TTL
2743-B Gunter Park Drive West
Montgomery, AL 36109
334.244.0766
www.TTLUSA.com

TRANSMITTAL

TO: Georgia Environmental Protection Division
Water Supply Program – Groundwater Withdrawal Unit
2 Martin Luther King Jr. Dr., S.E.
East Floyd Towers, Suite 1362
Atlanta, GA 30334-9000

DATE: July 24, 2019

ATTN: Mr. Bill Frechette

PROJECT:

Application for Industrial Groundwater Withdrawal Permit
Twin Pines Minerals, LLC
Saunders Mine

WE ARE SENDING:

One copy to Mark Fowler at Twin Pines Minerals, LLC

REMARKS:

If you have any questions, please call me at (334) 244-0766.

TTL, INC.

Sheryle G. Reeves, Professional Engineer

APPLICATION FOR INDUSTRIAL GROUNDWATER WITHDRAWAL PERMIT
TWIN PINES MINERALS, LLC
SAUNDERS MINE

Twin Pines Minerals, LLC

Submitted To:

Georgia Environmental Protection Division
Water Supply Program – Groundwater Withdrawl Unit
2 Martin Luther King Jr. Dr., S.E.
East Floyd Towers, Suite 1362
Atlanta, GA 30334-9000

Prepared for:

Twin Pines Minerals, LLC
2100 Southbridge Parkway, Suite 540
Birmingham, AL 35209

Prepared by:

TTL, Inc.
3516 Greensboro Avenue
Tuscaloosa, Alabama 35401

Project No. 000180200804.00

July 22, 2019

TTL

Georgia Environmental Prot

Application for a Permit to Use Groundwater

Part A – General System Information

(Part A must be accompanied by one copy of the Part B – Well Data form for each well in your system)

☒ New Permit

☐ Renewal

☐ Modify Existing GW Withdrawal Permit No. *Please enter GW Withdrawal Permit No.* ___-____

(Print or type ALL information)

Applicant Information

Contact Person: Steven R. Ingle	Phone: 205-545-8759 Fax: 205-518-8388	Email: single@twinpinesminerals.com

Company / Permittee: Twin Pines Minerals, LLC

Permittee Address: 2100 Southbridge Parkway, Suite 540 (No. and Street) Brimingham (City) Alabama (State) 35209 (Zip)

Water Use Name & Address (if different than above): Twin Pines Minerals, LLC- Saunders Mine, GA-94, St. George, GA

Permit For:

Monthly Average Withdrawal Limit requested: 1,440,000 per well; total 4,320,000 Gallons Per Day (GPD)

Annual Average Withdrawal Limit requested: 1,440,000 per well; total 4,320,000 Gallons Per Day (GPD)

For a beneficial use of Make-up water gallons of water per day, to be pumped from 3 well(s)

Averaging 24 hours pumping per day utilizing the Floridan aquifer(s) for a

☐ Consumptive use **OR**

☒ Nonconsumptive use

For...

☐ Sanitary Facilities

☐ Central Water Supply

☐ Cooling Water

☒ Process Water for Minerals mining processing

☐ Other (please specify) _____

Location Map

County where well(s) is located: Charlton County

All applications shall be accompanied by a map showing the location of the existing and proposed well(s); each well to be identified by number. The location map shall be the best map available, which may be a portion or a copy of a U.S. Geological Survey 7.5 min. quadrangle map, or latest county highway MAP, or city MAP, provided the submitted map is properly identified and should be no larger than 8½ x 11 inches.

And such other pertinent information submitted by the applicant or required by the Division.

Steven R. Ingle
Print or Type Name

[signature]
Sign Name

PRESIDENT
Title

7-22-19
Date

Return Application To:
Georgia Environmental Protection Division
Water Supply Program
Groundwater Withdrawal Unit
2 Martin Luther King Jr. Dr., S.E.
East Floyd Towers, Suite 1362
Atlanta, Georgia 30334-9000
Fax: (404) 651-9590

Georgia Environmental Protection
Department of Natural Resources

Application for a Permit to Use Groundwater

Part B – Well Data

(Submit one (1) form for each well in the system)

(Print or type ALL information)

Applicant Information

Contact Person: Steven R. Ingle	Phone: 205-545-8759 Fax: 205-518-8388	Email: single@twinpinesminerals.com
Company / Permittee: Twin Pines Minerals, LLC		

Address: 2100 Southbridge Parkway, Suite 540	Brimingham	Alabama	35209
(No. and Street)	(City)	(State)	(Zip)

Well Information:

Well No.: 1 (Key to attached location map)	Ground elevation at well (if available): ______
County where well(s) is located: Charlton County	Latitude: ______ Longitude: ______

Well Construction Description

☐ Existing well ☒ Proposed well

Name of aquifer(s) being or to be utilized Floridan

Well Drilling Information					☒ Rotary ☐ Percussion ☐ Bored			
Total depth of well: 650		ft.			Date drilled:			
Static water level: 93		ft.			Date to be drilled:			
					Driller:			
Drill Hole Diameter					**Grouting**			
Size 23	in., from	0	ft. to 125	ft.	☒ Yes ☐ No			
Size 17	in., from	125	ft. to 475	ft.	Type			
Size 11.5	in., from	475	ft. to 650	ft.	From 0	ft. to 125	ft.	
Size	in., from		ft. to	ft.	From 125	ft. to 475	ft.	
Size	in., from		ft. to	ft.	From	ft. to	ft.	
Casing Record					**Test Pump Data**			
Type material Carbon Steel					Pumped		Bailed	
Wall thickness					Estimated			
Weight/Foot					Date tested			
Size 18	in., from	0	ft. to 125	ft.	Pump rated	GPM		HP
Size 12	in., from	125	ft. to 475	ft.	Pump yield	GPM after		hrs of pumping
Size	in., from		ft. to	ft.	Water level before test	ft.		
Size	in., from		ft. to	ft.	Drawdown	ft.		
Size	in., from		ft. to	ft.	Specific Capacity	GPM/ft.		
Well Screen					**Permanent Pump Data (if available)**			
Type material NA					Pump type line shaft			
Size	in., from		ft. to	ft.	Outlet size			
Size	in., from		ft. to	ft.	Powered by			
Size	in., from		ft. to	ft.	Horsepower			
Size	in., from		ft. to	ft.	Rate 1000 GPM			
Size	in., from		ft. to	ft.	Pumping level			
					Average hours pumped per day 24			

Note: Detailed well construction specifications of a proposed well may be required by the Division upon review of the submitted application.

Complete WELL LOG on reverse side, if available.

Georgia Environmental Protection
Department of Natural Resources

Application for a Permit to Use Groundwater

Part B – Well Data

(Submit one (1) form for each well in the system)

(Print or type ALL information)

Applicant Information

Contact Person: Steve Ingle	Phone: 205-545-8759 Fax: 205-518-8388	Email: single@twinpinesminerals.com

Company / Permittee: Twin Pines Minerals, LLC

Address: 2100 Southbridge Parkway, Suite 540	Brimingham	Alabama	35209
(No. and Street)	(City)	(State)	(Zip)

Well Information:

Well No.: 2 (Key to attached location map)	Ground elevation at well (if available): _____
County where well(s) is located: Charlton County	Latitude: _____ Longitude: _____

Well Construction Description

☐ Existing well ☒ Proposed well

Name of aquifer(s) being or to be utilized Floridan

Well Drilling Information	☒ Rotary ☐ Percussion ☐ Bored
Total depth of well: 650 ft.	Date drilled:
Static water level: 93 ft.	Date to be drilled:
	Driller:
Drill Hole Diameter	**Grouting**
Size 23 in., from 0 ft. to 125 ft.	☒ Yes ☐ No
Size 17 in., from 125 ft. to 475 ft.	Type
Size 11.5 in., from 475 ft. to 650 ft.	From 0 ft. to 125 ft.
Size in., from ft. to ft.	From 125 ft. to 475 ft.
Size in., from ft. to ft.	From ft. to ft.
Casing Record	**Test Pump Data**
Type material Carbon Steel	Pumped Bailed
Wall thickness	Estimated
Weight/Foot	Date tested
Size 18 in., from 0 ft. to 125 ft.	Pump rated GPM HP
Size 12 in., from 125 ft. to 475 ft.	Pump yield GPM after hrs of pumping
Size in., from ft. to ft.	Water level before test ft.
Size in., from ft. to ft.	Drawdown ft.
Size in., from ft. to ft.	Specific Capacity GPM/ft.
Well Screen	**Permanent Pump Data (if available)**
Type material NA	Pump type line shaft
Size in., from ft. to ft.	Outlet size
Size in., from ft. to ft.	Powered by
Size in., from ft. to ft.	Horsepower
Size in., from ft. to ft.	Rate 1000 GPM
Size in., from ft. to ft.	Pumping level
	Average hours pumped per day 24

Note: Detailed well construction specifications of a proposed well may be required by the Division upon review of the submitted application.

Complete WELL LOG on reverse side, if available.

Georgia Environmental Protection
Department of Natural Resources

Application for a Permit to Use Groundwater

Part B – Well Data

(Submit one (1) form for each well in the system)

(Print or type ALL information)

Applicant Information

Contact Person: Steve Ingle	Phone: 205-545-8759 Fax: 205-518-8388	Email: single@twinpinesminerals.com
Company / Permittee: Twin Pines Minerals, LLC		

Address: 2100 Southbridge Parkway, Suite 540	Brimingham	Alabama	35209
(No. and Street)	(City)	(State)	(Zip)

Well Information:

Well No.: 3 (Key to attached location map)	Ground elevation at well (if available): ______
County where well(s) is located: Charlton County	Latitude: ______ Longitude: ______

Well Construction Description

☐ Existing well ☒ Proposed well

Name of aquifer(s) being or to be utilized Floridan

Well Drilling Information	☒ Rotary ☐ Percussion ☐ Bored
Total depth of well: 650 ft.	Date drilled:
Static water level: 93 ft.	Date to be drilled:
	Driller:
Drill Hole Diameter	**Grouting**
Size 23 in., from 0 ft. to 125 ft.	☒ Yes ☐ No
Size 17 in., from 125 ft. to 475 ft.	Type
Size 11.5 in., from 475 ft. to 650 ft.	From 0 ft. to 125 ft.
Size in., from ft. to ft.	From 125 ft. to 475 ft.
Size in., from ft. to ft.	From ft. to ft.
Casing Record	**Test Pump Data**
Type material Carbon Steel	Pumped Bailed
Wall thickness	Estimated
Weight/Foot	Date tested
Size 18 in., from 0 ft. to 125 ft.	Pump rated GPM HP
Size 12 in., from 125 ft. to 475 ft.	Pump yield GPM after hrs of pumping
Size in., from ft. to ft.	Water level before test ft.
Size in., from ft. to ft.	Drawdown ft.
Size in., from ft. to ft.	Specific Capacity GPM/ft.
Well Screen	**Permanent Pump Data (if available)**
Type material NA	Pump type line shaft
Size in., from ft. to ft.	Outlet size
Size in., from ft. to ft.	Powered by
Size in., from ft. to ft.	Horsepower
Size in., from ft. to ft.	Rate 1000 GPM
Size in., from ft. to ft.	Pumping level
	Average hours pumped per day 24

Note: Detailed well construction specifications of a proposed well may be required by the Division upon review of the submitted application.

Complete WELL LOG on reverse side, if available.

TWIN PINES, LLC – SAUNDERS MINE
GROUNDWATER USE APPLICATION

Twin Pines Minerals, LLC

TWIN PINES MINERALS
PROPOSED HEAVY MINERALS MINE
SAINT GEORGE, CHARLTON COUNTY, GEORGIA

Prepared for:

Twin Pines Minerals, LLC
2100 Southbridge Parkway, Suite 540
Birmingham, AL 35209

Prepared by:

TTL, Inc.
3516 Greensboro Avenue
Tuscaloosa, Alabama 35401

Project No. 000180200804.00, Phase 0300

July 22, 2019

TTL

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FIGURES

ATTACHMENTS

1 INTRODUCTION

Twin Pines Minerals, LLC (Twin Pines), is an Alabama-based minerals mining company proposing to mine heavy mineral sands (HMS) sedimentary deposits, which occupy a portion of a relict beach ridge along Trail Ridge in Charlton County. Twin Pines contracted TTL, Inc. (TTL) to assist in completing and submitting this application for a Groundwater Use Permit to use groundwater as part of the operations to mine and extract HMS from the deposit at the proposed Saunders Mine located near Saint George, Georgia in Charlton County. The proposed mining project consists of approximately 2,414-acres as depicted on the U.S. Geological Survey (USGS) 7.5-minute Topographic Maps of Moniac, Georgia and Saint George, Georgia (Figure 1). An aerial photographic map with site location is also included as Figure 2. The center of the site is located near latitude 30.52490044 and longitude -82.12419891. According to the USGS Topographic Map, the elevation at the site ranges from approximately 120 to 175 feet above mean sea level. The Twin Pines' project includes the extraction of the high-quality HMS reserves in a safe, cost effective and environmentally sound manner for export by truck, rail and eventual barge to national and international customers. The principal heavy minerals to be extracted in this proposed HMS operation are zircon, titanium minerals (ilmenite, leucoxene, rutile), and staurolite.

