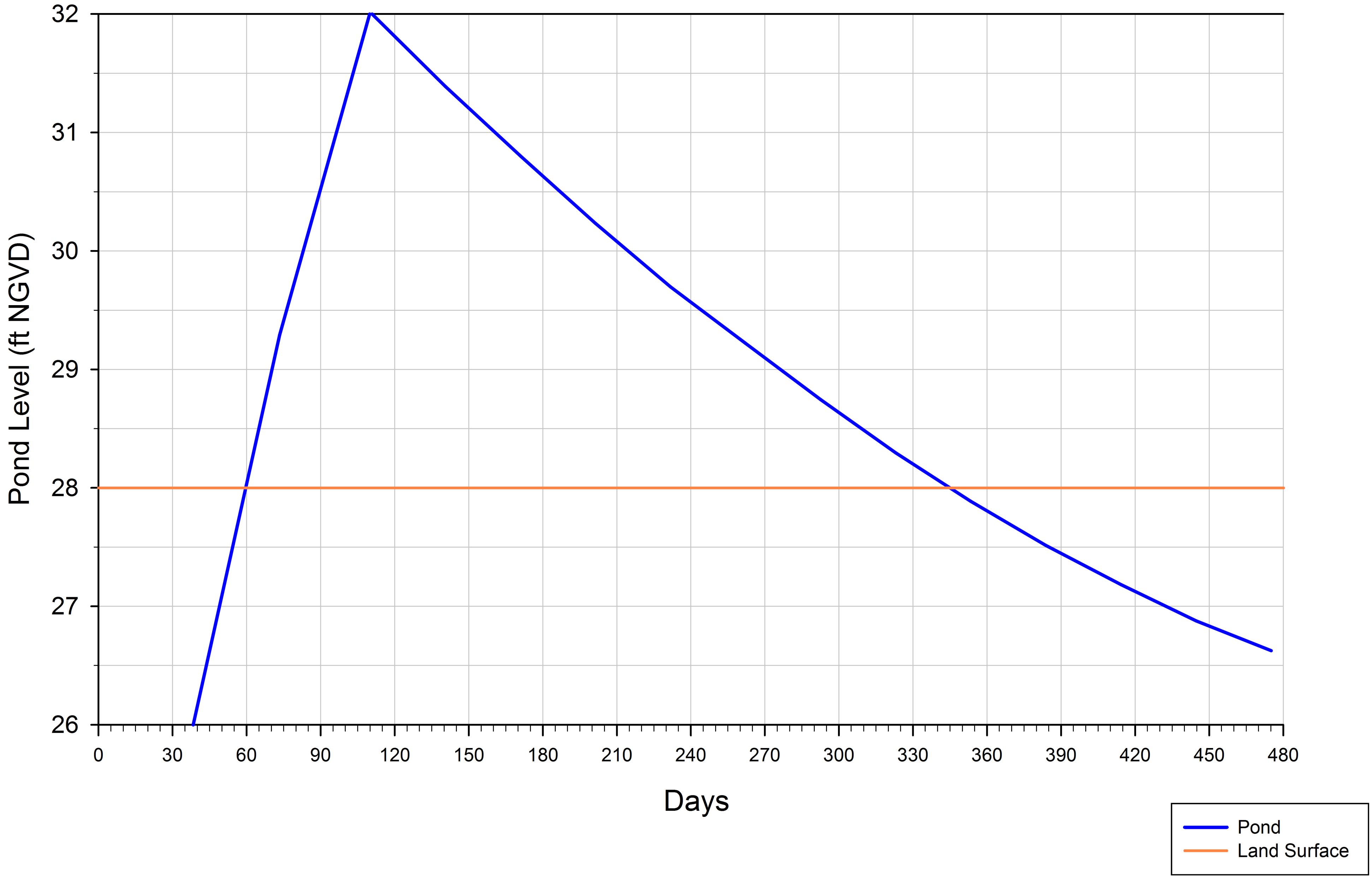
WATER FARM AREA MODEL GRID
McCARTY RANCH EXTENSION
PHASE I WATER FARM
CITY OF PORT ST. LUCIE

FIGURE 2



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POND LEVEL RECESSION FROM 32 FT NGVD
McCARTY RANCH EXTENSION PHASE I WATER FARM
CITY OF PORT ST. LUCIE, FLORIDA

