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

Twin Pines Minerals, LLC

Submitted To:

Georgia Environmental Protection Division
Water Supply Program – Groundwater Withdrawal Unit
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Project No. 000180200804.00
December 9, 2020

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1 INTRODUCTION

Twin Pines Minerals, LLC (Twin Pines), is an Alabama-based minerals mining company proposing to secure a mining permit to conduct a proposed heavy mineral sands (HMS) mining demonstration project at the Saunders Demonstration Mine site located near St. George, Charlton County, Georgia. The materials to be mined are 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 Demonstration Mine located near Saint George, Georgia in Charlton County. The proposed mining project consists of approximately 739.1 acres (577.4-acre mining area) 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.

Twin Pines expects to mine approximately 10-15 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 577.4 acres.

Twin Pines expects to begin construction upon obtaining the required authorizations and mining operations are expected to be conducted for a 4-year period. The proposed mining operation is expected to provide approximately 400 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 2.9 miles southeast from the nearest boundary of the Okefenokee Swamp National Wildlife Refuge, providing a substantial buffer of protection for this sensitive resource.

TPM reclamation plans are to restore land uses to the original pre-mining conditions, planted pine, or natural conditions which existed prior to conversion to timber silviculture land usage. 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 Environmental Protection Division (EPD), and concerned citizens during the planning process for the proposed mine.

2 PURPOSE AND NEED

The purpose of this demonstration mining project proposed by TPM is to gather data required to evaluate a groundwater hydrology model completed during the development of this project. This evaluation is necessary to demonstrate that HMS mining can be accomplished in an environmentally sensitive area with negligible impact to the site and surrounding resources. An additional purpose is to develop a high-quality HMS reserve to produce HMS concentrate products including titanium mineral concentrates and zircon concentrates to meet global demands in a safe, cost effective, and environmentally sound manner.

The TPM mining plan and the associated groundwater and surface water monitoring plan will be used to confirm the ability of HMS mining to be conducted within close proximity to sensitive environmental resources. As the economically viable locations for mining HMS within the United States are becoming scarce, it is vital that new mines be developed in such a manner as to minimize environmental impacts. TPM has completed extensive geologic and hydrogeologic evaluations of the Saunders Tract which culminated with the production of a groundwater hydrology model demonstrating that mining can be safely conducted within the demonstration mine area with negligible impact to the site, the surrounding area, and the Okefenokee Swamp. Small scale projects, such as the one proposed, that can demonstrate sound environmental practices for extracting heavy mineral resources in environmentally sensitive locations, represent good stewardship of the environment.

HMS deposits contain the primary ores of titanium dioxide (TiO_2) for the pigment industry and zircon ($ZrSiO_2$) used in refractory products. TiO_2 is primarily obtained from mining and processing the minerals ilmenite, rutile, and leucoxene. Leucoxene, not technically a mineral, is a higher quality derivative of ilmenite resulting from the preferential weathering and leaching of iron therefore increasing the TiO_2 percentage to greater than 70 percent. Zircon is recovered as a co-product from the processing of HMS deposits.

3 GENERAL DESCRIPTION OF THE MINING PROCESS

3.1 Introduction

Twin Pines has developed a mineral sand mining technique which utilizes a dragline excavator, 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. In general, a dragline is a more efficient method for moving bulk material where long mining cuts and pits can be utilized. Employing elongated cuts allows for simultaneous mining the mineral sands and tailings placement to occur in the same pit. This process will allow reclamation to occur at a faster rate as backfilling and rough grading may occur up to +/-500 feet behind the dragline dig face. This should allow reclamation to begin within days of mining, where typical methods take several months to greater than a year.

The dragline method involves a large crane-like earthmoving machine equipped with a bucket to scoop material. The 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.

Routine dewatering of the mine excavation is not expected. Dewatering will occur occasionally, typically only after the dragline has been shut down due to maintenance, malfunction, or emergency conditions (e.g. hazardous weather conditions). Excavation will be continuous, during wet and dry conditions.

A conveyor system is utilized to transport mined material to the mineral processing plants. The mineral processing plant locations allow mineral processing activities to be located in one location adjacent to the mining area, which decreases material transport distance and energy demands. Recycled process water ponds will also be constructed adjacent to the processing plant creating an efficient method for process water reuse and recirculation. The process water ponds will be lined with an impermeable liner to prevent water losses due to infiltration. **Attachment A** depicts the Saunders Demonstration 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.

3.2 Mine Progression

The mining sequence will be divided into separate phases, which will be active concurrently within the mining area. 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

3.2.1 Site Preparation

To initiate mining activities, the project area will be delineated by survey markers, boundary markers, and flagging in the field to indicate the locations of permanent infrastructure and mining boundaries. A pre-mining survey using 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 the beginning of mining activities. Timber will be harvested on average 4 to 6 months prior to mining being conducted in that area. Timber that is not merchantable and timber scraps will be removed by TPM and all areas within the limits of clearing and mining will be root raked, windrowed, and burned in compliance with Division of Forestry and/or county permits.

The first areas to be cleared will be for the processing facilities, initial mining area, and feed and tailings conveyors. Once the areas have been cleared, the permanent facilities and infrastructure will be constructed/installed along with the berms, stormwater controls, and other best management practices for sediment control.

The permanent facilities will consist of an interior road system, PCP/WCP processing facility, and MSP, described further in the next section. Process water ponds will be constructed adjacent to the processing plant. TPM will also install 2 deep water wells to provide make-up water during times of need locations shown on the site layout (**Figure 3**).

The feed and tailings conveyors will be constructed for the entire east-west length of the mining corridor to near Trail Ridge Road, where they will turn to the north towards the concentration plants, located near the northeastern portion of the mining area. A berm will be constructed along Georgia State Highway 94 to mitigate erosion and contain stormwater. Berms or other facilities may be constructed along T-Model and Trail Ridge Roads. Generally, 1 foot of topsoil within each mining cell will be removed by heavy equipment and transported to the topsoil storage piles adjacent to the pit. 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 sediment-laden waters 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 2 weeks in advance of 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) slope. As noted previously, silt fences and hay bales will be utilized along the outside of the topsoil storage piles to control post construction erosion.

The first step in the mining process will be rough clearing of the mining corridor ahead of the dragline. The mining corridor will be approximately 700 feet north to south which will allow for mining of 3 pit widths before relocating the feed/tailings conveyors. This corridor will be cleared immediately ahead of the dragline. This clearing will extend +/-500 feet ahead of the mining and progress as the dragline advances. The clearing of this 700-foot north to south corridor is required to facilitate the advancement of the apron feeder and mobile conveyors as mining progresses to the east in the initial pit.

3.2.2 Excavation, Processing, and Tailings Return

Excavation of the mining cuts will commence after the topsoil is removed. The mining process proceeds as follows: The dragline moves through the mining area excavating approximately 100-foot wide by 50-foot deep cuts, in an east to west or west to east direction as shown on **Figure 4**. A mining cut profile/cross-section is included as **Figure 5**. Mining rates are anticipated to vary from approximately 100-200 feet of pit length excavation per day. The excavated material is stockpiled nearby. It is then transferred to an apron feeder which feeds to a screen. The screen removes roots and other large objects. The material is then transferred to a pit/feed conveyor system. The oversized organic material will be placed near the screen area for future deposit into the mining pit 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 under-sized material from the trommel will be fed to the PCP as a slurry.

In the PCP, spiral concentrate and separate the heavy mineral sands from the lighter clays and quartz sand. The heavy mineral sands will be fed to the WCP. The WCP further separates the lighter minerals from the heavy mineral sands creating the heavy mineral sands concentrate that will be trucked to the MSP for final mineral separation. Process water is recovered from the tailings and heavy minerals sands via a series of dewatering screens and hydrocyclones throughout the process. Humates and clays are also separated from the process water as slimes within the PCP. The slimes will be separated from the process water in a thickener. The underflow from the thickener will be dewatered and temporarily stored before being transported back to and placed in the mined pit area for reclamation. TPM will utilize 3 lined process water ponds and 1 lined process water overflow pond to maintain the adequate volume needed operate the PCP/WCP. Discharge from the overflow pond may occur due to heavy rain events. Such discharge will be routed to a treatment pond and discharged through a NPDES-permitted outfall. Two deep Upper Floridan Aquifer make-up water wells will be used to supply makeup water as needed to maintain adequate process water reserves.

The HMS concentrate material from the WCP is transported to the MSP, via truck. Water needed for processing at the MSP will also be provided by the make-up water wells. Once water has been used in the mineral processing it may be recycled for re-use at the MSP or transported to the WCP to be used in the processing of sands. Water will be transported via truck to and from the MSP.

The MSP further separates the valuable and non-valuable mineral products such as zircon, titanium minerals (ilmenite, leucoxene, rutile), and staurolite 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 area will be temporarily stockpiled. Tailings and slimes 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 pit area for reclamation.

Water within the active mining pit is anticipated to be withdrawn only during upset conditions, i.e. equipment maintenance/failure, or due to a heavy rain event. This water will be pumped and treated, and either used as process water, or discharged through the NPDES-permitted outfall. Twin Pines will schedule equipment maintenance at times in the mining process when the active mining pit will be at its smallest aerial extent to minimize the amount of water to be withdrawn from the active pit after maintenance is completed. Due to the unknown nature of equipment failure(s) and heavy rain events Twin Pines will only withdraw the minimum amount of water from the active pit required to resume active mining.

3.2.3 Reclamation

Reclamation activities shall begin within 1 to 2 weeks of the commencement of mining with the placement of sand tails into the active mining pit as it advances. The reclamation will progress following the proposed mining progression plan and will be completed in a timely manner. Final site reclamation will be completed within 24 months following the completion of mining. Following completion of all mining activities, all structures, equipment, and material associated with the operation shall be removed. Backfilling of mined areas will use post-processed sands, spoil material and stockpiled topsoil.

As part of reclamation, the tailings and slimes are transported from their stockpiles to the open mined area where they are deposited. After the tailings are contoured and levels reach approximate pre-mining topography, the topsoil will be replaced to its original thickness. The area will then be re-graded and contoured to mimic pre-mining contours, based upon the pre-mining survey. The operation is a continuous process, while the dragline is operating, backfilling of the pit is occurring as well. A cross-section view of the dragline cut and backfill, perpendicular to the direction of the dragging movement, is shown in **Figure 5**.

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 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.

4 WELL SURVEY

TTL conducted a well survey to determine the location of public and/or private supply wells located adjacent to the proposed Saunders Demonstration 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 Demonstration 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.

Fulghum Fibers formerly operated a wood chipping mill located approximately 1 mile east of the proposed Saunders Demonstration Mine. Twin Pines has entered into a lease agreement for the former wood chip mill property and will construct the MSP at this location. TPM contracted TTL to conduct a Phase I Environmental Site Assessment (Phase I) for the property, prior to entering the lease agreement. Results of the Phase I confirmed the presence of the three potable water wells on the former chip mill property. Twin Pines **does not** plan to use the three wells on the chip mill property and will abandon the three wells during the construction of the MSP facility. The location of the three wells are shown on **Figure 3**. Once the abandonment of the three wells is complete TPM/TTL will submit well abandonment documentation to Georgia EPD in accordance with the Georgia Water Well Standards Act.

In order to determine the location and estimated number of private domestic supply wells that would be located adjacent to the proposed Saunders Demonstration 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**

5 WATER CONSERVATION PLAN

The objective of Twin Pines Saunders Demonstration 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.

5.1 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 Demonstration 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 Demonstration Mine will be to minimize the amount of make-up water (MUW) by recycling and reusing water. Water losses will be to evaporation retention on the tailings returning to the reclamation cut, and with minor amounts of water retained in the final product.

Pipelines transporting water at the PCP 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.

5.2 Water Flow Throughout Operation

The lined process water ponds 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 two wells (FPW-01 and FPW-02) into the Upper Floridan Aquifer east of the mining area to provide for a source of MUW for mineral separation 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) at the demonstration project Saunders Demonstration Mine. This daily permitted amount from the production wells in the UFA is for an estimated total of 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 ponds.

