GROUND WATER IMPACT ANALYSES FOR
THE WILD TURKEY SAND MINE
INDIAN RIVER COUNTY, FLORIDA

Prepared for:

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1.0 INTRODUCTION

BCI Engineers & Scientists, Inc. conducted a ground water model analysis in support of permitting the Wild Turkey Sand Mine. The Sand Mine is located in Indian River County, Florida east of Interstate 95 and north of State Road 60 (**Figure 1**). The objective of the investigation is to estimate potential impacts of mining operations on ground water of adjacent properties.

The proposed project is within an area of approximately 1,000 acres. Proposed mining will be in 20 acre blocks, allowing water levels of adjacent areas to recover as mining begins in a new block. At final build-out, mining operations will result in four reservoirs: two of about 80 acres, and two of about 46 acres. As mining operations proceed the water levels in a quarry will be maintained at approximately 35 ft below land surface (i.e., approximately -14 ft NGVD).

Currently, runoff through the area is controlled by the numerous ditches installed to keep the water table below the roots of citrus trees grown in the area. During mining, direct rainfall and ground water inflow to the mine pits will be pumped into dewatering ditches. The dewatering ditches form a perimeter around the active mining and sand/gravel storage areas. These ditches will also intercept and prevent offsite runoff from entering the mine cut. After mining has ceased, water levels within a reservoir will rise as a function of rainfall and ground water inflow rates, reaching equilibrium with the surrounding ground water.

During this project numerical and quasi-analytical simulations were used to characterize and compare ground water levels for conditions prior to mining and during mining.

1.1 Site Description

1.1.1 General

The area of the county where the proposed sand mine is sited has low topographic relief. Topographic surface elevations at the site are approximately 22 ft NGVD (**Figure 2**) with higher elevations along the east side of the property near Ranch Road. The predominant landuse at the site is citrus (**Figure 3**). On the property are also some shrub/brush and upland hardwood Forest. Adjacent to the property are citrus and pasture, with some wet prairies.

Soils at the site include: Wabasso Fine Sand, Pineda Fine Sand, and Riviera Fine Sand (**Figure 4**). These are *nearly level, poorly drained soils; some have a loamy subsoil at a depth of 20 to 40 inches, and some have a dark sandy subsoil underlain by loamy material at a depth of less than 40 inches ...consists of soils in broad sloughs, depressions and poorly defined drainage ways* (**Ref. 1**).

Hydrologically, Wabasso and Pineda Fine Sands are listed as B/D and Riviera Fine Sands are listed as C/D. This indicates that without lowering the water table through artificial means, these soils have a high runoff potential. Typically, the high water table of these soils without anthropomorphic changes is 0 to 1 feet below land surface. **Table 1** lists typical permeabilities of these soils with depth. All three of the soils have zones of lower permeability (< 0.2 inches/hour) between zones of higher permeability (> 6 inches/hour).

Table 1
Typical Soil Permeabilities

Riviera Fine Sand		Wabasso Fine Sand		Pineda Fine Sand	
Depth (inches)	**Permeability (inches/hour)**	**Depth (inches)**	**Permeability (inches/hour)**	**Depth (inches)**	**Permeability (inches/hour)**
0 – 26	6.0 – 20	0 – 24	6.0 – 20	0 – 23	6 – 20
26 – 31	< 0.2	24 – 35	0.6 – 2.0	23 – 40	< 0.2
31 – 40	< 0.2	35 – 48	< 0.2	40 – 80	2.0 – 6.0
40 – 80	0.6 to 6.0	48 – 80	6.0 – 20		

Note: Taken from **Ref. 1**

Sebastian Drainage District

The central part of the county is occupied by the ~~St. Johns River marsh~~, which drains to the north. Much of the property is in Flood Zone A (i.e., the 100-year flood zone) with the remaining portions in Zone X (i.e., the 500-year flood zone) and drains to the west (**Figure 5**). The property is bordered to the east by Lateral C Canal and to the west by Lateral D Canal with the sub-lateral canals running east west across the property: C-10 through C-13 West.

Annual rainfall amounts at Vero Beach Municipal Airport (approximately 4.8 miles from the site) range from 33 to greater than 60 inches/year, with a mean annual rainfall of approximately 50 inches/year. Rainfall rates are generally highest in the months of June and September, averaged 7.5 and 7.8 inches in these two months, respectively. Maximum rainfall depths of approximately 23.3 inches/month were reported for September 2004 when Hurricanes Frances and Jeanne visited the area. For the month of June, the maximum rainfall depth was 15.1 inches/month in 2002.

The closest weather station used to estimate ET to this site is at Fort Pierce, Florida. Average annual potential evapotranspiration (ET) of 48 inches/year was estimated by at this station for the period of 1998 through 2007 (**Ref. 2**).

Irrigation is generally applied to citrus in this area during the growing season from May through October and during drought conditions. The irrigation water requirement varies with climate, tree size and age, spacing of trees, ground covers, and seasonal growing condition. The required water volume ranges from 1 gallon/day/tree for small young trees to 60-70 gallon/day/tree for old large trees in July and August (Ref. 10). During winter months from December to February, the irrigation requirement is about 55-66 percent less than summer requirements (**Ref. 4**).

The monthly averaged daily high and low temperatures for this region are shown in **Table 2**. July and August are the hottest months. The coldest month is January followed by

February. But the average monthly low temperatures are above 53 degrees Fahrenheit for the entire year. January and February are also the months with minimum rainfall during the entire year. However, the evapotranspiration rates for these two months are not the lowest. They are higher than the rates of November and December.

Table 2
Monthly Averaged Temperatures for Vero Beach, Florida (degrees Fahrenheit).

Month	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
High	73	74	78	81	85	89	90	90	89	84	79	75
Low	53	54	58	62	67	72	73	73	73	69	62	55

Since this region is located in the tropical storm prone area, hurricanes will be a concern for the site. Hurricanes are often accompanied by heavy rainfalls, which can last for several days and inundate the low lying areas. In the past, these storms have disrupted power supplies and caused mass power outage for several weeks for each area they hit. **Figure 6** shows the storm tracks for hurricanes passing within the 50 nautical mile radius during the past 50 years[1]. A total of seven hurricanes have passed through this area since 1957. The most recent three storms occurred in 2004 and 2005. Hurricanes Frances and Jeanne caused severe floods for an extensive area across Central Florida in 2004. Hurricane Wilma (2005) moved into Atlantic Ocean from the coastline just south of this region. Wilma was a Category 5 storm before it moved inland from the Gulf of Mexico.

1.1.2 Hydrogeology

A detailed description of the geology at the site is provided in **Reference 2**. The ground water system of Indian River County is generally described as having three aquifers: the surficial aquifer, Intermediate aquifer, and Floridan aquifer. **Table 3** provides a list of characteristics for this system east of Interstate 95. West of Interstate 95 the Fort Thompson and Caloosahatchee Formation occurs and consists primarily of sand, silt, and clay.

The soils at the site are generally poorly graded sands with lenses of sandy clay, silty sand, and rock. For one soil boring taken at the site, a foot of cap rock was observed starting at a depth of seven feet below land surface. The cap rock refers to consolidated shell and coquina that may include zones of lower permeability and reduced infiltration. A more detailed description of the boring logs is provided in a separate report.

A ground water resource investigation for the site (**Ref. 3**) estimated ground water parameters at several locations within the county. One of the closest wells to the proposed Wild Turkey Sand Mine (i.e., Well No. 6) of 49.5 ft total depth had an estimated Specific Capacity of 5.3 gallons per minute per foot. That translates into an average saturated hydraulic conductivity

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[1] These data were obtained from the tropical storm data archive of National Hurricane Center, National Oceanic Administration Agency (NHC, NOAA's Website: http://maps.csc.noaa.gov/hurricanes/viewer.html).

(K_h) of between 5 and 6 ft/day for an aquifer of 105 to 130 ft thickness[2]. The upper 50 ft are the most productive interval of the surficial aquifer, and K_h could exceed 6 ft/day in these soils. In addition, preliminary soils testing provided estimated K_h values of approximately 1 ft/day (Rebecca Ascoli, personal communiqué).

Table 3
Aquifer Characteristics East of Interstate 95

Aquifer	Geological Unit	Description	Depth to top of Unit (ft)	Transmissivity (ft^2/day)
Surficial	Anastasia Formation	sand, shell, and coquina	0	200 to 11,000
	Tamiami Formation	interbedded sand and limestone		
Confining Unit & Intermediate Aquifer	Hawthorn Group	sand, shell, and limestone	105 to 130	Unknown
Florida Aquifer	Ocala Limestone Group	limestone and dolomite	Approx. 400 ft.	4,800 to 1,500,000
	Williston and Inglis Formations			

Note: Data taken from **Ref. 2** and **3**. The Ocala Limestone Group was reported as the Crystal River Formation in those publications.

Though the surficial aquifer is frequently used for irrigation, the Floridan aquifer is the major source of ground water in the county. This limestone aquifer is generally about 500 feet thick and of Eocene to Miocene age. The water of the Floridan aquifer can be highly mineralized but the yield is considerably greater than that of the Intermediate aquifer (**Ref. 2**). A ground water model of well fields for the City of Vero Beach use an estimated transmissivity of 408,000 ft^2/day with a leakance rate of 0.000468 day^{-1} between the surficial and Upper Floridan aquifers (**Ref. 5**).