The proposed mining area is separated into three mining blocks and an area of avoidance (no mining). The TIAA Mining Block consists of approximately 216 acres, Keystone Mining Block approximately 570 acres, Adirondack Mining Block approximately 481 acres, and the area of avoidance approximately 1,147 acres. Figure 3 depicts the mining blocks and area of avoidance. Twin Pines expects to mine approximately 25-40 acres per month and produce an HMS concentrate on-site. Mineral sands, titanium minerals - ilmenite, leucoxene and rutile, zircon, and staurolite occur in the upper 50 feet of sand in the Trail Ridge physiographic landform, which is an ancient beach ridge in Charlton County. After the HMS products have been separated, the final products will be containerized, bulk shipped or loaded on truck or rail dependent upon customer requirements. The total proposed mined acreage is 1,267 acres.

Twin Pines expects to begin construction upon obtaining the required authorizations and mining operations are expected to be conducted for an 8-year period. The proposed mining operation is expected to provide approximately 150-200 direct jobs and additional supporting subcontractor jobs.

Twin Pines is committed to protecting the environment and minimizing impacts to local citizens. Current work at the site includes the initial environmental screening to assess baseline conditions, developing an effective water management strategy, and identifying other environmental and operational concerns. The northern boundary of the site is located approximately 3.73 miles southeast from the nearest boundary of the Okefenokee Swamp National Wildlife Refuge, providing a substantial buffer of protection for this sensitive resource. Twin Pines reclamation plans are to restore land uses to the original pre-mining conditions, planted pine, as the site has been in silvicultural (timber) operations for many years. The reclamation process will begin immediately after mining in individual dragline cuts have been completed. Within 30 days of mining, the drag line cuts will be refilled with sand tailings. Thereafter, topsoil will be replaced to stabilize the reclaimed area and trees will be replanted within an 18-24 month period, depending on the planting season.

The proposed mining operation is designed to be water-efficient by recycling and recirculating water to minimize the amount required from the Upper Floridan Aquifer. Water will not be withdrawn from any natural surface water body. Sources for mine process water will include managing and reusing stormwater and withdrawals from the Upper Floridan Aquifer (UFA).

Twin Pines will operate the mine to be a low-impact neighbor to nearby residents. The active mining area will be designed so it will be bordered by a berm and/or forested buffers to minimize potential disturbances (noise and dust) as per the Surface Mining Land Use Plan (SMLUP) submitted to Georgia Environmental Protection Division Surface Mining Unit. Twin Pines has been in contact with area stakeholders, including Charlton County, Georgia EPD, and concerned citizens during the planning process for the proposed mine.

2 PURPOSE AND NEED

Twin Pines' purpose and need for the proposed mining project includes the extraction (maximum mineral recovery based on economic consideration and landowner commitments) of high quality heavy mineral reserves in a safe, cost effective and environmentally sound manner for export by truck, rail and eventual barge to national and international customers.

Mineral sand-derived products, particularly those containing titanium dioxide and zirconium, are in high demand worldwide in the pigment, aerospace, medical, foundry, and other industrial products. Elemental components, chiefly titanium, are used as the white pigments. Titanium dioxide is nontoxic and has replaced lead as the predominant pigment in paints and coatings.

Many deposits of HMS have been identified in the Atlantic Coastal Plain, including more than a dozen deposits that have been mined. Three Atlantic Coastal Plain districts have seen the bulk of the heavy mineral sands production and these districts are: (1) the Jacksonville district in northeastern Florida and southeastern Georgia, (2) a sequence of deposits along the Fall Zone in southeastern Virginia, and (3) the Lakehurst district in southern New Jersey. HMS are sediments containing dense (heavy) minerals that accumulate with sand, silt, and clay in coastal environments locally forming economic concentrations of heavy minerals.

Considerable resources of HMS in the form of detrital grains of titanium, ilmenite, leucoxene, and rutile, could exist in large areas of the Atlantic Coastal Plain. These heavy mineral sand deposits represent possible domestic sources of titanium that have yet to be developed. Identifying potential domestic resources of titanium is useful because titanium has significant industrial applications, and because the great majority of titanium mineral concentrates consumed in the U.S. are imported (91 percent in 2016; Ober, 2017). Only two HMS mining operations are currently (as of 2017) active in the U.S., due to closure of the HMS mines in southern Virginia.

Many prospective areas for HMS deposits in the Atlantic Coastal Plain occur near the modern shores or on barrier islands, for example, the coasts of South Carolina, southeastern Georgia, and northeastern Florida. Much of the modern coastal areas are covered by infrastructure. Thus, land-use and permitting considerations may limit mineral development along the modern coast.

2.1 General Description of the Mining Process

2.1.1 Introduction

Twin Pines has developed a mineral sand mining technique using a dragline excavator and/or conventional excavator/dozer trap, conveyor system for materials transport, and land-based permanent processing plants. This mining technique is different from conventional "wet mining", which utilizes a dredge and floating concentrator to mine and process heavy mineral-bearing sands. Dragline mining involves a large crane-like earthmoving machine equipped with a bucket to scoop material. Draglines can efficiently move large quantities of material. A large-capacity bucket swings from cables on the end of the boom, scooping material that is then moved to adjacent areas. Draglines are electrically powered and run by two employees, an operator and an oiler. When mining is occurring measures must be taken to protect the areas adjacent to the mine property. Berms are constructed to ensure that muddy water does not leave the mine property and affect local waterways.

A conveyor system is utilized to transport mined material to the mineral processing plants. The mineral processing plant locations are depicted on Figure 4. The mineral processing plant locations allow mineral processing activities to be located in a central location of the mining blocks, which decreases material transport distance and energy demands. Recycled process water ponds will also be constructed adjacent to each processing plant creating an efficient method for process water reuse and recirculation. Attachment A depicts the Saunders Mine - Process Flow Diagram. The flow diagram depicts the process water and mined materials flow through the mineral processing facility for the proposed mining and mineral processing operation under normal operating conditions.

Mining will commence after the topsoil is removed from the mining area. Once the topsoil removal process has been completed the conveyor system will be installed. The dragline excavator will then excavate and temporarily stockpile the mined material. The material will then be transferred onto the conveyor system for transport to the processing plant. After processing the tailings will be temporarily stockpiled adjacent to the processing plant. The tailings material will then be transported back to the open mining cut via a tailings conveyor system. The reclamation area will then be recontoured, covered with topsoil and revegetated to meet reclamation standards. The operation is a continuous process and while the dragline is operating, backfilling of the cut is occurring as well once the operation gets under way. On the TIAA Mining Block of the proposed mining area, excavator/dozer trap mining method will be utilized, instead of the dragline method, due to the shallower depth of mineral resource.

2.1.2 Mine Progression

The mining sequence will be divided into separate phases, which will be active concurrently within each mining block. The activities are described as follows:

Site Preparation
- Clearing
- Topsoil Removal
- Construction of Permanent processing plants and infrastructure

Mining
- Excavation
- Heavy Mineral Sand Processing

Reclamation

- Tailings Return/Placement
- Tailings Contouring to mimic per-mining topography
- Topsoil Return
- Planting

2.1.3 Site Preparation

To initiate mining activities, the project area will be delineated by survey markers and flagging in the field. A pre-mining survey based off of LiDAR will be used to create a topographic surface that will serve as a guide for design elevations for all post-mining reclamation. All merchantable timber will be harvested prior to mining activities. Timber will be harvested on average 4 to 6 months prior to mining. Timber that is not merchantable and timber scraps will be removed by Twin Pines and all areas within the limits of clearing and mining will be root raked, windrowed, and stockpiled for use during the reclamation process.

After the area has been cleared; the permanent processing facilities and infrastructure will be constructed/installed along with the berms, stormwater ponds, and other best management practices for sediment control. The berms will be constructed along the perimeter of the disturbed area to mitigate erosion and contain stormwater. Generally, 6 inches of topsoil within each mining area will be removed by heavy equipment and transported to the berms/topsoil storage piles around the perimeter of the mining area. Additionally, silt fencing and hay bales will also be utilized in appropriate locations for additional erosion control.

The topsoil storage piles/mining perimeter berms will serve to prevent stormwater runoff and muddy water within the active cut from leaving the site as well as preserve "seed banks" for native vegetation and a planting medium for later reclamation. Topsoil removal will be conducted two to six months in advance mining activities. The topsoil storage piles will be stabilized with an internal three horizontal to one vertical (3H:1V slope) and an external four horizontal to one vertical (4H:1V) slopes and seeded to prevent erosion. As noted previously, silt screens and hay bales will be utilized along the outside of the topsoil storage piles to control post construction erosion.

The permanent processing plants and conveyor systems, which are discussed in detail in Section 2.1.4, will also be constructed during site preparation phase. A recycled process water pond will be constructed adjacent to each processing plant. The process water ponds will be designed to maintain a volume of water to operate the PCP for approximately 48-hours without the addition of make-up water. Twin Pines will also install a well into the UFA at each processing plant to provide the needed make up water to operate the PCP.

2.1.4 Excavation, Processing, and Tailings Return

2.1.4.1 Keystone Mining Block and Adirondack Mining Block

Excavation of the mining cuts will commence after the topsoil is removed. The dragline mining process proceeds as follows: The dragline moves through the mining area excavating approximately 100-foot wide cuts, in an east to west or west to east direction as shown on Figure 5. The excavated material is stockpiled nearby. It is then transferred to an apron feeder which feeds to a screen. This screen removes roots and other large objects. The material is then transferred to a pit/feed conveyor system.

The oversized organic material removed by the screen will be placed near the screen area for future deposit during the reclamation process. The pit/feed conveyor system feeds a mainline feed conveyor system. The mainline feed conveyor system will incline (or feed a stacker conveyor) and then feed the trommel (screen). The trommel feeds the Pre-Concentration Plant (PCP).

In the PCP, spiral centrifuges concentrate and separate the heavy mineral sands from the lighter clays and quartz sand and then feeds the Wet Concentration Plant. The Wet Concentration Plant (WCP) further reduces and separates the material for processing. The material from the WCP is transported to the Mineral Separation Plant (MSP). The MSP separates valuable and non-valuable mineral products such as zircon, staurolite, rutile, ilmenite, etc. After products have been separated, the final products will be containerized, bulk shipped or loaded on truck or rail dependent upon customer requirements.

The tailings from the PCP/WCP will be temporarily stockpiled. Tailings will then be loaded onto the mainline tails conveyor system. The mainline tails conveyor system will convey material onto a reclamation conveyor. The reclamation conveyor deposits the tailings back into the mined area for reclamation.

2.1.4.2 TIAA Mining Block

On the TIAA portion of the proposed mining area, the excavator/dozer trap mining method will be utilized due to the shallower depth, less than 30 feet below ground surface, of mineral resource. This method has a limited reach, depending on the machine. It also has a lower excavation and production rate. There is more frequent relocation of the machine which results in lost production due to the relocation time.

The mining process proceeds as follows: Once the topsoil is removed and placed in berms at the perimeter of the mining area. The mining unit (excavator/backhoe/dozer trap) will mine the material and feed a screen. The material is then transferred to a pit/feed conveyor system. The oversized organic material removed by the screen will be placed near the screen area for future deposit during the reclamation process. The pit/feed conveyor system feeds a mainline feed conveyor system. The mainline feed conveyor system will incline (or feed a stacker conveyor) and then feed the trommel (screen). The trommel feeds the Pre-Concentration Plant (PCP). Once at the PCP, the process proceeds as described in Section 1.2.4.1.

2.1.5 Reclamation

As part of reclamation the tailings are transported from their stockpiles to the open mined area where they are deposited. The area will then be re-graded and contoured to mimic pre mining contours, based upon the pre-mining survey. After the tailings are contoured and levels reach approximate pre-mining topography, the topsoil will be replaced. The operation is a continuous process, while the dragline is operating, backfilling of the pit is occurring as well once the mining operation gets under way. A cross-section view of the dragline cut and backfill, perpendicular to direction of the draggling movement, is shown in Figure 6.

The topsoil contains native seeds, roots, and tubers which will be sufficient to re-establish vegetation and ground cover on the reclaimed land. Tree planting will be conducted during the winter months and the tree species and planting density will be based on landowner specifications (TIAA Block) or permit requirements, whichever takes precedence. Once planted, monitoring will be conducted according to permit requirements until the reclamation meets success criteria. Once the reclaimed areas meet success criteria, the appropriate regulatory agency will be petitioned for release from further monitoring.

3 WELL SURVEY

TTL conducted a well survey to determine location of public and/or private supply wells located adjacent to the proposed Saunders Mine. TTL contacted the Charlton County Health Department, Environmental Health Division for supply well information in the area. Charlton County reported no public supply wells are located in the vicinity of the proposed Saunders Mine. Charlton County representatives indicated that most all residences in the area would be on well water since there were no public water utilities in the area.

TTL contacted a local licensed professional water well driller. The driller indicated that domestic supply wells in the area would most likely be constructed to depths of about 100 to 140 feet below ground surface, into the Intermediate Aquifer within the Upper Hawthorn Group sediments.

TTL also contacted Fulghum Fibers, a wood chipping mill located approximately 1 mile east of the proposed Saunders Mine. A representative for Fulghum Fibers stated that they have three operating potable water wells on-site, though he did not have well construction details for the wells.