MUW from the Upper Floridan Aquifer wells will also be transported via water truck to the MSP to be used during the mineral separation process. Once the water has been used in the mineral separation process it will then be trucked to the WCP and recycled/introduced into the process water loop to decrease the need for additional MUW at the WCP.

5.3 Estimate of Upper Floridian Aquifer Quantity

The PCP plant is designed for optimum water conservation when compared to the typical "wet mining" process. The 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, infiltration to the surficial aquifer in the tailings/reclamation cell, and loss for sanitary usage. 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(s) and to transfer to the MSP for mineral processing via water truck. 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.

5.4 Percentage of Make-Up Water (MUW)

This proposed system at the Saunders Demonstration 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 retained on the tailings being deposited back into the reclamation cell going back into the Surficial Aquifer (16%) and the remaining moisture in the final product (<1%).

5.5 Water Conservation Measures

Twin Pines will implement the following conservation measures at the proposed Saunders Demonstration 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 PCP located in close proximity of the wet processing plant and lined process water ponds allow 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.

5.6 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.

5.7 Plumbing Ordinances and/or Codes

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

5.8 Recycle-Reuse

The proposed system at the demonstration project Saunders Demonstration 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.

5.9 Progress Reports

The proposed demonstration project Saunders Demonstration Mine is planning on operating for approximately 4 years. Twin Pines will submit a water conservation progress report every five (5) years of operation or at the end of operations whichever is first, to the Georgia 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.

Twin Pines will submit a summary water quality report to Georgia EPD on a quarterly basis during the first year and annually thereafter, in accordance with the Groundwater & Surface Water Monitoring & Adaptive Monitoring Plan; provided to Georgia EPD - Groundwater Withdrawal Unit as a standalone document. Water quality reports will include groundwater contour maps, results of water quality analysis for the period of monitoring, and trend graphs of concentrations. Water chemistry data will be evaluated and compared to background concentrations and applicable regulatory standards. In addition, a statistical summary of water quality data collected at each sampling location will be prepared and selected data will be presented graphically to illustrate trends or seasonal changes in water quality.

5.10 Water Use Data

Twin Pines will submit a monthly groundwater use data report to the Georgia EPD. The report will include data about the amount of water withdrawn during the reporting period.

6 GROUNDWATER USAGE

The proposed Twin Pines Saunders Demonstration Mine is designed to have minimal impact on the surficial aquifer system. The dragline mining method does not require the routine dewatering of the mining cut during mining operations. Dewatering will only occur occasionally, after equipment shutdowns due to maintenance/ malfunction or heavy rain events. This water will be pumped and treated, and either used as process water, or discharged through the NPDES-permitted outfall. Twin Pines will schedule routine equipment maintenance during times in the mining process when the active mining pit will be at its smallest extent to minimize the amount of water to be withdrawn from the active pit after maintenance is completed. Due to the unknown nature of equipment failure(s) and heavy rain events Twin Pines cannot predict the exact amount or length of time dewatering will occur after these events. Twin Pines will only withdraw the minimum amount of water from the active pit required to resume active mining.

Twin Pines will use a closed-loop processing system that will recycle/reuse process water 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 and tailings returned to the mining pit for reclamation. 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 4-year life span of the Saunders Demonstration Mine **(Attachment B)**. A summary of the results of the groundwater modeling study are provided below.

As part of the Twin Pines Minerals, LLC Demonstration Project, two production wells will be installed in the Floridan Aquifer, and each well will be pumped at 500 gpm for 4 years. The Theis (1935) solution was used to predict drawdown in each well. Solutions for each well were linearly superimposed using codes developed in MATLAB to predict the total drawdown. Three scenarios were developed using literature values: 1) a Base Case (determined from an average of literature values), a Maximum-Drawdown Case (determined from the literature values with the largest hydraulic diffusivity), and a Minimum-Drawdown case (determined from the literature values with the smallest hydraulic diffusivity). These results show that:

- The maximum drawdown at each well is 14.3 ft for the Base Case Scenario, 31.0 ft for the Maximum-Drawdown Scenario, and 6.7 feet for the Minimum-Drawdown Scenario.
- The maximum drawdown of the Floridan Aquifer at the edge of the ONWR is 3.8 ft in the Base Case Scenario, 13.2 ft for the Maximum-Drawdown Scenario, and 1.3 feet for the Minimum-Drawdown Scenario.
- One year after pumping stops (5 years), the upper Floridan Aquifer shows significant recovery and the drawdown has reduced to 1.3 ft for the Base Case Scenario at the edge of the ONWR.

We evaluated the leakage potential for the upper confining unit of the Floridan Aquifer to address public concern that pumping in the Floridan Aquifer will induce leakage from the Okefenokee Swamp, through the upper confining unit of the Floridan Aquifer (the Hawthorn Group in the vicinity of the proposed project), into the Floridan Aquifer. The evaluation showed:

- That the conditions leading to leakage across the upper confining unit in the vicinity of St. Mary's GA do not exist at the project site or the adjacent Okefenokee Swamp.
- Flaws in a study presented by Kitchens and Rasmussen (1995), which suggested that the Darcy flux (leakage) through the upper confining unit could be between 1.1×10^{-3} to 0.11 ft/day.
- That the volume per unit area of water removed from the surficial aquifer and the Okefenokee Swamp after 4 years of pumping in the Floridan Aquifer is negligible and insignificant (1.17×10^{-11} ft^3/ft^2) and that the time required to achieve a new equilibrium is long, greater than 289 years, compared to the duration of the project (4 years).

7 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.

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FIGURES

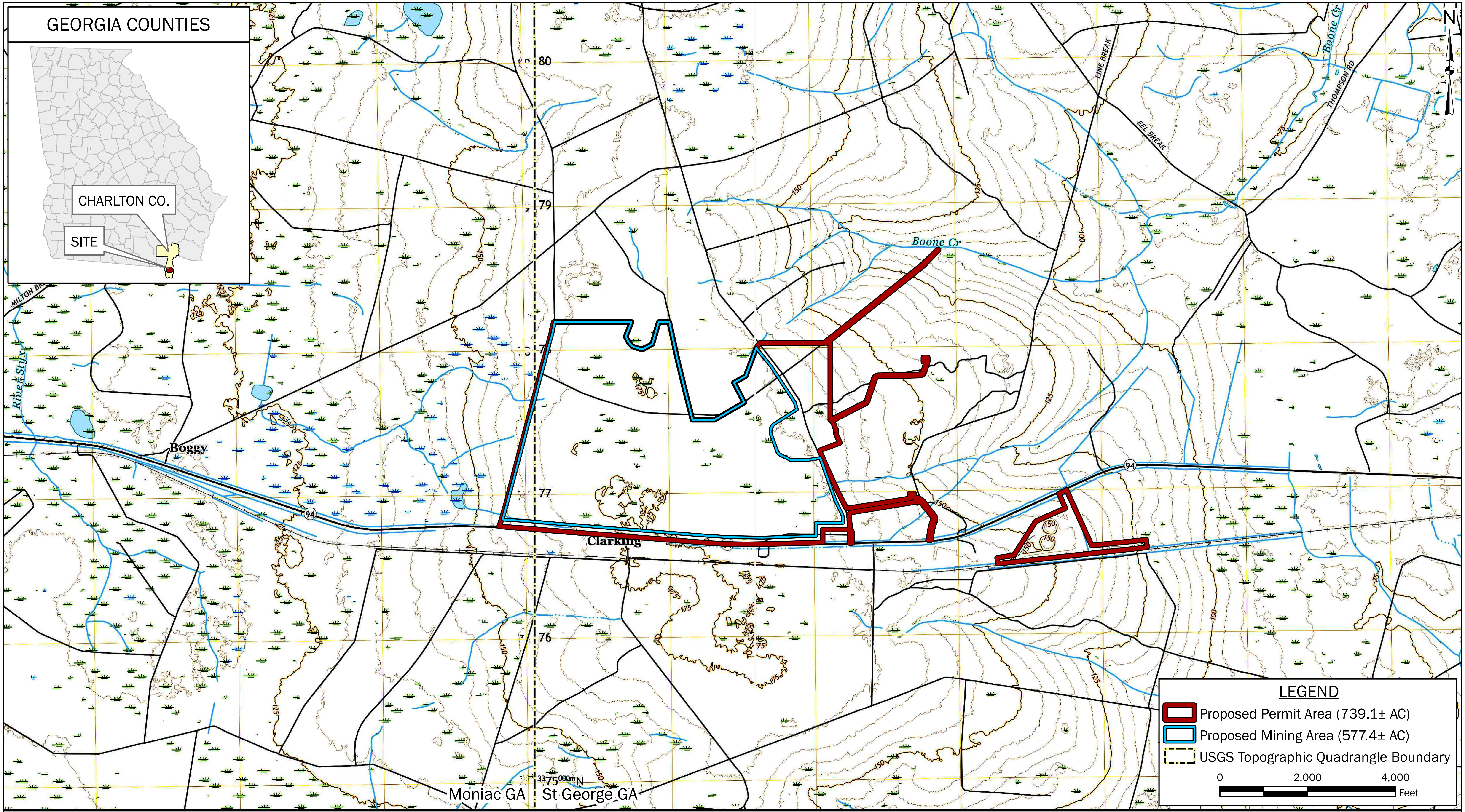

FIGURE 1: SITE LOCATION & TOPOGRAPHIC MAP

TWIN PINES MINERALS, LLC SAUNDERS DEMONSTRATION MINE

ST. GEORGE, CHARLTON COUNTY, GEORGIA

BASEMAP: Moniac (W) & Saint George (E), Georgia, USGS 7.5 Minute Quadrangle Map, 2020 (5-ft Contour Interval).

DRAWN BY: DEK
CHECKED BY: WW
DRAWING DATE: 12/4/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 2,000 ft