1.1.3 Ground Water

Estimated normal water levels within the surficial aquifer are 18 to 19 ft NGVD as controlled by the numerous canals and ditches adjacent and within the property. Ground water borings taken at the site encountered the water table at 2.5 to 3.5 feet below land surface. During mining, a dewatering ditch will receive pumped water from the internal rim ditch of the open mine cut. The distance between the dewater ditch and internal rim ditch will be approximately 100 ft. The dewater ditch will help maintaining aquifer water levels away from mining.

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[2] To estimate the hydraulic conductivity, it was assumed that the duration of pumping for Well 6 was 1.25 hour and that the specific yield was 0.2.

Figure 7 shows the location of active consumptive use permits (CUP) in the area of the proposed site. **Table 4** lists characteristics of these wells, which are open to the Floridan aquifer except for two surface water pumps (i.e., Stations 1691 and 2177). The average withdrawal rate of wells listed in the table is 890 gallons per day. Casing Depth are generally less than 400 ft, indicating that these well may be screened within the Hawthorn Group of the Intermediate aquifer.

Zones of salty water are known to occur in the Floridan aquifer, which increases with ground water withdrawals from the Floridan. **Figure 8** shows the potentiometric surface of the Floridan aquifer in the area of the proposed quarry. The Floridan aquifer is a confined aquifer meaning it is under pressure, confined by the clays of the Hawthorn formation. In this case, the potentiometric heads of 30 to 40 ft NGVD are approximately 10 to 20 ft greater than the surrounding topography. Thus, the Floridan aquifer exhibits characteristics of an artesian aquifer in the area of the proposed site. The artesian pressures mean that water flows from the Floridan to the Intermediate and surficial aquifers in an upward direction.

Figure 9 shows the recorded water levels for nested ground water monitoring wells at the northeast corner of the mine site. The location of these wells is indicated on **Figure 10**. **Table 5** lists the casing depth and total depth of these wells. The average potentiometric head of the Floridan aquifer is 38 ft NGVD, and the average head of the upper surficial aquifer is 21 ft NGVD; an average difference of 17 ft during the period of 2000 through 2007. The average difference in water levels between the upper part of the surficial aquifer and the lower part of the surficial aquifer is 0.2 ft during this period.

With a leakance of 0.000468 day^{-1} between the surficial and Upper Floridan aquifers, and a head difference of 17 feet, the average leakage from the Floridan into the surficial aquifer is approximately 35 inches/year.

Table 4
Description of Active CUP's near Project Site

Station ID	Permit ID[1]	Water Source	Casing Depth (ft)	Total Depth (ft)	Casing Diameter (inches)	Well Capacity (gpd)
1691	10818	Sebastian River, Dewatering				25000
7305	10714	Floridan Aquifer		700	4	200
7392	10732	Floridan Aquifer	200	1100	10	900
7393	10732	Floridan Aquifer	190	1100	6	400
7394	10732	Floridan Aquifer	200	1100	10	500
7396	10733	Floridan Aquifer	240	850	6	400
7398	10733	Floridan Aquifer	240	950	12	1400
7402	10733	Floridan Aquifer	240	950	12	1500
7403	10733	Floridan Aquifer	250	1020	12	2300
7405	10733	Floridan Aquifer	250	1020	12	2500
7406	10733	Floridan Aquifer	240	950	12	1200
7408	10733	Floridan Aquifer	240	950	10	1500
7409	10733	Floridan Aquifer	250	1020	12	2500
7446	1649	Floridan Aquifer			10	177
7539	10765	Floridan Aquifer	250	900	4	58
7540	10765	Floridan Aquifer	250	900	4	140
7541	10765	Floridan Aquifer	250	900	8	234
7557	10765	Floridan Aquifer	250	900	4	75
7804	10808	Floridan Aquifer			4	
7805	10808	Floridan Aquifer			4	
7836	10818	Floridan Aquifer		875	10	897
7837	10818	Floridan Aquifer		875	12	2533
8506	2303	Floridan Aquifer			6	498
8507	2303	Floridan Aquifer			6	463
8508	2303	Floridan Aquifer			6	478
8509	2303	Floridan Aquifer			6	421
8510	2303	Floridan Aquifer			4	
18613	1649	Floridan Aquifer			6	100
33835	2177	SRWCD Canal				

1. GRS Station Identifier (System Generated)

Note: zero values generally indicate missing, not set, or non-applicable values, which were replace with shading.

Table 5
Corrigan Ranch Monitor Well Characteristics

Unit Monitored	Casing Depth (ft)	Total Depth (ft)
Upper Surficial Aquifer	40	50
Lower Surficial Aquifer	76	86
Floridan Aquifer	390	442

In 1958 (**Ref. 2**) it was estimated that the potentiometric heads of the Floridan aquifer had fallen 10 feet since 1934 as a result of ground water withdrawals. The Floridan aquifer water levels have undoubtedly fallen further since 1958. Depressed water levels of the Floridan aquifer reduce the head gradient driving the flow of water upward from the Floridan aquifer, potentially decreasing the migration of higher chloride levels into the Intermediate and surficial aquifers. Depressed water levels of the surficial aquifer will partially restore the natural gradient (i.e., head difference) between the Floridan and surficial aquifers. However, these activities could potentially increase the rate that higher concentrations of chlorides migrate upward into the Intermediate and surficial aquifers.

2.0 MODEL(S) PROGRAM DESCRIPTIONS

A quasi-analytical method was used representing the active mine area using the program AQTESOLV (**Ref. 6**). This provided an estimate of ground water withdrawals during mining that could be used as a rough comparison for the subsequent modeling.

A quasi-three dimensional model MODFLOW (**Ref. 7**) was used to represent the surficial aquifer in the area of the wellfield. MODFLOW is a finite-difference model that simulates flow in three dimensions. For this project MODFLOW was used to represent flow and water levels of the surficial aquifer.

3.0 MODEL SETUP

3.1 AQTESOLV

Using AQTESOLV, the open mine pit was represented as a partially penetrating well with a constant pumping rate in an unconfined aquifer of 105 to 130 ft thickness. With an average saturated conductivity of 1 to 5 ft/day, the transmissivity is 130 to 650 ft^2/day. Constant head boundary conditions were set at approximately 500 feet from the center of the well. The program gives the user the option to change the model parameters to adjust the time drawdown and distance drawdown curves. In the calculations, a constant pumping rate over a period exceeding 900 days was applied to reach near steady-state conditions.

3.2 MODFLOW

MODFLOW was used to represent the surficial and Floridan aquifers in the area of the proposed mine. In these simulations, the Intermediate aquifer was represented as part of the confining unit. The surficial aquifer was assumed to be 130 feet thick with horizontal conductivities of 1 ft/day. The Floridan aquifer was represented as a constant head in the model simulations.

The surficial aquifer was represented as three model layers. The first layer represents the aquifer to the bottom of the recharge ditches (i.e., about 10 ft NGVD), the second layer represents the aquifer to the bottom of mining (i.e., -14 ft NGVD), and the third layer represents the unit to the bottom of the surficial aquifer[3]. Leakance values are used to represent vertical conductivities in MODFLOW. Between layers of the surficial aquifer, the leakance represents the net vertical conductivity between these two layers:

$$L^{-1} = \frac{m_1}{2K_{v1}} + \frac{m_2}{2K_{v2}}$$

where L is the leakance (1/day)
m_1 is the thickness of the upper layer
m_2 is the thickness of the lower layer
K_{v1} is the vertical conductivity through the upper layer
K_{v2} is the vertical conductivity through the lower layer

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[3] The leakance defined for this layer also represents the confinement between the surficial and Floridan aquifers. Simulations representing active mining used a bottom elevation of -15 ft NGVD to prevent numerical problems when using a constant head of -14 ft.

Table 6
Conductivities and Leakances of the Surficial Aquifer

Layer	Thickness (ft)	K_h (ft/day)	K_v (ft/day)	Leakance (1/day)
1	10	1	0.1	0.0057
2	25	1	0.1	0.0017
3	95	1	0.1	0.000468

Boundary conditions include topographic land surface, mine pits, dewatering ditches, canals, and extents of the model area. These boundaries were represented as follows:

- Constant heads were used to represent mine pits and ~~dewatering~~ water recharge ditches. The constant heads representing the mine pits are in model layer 2. The constant heads representing the dewatering ditch are in model layer 1.
- River cells were used to represent canals and agricultural ditches. The river conductance was set at five times the product of the channel width and channel length in the cell. Channel bottom widths were assumed to be 10 ft wide and have a depth of 7 feet below land surface. Water levels in canals were assumed to be two feet deep (i.e., water surface were set 5 feet below land surface).
- Simulations of the pre-mined conditions were used to select aerial recharge rates such that the simulated water table elevation does not exceed land surface elevations.
- Constant heads (i.e., 37 ft NGVD) were used to represent the Floridan aquifer.
- No flow boundary conditions were used at the model extents.

Conceptually, the agricultural ditches and canals are sinks that help reduce the water table elevations in the area. During mining, some canal sections could potentially act as a source of water to the open mine pit. The conductance values used to representing the agricultural ditches and canals indicate that leakage from and to these features are limited by aquifer characteristics and not bottom sediments characteristics.