In order to determine the location and estimated number of private domestic supply wells that would be located adjacent to the proposed Saunders Mine, TTL reviewed the Charlton County Tax Assessor maps to identify adjacent residences. Under the assumption that every residential structure (not including utility type buildings) would have a domestic supply well, the following table lists the inventory of estimated well sites by street address. Based on this survey, there are an estimated 11 private supply wells that would be located in the project vicinity, including the supply wells located at the Fulghum Fibers facility

Address	Number of Structures	Estimated Number of Wells
8006 GA-HWY 94	1	1
8024 GA-HWY 94	1	1
8208 GA-HWY 94	1	1
8242 GA-HWY 94	2	2
8296 GA-HWY 94	1	1
8374 GA-HWY 94	1	1
8422 GA-HWY 94	1	1
8906 GA-HWY 94	NA (Chip Mill)	3
	Total Estimated Wells	**11**

4 WATER CONSERVATION PLAN

The objective of Twin Pines Saunders Mine Water Conservation Plan is to minimize water use and maximize water recycling and recirculation. The Water Conservation Plan will be utilized to set site operating policies and procedures.

4.1 Water Conservation Policy

Potable, drinking water, and other water sources, like other natural resources, are limited and must be conserved. Twin Pines is committed to conserving water at its operations and will also conserve water in its Charlton County mining operation. The Saunders Mine operation will be essentially a closed-loop system. The proposed mining operation is designed to be water-efficient by recycling and re-circulating water to minimize the amount of make-up water required from the Upper Floridan Aquifer.

The proposed Water Conservation Plan at the Twin Pines Saunders Mine will be to minimize the amount of make-up water (MUW) by recycling and reusing water. Water losses will be to evaporation and infiltration of water in the tailings/reclamation cut, with minor amounts of water retained in the final product.

Pipelines transporting water at the PCPs will be inspected on a regular basis as part of the daily operations and maintenance program. Pipelines will be above ground, expediting leak detection. Leaks will be immediately repaired in an effort to conserve water. Meters will be installed at various points in the process loop in order to manage mineral production and water use. Meters will be maintained, calibrated, and tested according to manufacturer's recommendations.

4.2 Water Flow Throughout Operation

The Process Water Pond will be utilized as the primary water supply to extract and process the ore, tailings, and final heavy mineral product. The MUW use will be based on the amounts of water lost to evaporation and infiltration from the tailings/reclamation cell into the surficial aquifer. Attachment A illustrates the normal operating conditions mine water balance, the process flow and water use for the proposed mining and mineral extraction operations.

Twin Pines will install a well into the Upper Floridan Aquifer at each of the Pre-Concentration Plant locations for the Saunders Mine to provide for a source of MUW for mining activities.

Twin Pines will apply for a Groundwater Use permit, requesting a maximum daily permitted amount from the UFA of 1.44 million gallons per day (mgd), per well for a total of 4.32 mgd at the Saunders Mine. This daily permitted amount from the production wells in the UFA is for an estimated 1000 gallons per minute (gpm) for 24 hours a day to provide make-up water under worst case scenario conditions. Under normal operating conditions Twin Pines estimates pumping approximately 500 gpm to maintain the optimal water volume in the process water pond.

4.3 Estimate of Upper Floridian Aquifer Quantity

The PCP plant is designed for optimum water conservation when compared to the typical "wet mining" process. The PCP plants will be centrally located within the Saunders Mine area. The proposed groundwater use, from the production wells in the UFA, is needed for the operation of the closed-loop processing system to support mineral extraction. This mining technique uses a closed loop system designed for water reuse and recycling. It is estimated that 83% of the water within the system is reused. Approximately 17% is lost to evaporation, retention on processed minerals and infiltration to the surficial aquifer in the tailings/reclamation cell. This process reduces environmental impacts by decreasing UFA withdrawals.

Twin Pines will only pump water from the UFA wells when water is needed to be added to maintain the optimal water volume in the process water pond. Water usage will be monitored by installing flow meters on the production wells in the UFA and throughout the mineral processing system. Twin Pines will perform regular meter maintenance, testing, and calibration to ensure best practice water conservation. Attachment A illustrates the process flow for the proposed mining operations.

4.4 Percentage of Make-Up Water (MUW)

This proposed system at the Saunders Mine operations inherently minimizes the amount of MUW needed by recycling and reusing water. Water losses are primarily due to evaporation and infiltration of water in the tailings back into the Surficial Aquifer (16%) and the remaining moisture in the final product (<1%).

4.5 Water Conservation Measures

Twin Pines will implement the following conservation measures at the proposed Saunders Mine:

- Recycling and reuse of water within the mining system
- Pipeline inspection and detection of leaks,
- Meter maintenance, testing, replacement, calibration,
- Promote a water conservation education program,
- Prevention of unauthorized or excessive water use.

This will be a new mine site using a mining technique that is different from conventional "wet mining", which utilizes a dredge and floating concentrator to mine and process heavy mineral- bearing sands. The "dragline" method is flexible and allows for strategic recovery of existing ore resources. The maximum mining depth is 50 feet. More precision is possible than with typical dredge mining methods. In addition, having the PCPs located in close proximity of the wet processing plant and process water pond allows for concentrating activities in one centralized location, thereby decreasing energy demands and creating an efficient method for process water reuse and recirculation.

Most of the pipelines will be installed above ground and will be inspected on a regular basis. When the mining operation is active, Twin Pines will train their employees to inform them of the importance of water conservation practices at the plant.

4.6 Water Conservation Measures and Upgrades

Conservation measures and improvements are selected based on operational benefit and cost savings. Measures and improvements will be reviewed periodically as part of the audit and review process by site management and those measures deemed appropriate will be implemented.

4.7 Plumbing Ordinances and/or Codes

Twin Pines will be in compliance with applicable plumbing code provisions requiring the use of ultralow flow plumbing fixtures and the installation of other applicable water saving technologies for the water distribution system to support water conservation. However, the proposed Saunders Mine will not be operating a water system and therefore will not be enforcing plumbing ordinances.

4.8 Recycle-Reuse

The proposed system at the Saunders Mine operations inherently minimizes the amount of unaccounted for water by recycling and reusing water. Attachment A depicts the process flow diagram and details how the process water is recycled and re-used.

4.9 Progress Reports

The proposed Saunders Mine is planning on operating for approximately 8 years. Twin Pines will submit a water conservation progress report every five (5) years of operation to the Georgia Environmental Protection Division (EPD) in accordance to Georgia Rule 391-3-2.04(11)(h). The report will outline water use and recycling in the mineral processing closed-loop system, describing improvements and summarizing water conservation activities at the mine.

4.10 Water Use Data

Twin Pines will submit an annual water use data report to the Georgia EPD. The report will include data about the amount of water used during the reporting year including estimates of MUW.

5 GROUNDWATER USAGE

The proposed Twin Pines Saunders Mine is designed to have minimal impact on the surficial aquifer system. The dragline mining method does not require the dewatering of the mining cut during mining operations. Twin Pines will use a closed-loop processing system that will recycle/reuse process to minimize the need for make-up water. Losses of water will consist primarily of evaporation and infiltration into the surficial aquifer system from the tailings stockpile. Make-up water will be sourced from the Upper Floridan Aquifer (UFA).

Twin Pines conducted a groundwater modeling study for the effects on the Upper Floridan Aquifer system during the anticipated 8-year life span of the Saunders Mine (Attachment B). The minimum drawdown simulated by the model in the UFA showed a drawdown of 14.8 feet and a maximum drawdown of 80.8 feet. The model shows that the effect on the aquifer diminishes as the radius from the well increases and significant aquifer recovery is evident after pump shutdown, therefore it is not anticipated that the any adverse effects on the aquifer will occur as a result of this mining project during its lifespan.

6 SIGNATURES OF PROFESSIONALS

Project Professional, T. West White prepared this report, with final senior review by Principal Engineer, Sheryle G. Reeves.

Should you have any questions, please contact either of us at (334)-244-0766.

T. West White
Project Professional

Sheryle G. Reeves, P.E.
Principal Engineer

FIGURES

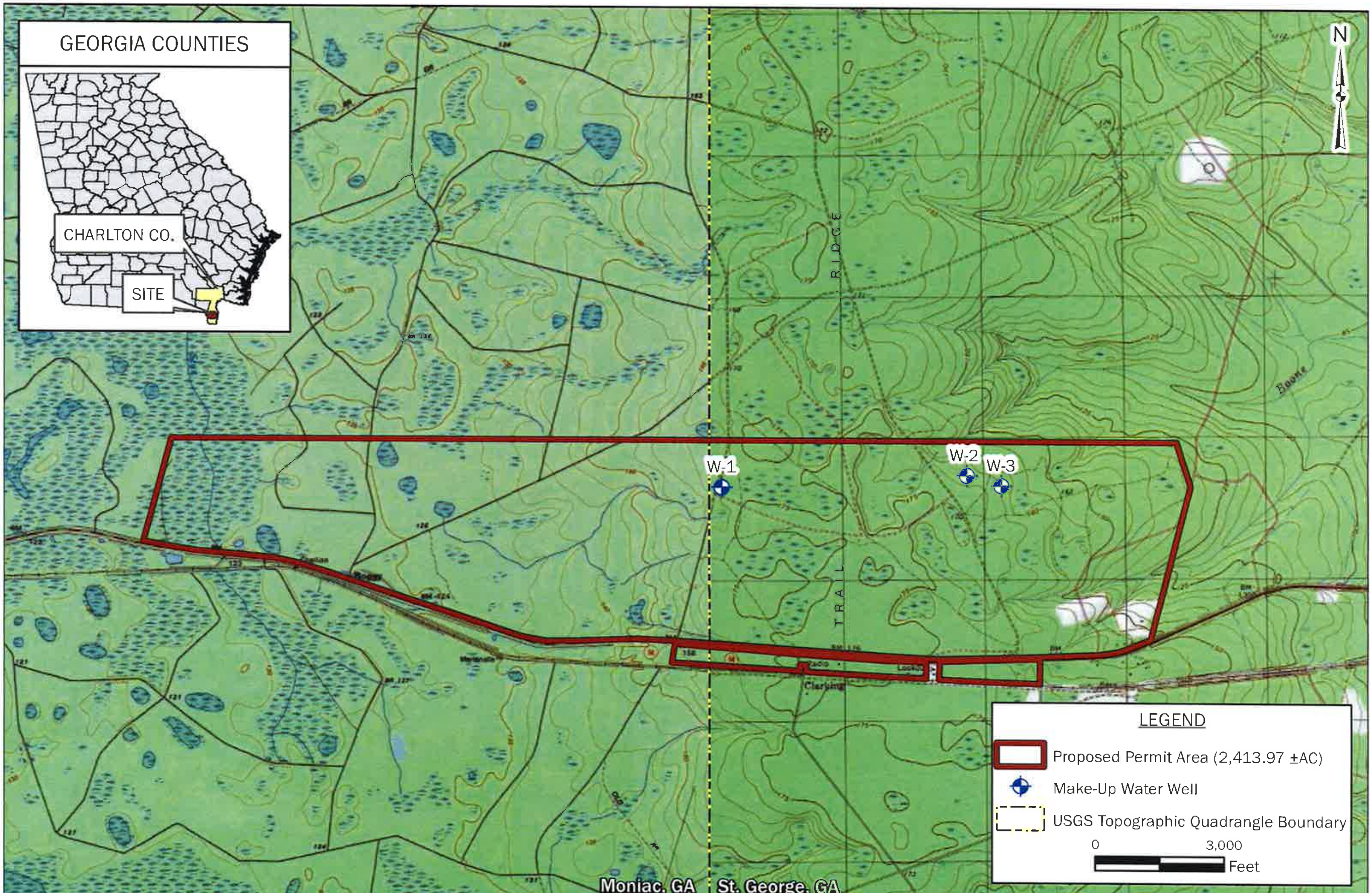

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FIGURE 1: SITE LOCATION & TOPOGRAPHIC MAP

TWIN PINES MINERALS

SAUNDERS MINE

BASEMAP: Moniac, Georgia & Saint George, Georgia USGS 7.5 Minute Quadrangle Map, 1994.

DRAWN BY: CMS
CHECKED BY: WW
DRAWING DATE: 7/23/2019
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROXIMATE SCALE: 1" = 3,000'

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FIGURE 2: SITE LOCATION & AERIAL PHOTOGRAPH

TWIN PINES MINERALS

SAUNDERS MINE

BASEMAP: DigitalGlobe. 1/24/2016 and 9/17/2017.