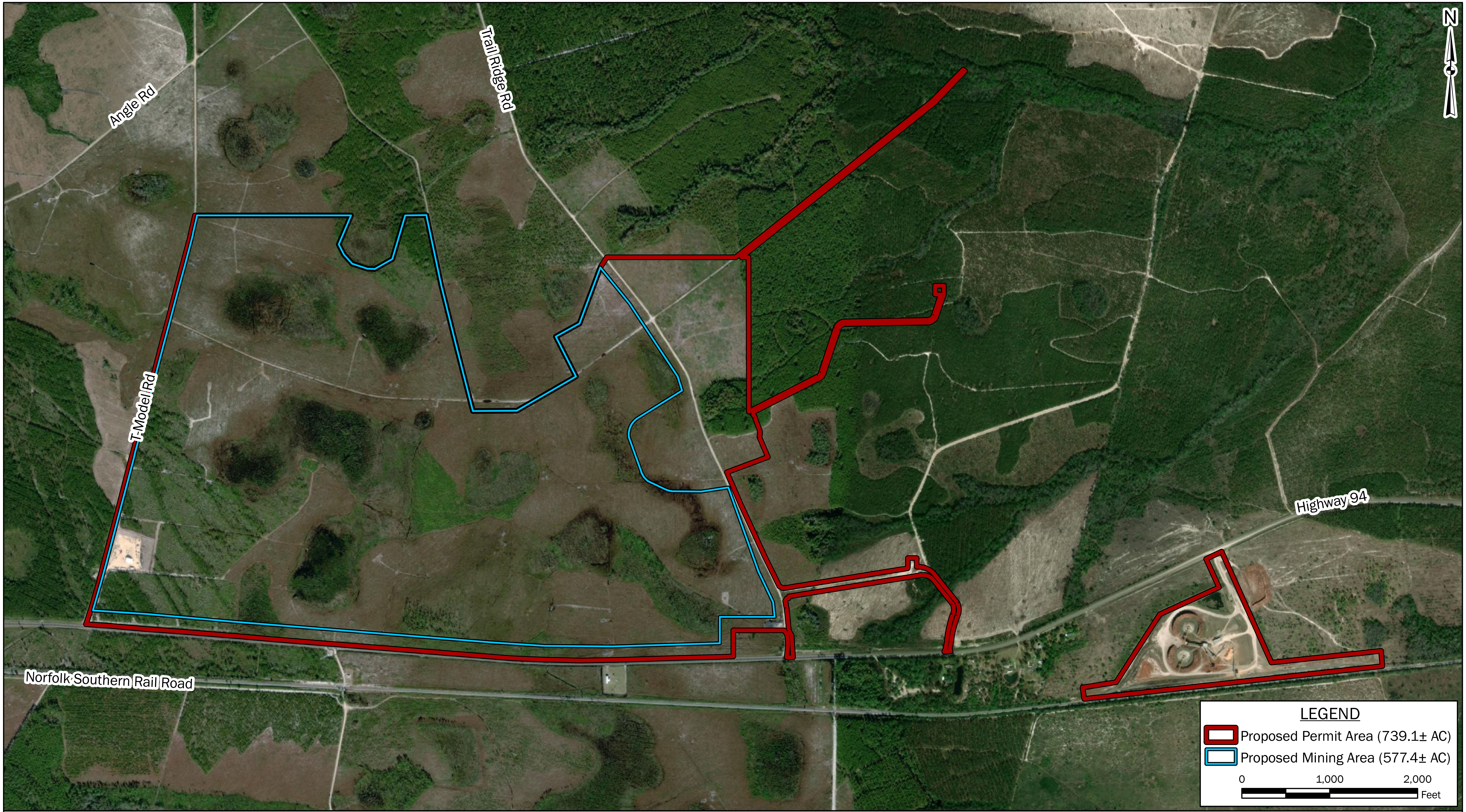

FIGURE 2: SITE LOCATION MAP & AERIAL PHOTOGRAPH
TWIN PINES MINERALS, LLC SAUNDERS DEMONSTRATION MINE
ST. GEORGE, CHARLTON COUNTY, GEORGIA
BASEMAP: Maxar, Vivid Imagery, 11/20/2019 (West, 0.5 m Resolution) & 3/24/2018 (East, 0.46 m Resolution).

DRAWN BY: DEK
CHECKED BY: WW
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REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
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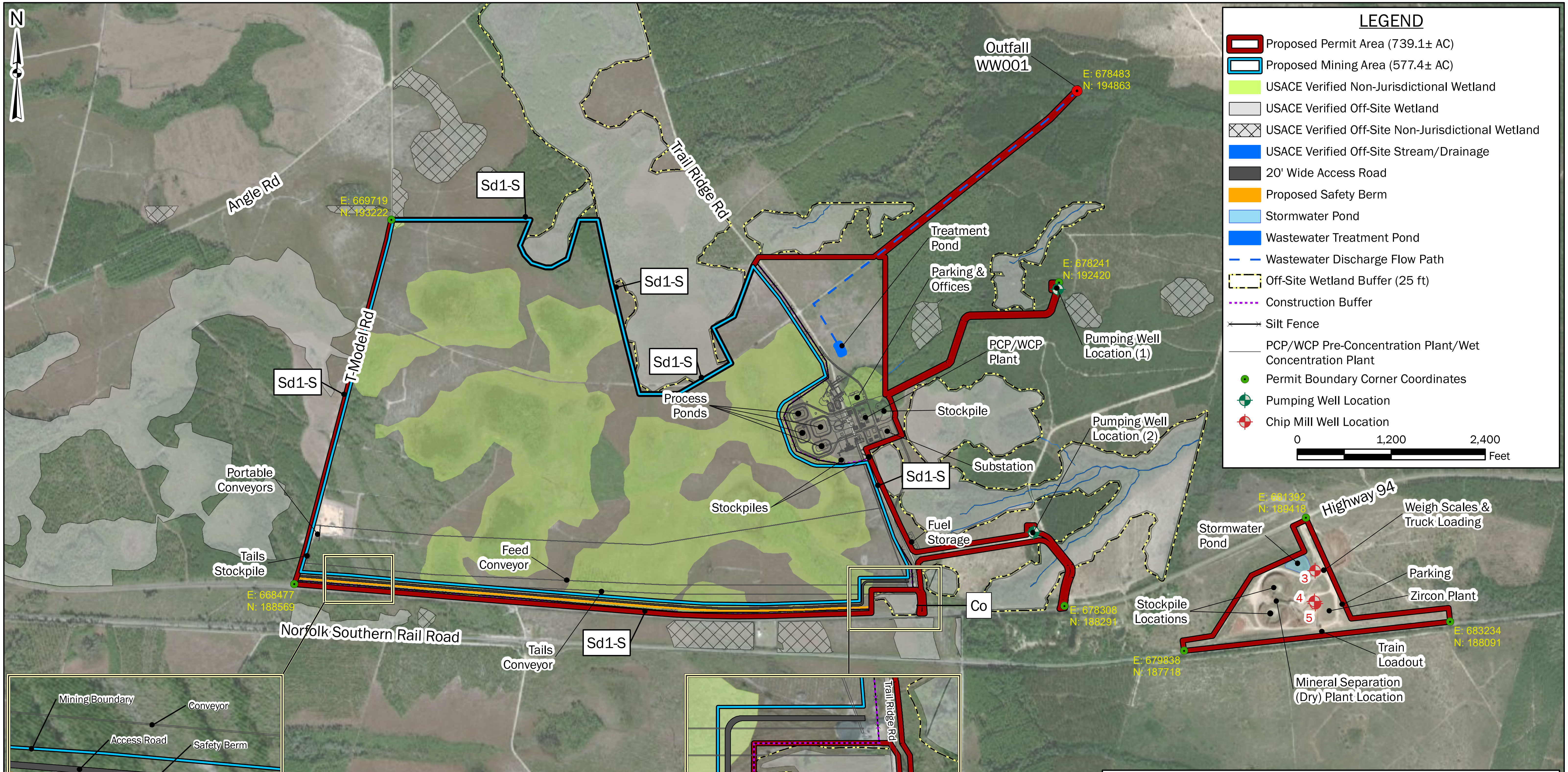


NOTES
- Access road to be installed between proposed berm and proposed mining area.
- Undisturbed buffer to be located between the proposed berm and Highway 94.
- Co = Construction Entrance Location
- Sd1-S = Silt Fence (and Construction Buffer) Location

TTL

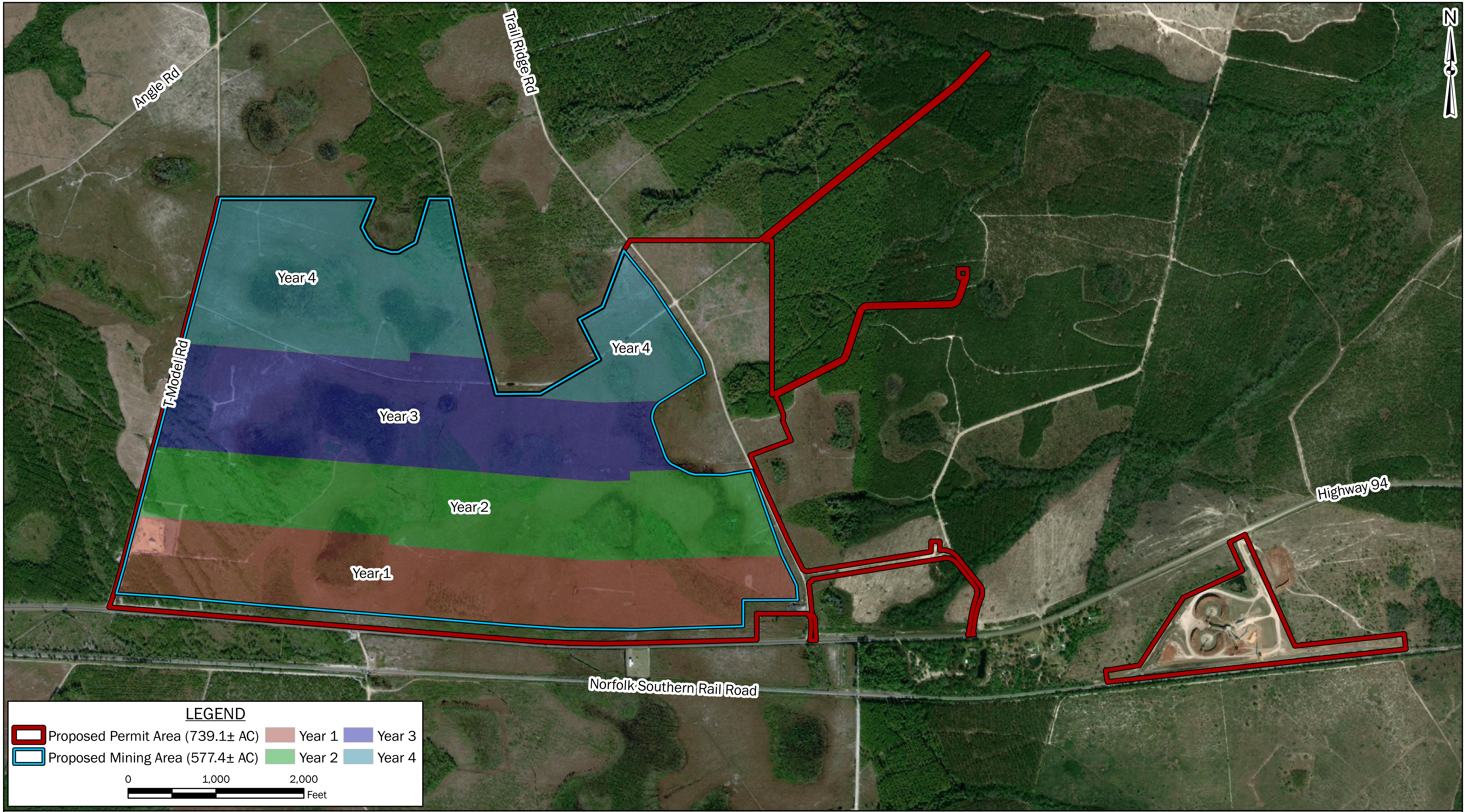
FIGURE 3: PROPOSED SITE LAYOUT

TWIN PINES MINERALS, LLC SAUNDERS DEMONSTRATION MINE

ST. GEORGE, CHARLTON COUNTY, GEORGIA

BASEMAP: Maxar, Vivid Imagery, 11/20/2019 (West, 0.5 m Resolution) & 3/24/2018 (East, 0.46 m Resolution).