In the steady-state simulations, a constant grid spacing of 100 ft (i.e., square grids) was used with at total of 226 rows and 151 columns.

5.0 MODEL RESULTS

5.1 AQTESOLV

Using AQTESOLV, the pumping rate at the well was varied so that near steady-state drawdowns of 35 ft occur at the mine pit. **Table 7** summarizes the results from these simulations. **Appendix A** contains printouts of time-drawdown and distance-drawdown curves from the model simulations.

Table 7
Estimated Near Steady-State Pumping Rates Using AQTESOLV

Aquifer Thickness (ft)	K_h (ft/day)	K_v/K_h	Pumping Rate (gpm)
105	1	0.5	450
105	5	0.5	2500
130	1	0.5	450
130	5	0.5	2500
130	1	0.1	400

Notes: K_h = horizontal conductivity, K_v = vertical conductivity, ft = feet, gpm = gallons per minute
Does not include surge pumping for rainfall or other recharge events

Similar results could be obtained using the Dupuit-Forcheimer equation:

$$Q = AK_h \frac{h_1^2 - h_2^2}{L^2}$$

A is the cross sectional area of flow[4]. That is, it is the pit perimeter times depth of water below the pit (88,671 ft^2).
K_h is the hydraulic conductivity of the soils (1 to 5 ft/day).
h_1 is the depth of the water table at the dewatering ditch (130 ft).
h_2 is the depth of water at the mine pit (95 ft).
L is the distance from the dewatering ditch from the edge of mine pit (100 ft).

Using the Dupuit-Forcheimer equation:

- With K_h equal 1 ft/day, Q is 363 gpm
- With K_h equal 5 ft/day, Q is 1813 gpm.

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[4] In this case, flow is limited by the cross sectional area of the aquifer below the pit and not the area of the pit bottom.

5.2 MODFLOW

A constant negative recharge rate of 26 inches/year (i.e., -0.006 ft/day) was used to offset the inflows from the Floridan aquifer as simulated in the model. This rate was estimated in a trail-and-error manner to keep the water table at or below land surface. **Figure 11** shows the simulated water levels in the upper layer of the model. The simulated average depth to the water table was 4.1 ft.

Figure 12 shows the simulated drawdown near an open mine pit. In these simulations drawdown past the dewatering ditches is shown. Using MODFLOW, the estimated drawdown is approximately 2 ft. Simulated drawdowns exceeding 0.5 ft occurred at a maximum distance of approximately 900 ft from the dewatering ditch.

The percent error in these simulations was less then 0.01, and no numerical incongruencies were apparent. **Table 8** lists components of the water budget simulated using MODFLOW. These simulations indicate inflows to the mine pit of 131 gpm, with less than 20-percent of the flow supplied by the dewatering ditch.

Output files from the MODFLOW simulations are included in **Appendix B**.

Table 8
Simulated Water Budget Using MODFLOW

Model Layer	Component	Existing (inches/year)	Active Mining (inches/year)	[Existing-Active] (inches/year)
1	Net Recharge	-26.28	-26.17	0.15
	Canals	-1.30	-1.44	-0.06
	Dewatering Ditch	0	0.06	-0.06
	Flow from Layer 2	27.58	27.60	0.02
2	Flow up to Layer 1	-27.58	-27.60	0.03
	Flow from Layer 3	28/59	28/99	-0.3
	Open Mine Cut	0	-0.32	0.32
3	Flow up to Layer 2	-27.58	-27.88	0.3
	Flow from Layer 4 (Upper Floridan Aquifer)	27.58	27.88	-0.3

6.0 MODEL LIMITATIONS

6.1 AQTESOLV

The assumptions for the equations used in this analysis include:

1. The aquifer has infinite aerial extent
2. The aquifer is homogeneous and has uniform thickness
3. The water table surface is initially horizontal
4. The pumping well partially penetrates the aquifer
5. Flow is unsteady
6. The well diameter is small and its storage can be neglected
7. There is no rainfall recharge or leakage from other aquifers

In this analysis, the well with a radius of 400 feet represents the open mine cut, which has significant storage and does not meet the conditions of assumption six. However the mine pit will not be instantly dug. Rather, pumping will progress with the mining and for the conditions of this investigation near steady-state conditions are of interest. This will diminish the importance of the sixth assumption.

The constant head boundary conditions used to represent the perimeter ditch are not partially penetrating. So, no drawdown proceeds past these boundary conditions. This may unrealistically limit the extent of drawdown and overestimating the flow rates back to the mine pit.

Calculations using the Dupuit-Forcheimer equation assume steady-state conditions. The Dupuit-Forcheimer equation as used here, does not account for a seepage face forming above the floor of the open mine pit.

6.2 MODFLOW

Steady-state conditions were simulated using MODFLOW. During conditions of drought, water levels in the agricultural ditches will be lower and possible dry. This means that the zone of mine impacts will extend further into adjacent property. During wetter periods, water levels in the agriculture ditches and canals could be higher than represented in the model simulations. In that case, the mine impacts will not extend as far into adjacent property.

The conductance values used in the model simulations are potentially large meaning the leakage to and from canal and agricultural ditches are limited by aquifer characteristics and not by ditch bottom sediments. Sediment deposition within the ditches and canals is likely heterogeneous; some areas having higher bottom permeabilities than others. Ditch geometries will differ between canals and canal sections. The effect of these differences was not represented in the model.

The potentiometric surface of the Floridan aquifer was represented as constant heads in the model simulations. Higher potentiometric surface elevations could reduce estimated impacts of mining to the water table. Conversely, lower potentiometric surface elevations could increase the estimated impacts of mining to the water table. However, these impacts would not occur instantaneously, and the model represents an average conditions.

A constant negative recharge rate was used to represent the combined effects of ET and runoff in the steady-state simulations. This rate was not changed between the pre-mined and active-mining scenarios. However, there could possibly be decreased runoff and lower ET as a result of mine drawdown. This means that model potentially overestimates drawdown away from the mine cut.

7.0 DISCUSSION AND CONCLUSIONS

Without further site specific information, some conditions at the site remain unknown. These conditions include the total thickness of the aquifer and the ratio of vertical to horizontal conductivity of the soils. In addition, leakance rates and permeabilities for the lower aquifers (i.e., Intermediate and Floridan) were estimated for a site close to Vero Beach not on the proposed mine site.

The simulations generally indicate that there will be drawdown away from the mine cut, with drawdowns exceeding 0.5 ft extending 900 ft or more past the dewatering ditches. These drawdowns will be associated with increased flow from the Floridan aquifer and agricultural canals in the area. There are several freshwater marshes within 900 feet of the property that might warrant additional monitoring during the period of mining.

The Corrigan Ranch monitor well is near the property and could be used as an indicator of potential ground water changes with installation of continuous monitoring equipment.

Excess water from the pit after satisfying the needs of the dewatering ditches could be used to maintain higher water levels in the nearby agricultural ditches. This might help offset impacts to the water table, especially during periods of drought.

A continuous ground monitoring program will be developed and discussed in a separate document and data gathered during the mining operating period. The purpose of the monitoring program will be to document ground water elevations during mine operations.

7.1 AQTESOLV

The AQTESOLV simulations were used to represent a near steady-state condition with 35 ft of drawdown at the mine pit. The estimated pumping rate at the mine pit based on these calculations is 450 to 2500 gpm at near steady-state conditions - assuming that there are no impacts beyond the recharge ditch. These simulations do not include additional surge capacity that may be required to overcome rainfall or other recharge events. Estimated pumping rates could be lower with greater vertical stratification than used in the model simulations. Calculations based on the Dupuit-Forcheimer equation provided similar results to those obtained using AQTESOLV.

These analytical simulations assume near steady-state conditions. These equations provide a preliminary estimate of ground water inflows to the mine pit, but do not consider impacts beyond the recharge ditch.

7.2 MODFLOW

The MODFLOW simulations indicate a maximum drawdown of approximately 2 ft beyond the dewatering ditches could be induced by mining. However, these larger impacts are close to the dewatering ditch and simulated drawdown is less than 0.5 ft at distances greater than 900 ft from the dewatering ditches. The simulations indicate that drawdown beyond the dewater ditch is limited by decreased leakage to agricultural ditches and canals in the area.

The MODFLOW simulations indicate seepage rates into the mine cut of 130 gpm, and that approximately 20 percent of the seepage into the mine cut is derived from the dewatering ditches.

MODFLOW simulations indicate increased upward flow from the Floridan aquifer of approximately 0.3 inches/year over the 12 square mile area represented by the model.

7.3 Recommendations

1. Install monitoring wells at the edge of the mine property and near areas of active mining. This could include 5 monitor wells (one at each edges of the property) and several additional monitor wells just outside one or more selected dewatering ditch configurations.
2. Add continuous monitoring equipment at the existing Corrigan Ranch monitor wells.
3. Keep records of dewatering pumping rates and water levels within the rim ditches, dewatering ditch, and inactive mine reservoirs.
4. Keep daily records of rainfall depths using an onsite rain gage.
5. Use the existing irrigation canals on the site to reduce offsite ground water impacts.
6. Refine ground water computer models to better simulate ground water conditions during mining.
7. Conduct onsite pump test to estimate soil conductivities (horizontal and vertical).
8. Drill deep borings to estimate the total surficial aquifer thickness at the site.

