Twin Pines Minerals, LLC

IMPACT OF THE PROPOSED TWIN PINES MINE ON THE TRAIL RIDGE HYDROLOGIC SYSTEM

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PROPOSED HEAVY MINERALS MINE
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INTRODUCTION

On July, 3 2019, Twin Pines Minerals (TPM) submitted an individual permit application to the U.S. Army Corps of Engineers for impacts to waters of the United States to develop a heavy mineral sand mine along Trail Ridge in Charlton County, Georgia. The proposed mine is located 3.2 miles west of St. George, Georgia, on Georgia State Highway Route 94 (Figure 1). Trail Ridge is a one (1) mile-wide and 100-mile-long topographic ridge that separates the Okefenokee Basin and Swamp from the coastal plain of Georgia (Force and Rich, 1989). It represents the crest of a former beach complex and was formed as inland sand dunes near the proposed Twin Pines Mine (e.g., Pirkle et al., 1993). The ridge is underlain by a shallow aquifer, locally known as the Surficial Aquifer, and forms a hydrologic divide between the Okefenokee swamplands to the west and the Saint Mary's River to the east. At the proposed mine site, the water table is very shallow with water depths of only a few feet. The Surficial Aquifer is perched on clays of the upper Hawthorn Group, which is considered to be the upper confining unit to the Floridian Aquifer in the region (e.g., Williams and Kuniansky, 2016).

The proposed permit area is approximately 2,414 acres area, located southeast of the Okefenokee National Wildlife Refuge (ONWR) boundary; however, TPM will only mine an approximate 898-acre area located about 2.7 miles from the ONWR boundary (Figure 2). The area extending from the western mining boundary to the edge of the permit boundary will be avoided and will provide a buffer to the ONWR.

Twin Pines Mine proposes a novel approach for mining heavy minerals. Twin Pines will use a mobile drag line to excavate mineralized sands from a small trapezoidal mine pit (maximum size: 500 feet (ft) long, bottom width of 100 ft, and 25 to 50 ft deep). The excavated materials will be moved to on-site processing facilities using a mobile conveyor, where the heavy minerals will be removed from the sand. About 98% of the mined sand will then be returned as spoils to the inactive portion of the mine pit. The mine pit will advance approximately 100 feet per day. As the pit advances into unmined areas, the inactive portion of the pit will be filled with spoil at the same rate as the pit advances and reclaimed. The average time that a portion of the pit will remain open is approximately five (5) days. Following the return of spoils to the mine pit, piezometers will be installed to monitor the recovery of groundwater levels. The topography of the reclaimed mine spoils will be returned as close to pre-mining elevations as possible. The post-project wetland area will be roughly equivalent to the pre-project wetland area, and upland areas will be re-constructed for longleaf pine. The proposed mining activities will be completed in 11 years (Figure 3).

The study area consists of approximately 12,000 acres of land located near St. George, Charlton County, Georgia. This area is comprised of five (5) tracts identified as Loncala, Dallas Police & Fire, Keystone, TIAA, and Adirondack. Reference to "study area" in this report refers to activities conducted within the proposed mining area and adjacent tracts.

The objective of this report is to document groundwater models created to evaluate the impact of the proposed Twin Pines Mine on the hydrologic system underlying Trail Ridge. Two (2) types of models were developed: numerical models and analytical models.

Two (2) numerical models were developed using the U.S. Geological Survey code MODFLOW-2005 (Harbaugh, 2005) to simulate three-dimensional, steady-state groundwater flow in the Surficial Aquifer at the study area. First, a model representing pre-mining conditions was created and calibrated to match observed water levels in piezometers and wells. The second model represents post-mining conditions and is based on the original calibrated model, except the calibrated hydraulic conductivity values of the aquifer within the mined zone were homogenized to represent the mine pit filled with spoil. The pre-mining and post-mining models were compared to evaluate changes in the groundwater discharge to the model boundaries (e.g., the swamps to the west and the groundwater system to the east). The models compare changes in the groundwater discharge to streams along Trail Ridge and changes in the water table position at the mine and near the Okefenokee swamp due to the proposed mining project. This comparison shows that the proposed mining activities will have negligible impact on the hydrologic system of Trail Ridge and the Okefenokee Swamp.

An analytical model was developed to evaluate drawdown in the Surficial Aquifer caused by the moving mine pit. The model shows that, even in a highly conservative (extreme) modeling scenario, perturbations in the water table due to the moving mine will quickly recover.