DRAWN BY: DEK
CHECKED BY: WW
DRAWING DATE: 12/4/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 1,200 ft



TTL

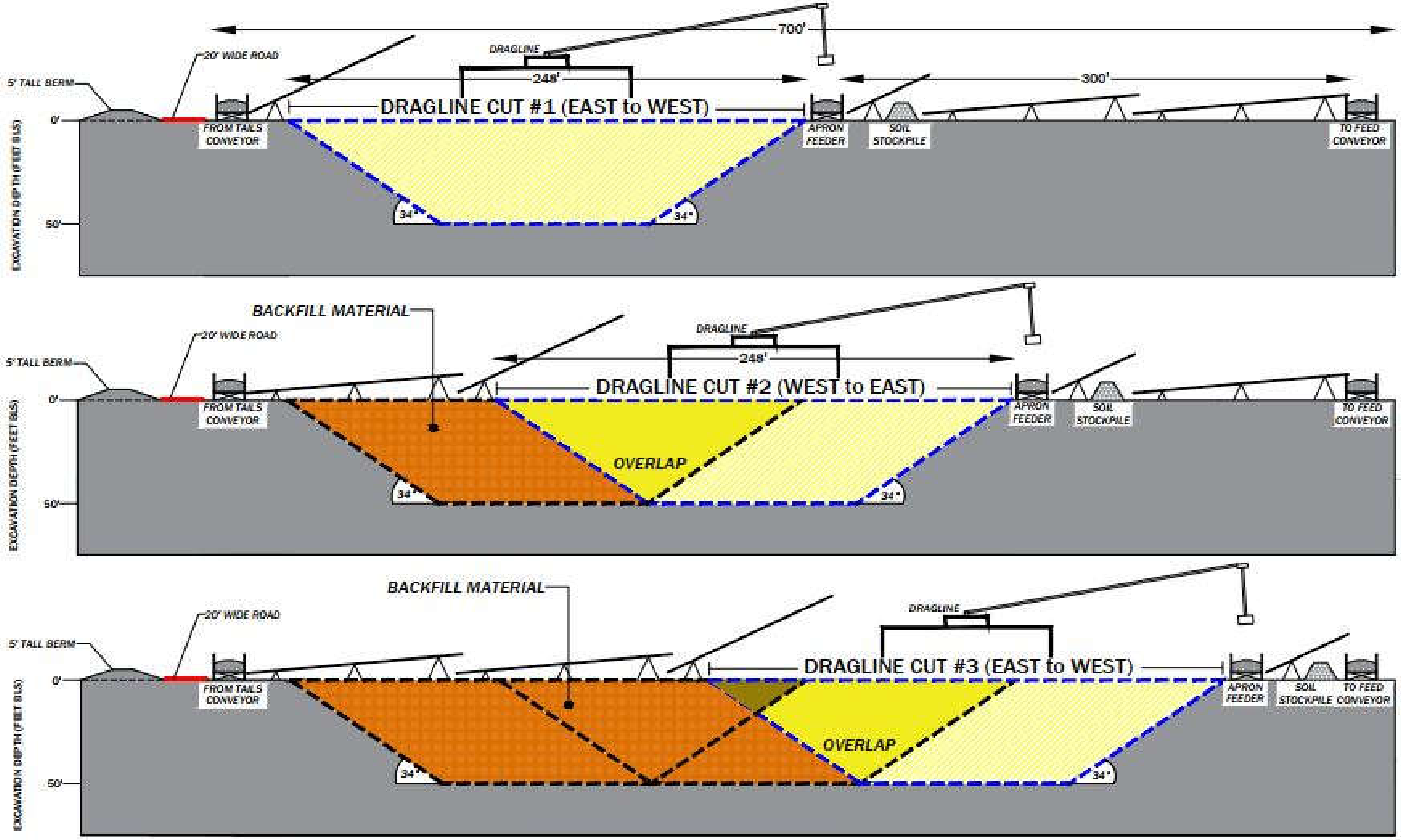
FIGURE 4: ESTIMATED PROGRESSION OF MINING

TWIN PINES MINERALS, LLC SAUNDERS DEMONSTRATION MINE

ST. GEORGE, CHARLTON COUNTY, GEORGIA

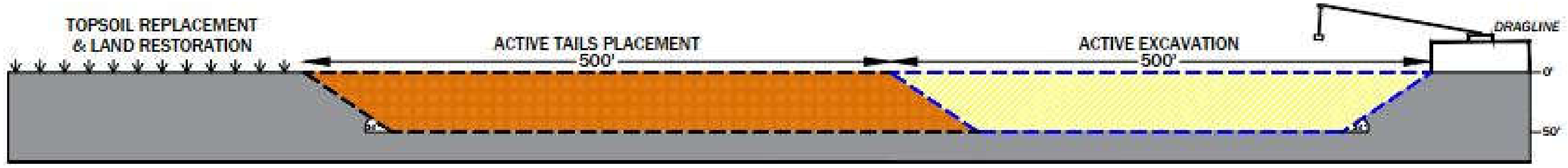
BASEMAP: Maxar, Vivid Imagery, 11/20/2019 (West, 0.5 m Resolution) & 3/24/2018 (East, 0.46 m Resolution).

DRAWN BY: DEK
CHECKED BY: WW
DRAWING DATE: 12/4/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 1,000 ft



SECTION A - A'

NOT TO SCALE



SECTION B - B'

NOT TO SCALE

LEGEND

⬛	UNEXCAVATED MATERIAL
▨	DRAGLINE EXCAVATION
🟧	BACKFILLED MATERIAL
🟨	OVERLAP

FIGURE 5: IMPACT EXCAVATION DESIGN - CROSS-SECTIONS OF TYPICAL MINING PIT

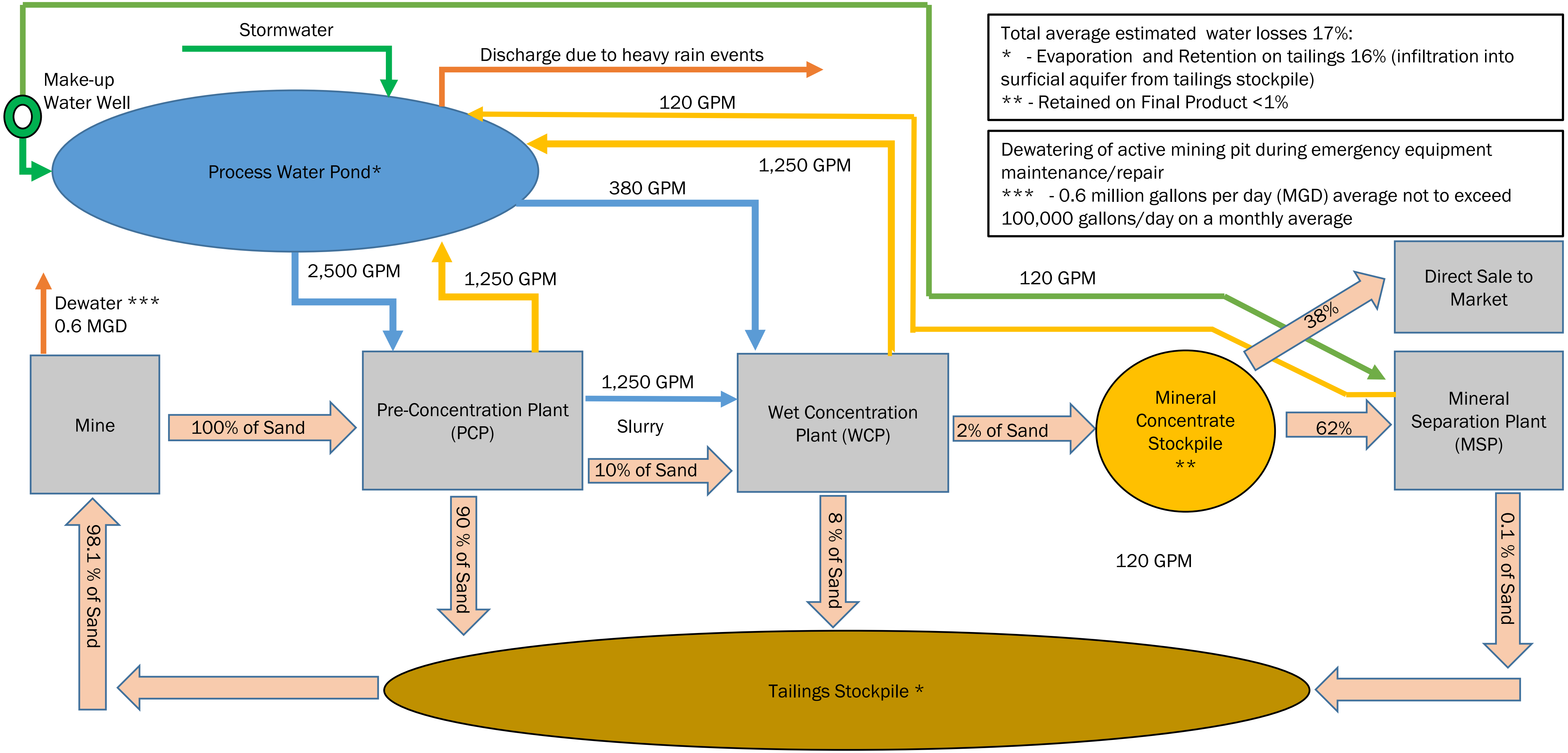
TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: WW
DRAWING DATE: 12/4/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 1,200 ft

ATTACHMENT A

PROCESS FLOW DIAGRAM



Total average estimated water losses 17%:
* - Evaporation and Retention on tailings 16% (infiltration into surficial aquifer from tailings stockpile)
** - Retained on Final Product <1%

Dewatering of active mining pit during emergency equipment maintenance/repair
*** - 0.6 million gallons per day (MGD) average not to exceed 100,000 gallons/day on a monthly average

Stormwater

Discharge due to heavy rain events

Make-up Water Well

Process Water Pond*

120 GPM

1,250 GPM

380 GPM

2,500 GPM

1,250 GPM

120 GPM

Dewater ***
0.6 MGD

Mine

100% of Sand

Pre-Concentration Plant (PCP)

1,250 GPM

Slurry

10% of Sand

Wet Concentration Plant (WCP)

2% of Sand

Mineral Concentrate Stockpile **

38%

Direct Sale to Market

62%

Mineral Separation Plant (MSP)

98.1 % of Sand

90 % of Sand

8 % of Sand

120 GPM

0.1 % of Sand

Tailings Stockpile *

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

AN EVALUATION OF DRAWDOWN FROM FLORIDAN WELLS FPW-01 AND FPW-02 AT THE TWIN PINES MINERALS, LLC MINE SITE

AN EVALUATION OF DRAWDOWN FROM FLORIDAN WELLS FPW-01 AND FPW-02 AT THE TWIN PINES MINERALS, LLC MINE SITE

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INTRODUCTION

Twin Pines Minerals, LLC is proposing to drill two production wells (FPW-01, FPW-02) in the upper Floridan aquifer at their proposed demonstration mine site located in Charlton county, Georgia (Figure 1). The production wells will supply water for heavy-minerals concentration plants at the mine, and each well will be pumped at a maximum of 500 gallons per minute (gpm). The proposed demonstration mine will operate for 4.0 years, and pumping will begin at the start of mining and will end upon the completion of mining.

The USGS (Bellino, 2019) estimated that pumping rates from the Floridan Aquifer in 2010 were 11.1 million gallons per day from the four counties containing the Okefenokee Swamp, including Charlton County, Ware County, Brantley County, and Clinch County. Twin Pines Minerals, LLC proposes to pump 1.44 million gallons per day.

In the following report, we first estimate the drawdown in the Floridan Aquifer caused by pumping from the proposed production wells. We use literature values to consider three pumping scenarios: a Base Case (determined from an average of literature values), a Maximum-Drawdown Case (determined from the literature values with the largest hydraulic diffusivity), and a Minimum-Drawdown case (determined from the literature values with the smallest hydraulic diffusivity). The maximum drawdown is determined for each case at the pumping wells and the closest boundary of the Okefenokee National Wildlife Refuge (ONWR).

The public has expressed concern that pumping in the Floridan Aquifer could lead to leakage through the upper confining unit of the Floridan Aquifer, potentially influencing water levels in the Okefenokee National Wildlife Refuge (ONWR). We first show that the conditions leading to leakage across the upper confining unit in the vicinity of St. Mary's, GA do not exist at the project site or the adjacent ONWR. Second, we examine the flaws in a study presented by Kitchens and Rasmussen (1995), which suggested that significant leakage could occur from the Okefenokee Swamp, through the upper confining unit of the Floridan Aquifer, into the Floridan Aquifer. Finally, we use a conservative analytical approach to show that the volume per unit area of water removed from the surficial aquifer and the ONWR is insignificant after 4.0 years of pumping in the Floridan Aquifer.

DRAWDOWN MODELING

The Theis (1935) solution is used to predict well drawdowns (s) caused by pumping in wells FPW-01 and FPW-02 over the 4.0 year life of the mine. The Theis (1935) equation is given by

$$s(r,t) = \frac{Q}{4\pi T} W(u)\,, \qquad (1)$$

where Q is the pumping rate (500 gpm or 96,250 ft^3/day for each well), r is the radial distance from the well, T is the aquifer transmissivity, and $W(u)$ is the Theis well function, given by the exponential integral

$$W(u) = \int_{u}^{\infty} \frac{e^{-y}}{y} dy \,. \qquad (2)$$

The variable u is

$$u = \frac{r\, S}{4Tt}, \qquad (3)$$

where S is the aquifer storage coefficient and t is time. The Theis solution assumes that the aquifer is infinite, confined, and homogeneous; that equipotentials are vertical; and that the well diameter is negligible. The total drawdown from both wells in the aquifer is determined by linearly superimposing (summing) the contributions from each well.