7.4 Conclusions

1. The modeling supports the mining permit needs by demonstrating small impacts to ground water on adjacent properties. The simulations results indicate that drawdown falls to less than 0.5 feet at distance greater than 900 feet from the dewatering ditch.

2. The computer simulations indicate almost no drawdown at nearby active permitted wells. This is because of the large distances from the proposed mine pits to existing wells. In addition, the wells are open to the Intermediate and Floridan aquifers and not the surficial aquifer where mine impacts are most significant.

3. The modeling may be conservative, since it does not represent reduced hydraulic conductivities expected for a clay layer 60 feet below grade as shown in the boring logs. In addition, a single negative recharge rate is used in both the pre-mined and active mining

scenarios. However, there could be localized decreases in the negative recharge rates (i.e., less runoff during rain events) decreasing estimates of onsite and offsite drawdown.

4. There are a number of measures that if implemented could help reduce offsite impacts including the following:
    a. Increase the size and number of perimeter ditches and use them as recharge elements to minimize impacts to adjacent property.
    b. Dredge the existing agricultural ditches to remove any accumulated sediments.
    c. Provide surface water augmentation to sensitive wetlands and marshes within areas of ground water impact.

8.0 REFERENCES

1. Soil Conservation Service. 1987. Soil Survey of Indian River County, Florida. U.S. Department of Agriculture.

2. Bermes, Boris J. 1958. Interim Report on Geology and Ground-Water Resources of Indian River County, Florida. Information Circular No. 18. Florida Geological Survey.

3. Toth, David J. and Ching-tzu Huang, 1998. Investigation of Ground water Resources in Central Indian River County, Florida. St. John River Water Management District. Palatka Florida.

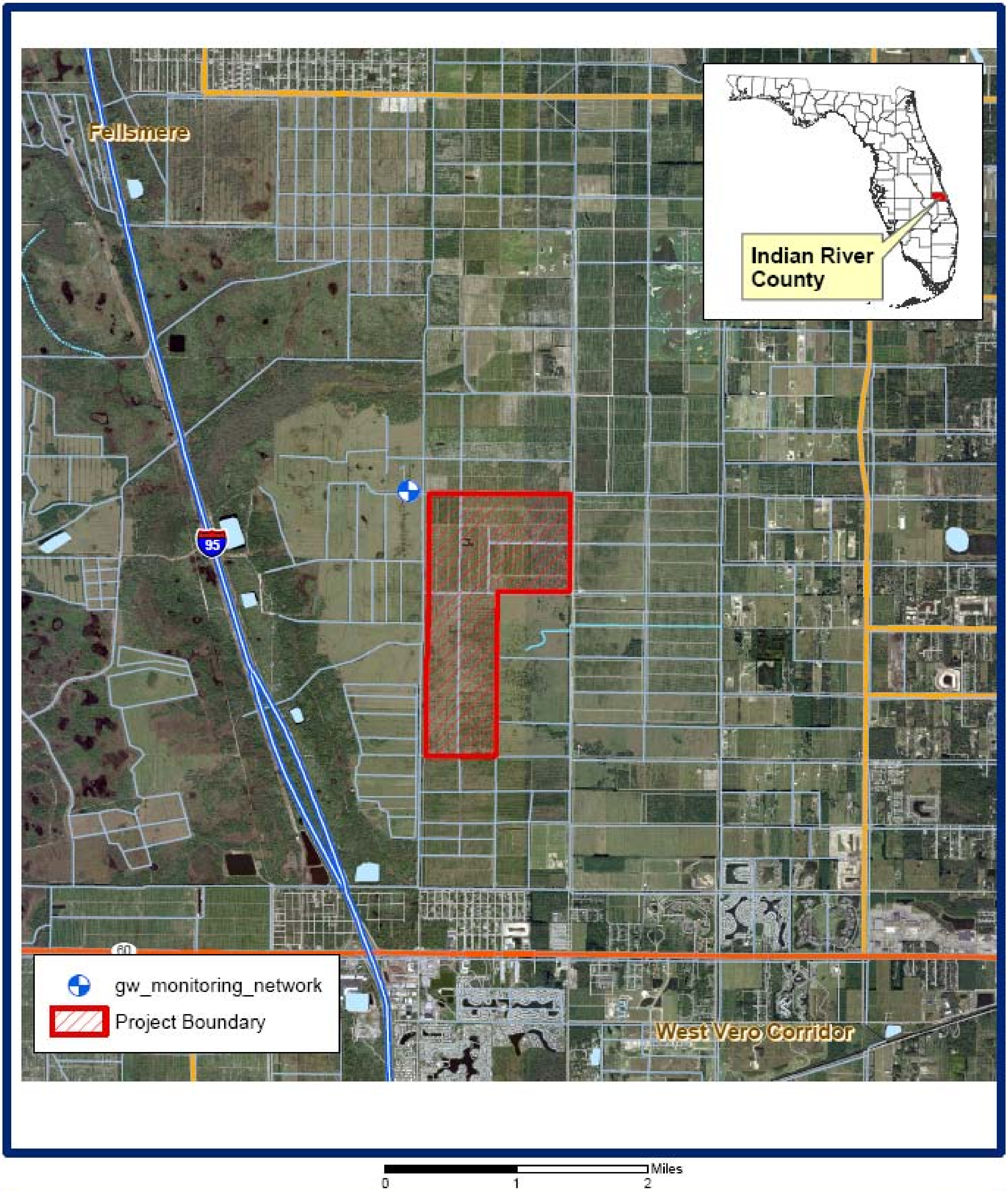
4. Division of Agricultural Water Policy, Florida Department of Agriculture and Consumer Services. 2005. Best Management Practices (BMPS) for Indian River Area Citrus Groves.

5. Toth, David J. 1994. Projected Aquifer Drawdowns City of Vero Beach and Indian River County Wellfields, Indian River County, Florida. St. John River Water Management District, Palatka Florida

6. AQTESOLV for Windows Version 4.02, Developed by Glenn M. Duffield, HydroSolve, Inc

7. McDonald, Michael G. and Arlen W. Harbaugh. 1984. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. U.S. Geological Survey.

FIGURES



Notes:
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2- This map is intended
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Figure 1.
LOCATION MAP

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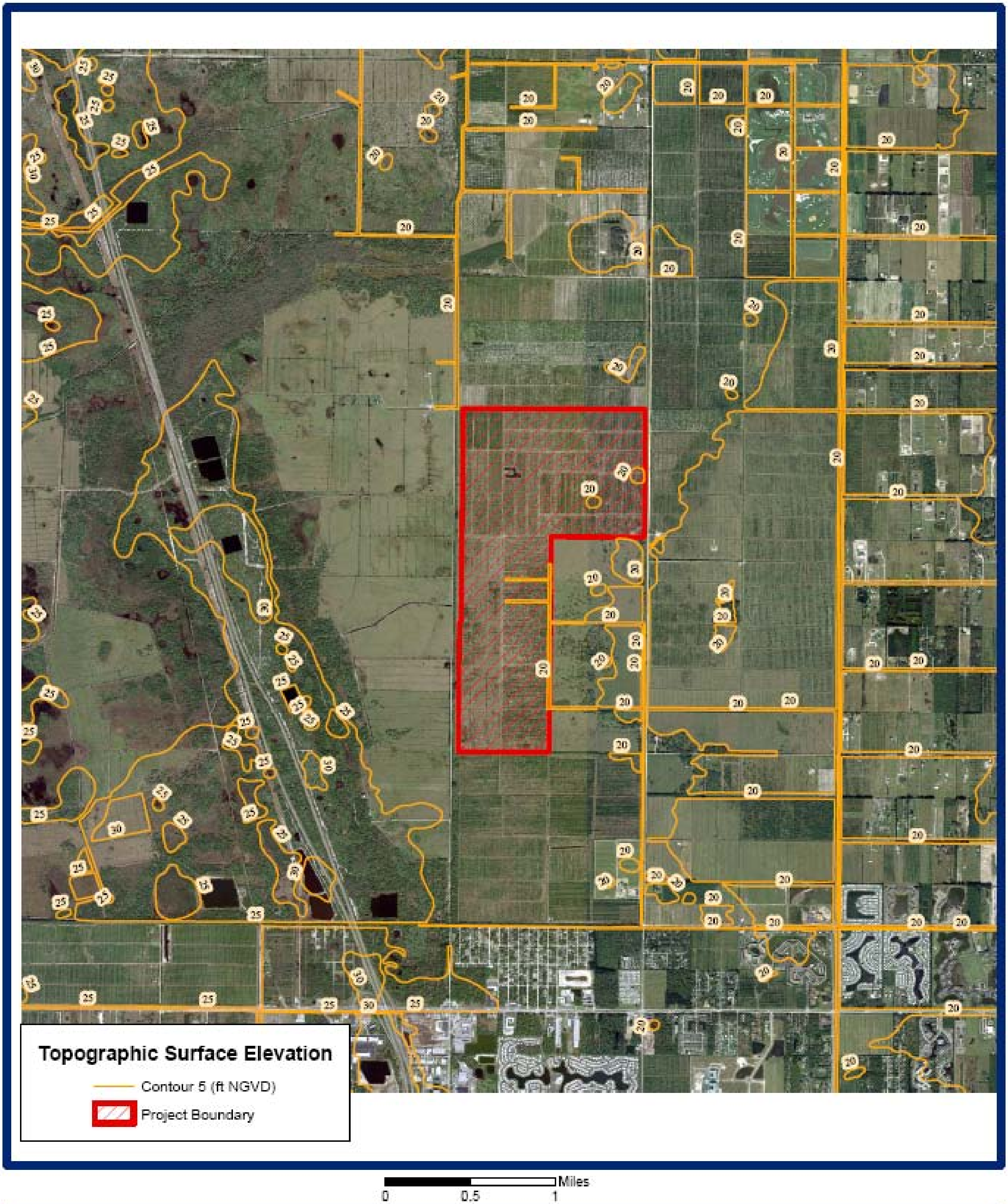