CONCEPTUAL MODEL OF GROUNDWATER FLOW

Trail Ridge is a classic example of a topographically-driven hydrologic system as illustrated in the site conceptual model (Figure 4). The water table is shallow and mimics the ground surface (Figure 5). Much of the precipitation that falls on Trail Ridge is returned to the atmosphere by evaporation and transpiration. Precipitation that is not evaporated or transpired to the atmosphere infiltrates to recharge the Surficial Aquifer. Groundwater recharge on Trail Ridge causes the water table to mound close to the land surface. In the absence of recharge, water would flow from the Okefenokee Swamp in the west (where water levels are ~ 120 ft) to the east (where water levels are < 80 ft) and the water table would linearly decline to the east.

Groundwater mainly flows from the centerline of Trail Ridge to the west and to the east and small amounts of groundwater discharges to local streams, particularly on the eastern side of the study area. Along the western margin of the study area, groundwater flow provides water to the Okefenokee Swamp and related wetlands. On the eastern side, groundwater provides base flow to streams.

The hydrology and geology of Trail Ridge in the study area has been extensively characterized (e.g., Holt et al., 2019a; 2019b; 2019c; 2019d, 2019e, 2019f, and 2019g). 387 exploratory borings were cored and described by TPM. An additional 217 borings were completed and described by TTL including 86 piezometers installed in the Surficial Aquifer, and 2 deep pumping wells and 22 observation wells were drilled in the northern and southern portions of the study area (Figure 6). Soil cores reveal that the upper part of the Surficial Aquifer is heterogeneous, consisting mainly of unconsolidated sands interspersed with irregular, discontinuous zones of semi-consolidated to consolidated sands cemented by humate (Figures 7 and 8). Deeper within the Surficial Aquifer, unconsolidated sands are interbedded with discontinuous lenses of clayey sands, silty-clayey sands, and local clays units, likely derived from the underlying Hawthorn Group. Six (6) subsurface units have been identified within the Surficial Aquifer in the study area; these units are briefly described below:

1) The majority of the sediment underlying Trail Ridge is part of an unconsolidated sand unit that generally consists of silty sands (SM) and well sorted sands (SP). Subsurface boring data collected from the project area indicates that this unit extends from land surface to the top of the Hawthorn Group sediments.
2) Semi-consolidated sands generally consist of fine- to medium-grained silty sands (SM) and well sorted sands (SP) and silty-clayey sand (SC-SM) with a color range from black to brown. The general characteristics of semi-consolidated sand unit includes sands that are moderately cohesive due to the presence of minor amounts of humate.
3) Consolidated black sands consist of fine- to medium-grained silty sands (SM) and well sorted sands (SP) and are generally described as black in color. These sands are cemented by humate.

4) Silty-clayey sands are black to brown to grey and generally consist of fine- to medium-grained sands with silt and less than five percent clay content. These sands are loosely cohesive due to the presence of small amounts of clay.
5) The clayey sand unit generally consists of fine- to medium-grained silty sands with clay content between 10 to 40 percent and ranges in color from yellow to brown to grey. The general characteristics of the clayey sand unit includes sands that are cohesive due to moderate clay content.
6) The clay unit at the site consists of silty clays, sandy clays, and fat clays and ranges in color from brown to grey to greenish grey closer to the Hawthorn Group. The clay layer is generally firmer and more compact than the surrounding sand units.

The Surficial Aquifer is underlain by the sediments of the Hawthorn Group. The Hawthorn Group is approximately 350 ft thick under Trail Ridge (e.g., Williams & Kuniansky, 2016) and consists of low-permeability, calcareous clays that effectively isolate the Surficial Aquifer from the deeper Floridian aquifer. The hydraulic conductivity of three samples of the upper Hawthorn are 3.7×10-2 feet per day (ft/d), 2.6×10-5 ft/d, and 4.5×10-5 ft/d (Holt et al., 2019f).

THREE-DIMENSIONAL GROUNDWATER FLOW MODELS

Three-dimensional groundwater flow models were developed for a broad region beyond the extent of site characterization activities for Twin Pines Mine (Figure 9). The east and west model boundaries were selected to approximately parallel Trail Ridge and encompass a significant part of the Okefenokee Wildlife Refuge. The northern and southern boundaries were extended beyond the limits of property tracts investigated by Twin Pines. These models numerically approximate solutions to the governing equation for steady-state flow in heterogeneous aquifers:

$$\frac{\partial}{\partial x}\left(K_h \frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_h \frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_v \frac{\partial h}{\partial z}\right)=0 \qquad (1)$$

where h is the hydraulic head; K_h is the horizontal hydraulic conductivity; K_v is the vertical hydraulic conductivity; and x, y, and z are spatial coordinates. The solution of Equation 1 requires boundary conditions around the entire model domain.