FIGURE 3

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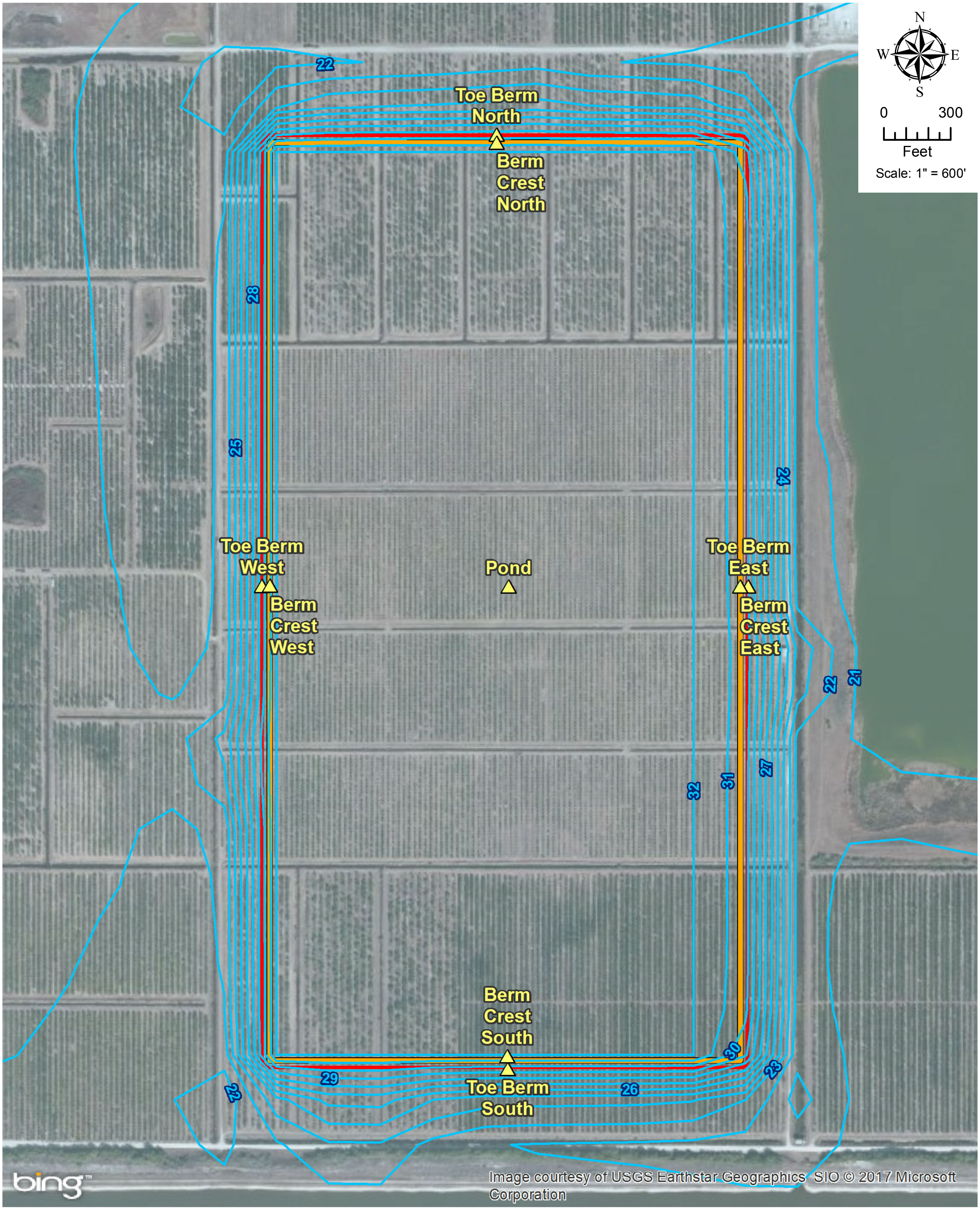

Hydrograph Location
Water Table Contour (Interval = 1 ft NGVD)
Top of Berm
Outside Toe of Berm

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FULL POND WATER TABLE CONTOURS
McCARTY RANCH EXTENSION
PHASE I WATER FARM
CITY OF PORT ST. LUCIE