DRAWN BY:AGW
CHECKED BY: CMS
DRAWING DATE: 7/2/2019
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROXIMATE SCALE: 1" = 3,000'

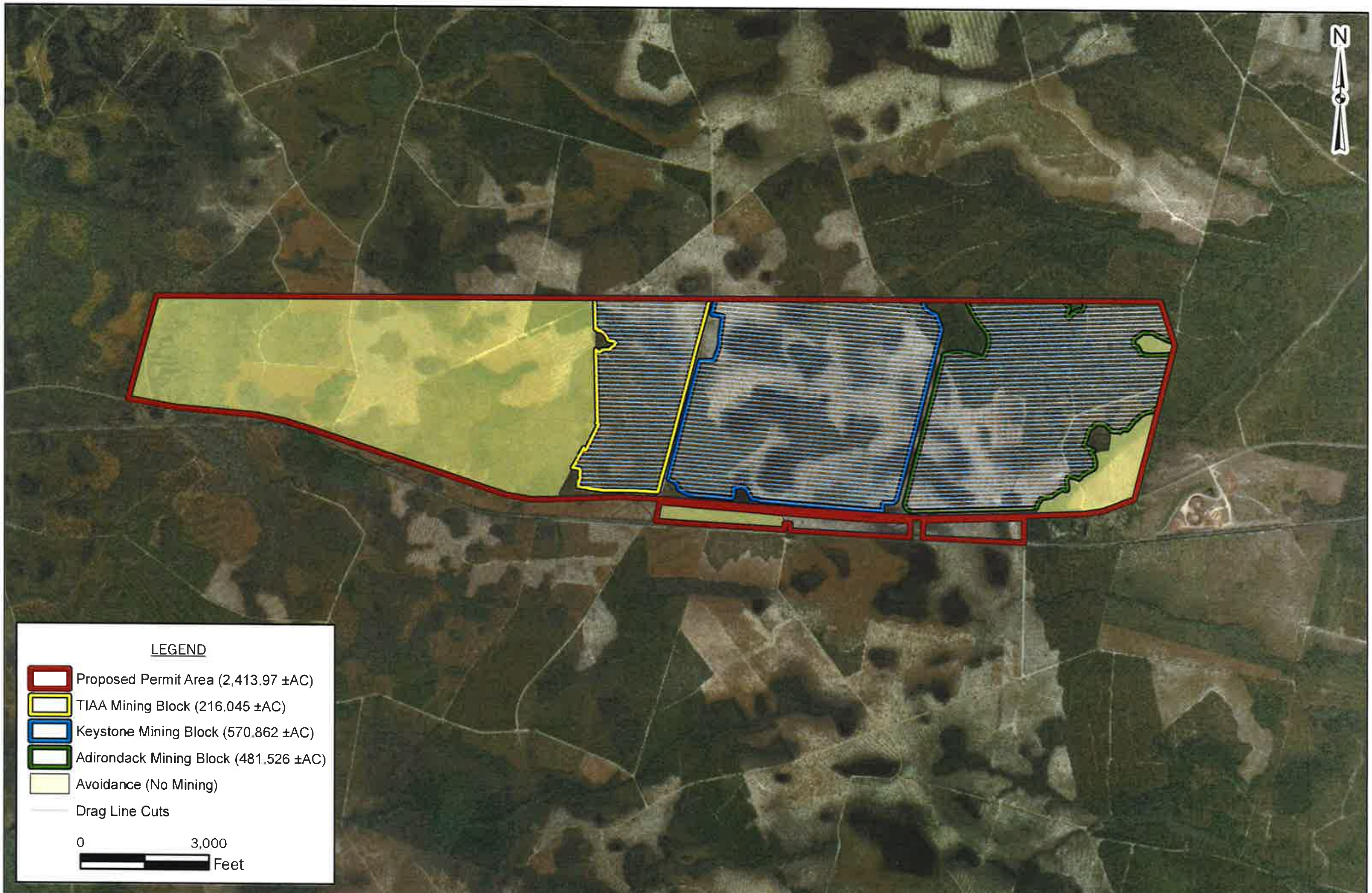

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FIGURE 3: MINING BLOCKS
TWIN PINES MINERALS
SAUNDERS MINE

BASEMAP: DigitalGlobe, 2/15/2018 and 3/24/2018.

DRAWN BY: CMS
CHECKED BY: AGW
DRAWING DATE: 7/2/2019
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROXIMATE SCALE: 1" = 3,000'

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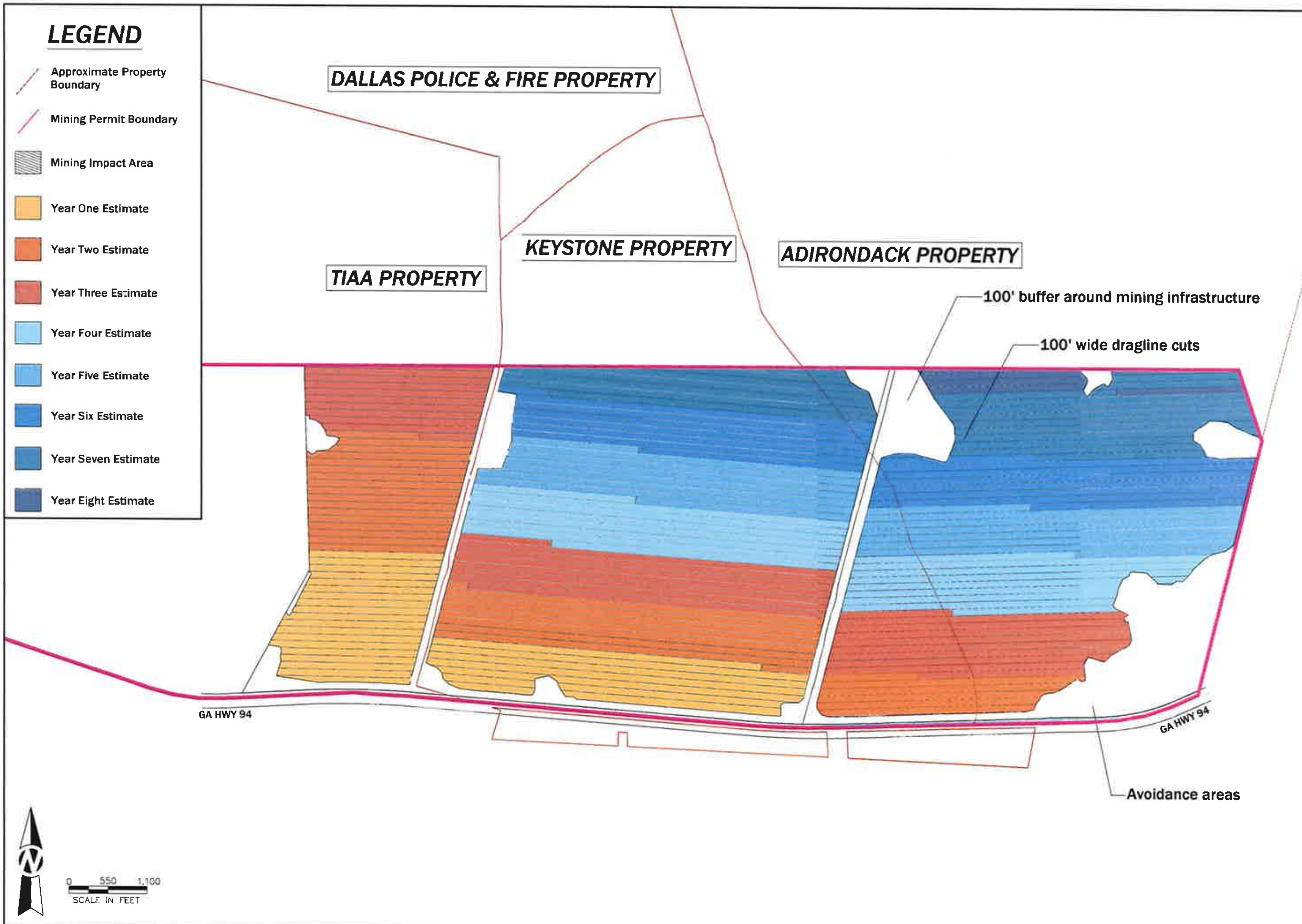
FIGURE 4: PROPOSED SITE LAYOUT MAP

TWIN PINES MINERALS

SAUNDERS MINE

BASEMAP: DigitalGlobe, 1/24/2016 & 9/17/2017.

DRAWN BY: CMS
CHECKED BY: AGW
DRAWING DATE: 6/29/2019
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROXIMATE SCALE: 1" = 1,500'



ESTIMATED MINING PRODUCTION TIMELINE

TWIN PINES MINERALS

SAUNDERS MINE

ST. GEORGE, CHARLTON COUNTY, GEORGIA

Drawn By: ACP
Checked By: JMT/JRS
Date: 07/19/2019
Proj. No.: 00018020804.00
File Name: General Map_client

FIGURE 5.

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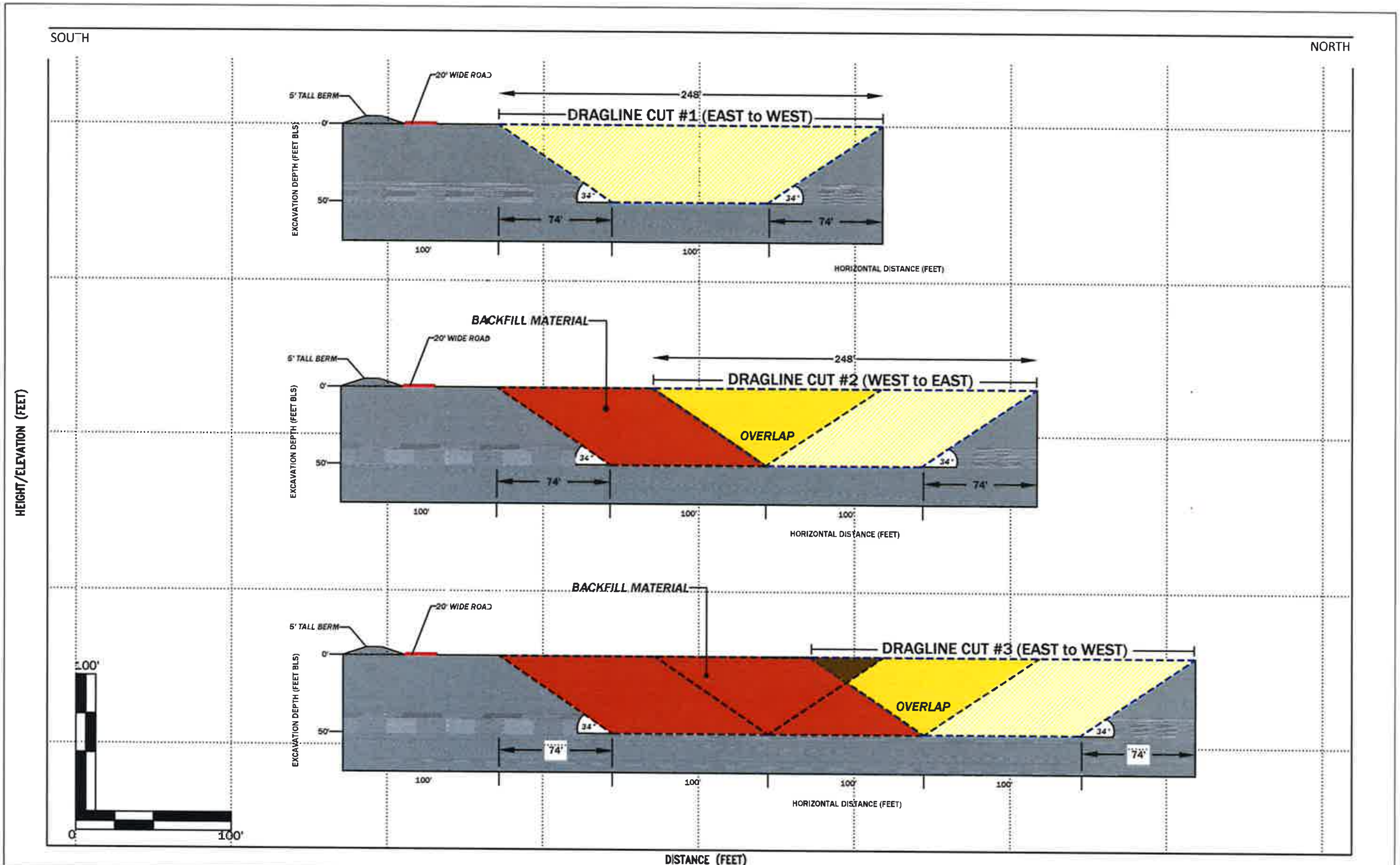