MODFLOW-2005

MODFLOW is the U.S. Geological Survey's (USGS's) modular finite-difference flow model, which is a computer code that solves the groundwater flow equation. The program is used by hydrogeologists to simulate the flow of groundwater through aquifers. This model was constructed in the early 1980's, and various versions of the model have been used for over 35 years by academics, private consultants, and government scientists to simulate groundwater flow. MODFLOW is considered an international standard for simulating and predicting groundwater conditions and groundwater/surface-water interactions. MODFLOW-2005 (Harbaugh, 2005), was used to conduct modeling for the Twin Pines project.

Groundwater Flow Model Construction

MODFLOW-2005 (Harbaugh, 2005) was to used simulate steady-state groundwater flow in the model domain. MODFLOW-2005 uses an integrated-finite difference formulation to numerically approximate solutions to Equation 1, given a predetermined set of boundary conditions. In the following discussion, the model spatial discretization and boundary conditions are described, and the methodology used to determine the initial spatial pattern of horizontal and vertical hydraulic conductivity is discussed. In addition, the methods used for determining the initial vertical and horizontal hydraulic conductivity are discussed, and the implementation of the model is described.

Spatial and Temporal Discretization
Prior to simulating groundwater flow using MODFLOW-2005, the study area was subdivided into an orthogonal grid of blocks, called cells or grid blocks. The horizontal and vertical hydraulic conductivity is uniform within the block. In the horizontal plane, the study area was subdivided into 62 rows in the y-direction and 64 columns in the x-direction (Figure 10). Each grid block is ~495 ft wide and ~503 ft long. In the vertical direction, 15 model layers were assigned. Because a deformed model grid was used, model layers vary in thickness from a minimum of 0.1 ft to a maximum of 10.0 ft (Figure 11 and 12). The top of the model is the land surface (Figure 13), and the base of the model is the top of the Hawthorn (Figure 14).

In MODFLOW-2005, time is subdivided into a series of time intervals or stress periods. Since our simulation is at a steady state only one stress period, of length one (1) day, is required.

Boundary Conditions
As described above, the partial differential equation governing steady-state groundwater flow in a heterogeneous aquifer requires the definition of boundary conditions for all model boundaries. In the following, the selection of boundary conditions for this model is discussed.

The groundwater contours along Trail Ridge are generally oriented north-south and flow lines are generally oriented to the east or west perpendicular to the contours (Figure 5). When flow is at a steady state, streamlines are stationary and are no flow boundaries. As a result, no flow boundaries are assigned to the northern and southern edges of the model domain (Figure 10).

Along the western and eastern boundaries of the model domain, groundwater likely occurs within a few feet of the land surface. In addition, the difference between the water table elevation at these boundaries and the center of Trail Ridge is great, exceeding 50 feet; therefore, these boundaries are considered to be constant head (constant water table) boundaries, and the head values are assigned to be at a depth of one (1) ft below the land surface along the boundaries (Figure 10).

The base of the Surficial Aquifer is the low permeability Hawthorn (Figure 14) (Holt et al., 2019b; 2019f, 2019g). Because the permeability of the Hawthorn is much lower than that of the Surficial Aquifer Materials, the lower boundary of the model is assigned to be a no-flow boundary.

The top boundary of the model receives groundwater recharge. Our initial rate of recharge was determined by subtracting the average annual potential evapotranspiration rate from the average annual precipitation rate at the site as reported in Holt et al. (2019e). The initial recharge rate of 4.54 inches per year (in/yr) was applied to the entire upper surface of the model domain.

Streams flowing from Trail Ridge are typical gaining streams that derive some or all their flow from aquifer base flow (the aquifer discharges into the stream bed). Conceptually, these streams are similar to drains that remove water from the groundwater system at a rate proportional to the head difference between the aquifer and the stream. Drain boundary conditions are assigned to the location of the major streams within the model domain (Figure 10).

Initial Aquifer Hydraulic Conductivity
The spatial distribution of semi-consolidated and consolidated sands is highly complex in the upper part of the Surficial Aquifer. Units identified in adjacent boreholes are difficult to correlate, and zones of semi-consolidated sand appear to grade laterally and vertically into zones of consolidated sand.

Because of these complications, it is not possible to identify unique stratigraphic units in the upper part of the Surficial Aquifer. Consequently, a geostatistical approach was used based on indicator kriging (e.g., Journel, 1978) to define the spatial variations in hydraulic conductivity within the Surficial Aquifer.