Two MATLAB codes were developed to predict the drawdown (Appendices A, B, and C). The first MATLAB code (Appendix A) calculates the time-dependent drawdown at a specified location (e.g., near the pumping well or at the edge of the ONWR). The second MATLAB code (Appendix B) predicts the spatial drawdown due to pumping at several wells at a specified time. Both codes allow the user to define the number of wells, aquifer properties (T and S), and a pumping schedule for each well. Example MATLAB commands for each code are shown in Appendices A and B. Both codes require the text file Welldat.dat (Appendix C), which includes the X-location, Y-location, time that pumping starts, time that pumping ends, and pumping rate for each well.

Both MATLAB codes require estimates of T and S. Williams and Kuniansky (2016) report T and S values for 11 wells in the upper Floridan Aquifer. One well had an anomalously low T value and was excluded from our analysis. The T and S 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 were determined by selecting the well pairs with the highest and lowest hydraulic diffusivity (Table 1).

The predicted drawdown at the proposed production wells is shown for each scenario in Figures 2 and 3. The maximum drawdown of the Floridan Aquifer at each of the wells and at the closest boundary of the ONWR is shown in Table 2. The pumping schedules for both wells are identical, and drawdown peaks when the wells are shutoff at 4.0 years. The maximum drawdown at each well is 14.3 ft for the Base Case, 31.0 ft for the Maximum-Drawdown Scenario, and 6.7 feet for the Minimum-Drawdown Scenario.

The aerial distribution of the predicted drawdown in the Floridan Aquifer for the Base Case scenario is shown in Figures 4 – 7, representing times of 1 year, 2 years, 4 years, and 5 years. Near the pumping wells, drawdown appears elliptical, and at larger distances the drawdown appears radial. The drawdown in the Floridan Aquifer at the nearest edge of the ONWR is 2.7 ft after 1 year of pumping, 3.2 ft after 2 years of pumping, and 3.8 ft after 4 years of pumping. One year after pumping (5 years), the upper Floridan Aquifer shows significant recovery (Figure 7) and the drawdown has reduced to 1.3 ft. For the Maximum-Drawdown Scenario, the drawdown at the edge of the ONWR is 13.2 ft after 4 years (Table 2), and the drawdown for the Minimum-Drawdown Scenario is 1.3 ft after 4 years.

LEAKAGE POTENTIAL FOR THE UPPER CONFINING UNIT OF THE FLORIDAN AQUIFER (HAWTHORN GROUP)

Based on groundwater data from a long-term pumping site in St. Mary's Georgia (e.g., Peck et al., 2005), members of the public have expressed concern that pumping in the Floridan Aquifer will induce leakage from the Okefenokee Swamp, through the upper confining unit of the Floridan Aquifer (the Hawthorn Group in the vicinity of the proposed project), into the Floridan Aquifer. Here, we address these issues. First, we show that the conditions leading to leakage across the upper confining unit in the vicinity of St. Mary's, GA do not exist at the project site or the adjacent ONWR. Second, we reveal the flaws in a study presented by Kitchens and Rasmussen (1995), which suggested that the Darcy flux (leakage) through the upper confining unit could be between 1.1×10^{-3} to 0.11 ft/day. Finally, we use a conservative analytical approach to show that the volume per unit area of water removed from the surficial aquifer and the Okefenokee Swamp after 4 years of pumping in the Floridan Aquifer is negligible and insignificant (1.17×10^{-11} ft^3/ft^2) and that the time required to achieve a new equilibrium is long, greater than 289 years, compared to the duration of the project (4 years).

Leakage Near St. Mary's, Georgia

In St. Mary's, Georgia (Camden County), a pulp and paper mill that pumped 35.6 million gallons per day from the Upper Floridan aquifer ceased operation in October 2002 (Peck et al., 2005). Following the cessation of pumping, recovery was observed in nearby confined surficial, upper Brunswick, and Upper and Lower Floridan aquifer monitoring wells over a period of 8 to 12 months (Peck et al., 2005). While the plant was operating, there was a downward gradient between the surficial and Brunswick aquifers. Once pumping stopped, the gradient reversed with a total apparent recovery response of 17.6 ft in a Brunswick well after 12 months. In the St. Mary's area, substantial leakage occurred across the upper confining unit due to local pumping in the Floridan aquifer. This type of leakage cannot occur in the vicinity of the proposed Twin Pines Minerals, LLC mine.

Around St. Mary's, GA, the upper confining unit Floridan Aquifer contains the upper and lower Brunswick aquifers (Clarke et al., 1990). Both units consist of phosphatic, slightly dolomitic sand and local carbonates. The upper Brunswick aquifer is found between geophysical markers A and B of Williams and Kuniansky (2015), while the lower Brunswick aquifer occurs between geophysical markers B and C (Williams and Kuniansky, 2015; Steele and McDowell, 1998). In Camden County GA, high transmissivity values are reported for the upper and lower Brunswick aquifer due to thicker, more permeable sand and carbonate beds (Clarke, 2003). The Brunswick aquifers pinch-out west of St. Mary's GA, and are absent in the vicinity of Folkston GA and beneath the Okefenokee Swamp (e.g. Payne et al., 2005). A series of calibrated groundwater flow models developed by the USGS (Payne et al., 2005; Cherry, 2015; and Cherry, 2019) assign a vertical hydraulic conductivity of 1×10^{-5} ft/d to the upper confining unit (Hawthorn Group) in the vicinity of the proposed mine and the Okefenokee swamp.

West of Folkston, GA, the upper confining unit (Hawthorn Group) consists of greenish-gray, low-permeability clays. At the Twin Pines Minerals, LLC site, the upper confining unit is ~ 325 ft thick (Williams and Kuniansky, 2015). Where clays are present in the upper confining unit, the vertical hydraulic conductivity is small (less than 1×10^{-4} ft/d), and leakage across the upper confining unit is negligible (Williams and Kuniansky, 2015). Below the Okefenokee Swamp, the upper Floridan aquifer is overlain by more than 300 ft of low-permeability sediments that effectively isolate the Floridan aquifer from vertical leakage and recharge (Torak et al., 2010).

Kitchens and Rasmussen (1995) Study

Kitchens and Rasmussen (1995) determined an impulse response function that related time series observations of water level in the swamp to observations of water levels in a well located in the Floridan aquifer beneath the swamp using regression deconvolution. Based on their deconvolution, they estimated an average time lag of one month for the aquifer to respond to changes in swamp water levels. They then estimated the hydraulic diffusivity of the upper confining unit to be 3,143 ft^2/d. Using this diffusivity value with a range of specific storage values derived from the literature for clays, they estimated the hydraulic conductivity of the upper confining unit to range from 1.1 ft/day to 0.011 ft/day. Using these hydraulic conductivity values and assuming a downward hydraulic gradient of 0.1, the authors estimated the Darcy flux (leakage) through the upper confining unit to be between 1.1×10^{-3} to 0.11 ft/day.

There are several flaws with this analysis. First, measured hydraulic conductivities in the upper confining unit are much lower than those estimated by Kitchens and Rasmussen (1995). Where clays are present in the upper confining unit, the vertical hydraulic conductivity is small (less than 10^{-4} ft/day), and leakage across the upper confining unit is negligible (Williams and Kuniansky, 2015). Calibrated groundwater models that include the proposed mine and the Okefenokee Swamp area use a vertical hydraulic conductivity of 10^{-5} ft/day for the upper confining unit (Payne et al., 2005; Cherry, 2015; and Cherry, 2019). Samples of the upper confining unit taken at the Twin Pines Minerals, LLC site show hydraulic conductivity values of 3.66×10^{-2} ft/day, 2.63×10^{-5} ft/day, and 4.56×10^{-6} ft/day (Holt et al., 2019), consistent with the values used in calibrated groundwater models.

A second flaw is that the model of Kitchens and Rasmussen (1995) assumes that all the fluctuations in the water levels of the Floridan aquifer are due strictly to vertical leakage through the upper confining unit. This is not the case. The Floridan aquifer is recharged from areas west of the Okefenokee Basin (Torak et al., 2010). Because of the high permeability of the Floridan aquifer, Floridan aquifer water levels beneath the swamp will respond rapidly to increases in recharge west of the swamp. We can estimate the time required for recharge to influence water levels in the Floridan Aquifer beneath the Okefenokee Swamp using an aquifer time constant. The time constant can be defined as

$$\tau_h = \frac{S\ L^2}{T}, \tag{4}$$

where L is the distance to the point of recharge. The time constant is related to a half-life and nominally represents the time required to move from one steady state condition to another. Using the Base Case values of T and S reported above and a distance (L) of 10 miles, the time constant is 172 days, indicating that head changes caused by recharge will quickly manifest beneath the swamp.

A third flaw in their model is that they assume that the hydraulic gradient is always downward. Torak et al. (2010) reported that the Floridan aquifer had artesian conditions during September 2006 in the Okefenokee Basin and Swamp. Torak et al. (2010) attribute the elevated groundwater levels and artesian condition in the vicinity of the Swamp to lower permeability of the Floridan aquifer and more than 300 ft of low-permeability overburden.

Impact of Floridan Pumping on Leakage from the Okefenokee Swamp

The change in the vertical flow between the Okefenokee Swamp and the Floridan Aquifer can be determined using an analytical approach. The governing equation for one dimensional, saturated groundwater flow in a homogeneous aquifer is

$$S_s \frac{\partial h}{\partial t} = K \frac{\partial^2 h}{\partial x^2}, \tag{5}$$

where S_s is the specific storage of the upper confining unit (assumed to be 10^{-4} 1/ft), K is the hydraulic conductivity of the upper confining unit (assumed to be 10^{-4} ft/day from Williams and Kuniansky, 2015), x is the vertical coordinate, and h is the hydraulic head. Equation 5 can be solved using the following boundary and initial conditions

$$h(x=0,t) = h_1 = 0 \text{ ft}, \tag{6}$$

$$h(x=L,t) = h_0 = -3.788, \tag{7}$$

$$h(x,t=0) = 0 \text{ ft}, \tag{8}$$

to yield (Crank, 1975)

$$h(x,t) = h_1 + (h_2 - h_1)\frac{x}{L} + \frac{2}{\pi}\sum_{n=1}^{\infty}\left[\left(\frac{h_2\cos(n\pi) - h_1}{n}\right)\sin\left(\frac{n\pi x}{L}\right)\exp\left(-\frac{Kn^2\pi^2 t}{S_s L^2}\right)\right], \tag{9}$$

where L is the thickness of the upper confining unit (325 ft). Here we assume that there is an instantaneous decrease of the head in the upper Floridan Aquifer of -3.788 ft (the maximum drawdown at the ONWR boundary for the Base Case Scenario) and that this head change persists for 4.0 years; this is conservative, as the decrease in head in the Floridan will be gradual and reach -3.788 ft at 4.0 years. Figure 8 shows the change in the hydraulic head in this situation. Note that most of the head change in the confining unit occurs below 200 ft.

Using the results shown in Figure 8, we can calculate the Darcy flux using

$$q(x,t) = -K\frac{dh(x,t)}{dx}, \tag{10}$$

Integrating Equation 6 with respect to time gives the total volume of flow per unit area passing location (x) at time (t), e.g.,

$$\frac{V(x,t)}{A} = -\int_0^t K \frac{dh(x,t)}{dx} dt \, , \tag{11}$$

At the top of the confining unit (x=0), the total volume per unit area of water lost from the surficial aquifer due to a hydraulic head decrease of 3.788 ft in the Floridan Aquifer is 1.17×10^{-11} ft^3/ft^2. This would mean that an area of 3,587 square miles would lose a total of 1.17 cubic feet of water after 4 years of pumping. This volume of water is insignificant compared to the evapotranspiration of a 3,587 square mile area in the same period.