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Figure 2.
TOPOGRAPHY

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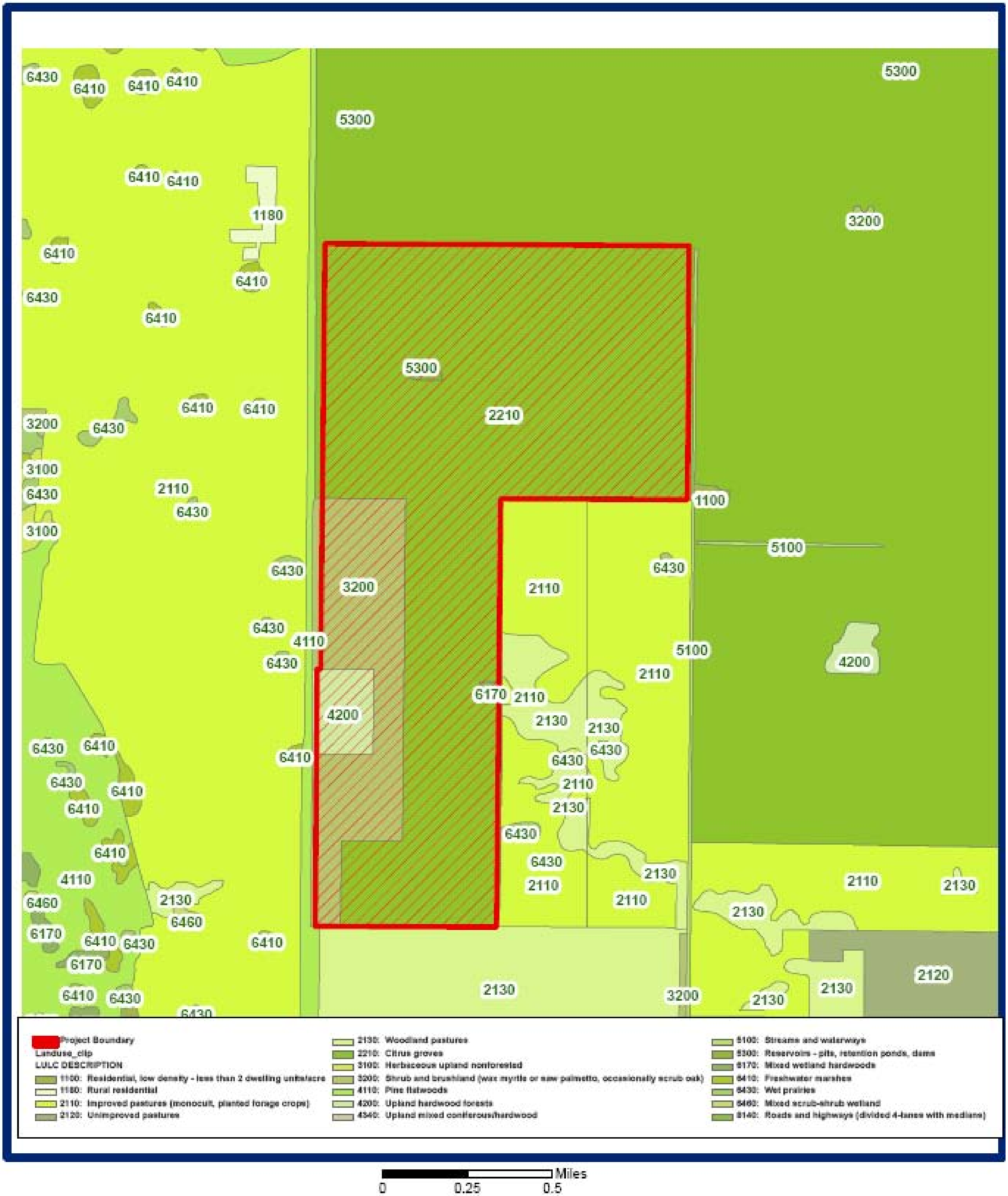

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Figure 3.
LAND USE MAP

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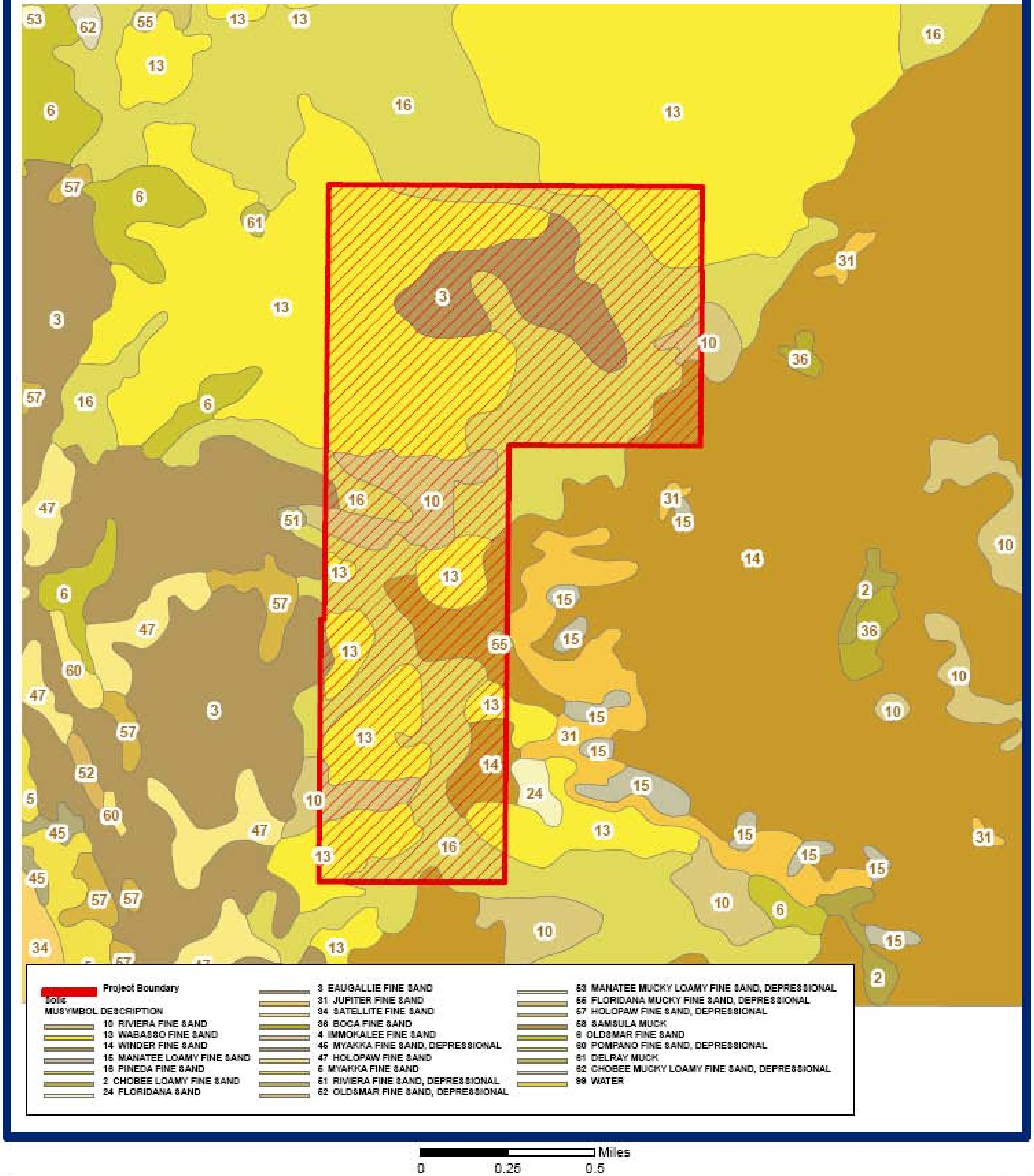