FIGURE 4

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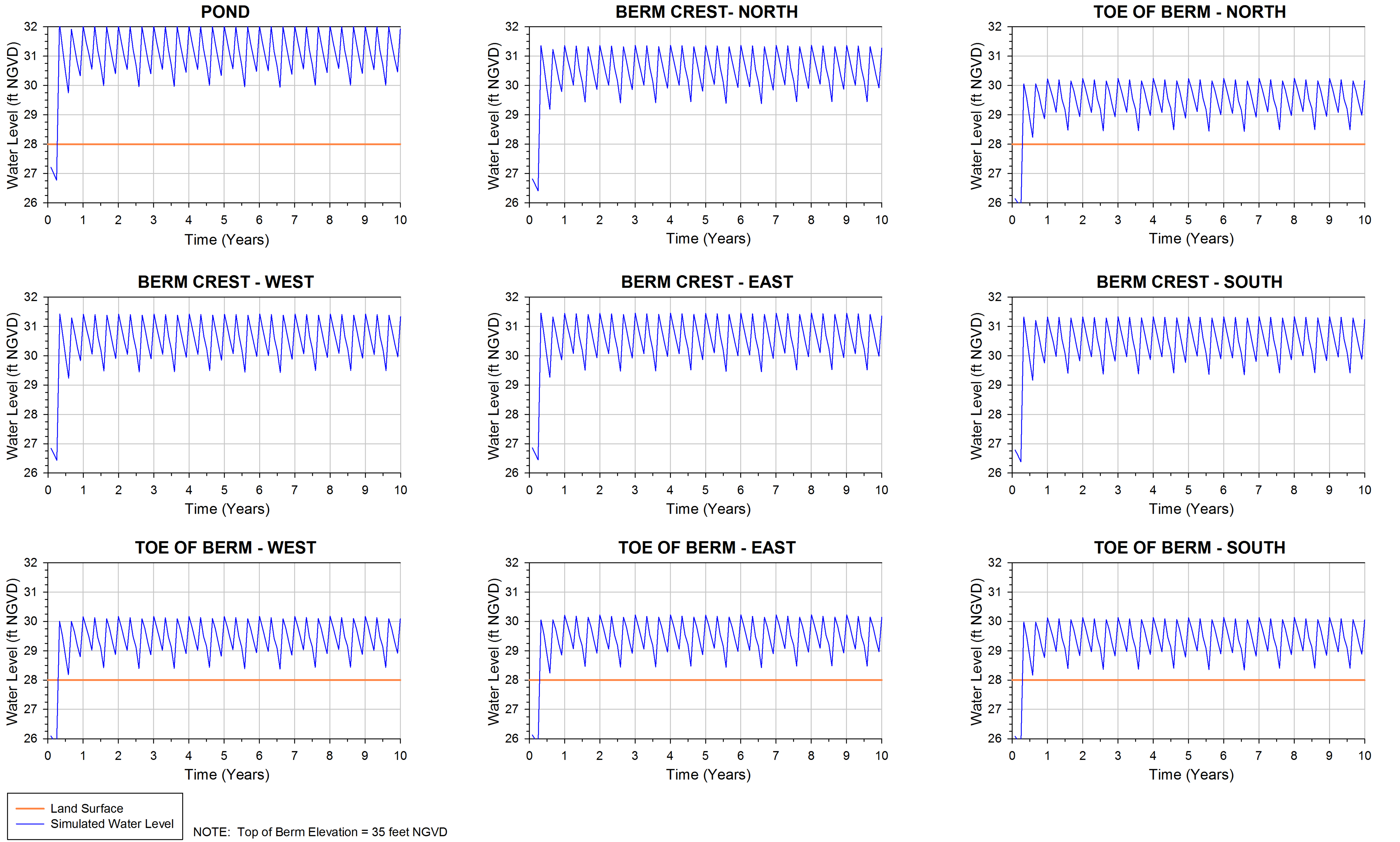

NOTE: Top of Berm Elevation = 35 feet NGVD

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10 YEAR SIMULATED WATER LEVELS
McCARTY RANCH EXTENSION PHASE I WATER FARM
CITY OF PORT ST. LUCIE

FIGURE
5

Y:/Projects/2014/14.66.5445B.../Sigma Plot/10yr-WL-graphs.jnb