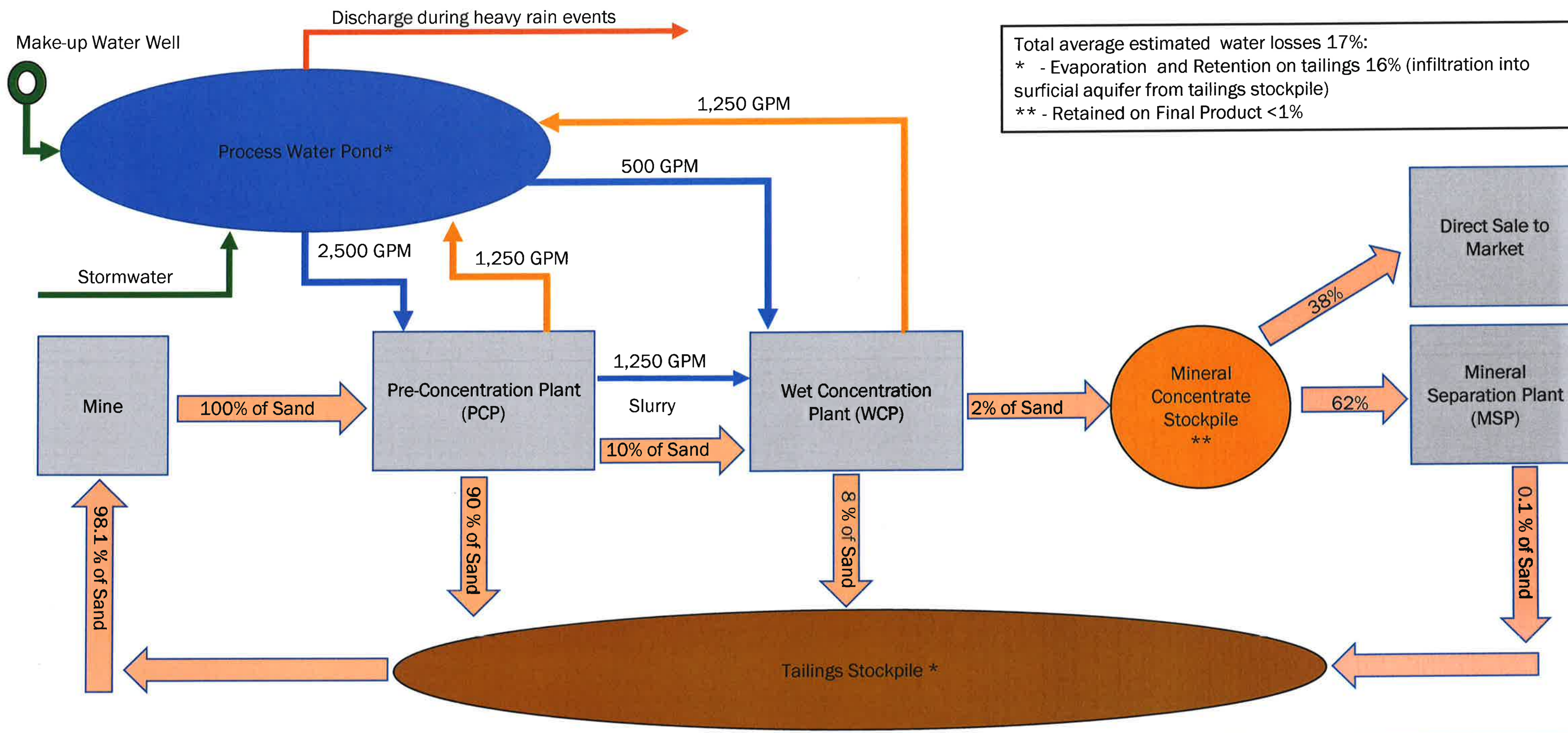
DRAWN BY:	ACP
CHECKED BY:	JMT
TTL PROJECT NO.:	000180200804.00
DATE:	07/19/2019
FILE PATH:	

Figure 6.
Impact Excavation Design

Twin Pines Minerals
Saunders Mine
St. George, Charlton County, Georgia

ATTACHMENT A

PROCESS FLOW DIAGRAM



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PROCESS FLOW DIAGRAM

TWIN PINES MINERALS
SAUNDERS MINE
ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: WW
CHECKED BY: SR
DATE: 07/22/2019
Proj. No.: 000180200804.00
ATTACHMENT A

ATTACHMENT B

DRAWDOWN MODELING FOR WELLS

FPW-01, FPW-02, AND FPW-03 AT THE TWIN PINES MINE SITE

DRAWDOWN MODELING FOR WELLS FPW-01, FPW-02, AND FPW-03 AT THE TWIN PINES MINE SITE

Robert M. Holt

University of Mississippi

Department of Geology and Geological Engineering

Professor

J. Mark Tanner, P.G.

TTL, Inc.

Senior Principal Geologist

TTL, Inc. Project No. 000180200804.00

Date: July 24, 2019

J. Mark Tanner, P.G.
Senior Principal Geologist
Georgia License No. 886

Twin Pines Minerals is proposing to drill three production wells designated (FPW-01, FPW-02, FPW-03) in the upper Floridian aquifer at their proposed mine site located in Charlton county, Georgia (Figures 1A and 1B). The production wells will supply water for heavy-minerals concentration plants at the mine and will be pumped at 1,000 gallons per minute. The proposed mine will operate for eight years, and mining operations and pumping will be staged. Well FPW-01 will operate from year 0 to 3, well FPW-02 will operate from year 0.5 to 7, and well FPW-03 will be pumped from year 1 to 8.

The objective of this report is to predict the drawdown from these wells during the eight-year life of the mine. The Theis (1935) solution is used to predict well drawdown, and the total drawdown in the aquifer is determined by linearly superimposing the contributions from each well. Two MATLAB codes were developed to predict the total drawdown (Appendices A, B, and C).

Williams and Kuniansky (2016) report transmissivity and storage coefficient values for 11 wells in the upper Floridian Aquifer. One well had an anomalously low transmissivity value, and therefore was excluded from our analysis. The transmissivity and storage coefficient values for the remaining 10 wells were averaged to define a Base Case scenario (Table 1). Hydraulic properties for the "Minimum-Drawdown" and "Maximum-Drawdown" scenarios (Table 2), were determined by selecting the well pairs with the highest and lowest hydraulic diffusivity (Table 1).

The predicted drawdown at each of the proposed production wells is shown in Figures 2 – 4. The maximum drawdown at each of the wells is shown in Table 2. FPW-02 does not begin pumping until year 0.5, and FPW-03 begins pumping after year 1. Pumping ceases for FPW-01 at year 3, FPW-02 is not pumped after year 7, and pumping stops at FPW-03 at year 8. The drawdown at each well is impacted by the pumping schedule of the other wells. For example, pumping at FPW-01 causes drawdown at FPW-02 and FPW-03 before these wells begin pumping, and pumping at FPW-02 and FPW-03 leads to additional drawdown at FPW-01. Figure 2 shows the drawdown for the Base Case scenario, and the maximum observed drawdown is 35.6 ft at FPW-02 (Table 2). Drawdown for the Maximum-Drawdown scenario is displayed in Figure 3, and the greatest drawdown is 80.8 ft at FPW-02 (Table 2). The Minimum-Drawdown scenario is illustrated in Figure 4, and, again, the largest drawdown is at FPW-02 (16.5 ft, Table 2). Because FPW-02 is between FPW-01 and FPW-03, the drawdown at FPW-02 always exceeds the drawdown at the other wells.

The aerial distribution of the predicted drawdown in the Floridian Aquifer for the Base Case scenario is shown in Figures 5 – 8. Figure 5 shows the drawdown after 1 year (365 days). All three wells are pumping, and most of the drawdown is concentrated around the wells. The drawdown at 5 years (1,825 days) (Figure 6) is primarily influenced by pumping in FPW-02 and FPW-03, as FPW-01 stops pumping at year 3. At 8 years (2,920 days) (Figure 7), only FPW-03 is pumping, and the drawdown has decreased substantially from year 5. All pumping wells are shut down after year 8. Ten days after pumping at FPW-03 ceases (2,930 days), the upper Floridian Aquifer shows significant recovery (Figure 8).

References Cited

Williams, L. J., and Kuniansky, E. L., 2016, Revised hydrogeologic framework of the Floridian Aquifer System in Florida and parts of Georgia, Alabama, and South Carolina: U.S. Geological Survey Professional Paper 1807, 140 p.

Theis, C.V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage: Transactions of the American Geophysical Union, 16th Annual Meeting, p. 519-524.

TABLES

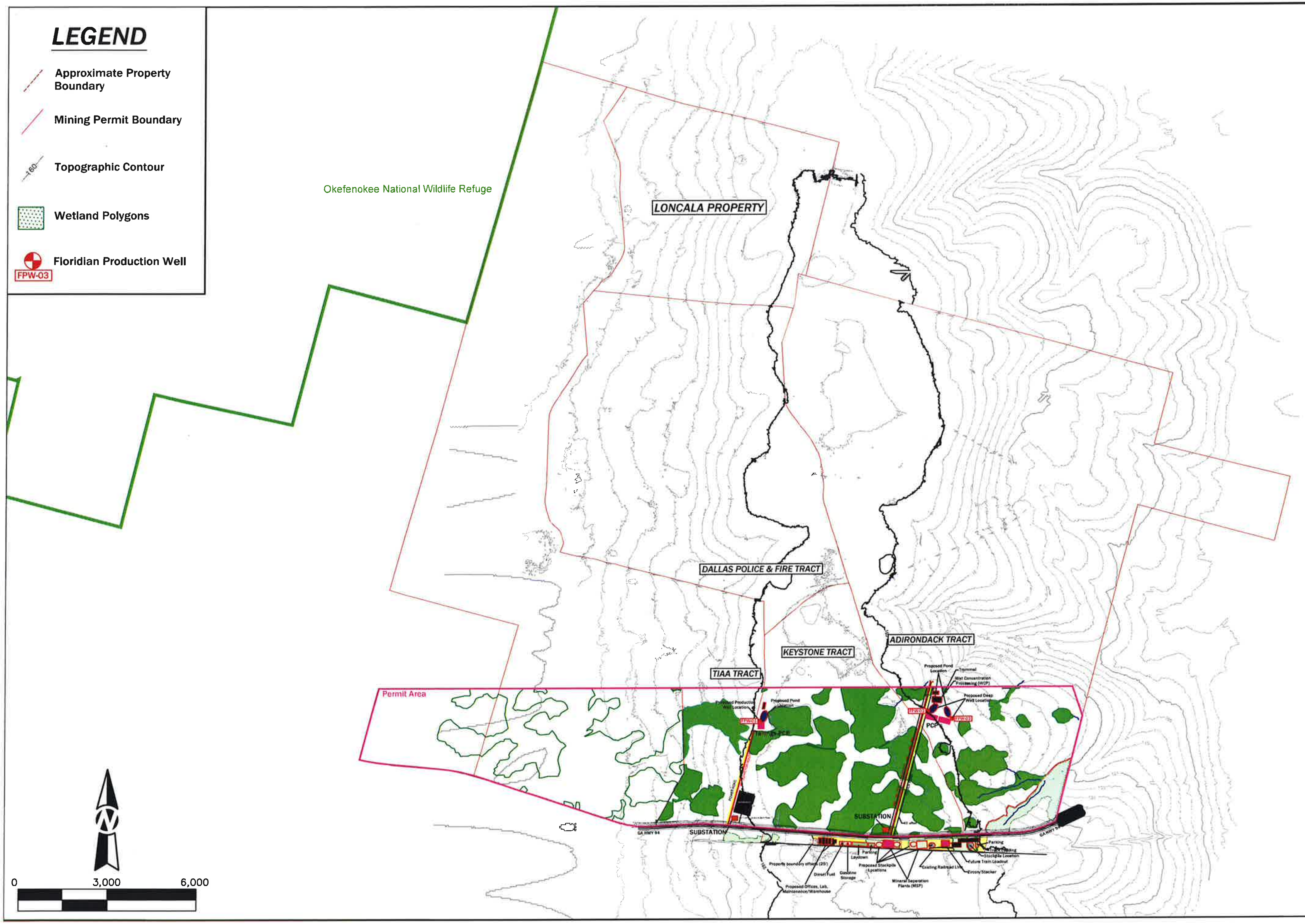
Well ID	Transmissivity (ft^2/day)	Storage Cofficient (dimensionless)	Hydraulic Diffusivity (ft^2/day)
IWSD-TW*	36000	1.00E-02	3.60E+06
ROMP14	6570	9.90E-04	6.64E+06
ROMP39	12000	1.60E-04	7.50E+07
36Q330	40000	2.00E-04	2.00E+08
ROMP43	13000	2.00E-05	6.50E+08
OSF-97	15500	2.20E-05	7.05E+08
ROMP45.5	26000	3.00E-05	8.67E+08
I75-TW	16000	1.70E-05	9.41E+08
M505	9880	7.30E-06	1.35E+09
BICY-TW**	11000	5.00E-06	2.20E+09
Average	**18595**	**1.15E-03**	

Table 1. Hydraulic properties for the upper Floridian Aquifer in north Florida (Williams and Kuniansky, 2016). *The hydraulic properties for well IWSD-TW were used for the minimum-drawdown scenario, and **the hydraulic properties for well BICY-TW were used for the maximum-drawdown scenario.

Well ID	Base Case Drawdown (ft)	Maximum Drawdown Scenario (ft)	Minimum Drawdown Scenario (ft)
FPW-01	32.3	75.1	14.8
FPW-02	35.6	80.8	16.5
FPW-03	35.4	80.4	16.4

Table 2. Maximum drawdown at each pumping well over the eight-year life of the project for the Base Case, the Maximum Drawdown Scenario, and the Minimum Drawdown Scenario.