Finally, we can estimate the time required for water levels in the swamp to respond to changes in water levels in the Floridan Aquifer using a time constant for groundwater flow. The time constant can be defined as

$$\tau_h = \frac{S_s L^2}{K} \, , \tag{12}$$

For the upper confining unit, the time constant is estimated to be 289 years. Drawdown in the Floridan aquifer from pumping at the Twin Pines Minerals, LLC mine will have a negligible effect on water levels in the Okefenokee Swamp.

SUMMARY

As part of the Twin Pines Minerals, LLC Demonstration Project, two production wells will be installed in the Floridan Aquifer, and each well will be pumped at 500 gpm for 4 years. The Theis (1935) solution was used to predict drawdown in each well. Solutions for each well were linearly superimposed using codes developed in MATLAB to predict the total drawdown. Three scenarios were developed using literature values: 1) a Base Case (determined from an average of literature values), a Maximum-Drawdown Case (determined from the literature values with the largest hydraulic diffusivity), and a Minimum-Drawdown case (determined from the literature values with the smallest hydraulic diffusivity). These results show that:

- The maximum drawdown at each well is 14.3 ft for the Base Case Scenario, 31.0 ft for the Maximum-Drawdown Scenario, and 6.7 feet for the Minimum-Drawdown Scenario.
- The maximum drawdown of the Floridan Aquifer at the edge of the ONWR is 3.8 ft in the Base Case Scenario, 13.2 ft for the Maximum-Drawdown Scenario, and 1.3 feet for the Minimum-Drawdown Scenario.
- One year after pumping stops (5 years), the upper Floridan Aquifer shows significant recovery and the drawdown has reduced to 1.3 ft for the Base Case Scenario at the edge of the ONWR.

We evaluated the leakage potential for the upper confining unit of the Floridan Aquifer to address public concern that pumping in the Floridan Aquifer will induce leakage from the Okefenokee Swamp, through the upper confining unit of the Floridan Aquifer (the Hawthorn Group in the vicinity of the proposed project), into the Floridan Aquifer. The evaluation showed:

- That the conditions leading to leakage across the upper confining unit in the vicinity of St. Mary's GA do not exist at the project site or the adjacent Okefenokee Swamp.

- Flaws in a study presented by Kitchens and Rasmussen (1995), which suggested that the Darcy flux (leakage) through the upper confining unit could be between 1.1×10^{-3} to 0.11 ft/day.
- That the volume per unit area of water removed from the surficial aquifer and the Okefenokee Swamp after 4 years of pumping in the Floridan Aquifer is negligible and insignificant (1.17×10^{-11} ft^3/ft^2) and that the time required to achieve a new equilibrium is long, greater than 289 years, compared to the duration of the project (4 years).

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Williams, L.J., and Kuniansky, E.L., 2015, Revised hydrogeologic framework of the Floridan aquifer system in Florida and parts of Georgia, Alabama, and South Carolina: U.S. Geological Survey Professional Paper 1807, 140 p., 23 pls.

Table 1. Hydraulic properties for the upper Floridan 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	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 2. Maximum drawdown at each pumping well over the 4.0 year life of the project for the Base Case, the Maximum Drawdown Scenario, and the Minimum Drawdown Scenario.

Well ID/Location	Base Case Drawdown (ft)	Maximum Drawdown Scenario (ft)	Minimum Drawdown Scenario (ft)
FPW-01	14.3	31.0	6.7
FPW-02	14.3	31.0	6.7
ONWR – Closest Edge	3.8	13.2	1.3

- ONWR = Okefenokee National Wildlife Refuge

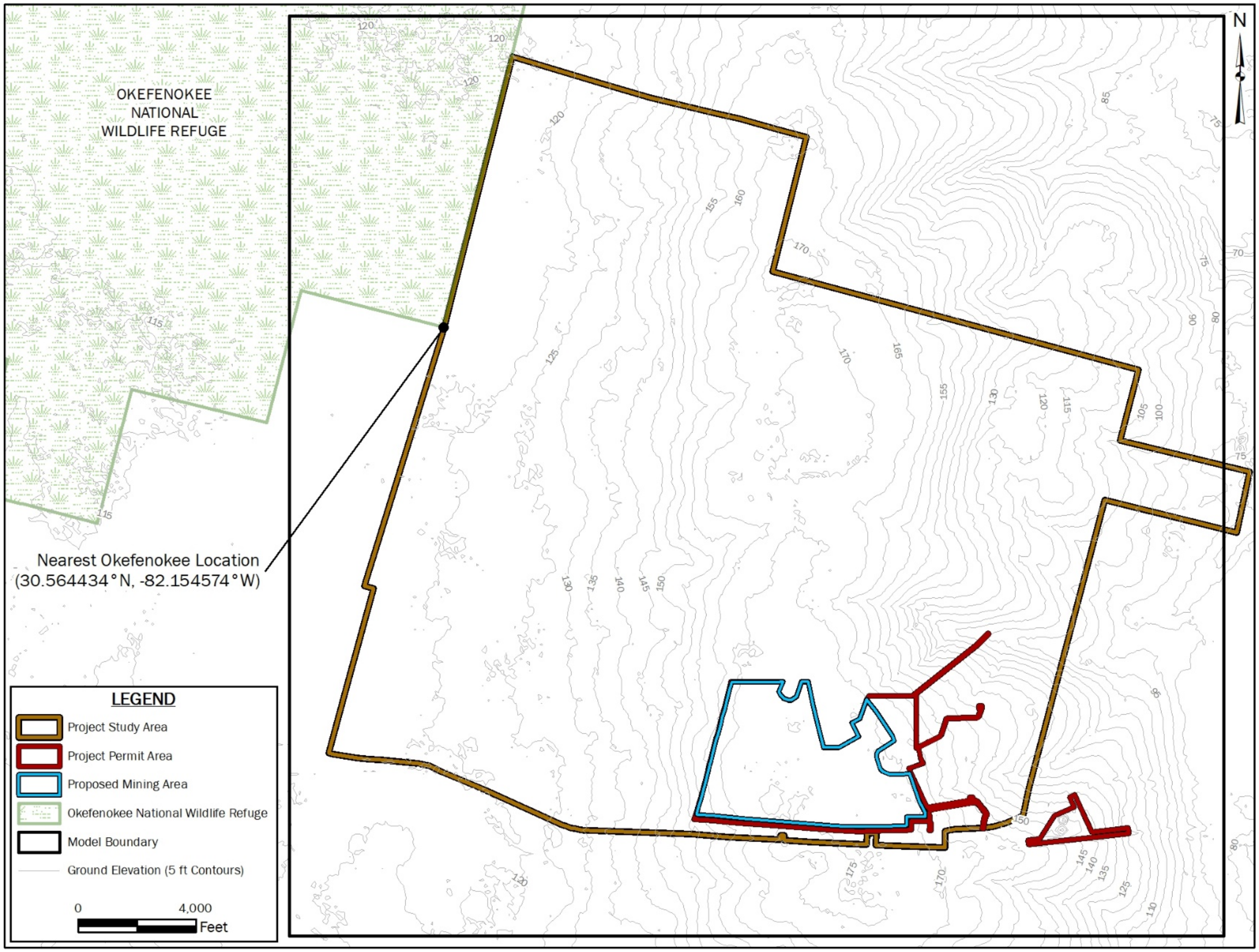

Figure 1. Location of proposed production wells at the Twin Pines Minerals, LLC mine site.

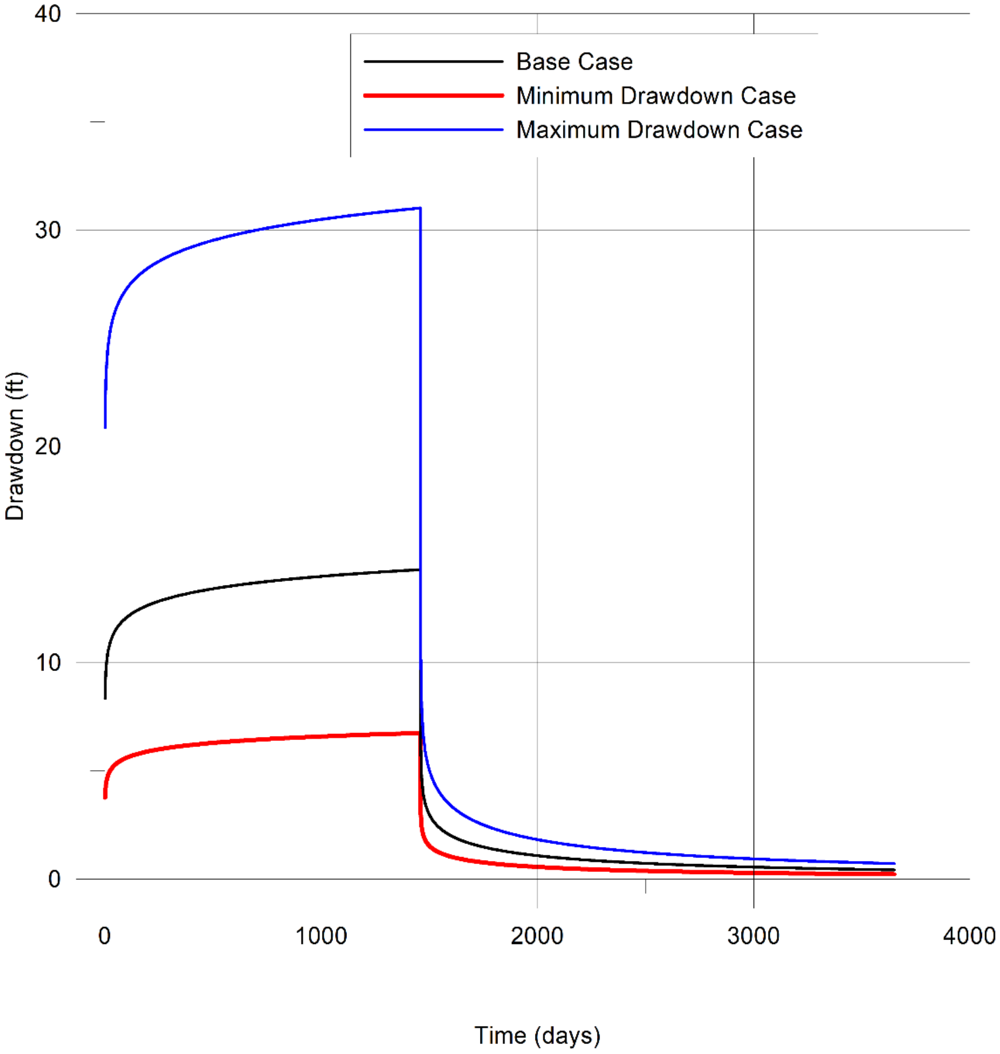

Figure 2. Predicted drawdown at well FWP-01 for the Base-Case Scenario, the Minimum-Drawdown Scenario, and the Maximum-Drawdown Scenario. Drawdowns are predicted for a ten-year (3,650 day) period.