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Figure 4.
SOILS MAP

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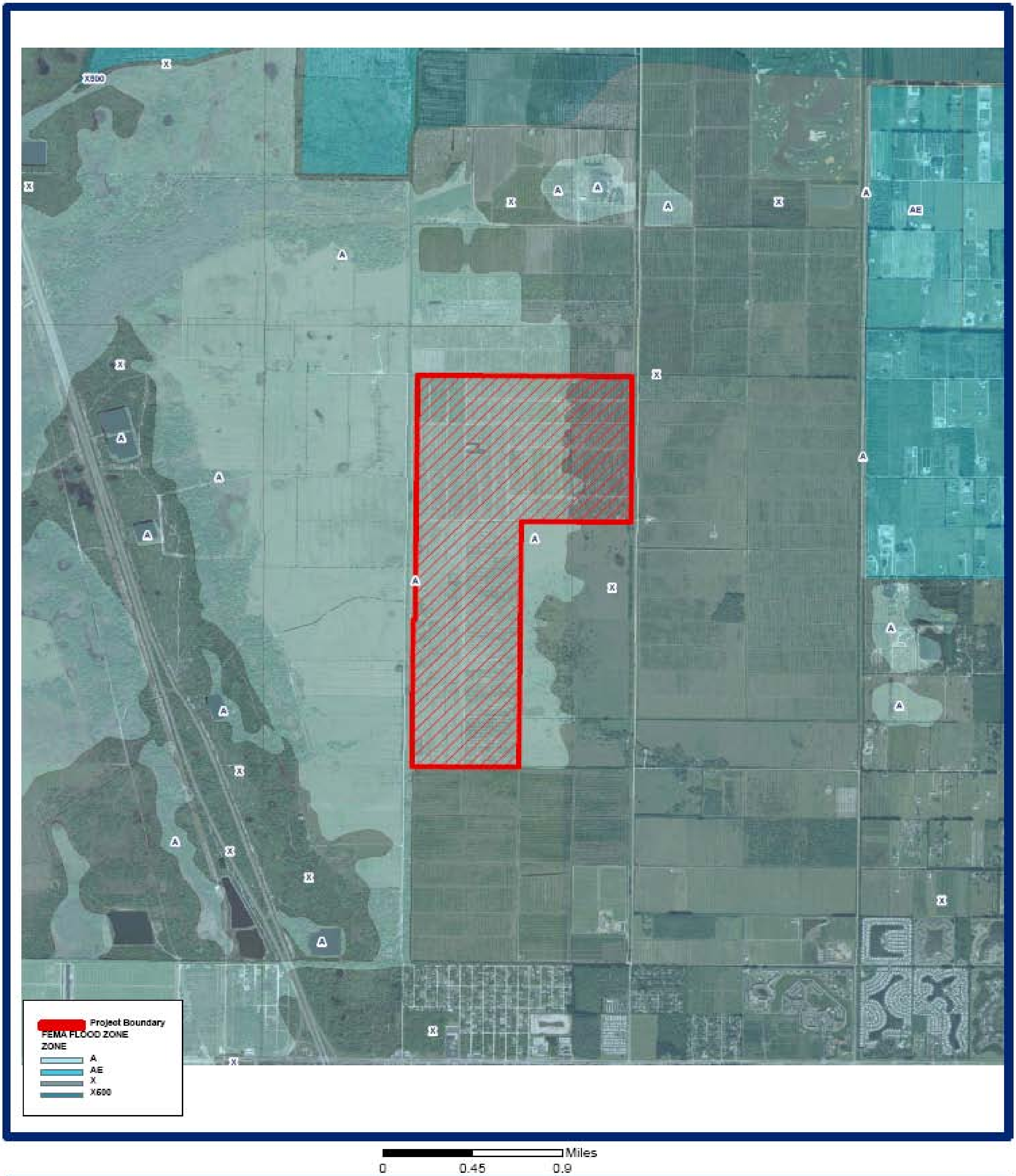

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Figure 5.
FEMA FLOOD ZONES

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Figure 6
Historical Hurricanes with Paths near Site

Source: National Hurricane Center, NOAA

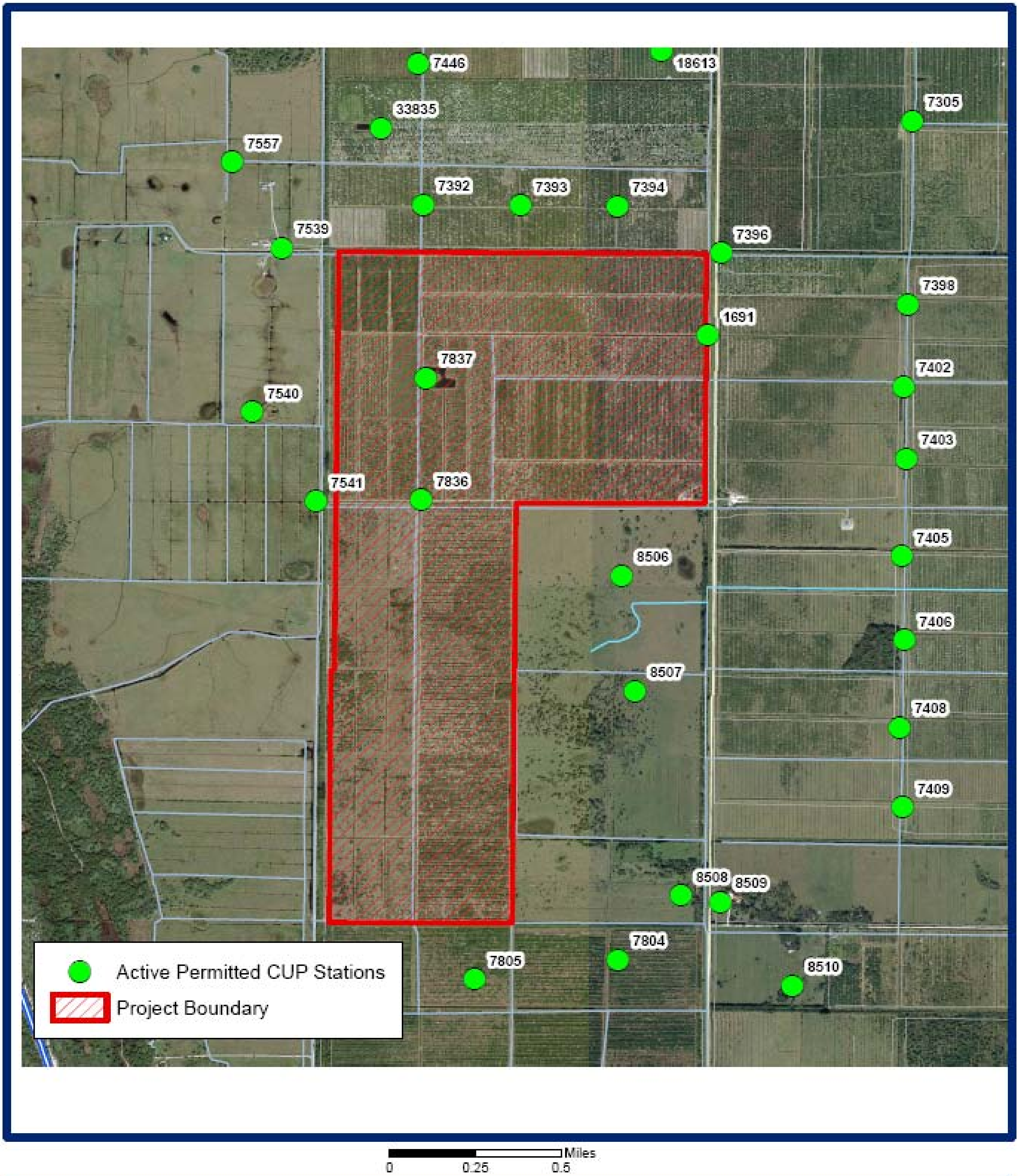

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Figure 7
Active Consumptive Use Permits Near Site