FIGURES



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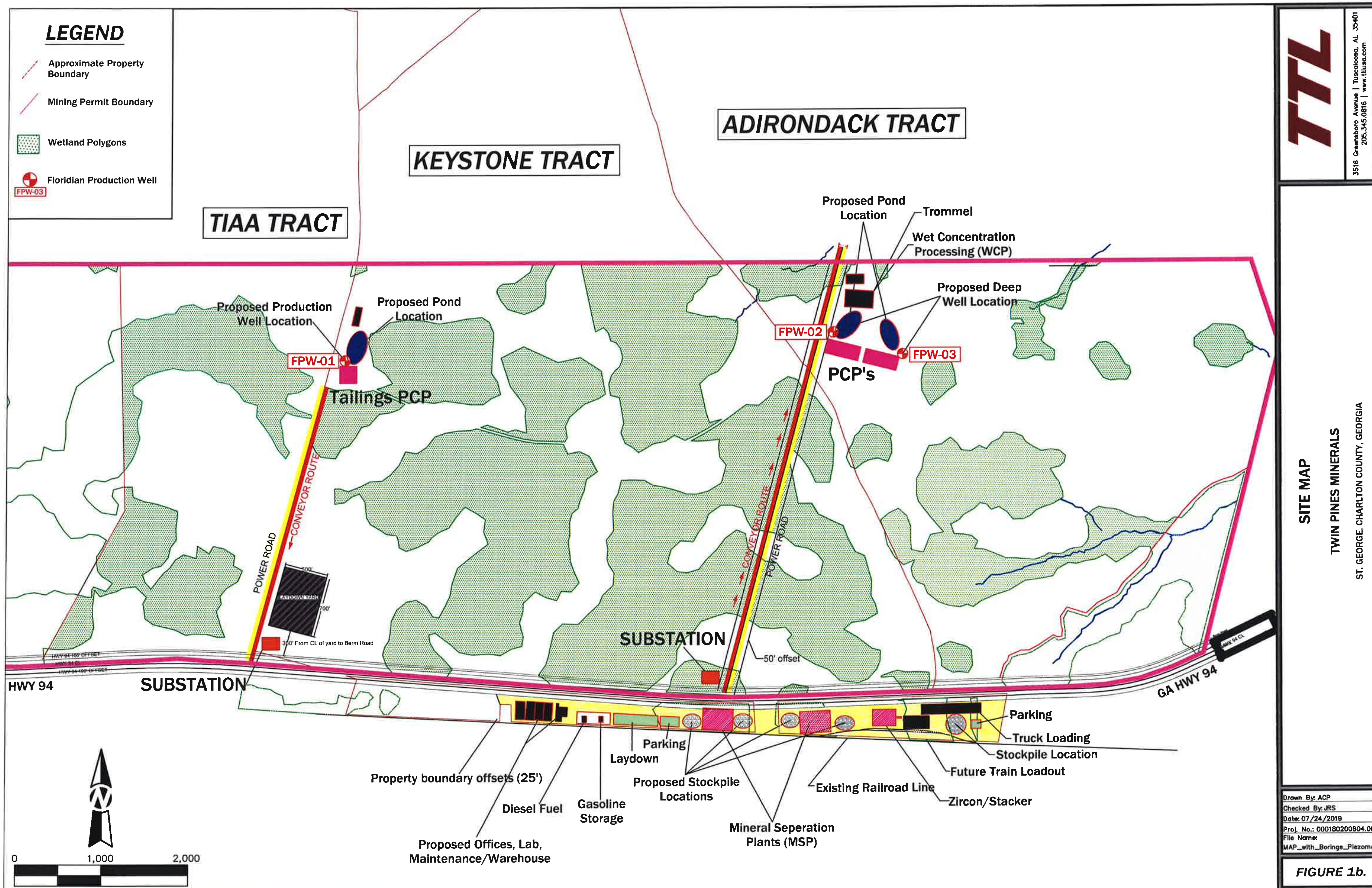
SITE MAP
TWIN PINES MINERALS
ST. GEORGE, CHARLTON COUNTY, GEORGIA

Drawn By: ACP
Checked By: JRS
Date: 07/24/2019
Proj. No.: 000180200804.00
File Name: MAP_with_Borings_Piezomete

FIGURE 1a.


LEGEND
Approximate Property Boundary
Mining Permit Boundary
Wetland Polygons
Floridian Production Well
FPW-03
TIAA TRACT
KEYSTONE TRACT
ADIRONDACK TRACT
Proposed Production Well Location
Proposed Pond Location
FPW-01
Tailings PCP
Proposed Pond Location
Trommel
Wet Concentration Processing (WCP)
Proposed Deep Well Location
FPW-02
FPW-03
PCP's
CONVEYOR ROUTE
POWER ROAD
LAYDOWN YARD
500'
700'
300' From CL of yard to Berm Road
SUBSTATION
50' offset
HWY 94
SUBSTATION
GA HWY 94
Parking
Truck Loading
Stockpile Location
Future Train Loadout
Existing Railroad Line
Zircon/Stacker
Parking
Laydown
Property boundary offsets (25')
Diesel Fuel
Gasoline Storage
Proposed Stockpile Locations
Mineral Seperation Plants (MSP)
Proposed Offices, Lab, Maintenance/Warehouse
0
1,000
2,000
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SITE MAP
TWIN PINES MINERALS
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Date: 07/24/2019
Proj. No.: 000180200804.00
File Name:
MAP_with_Borings_Piezomete
FIGURE 1b.

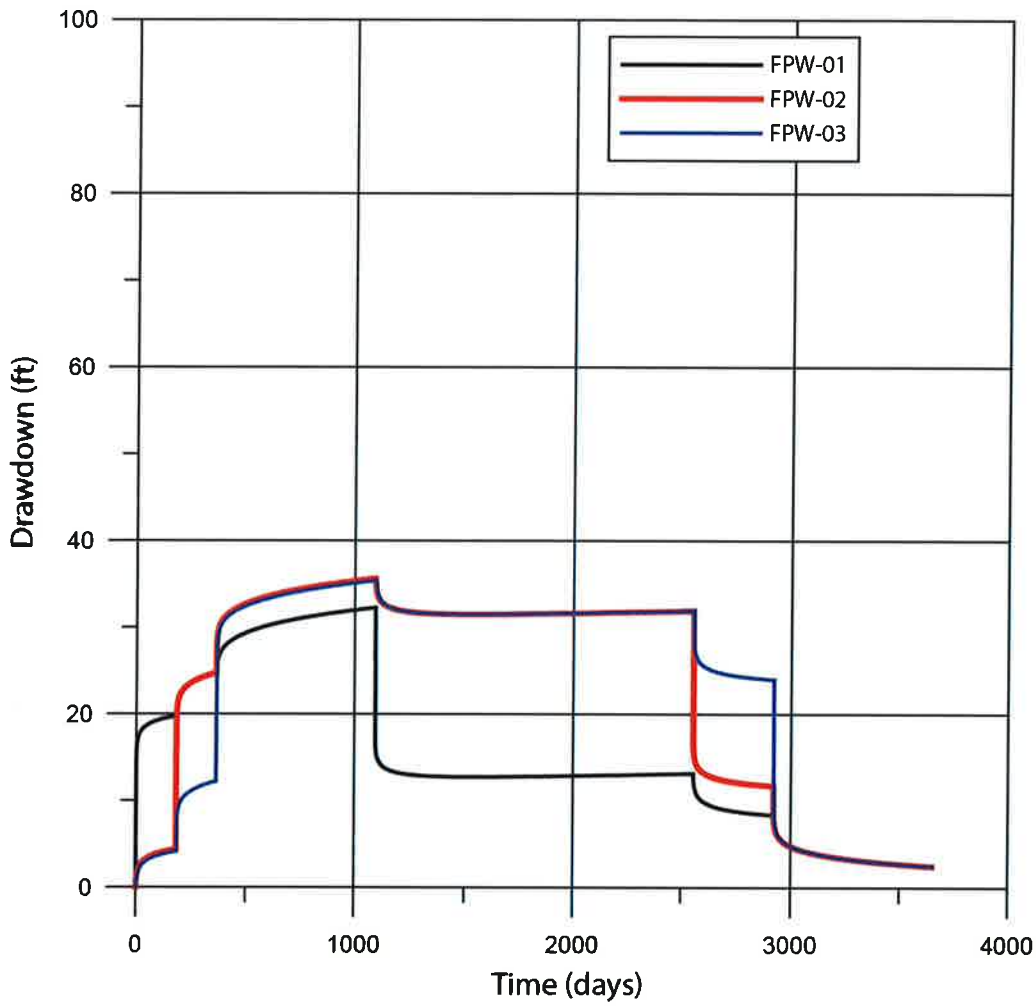


Figure 2. Predicted drawdown at each of the pumping wells for the Base Case Scenario. Drawdowns are predicted for a ten-year (3,650 day) period.

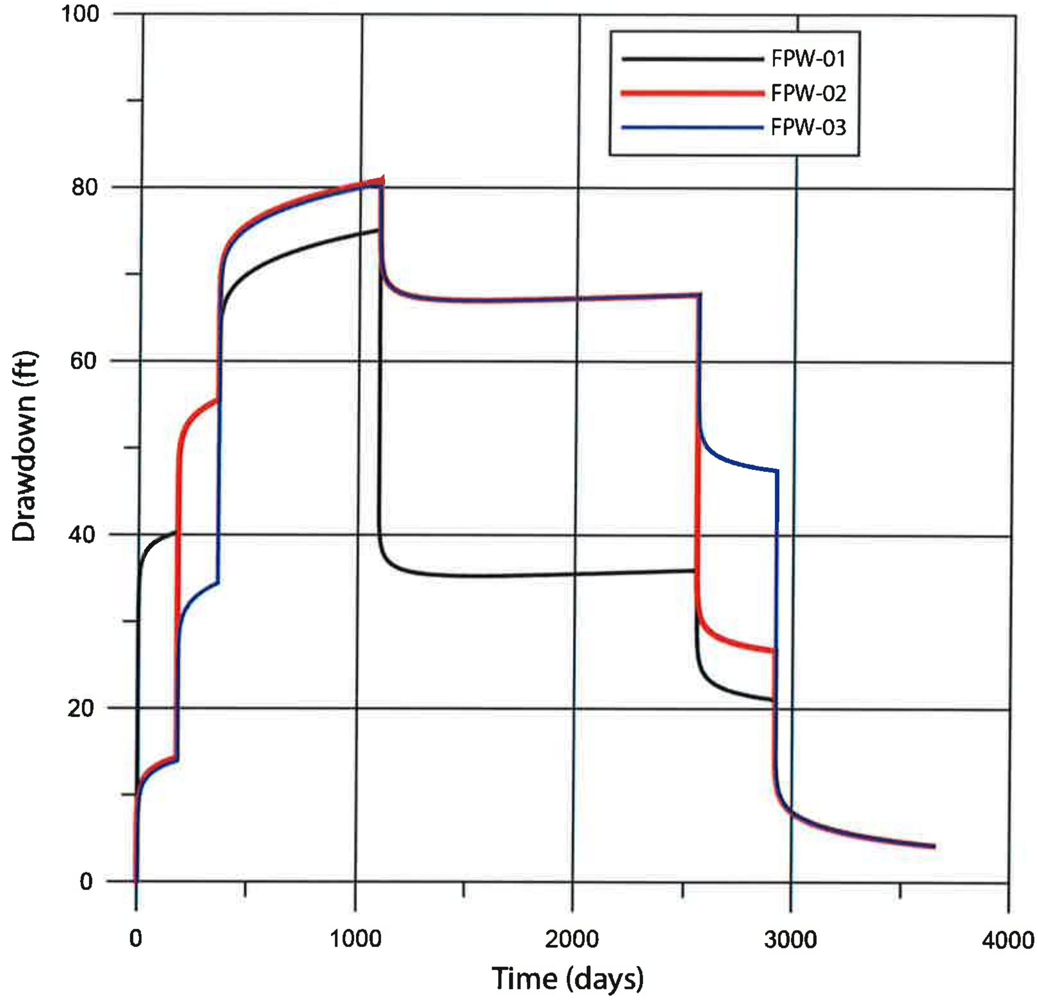


Figure 3. Predicted drawdown at each of the pumping wells for the Maximum Drawdown Scenario. Drawdowns are predicted for a ten-year (3,650 day) period.