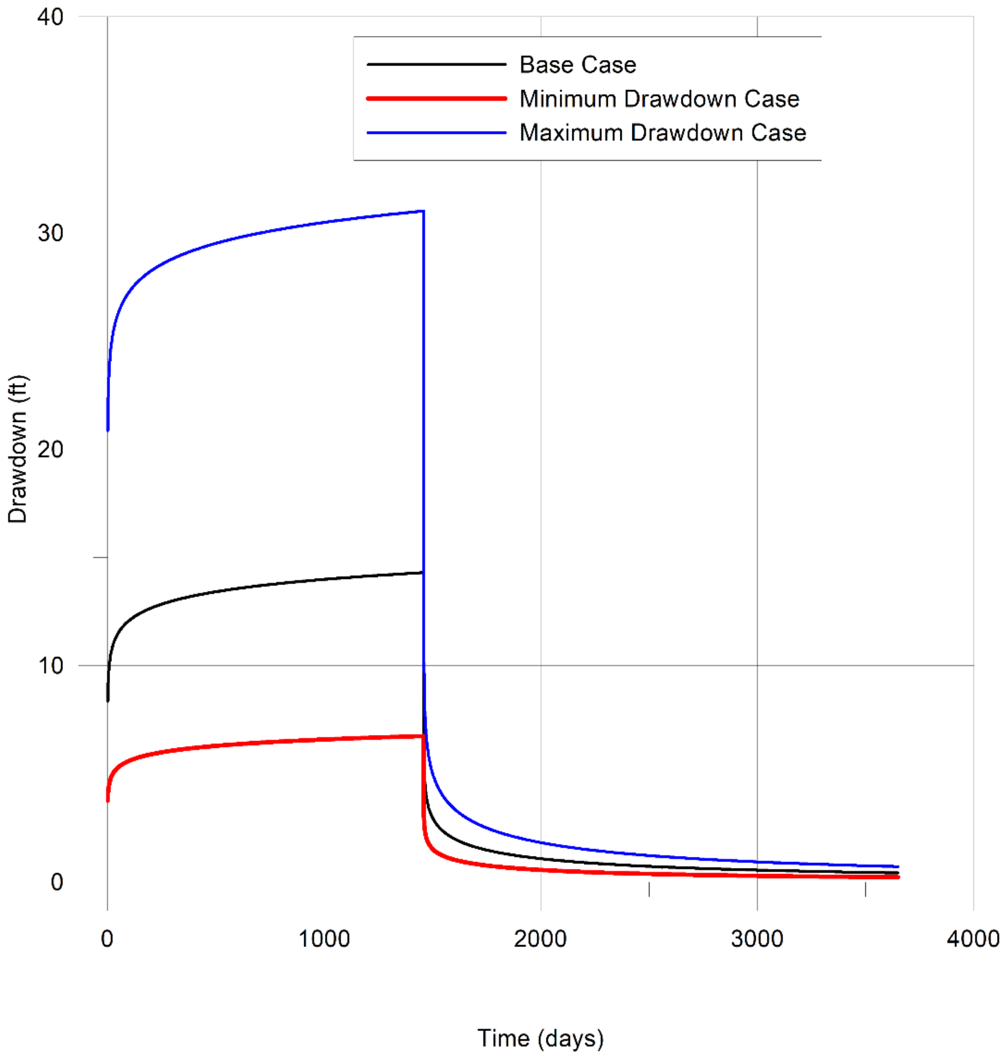

Figure 3. Predicted drawdown at well FWP-02 for the Base-Case Scenario, the Minimum-Drawdown Scenario, and the Maximum-Drawdown Scenario. Drawdowns are predicted for a ten-year (3,650 day) period.

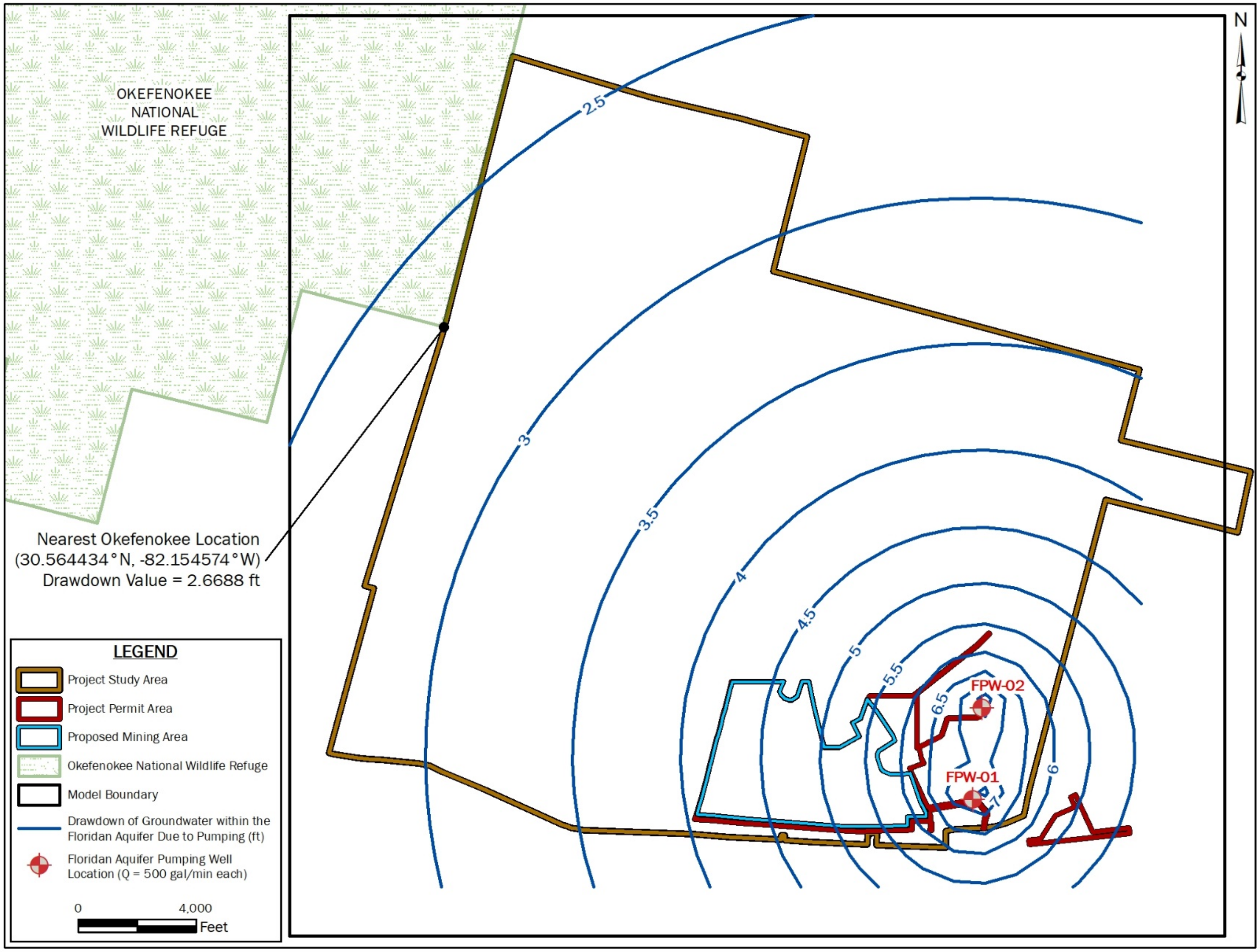

Figure 4. Drawdown (ft) in the Floridan Aquifer after 1 years of pumping.

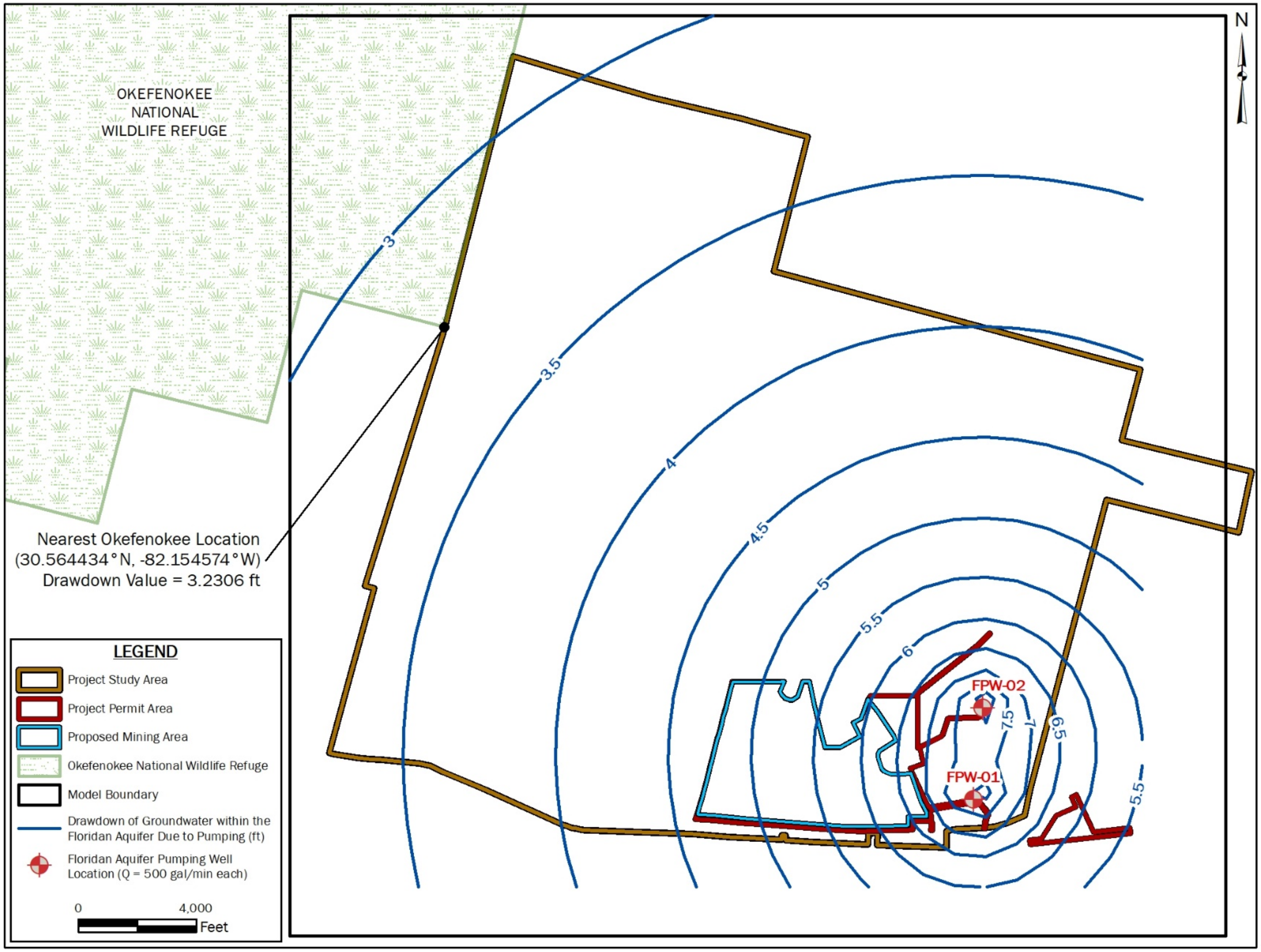

Figure 5. Drawdown (ft) in the Floridan Aquifer after 2 years of pumping.