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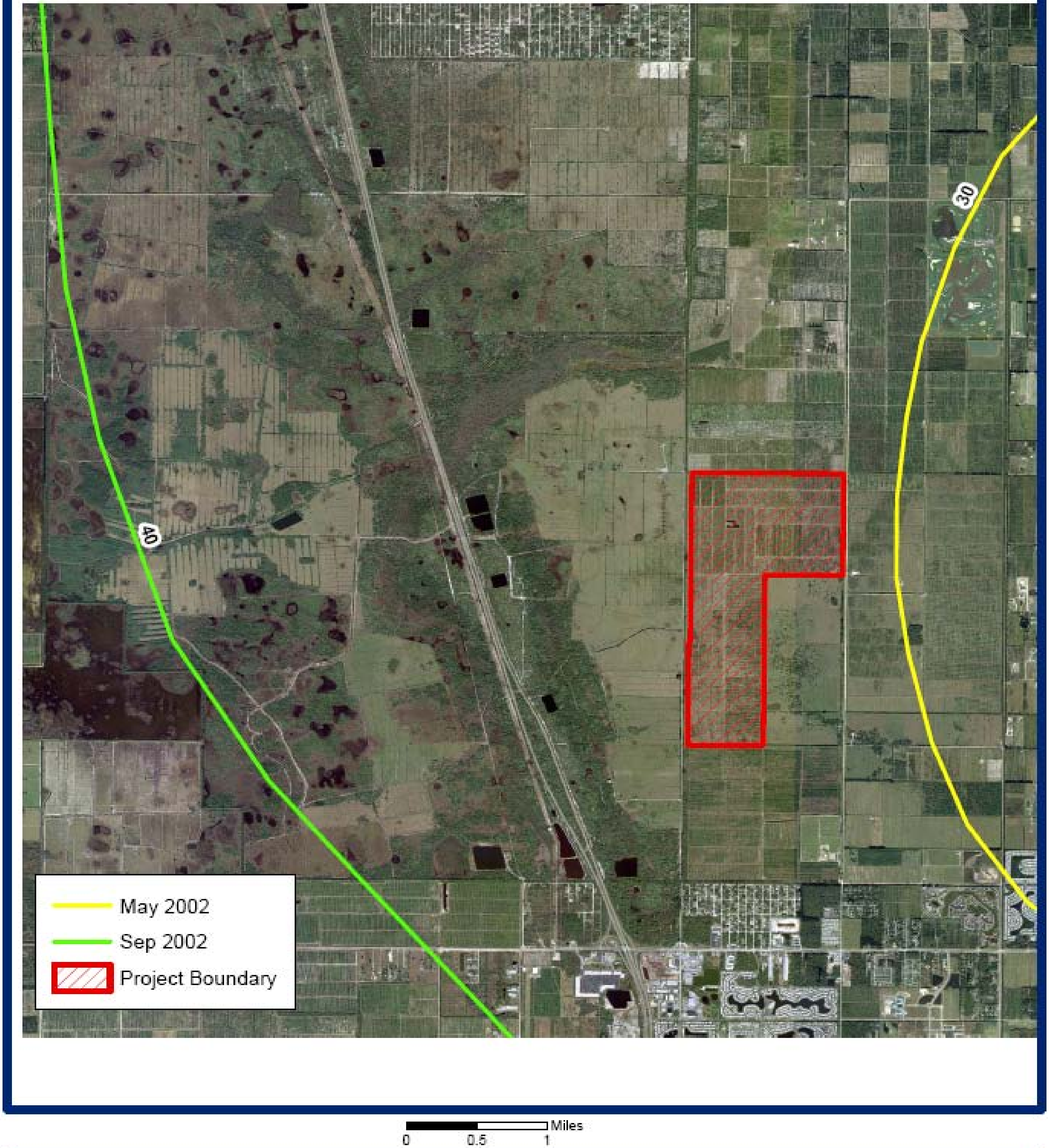

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Figure 8
FLORIDIAN POTENTIOMETRIC
SURFACE ELEVATIONS OF 2002

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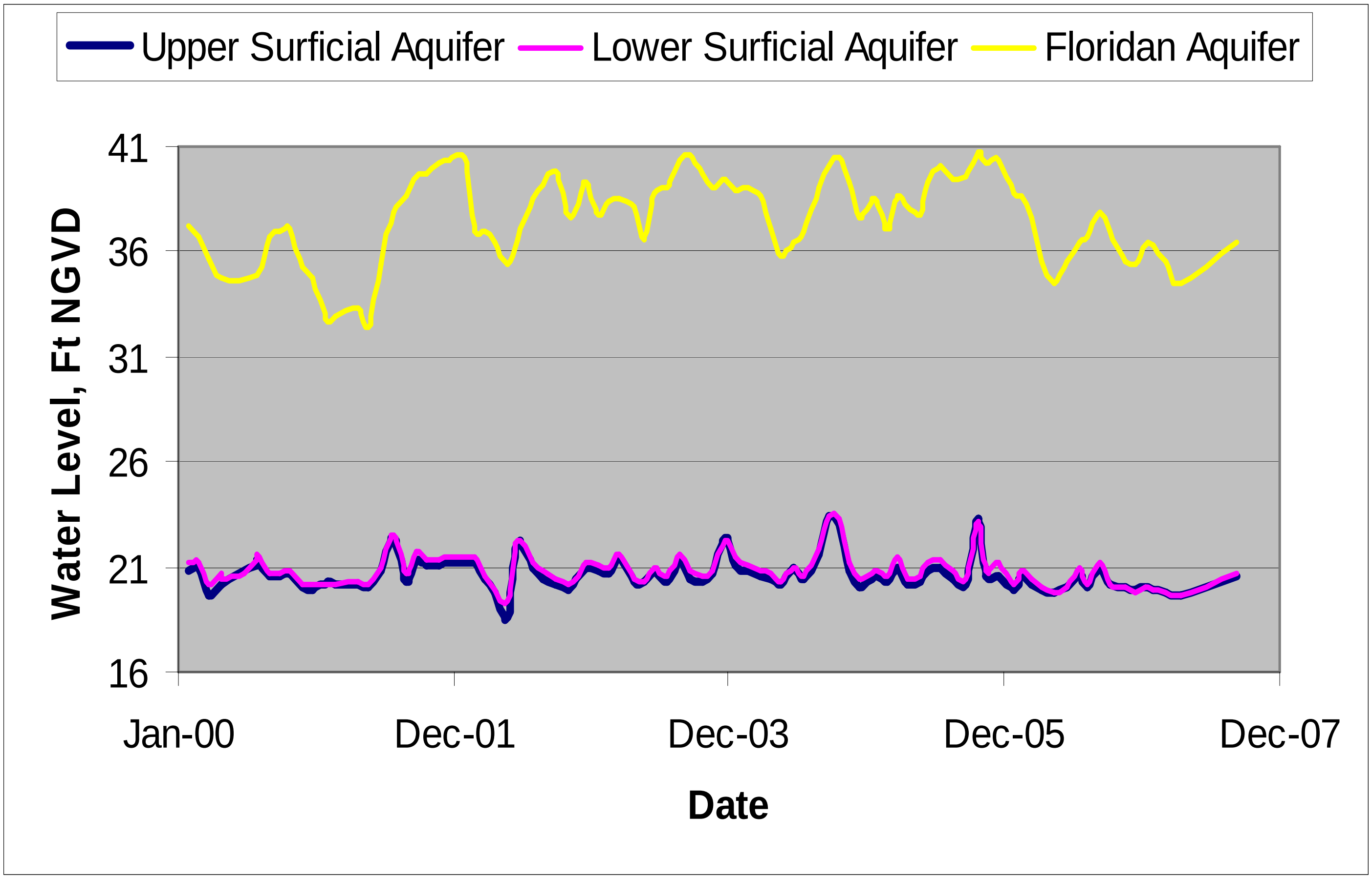
Figure 9
Recorded Water Levels at the Corrigan Ranch Monitor Well



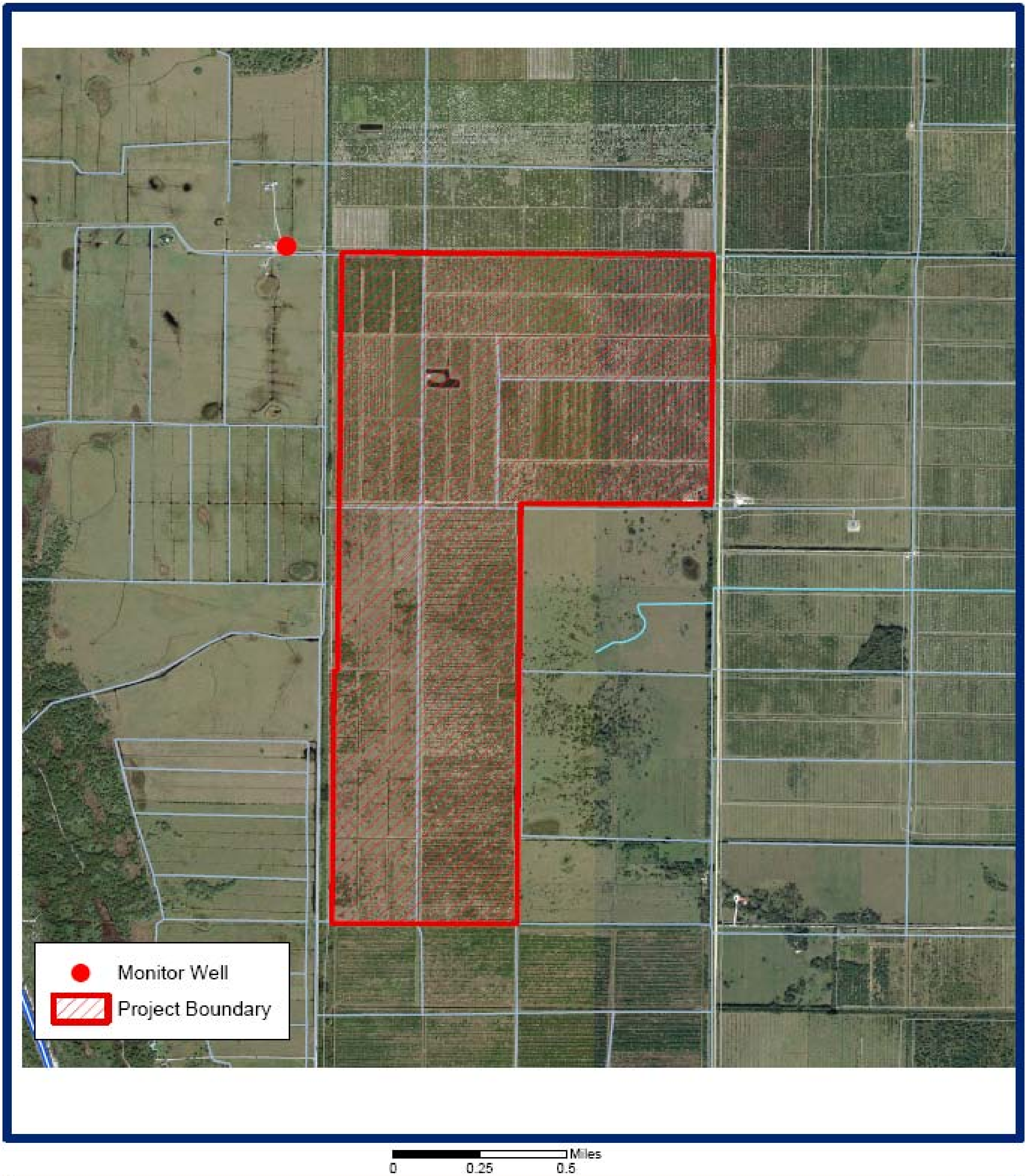


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Figure 10
Location of the Corrigan Ranch
Monitor Well