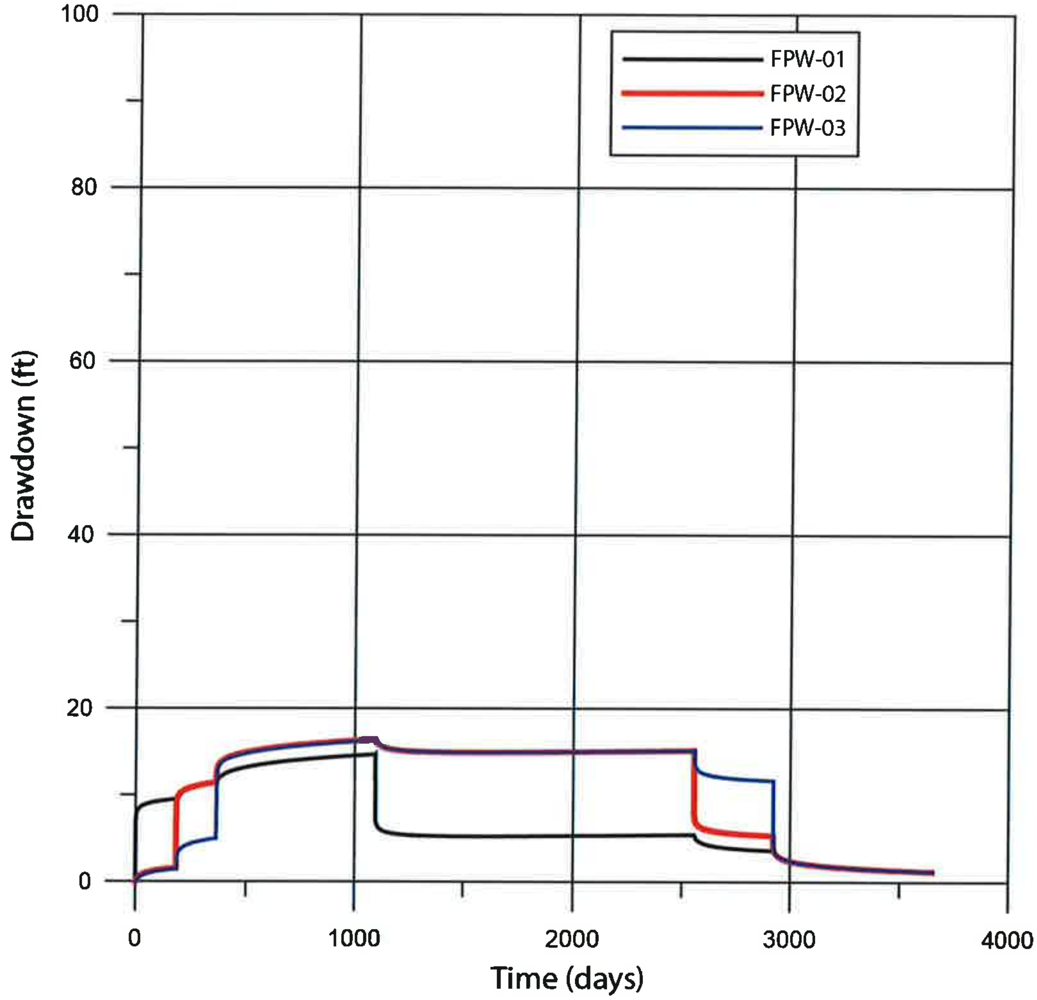
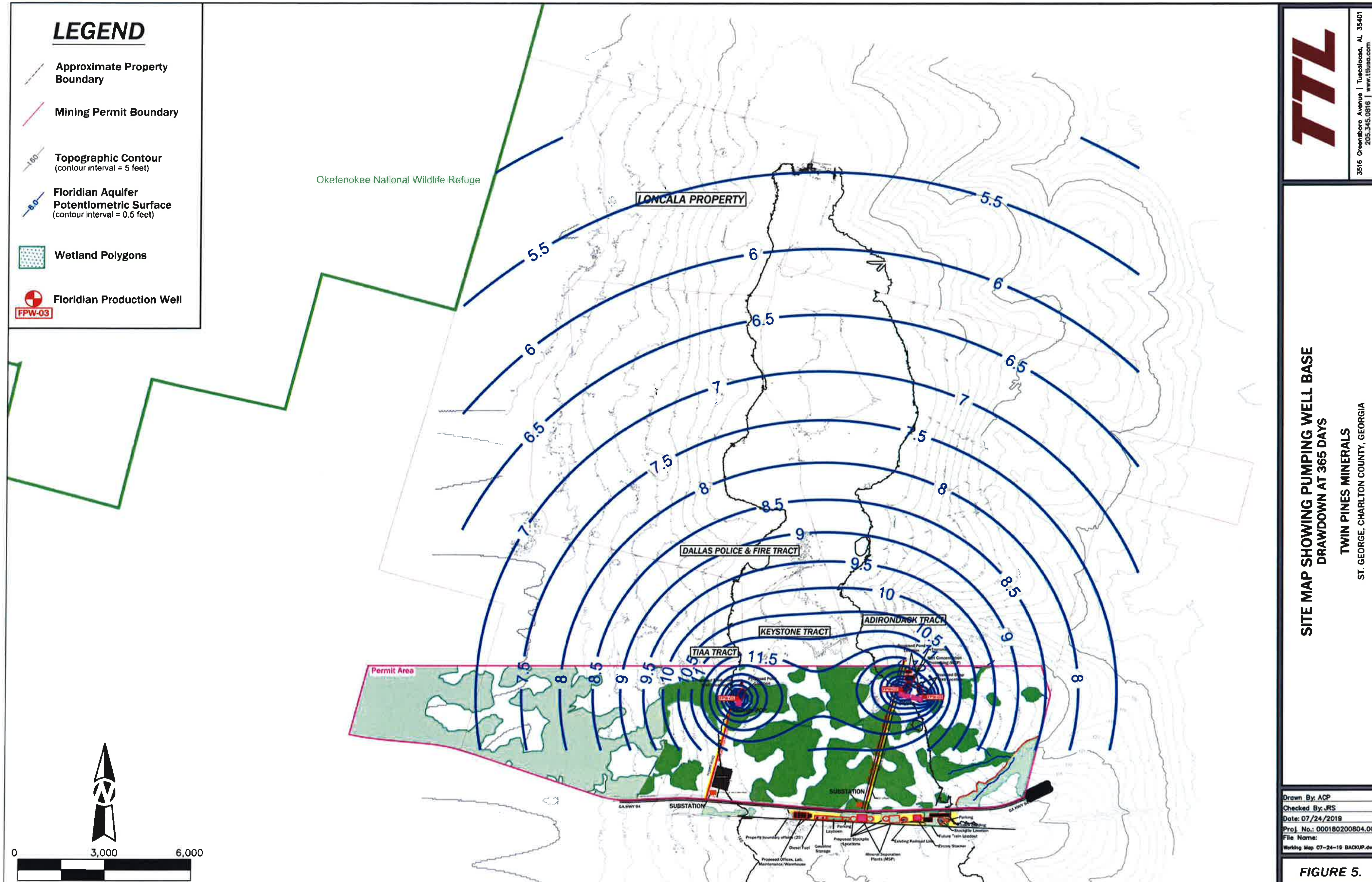


Figure 4. Predicted drawdown at each of the pumping wells for the Base Case Scenario. Drawdowns are predicted for a ten-year (3,650 day) period.


LEGEND
Approximate Property Boundary
Mining Permit Boundary
Topographic Contour (contour interval = 5 feet)
Floridian Aquifer Potentiometric Surface (contour interval = 0.5 feet)
Wetland Polygons
Floridian Production Well
FPW-03
Okefenokee National Wildlife Refuge
LONCALA PROPERTY
DALLAS POLICE & FIRE TRACT
KEYSTONE TRACT
ADIRONDACK TRACT
TIAA TRACT
Permit Area
SUBSTATION
0
3,000
6,000
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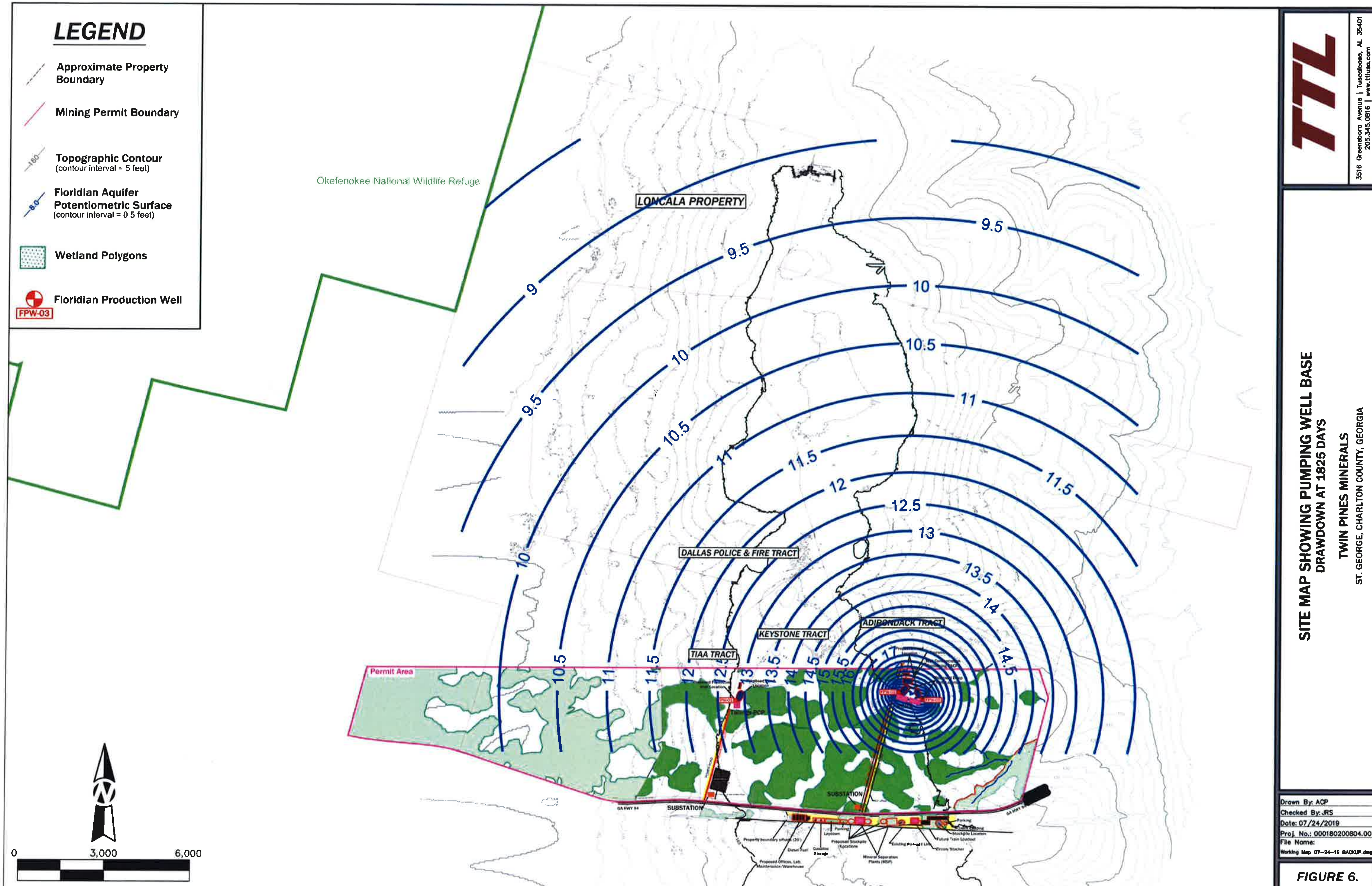
SITE MAP SHOWING PUMPING WELL BASE
DRAWDOWN AT 365 DAYS
TWIN PINES MINERALS
ST. GEORGE, CHARLTON COUNTY, GEORGIA
Drawn By: ACP
Checked By: JRS
Date: 07/24/2019
Proj. No.: 0001802008804.00
File Name:
Working Map 07-24-19 BACKUP.dwg
FIGURE 5.


LEGEND
Approximate Property Boundary
Mining Permit Boundary
Topographic Contour
(contour interval = 5 feet)
Floridian Aquifer Potentiometric Surface
(contour interval = 0.5 feet)
Wetland Polygons
Floridian Production Well
FPW-03
Okefenokee National Wildlife Refuge
LONCALA PROPERTY
DALLAS POLICE & FIRE TRACT
KEYSTONE TRACT
ADIRONDACK TRACT
TIAA TRACT
Permit Area
SUBSTATION
0
3,000
6,000
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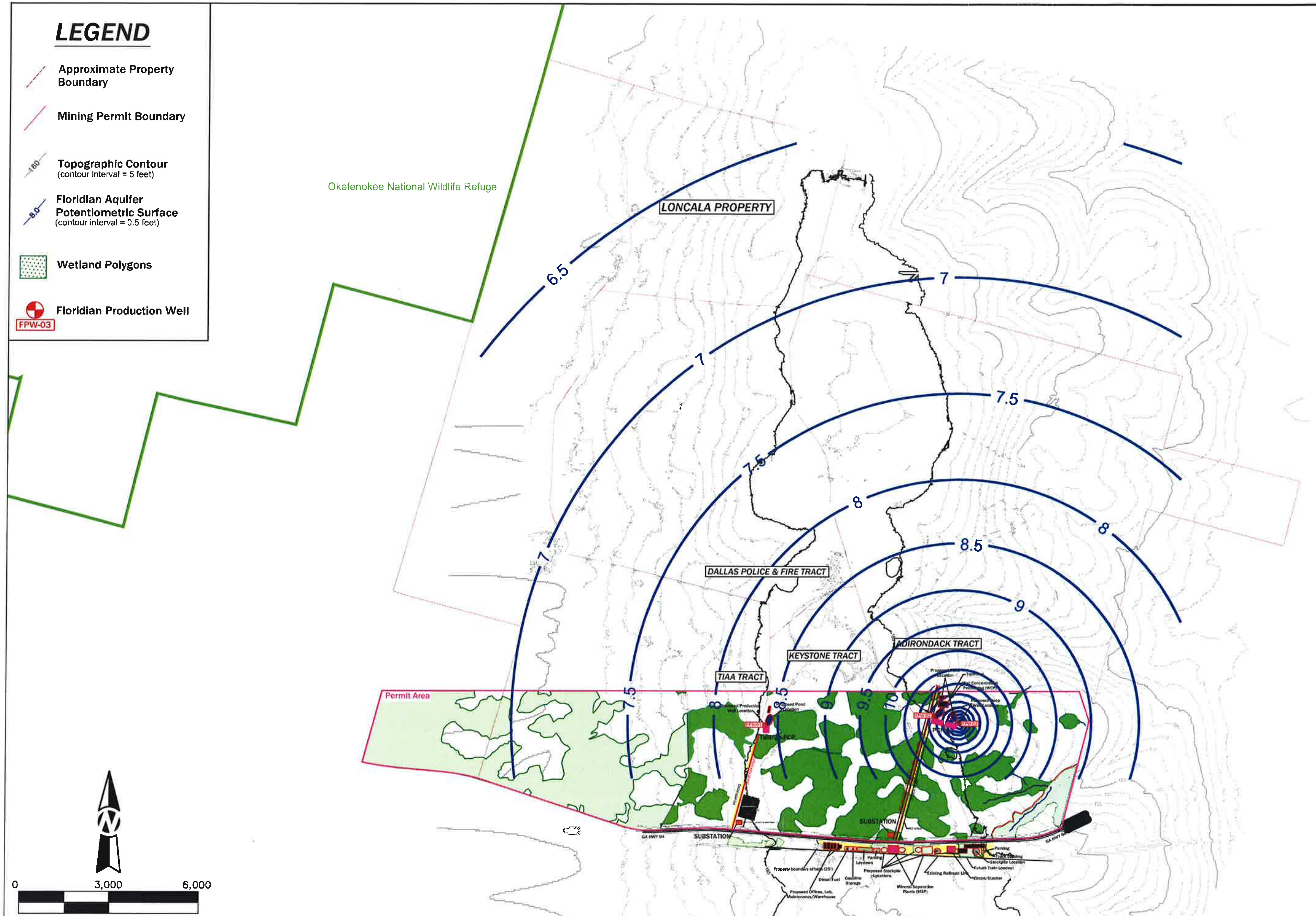
SITE MAP SHOWING PUMPING WELL BASE
DRAWDOWN AT 1825 DAYS
TWIN PINES MINERALS
ST. GEORGE, CHARLTON COUNTY, GEORGIA
Drawn By: ACP
Checked By: JRS
Date: 07/24/2019
Proj. No.: 000180200804.00
File Name:
Working Map 07-24-19 BACKUP.dwg
FIGURE 6.