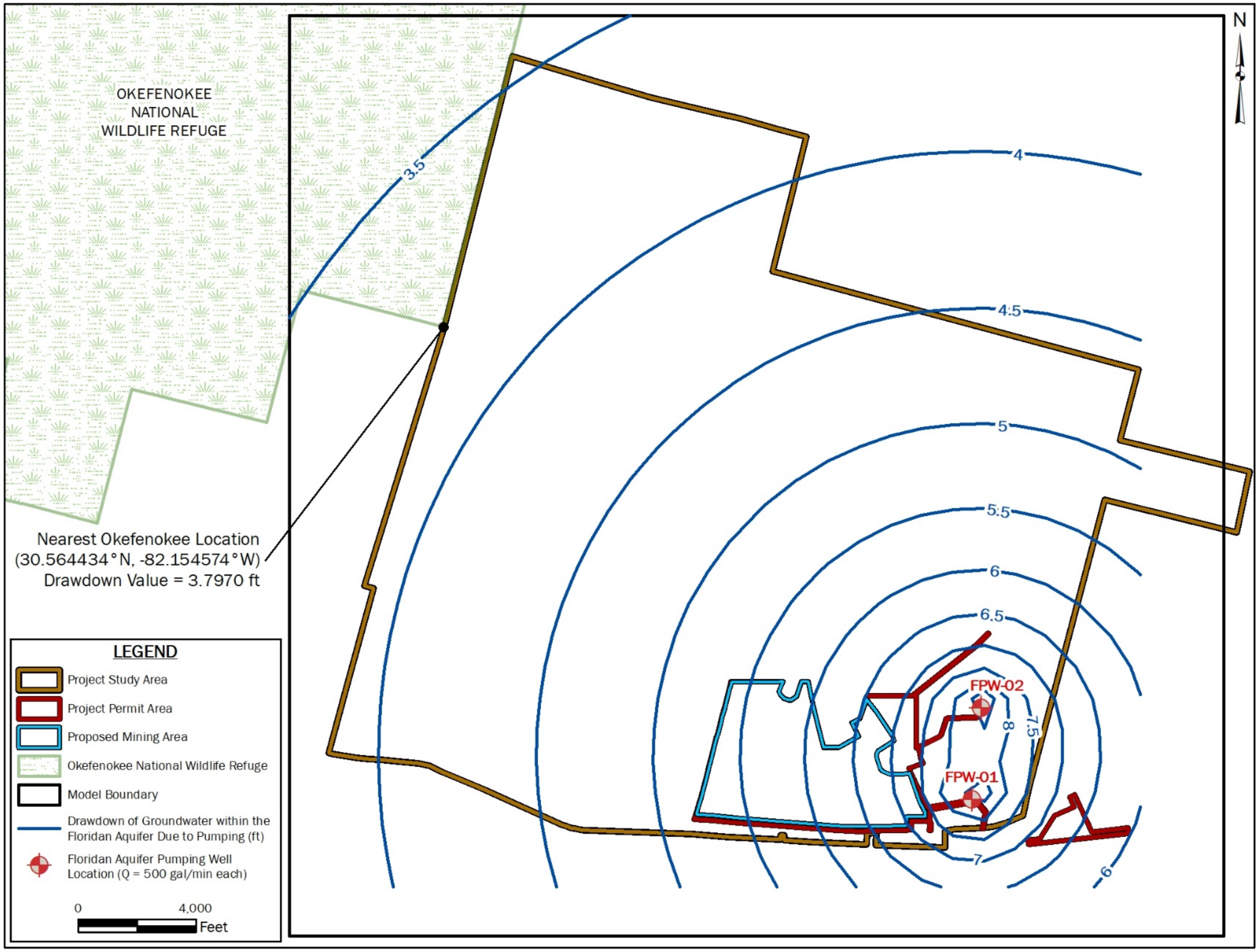

Figure 6. Drawdown (ft) in the Floridan Aquifer after 4 years of pumping.

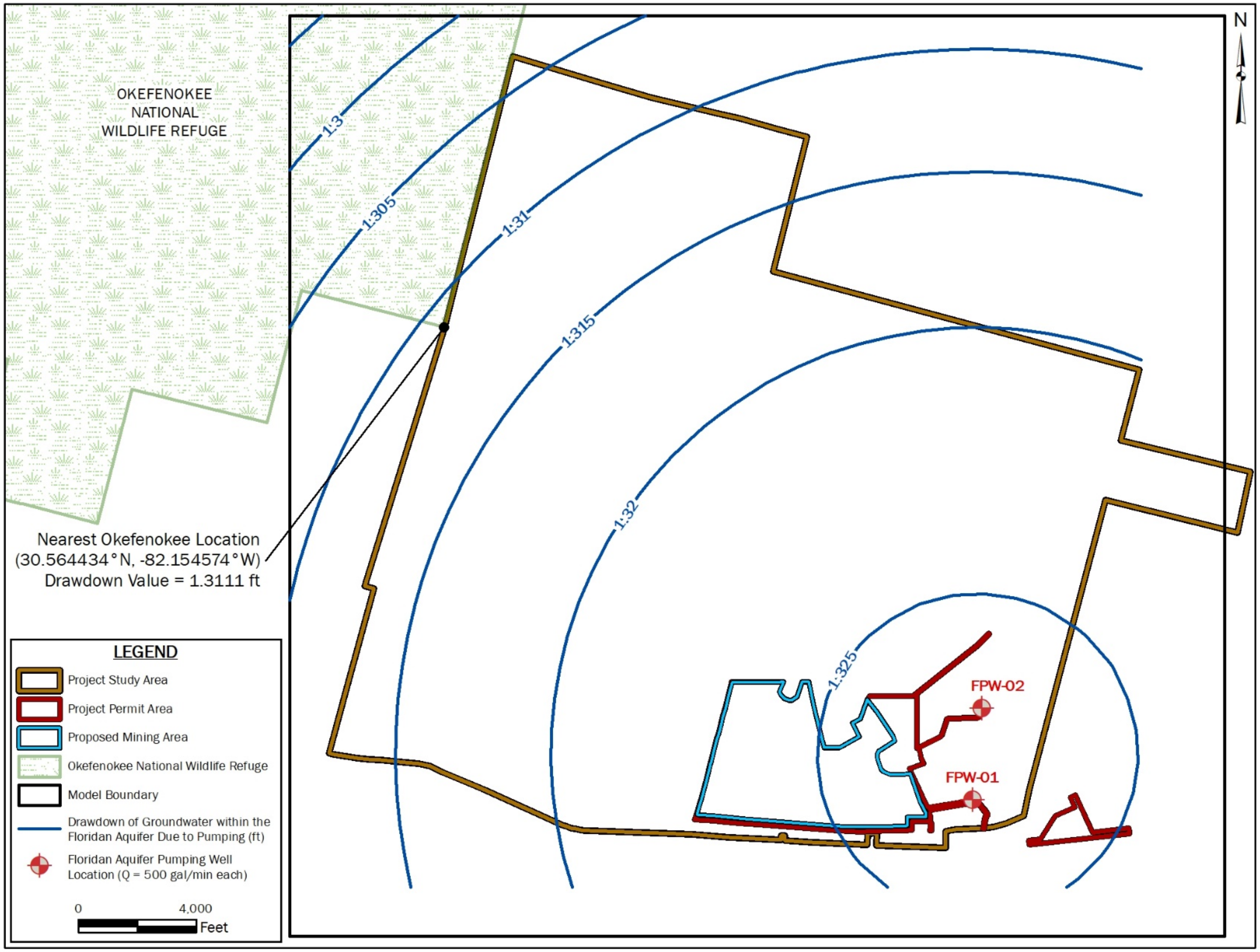

Figure 7. Drawdown (ft) in the Floridan Aquifer after 5 years (one year after pumping stopped).

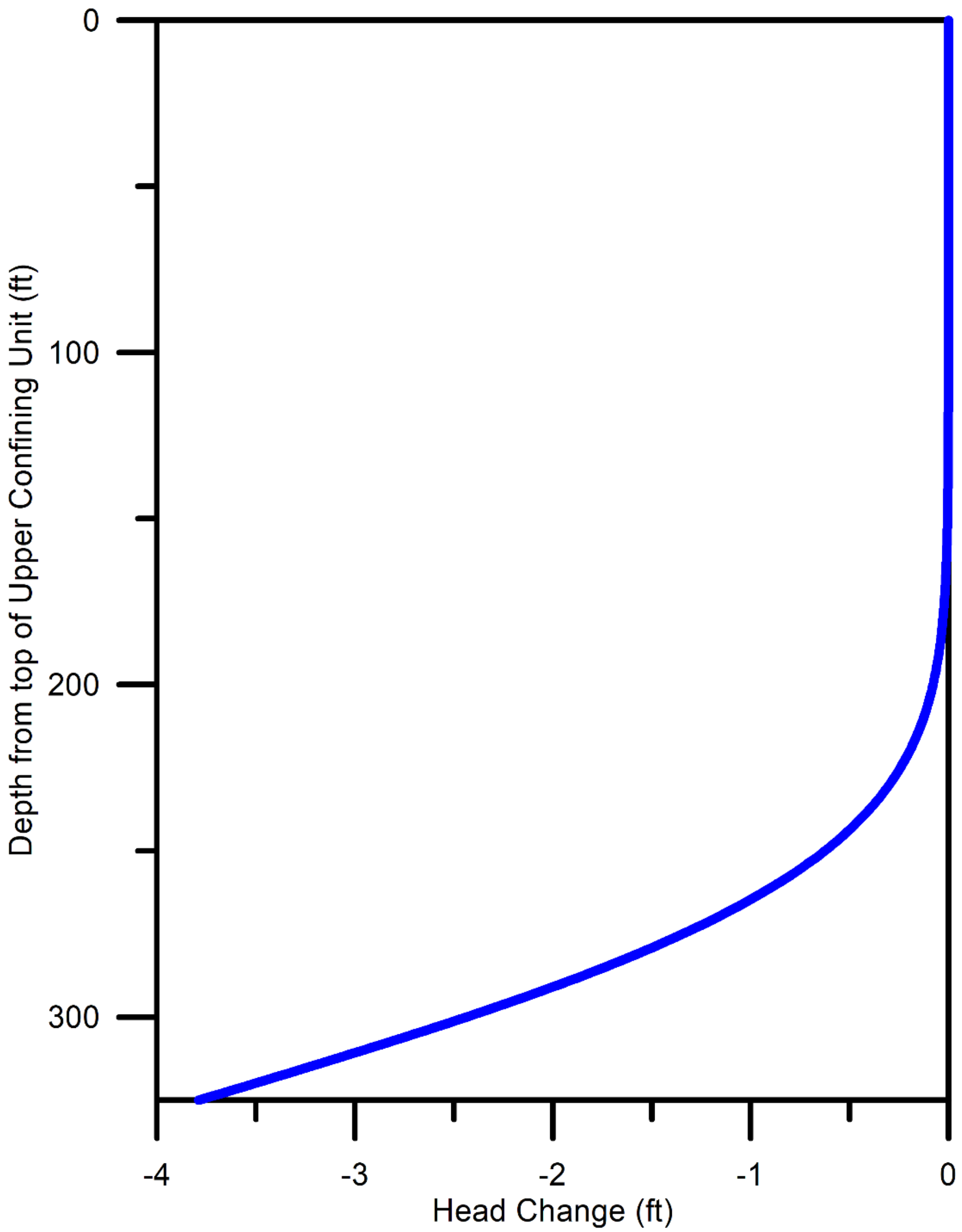

Figure 8. Head change in the upper confining unit of the Floridan Aquifer after 5.5 years of a constant decrease in the head in the Floridan Aquifer of 4.049 ft.

Appendix A

MATLAB Code for Predicting the Drawdown History at Wells

Appendix B

MATLAB Code for Predicting the Areal Drawdown

```
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(2,3650,677915.715,189234.47,1,18595,1.15e-3)
```

Well 2

```
 Theis_Time_Superposition_FLAQ(2,3650,678226.035,192335.26,1,18595,1.15e-3)
```

Minimum Drawdown
Well 1

```
 Theis_Time_Superposition_FLAQ(2,3650,677915.715,189234.47,1,36000,1.00E-02)
```

Well 2

```
 Theis_Time_Superposition_FLAQ(2,3650,678226.035,192335.26,1,36000,1.00E-02)
```

Maximum Drawdown
Well 1

```
 Theis_Time_Superposition_FLAQ(2,3650,677915.715,189234.47,1,11000,5.00E-06)
```

Well 2

```
 Theis_Time_Superposition_FLAQ(2,3650,678226.035,192335.26,1,11000,5.00E-06)
```

Drawdown at the edge of the swamp - base case

```
Theis_Time_Superposition_FLAQ(2,4015,659996,205260,0.5,18595,1.15e-3)
```

Drawdown at the edge of the swamp - Minimum Drawdown

```
Theis_Time_Superposition_FLAQ(2,4015,659996,205260,0.5,36000,1.00E-02)
```

Drawdown at the edge of the swamp - Maximum Drawdown

```
Theis_Time_Superposition_FLAQ(2,4015,659996,205260,0.5,11000,5.00E-06)
```

Appendix C

Input File Welldat.dat for MATLAB Codes

```
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
%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(355,527,200,200,612618,186269,2,18595,1460,1.15e-3)
```

Minimum Drawdown D=3.60E+06 ft2/day

```
Theis_Superposition_N_wells_FLAQ(355,527,200,200,612618,186269,2,36000,1460,1.00e-2)
```

Maximum Drawdown D=2.20E+09 ft2/day

```
Theis_Superposition_N_wells_FLAQ(355,527,200,200,612618,186269,2,11000,1460,5.00e-6)
```

Contents of text file welldat.dat:

```
677916.21     189234.47     0        1460           96250
678226.53     192335.26     0        1460           96250
```