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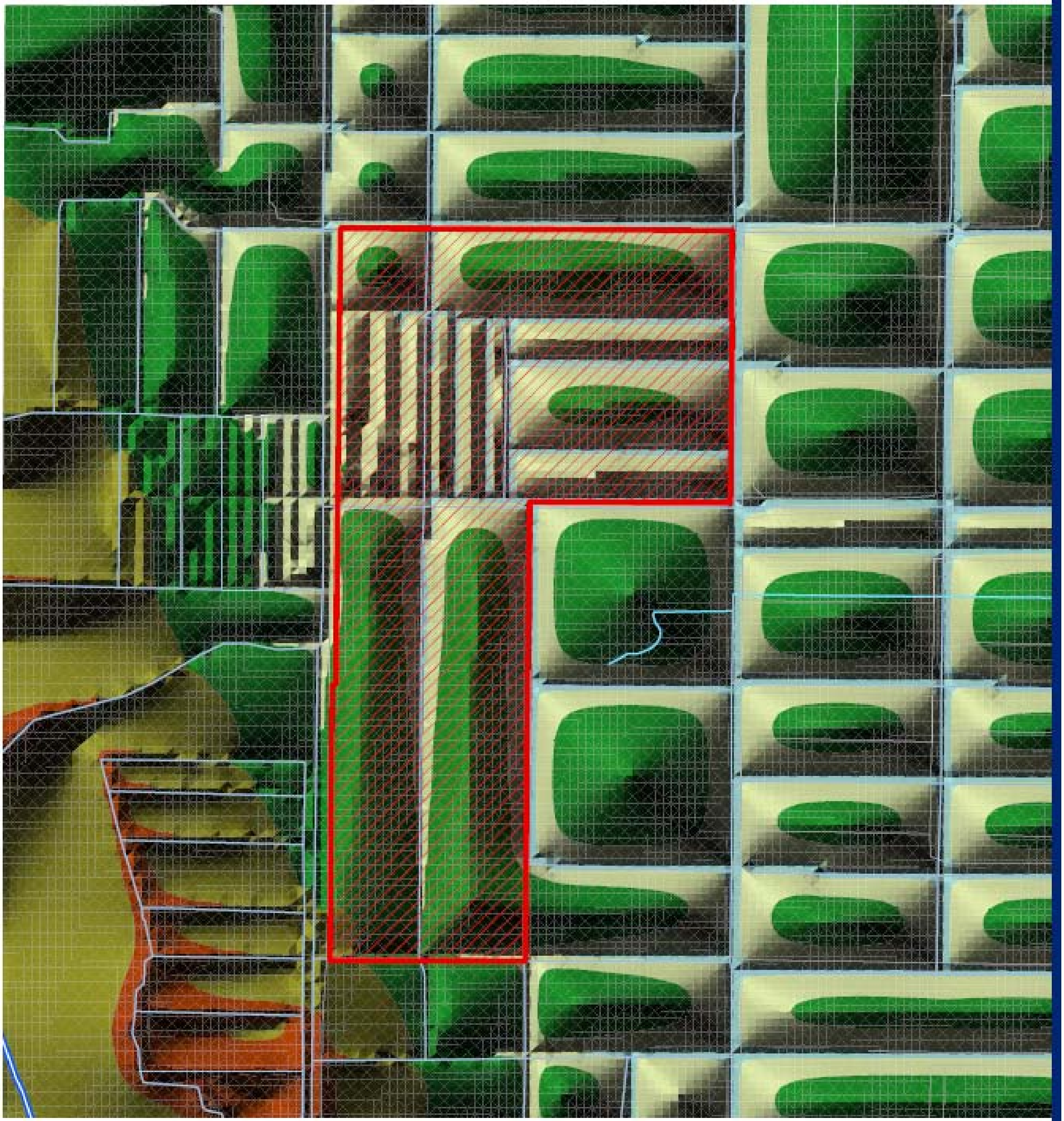

🟥 Project Boundary

Water Table Elevation (ft NGVD)

⬜	23.932 - 24.857
⬜	23.007 - 23.932
🟫	22.082 - 23.007
🟫	21.157 - 22.082
🟧	20.232 - 21.157
🟨	19.307 - 20.232
🟩	18.382 - 19.307
🟨	17.457 - 18.382
🟦	16.531 - 17.457

File Path:

Figure 11. Simulated Pre-Mined Water Table Elevations Using MODFLOW

0 0.25 0.5 Miles

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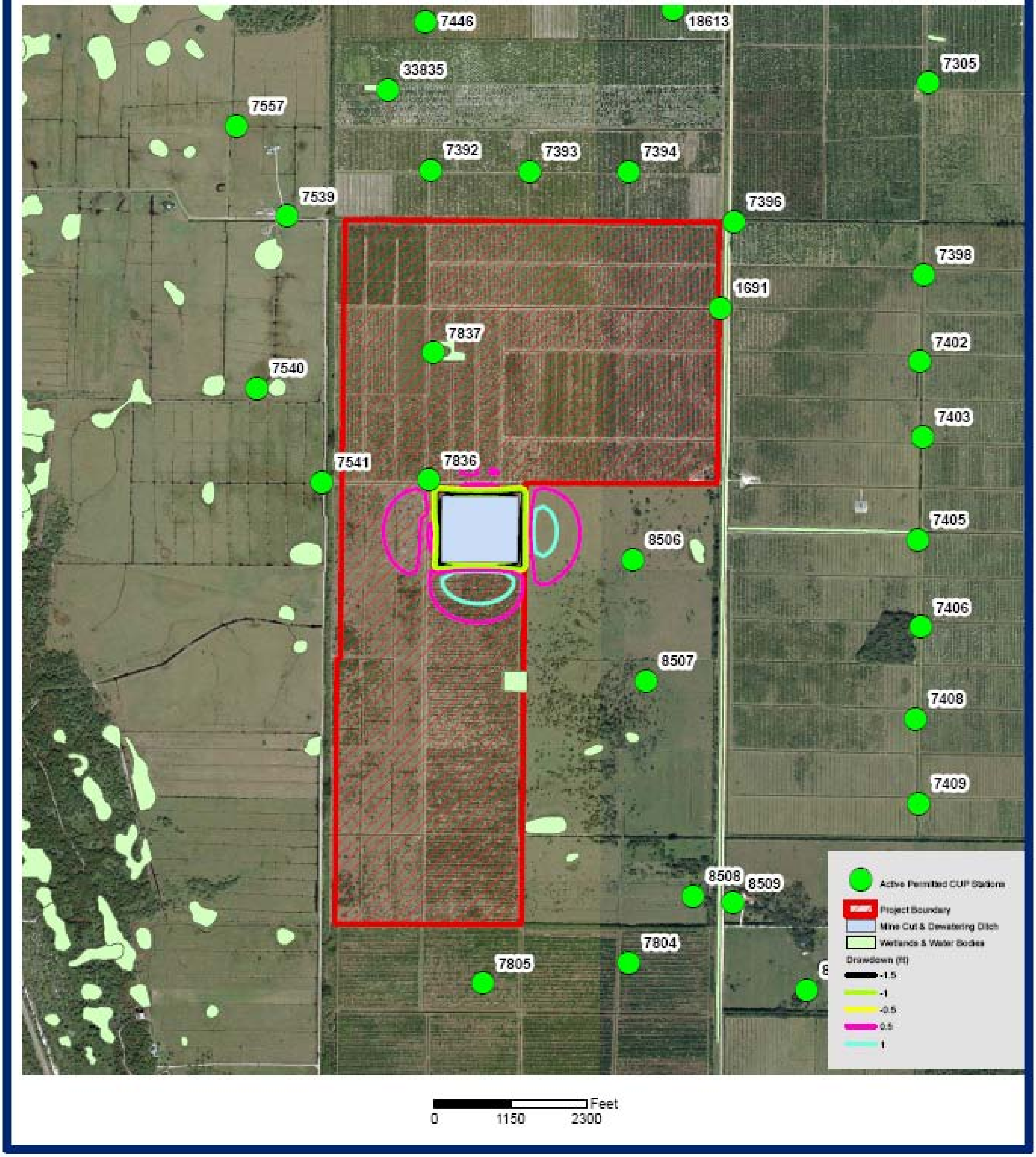

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Figure 12. Simulated Drawdown with Active Mining Using MODFLOW

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