SITE MAP SHOWING PUMPING WELL BASE
DRAWDOWN AT 2920 DAYS

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

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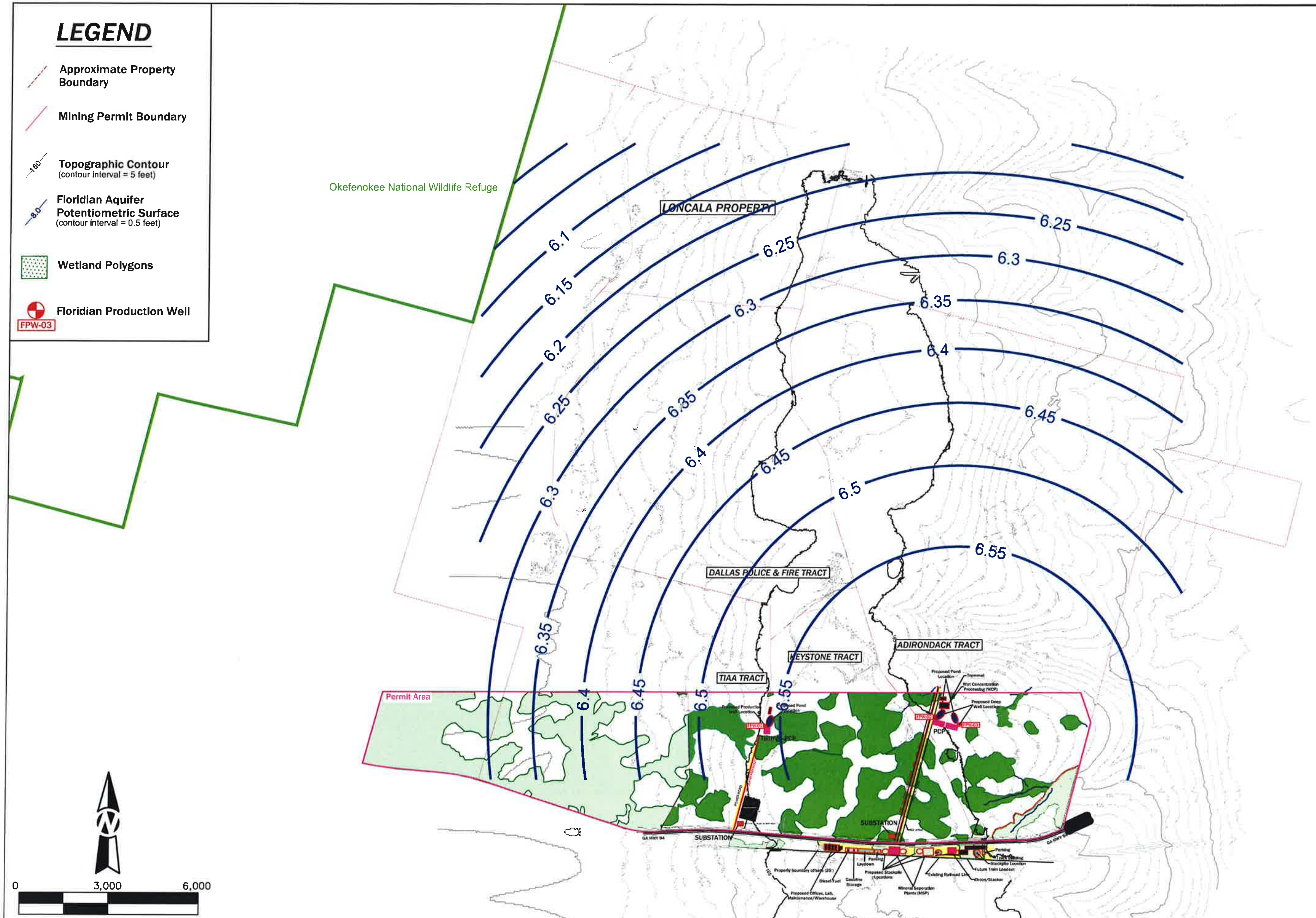
Proj. No.: 000180200804.00
File Name:
Working Map 07-24-19 BACKUP.dwg

FIGURE 7.



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SITE MAP SHOWING PUMPING WELL BASE
DRAWDOWN AT 2930 DAYS

TWIN PINES MINERALS
ST. GEORGE, CHARLTON COUNTY, GEORGIA

Drawn By: ACP
Checked By: JRS
Date: 07/24/2019
Proj. No.: 000180200804.00
File Name:
Working Map 07-24-19 BACKUP.dwg

FIGURE 8.

Appendix A

MATLAB Code for Predicting the Drawdown History at Wells

```
function hh=Theis_Time_Superposition_FLAQ(Nwell,nt,x,y,delt,T,S)
%nr = number of times to evaluate
%delt = time step
%Q = Volumetric discharge (L^3/T)
%T = K*B = Transmissivity
%t = time to evaluate pressures
%S = Storage Coefficeint (dimensionless)
%h = Drawdown
%welldat= a predefined array (in file 'welldat.dat' of length Nwell with
%           x,y,start time,end time,Q data for each well
welldat=dlmread('welldat.dat');
for i=1:nt
    t(i)=delt*i;
    for m=1:Nwell
        if (welldat(m,3)<=t(i))&&(welldat(m,4)>=t(i))
            %calculate radial distance from point x,y to the well
                r=((x-welldat(m,1))^2+(y-welldat(m,2))^2)^0.5;
            %calculate well function
                u=S*(r)^2/(4*T*(t(i)-welldat(m,3)));
            %calculate drawdown
                hw(m)=(welldat(m,5)/(4*3.14151*T))*expint(u);
        elseif (welldat(m,4)<=t(i))
            %calculate radial distance from point x,y to the well
                r=((x-welldat(m,1))^2+(y-welldat(m,2))^2)^0.5;
            %calculate well function for pumping
                u1=S*(r)^2/(4*T*(t(i)-welldat(m,3)));
                u2=S*(r)^2/(4*T*(t(i)-welldat(m,4)));
             %calculate drawdown
                hw(m)=(welldat(m,5)/(4*3.14151*T))*expint(u1)-(welldat(m,5)/(4*3.↙
14151*T))*expint(u2);
        else
                hw(m)=0;
        end
    end
    %superimpose drawdowns
    h(i)=sum(hw);
    hh(i,1)=t(i);
    hh(i,2)=h(i);
end
figure;
plot(t,h)
grid on
end
```

Example input for Theis_Time_Superposition_FLAQ.m

Base Case

Well 1

```
Theis_Time_Superposition_FLAQ(3,3650,669590.2255,192089.876,1,18595,1.15e-3)
```

Well 2

```
Theis_Time_Superposition_FLAQ(3,3650,675277.2592,192406.5268,1,18595,1.15e-3)
```

Well 3

```
Theis_Time_Superposition_FLAQ(3,3650,676086.9313,192148.2574,1,18595,1.15e-3)
```

Minimum Drawdown

Well 1

```
Theis_Time_Superposition_FLAQ(3,3650,669590.2255,192089.876,1,36000,1.00E-02)
```

Well 2

```
Theis_Time_Superposition_FLAQ(3,3650,675277.2592,192406.5268,1,36000,1.00E-02)
```

Well 3

```
Theis_Time_Superposition_FLAQ(3,3650,676086.9313,192148.2574,1,36000,1.00E-02)
```

Maximum Drawdown

Well 1

```
Theis_Time_Superposition_FLAQ(3,3650,669590.2255,192089.876,1,11000,5.00E-06)
```

Well 2

```
Theis_Time_Superposition_FLAQ(3,3650,675277.2592,192406.5268,1,11000,5.00E-06)
```

Well 3

```
Theis_Time_Superposition_FLAQ(3,3650,676086.9313,192148.2574,1,11000,5.00E-06)
```

Appendix B

MATLAB Code for Predicting the Areal Drawdown

```
function hh=Theis_Superposition_N_wells_FLAQ(nx,ny,delx,dely,xst,yst,Nwell,T,t,S)
%nx=number of points to evaluate in the x-direction
%ny=number of points to evaluate in the y-direction
%delx = Distance between points in the x-direction
%dely = Distance between points in the y-direction
%xst = starting x-coordinate of plot
%yst = starting y-coordinate of plot
%Nwell= number of wells
%welldat= a predefined array (in file 'welldat.dat' of length Nwell with
%            x,y,start time,end time,Q data for each well
%T = K*B = Transmissivity
%t = time to evaluate pressures
%S = Storage Coefficeint (dimensionless)
%h(k,5) = Drawdown
%h3(i,j) = 2D array of drawdowns for plotting
welldat=dlmread('welldat.dat');
for i=1:nx+1
    %define x location
    x=(i-1)*delx+xst;
    for j=1:ny+1
        %define y location
        y=(j-1)*dely+yst;
        %define global index for output
        k=(i-1)*(nx+1)+j;
        %calculate the drawdown for each well
        for m=1:Nwell
            if (welldat(m,3)<=t)&&(welldat(m,4)>=t)
                %calculate radial distance from point x,y to the well
                r=((x-welldat(m,1))^2+(y-welldat(m,2))^2)^0.5;
                %calculate well function
                u=S*(r)^2/(4*T*(t-welldat(m,3)));
                %calculate drawdown
                hw(m)=(welldat(m,5)/(4*3.14151*T))*expint(u);
            elseif (welldat(m,4)<=t)
                %calculate radial distance from point x,y to the well
                r=((x-welldat(m,1))^2+(y-welldat(m,2))^2)^0.5;
                %calculate well function for pumping
                u1=S*(r)^2/(4*T*(t-welldat(m,3)));
                u2=S*(r)^2/(4*T*(t-welldat(m,4)));
                %calculate drawdown
                hw(m)=(welldat(m,5)/(4*3.14151*T))*expint(u1)-(welldat(m,5)/(4*3.↙
14151*T))*expint(u2);
            else
                hw(m)=0;
            end
        end
        %superimpose drawdowns
        h(k)=sum(hw);
        %setup output array
        hh(k,1)=x;
```

```
        hh(k,2)=y;
        hh(k,3)=h(k);
        h3(j,i)=h(k); %build array for plotting
    end
end
maxdd=hh(11959,3)
%define x-coordinate vector for plot
for i=1:nx+1
    xx(i)=(i-1)*delx+xst;
end
%define y-coordinate vector for plot
for j=1:ny+1
    yy(j)=(j-1)*dely+yst;
end
%contour plot drawdowns
figure;
[C,h]=contour(xx,yy,h3);
%[C,h]=contour(h3);
clabel(C,h);
end
```

Example input for Theis_Superposition_N_wells_FLAQ.m

Base Case

Theis_Superposition_N_wells_FLAQ(118,107,200,200,659957,190269,3,18595,100,1.15e-3)

Minimum Drawdown D=3.60E+06 ft2/day

Theis_Superposition_N_wells_FLAQ(118,107,200,200,659957,190269,3,36000,100,1.00e-2)

Maximum Drawdown D=2.20E+09 ft2/day

Theis_Superposition_N_wells_FLAQ(118,107,200,200,659957,190269,3,11000,100,5.00e-6)

Appendix C

Input File Welldat.dat for MATLAB Codes

669590.7203	192089.876	0	1095	192500
675277.754	192406.5268	182.5	2555	192500
676087.4261	192148.2574	365	2920	192500