Indicator kriging generates a map of the probability that a particular soil type is present. Indicator kriging requires transforming borehole soil type data. A value of 1 is assigned where the target soil type is present and a value of 0 is assigned where it is absent. Variograms were created for each of the soil types and used in a three-dimensional indicator kriging algorithm provided in S-GeMS (Stanford Geostatistical Modeling Software) (Remy, 2005). The resulting maps show the probability that each of the six soil types and the Hawthorn Group were present in every model grid block. For each grid block, the probabilities were normalized so that they summed to 1.0. These probabilities were used to determine the horizontal and vertical hydraulic conductivity for each grid block. The horizontal hydraulic conductivity was determined using an arithmetic mean of each of the soil type hydraulic conductivities, weighted by the probability that each soil type was present in the grid block. Similarly, the vertical hydraulic conductivity was determined using a probability-weighted harmonic mean.

Hydraulic conductivity values for each soil type were selected (Table 1) to ensure that the vertical and horizontal hydraulic conductivity in grid blocks far from soil boring locations were consistent with those calculated from pumping tests and slug tests (Holt et al., 2019a), e.g., a horizontal hydraulic conductivity of 6.36E-03 centimeters per second (cm/s) (18 ft/d) and a vertical hydraulic conductivity of 2.60E-04 cm/s (0.74 ft/d) . Laboratory testing data could not be used to assign the soil-type hydraulic conductivity values, because the soil samples were contaminated by drilling muds, lowering the measured hydraulic conductivity (Holt et al., 2019f)

The initial model hydraulic conductivity values for each model layer are shown in Figures 15 – 29.

MODFLOW-2005 Implementation
The input files for MODFLOW-2005 were prepared using the commercially available program Visual MODFLOW, which was produced by Waterloo Hydrogeologic. Geospatial data were imported into Visual MODFLOW, including the elevations of model horizons, hydraulic conductivity fields, the domain boundary, and stream locations. Boundary conditions were assigned, and the numerical grid and resulting hydraulic property fields were created within Visual MODFLOW. Visual MODFLOW was then used to generate the required input files for MODFLOW-2005, run MODFLOW-2005, and post-process the simulation results.

Model Calibration
Trial and error approaches were used to calibrate the recharge rate and the leakance per unit length for each reach of drains (representing streams). These parameters were systematically varied until the model produced maximum head values that were close to those observed in piezometers and wells.

Following the trial and error calibrations, the program PEST (Doherty and Hunt, 2010) was used to automatically calibrate the hydraulic conductivity values. Average groundwater levels measured in piezometers were used as calibration targets (Table 2). Within PEST, the distribution of hydraulic conductivity is described by a set of pilot points with their starting values set to the hydraulic conductivity determined from the grid block in which they reside. PEST then runs MODFLOW-2005 and determines the difference between the observed heads and the modeled heads at observation points, the objective function. PEST uses an optimization algorithm to alter the values of hydraulic conductivity at the pilot points. These new hydraulic conductivity values are spatially interpolated to other active cells using kriging. As the calibration process proceeds, PEST adjusts the values of hydraulic conductivity at the pilot points and interpolates the new values across the model domain, until the differences between the observed and modeled heads are minimized. Regularization during the calibration process prevents overfitting and spurious parameter estimates by imposing a numerical penalty on the objective function for deviations from the initial estimates (Doherty and Hunt, 2010). For this model, 207 pilot points were regularly distributed amongst the 15 model layers, and a singular-value-decomposition-assisted regularization approach with 30 super-parameters was used.

Because the initial calibrated models produced water tables that greatly exceed the elevation of the land surface in areas with no piezometers or wells, a number of “soft” calibration targets were added to the calibration target data set (Table 2). At the location of these soft targets, the water table position was set to 2 ft below the land surface. The objective function (difference between observed and modeled heads) was essentially minimized on the completion of 25 PEST iterations (Figure 30).

Groundwater Flow Model Results

The trial and error calibration approach led to a reduction of the initial recharge rate. A recharge rate of 4.54 in/yr led to unreasonably high modeled head values. Applying a recharge rate of 2.8 in/yr produced head values near an elevation of 170 ft along the centerline of Trail Ridge. The difference between the initial and final recharge rates is likely due to groundwater evapotranspiration from phreatophytes in the presence of a shallow water table.

Final leakance per unit length values ranged from 0.001 – 0.1 ft/d for the drain boundaries representing streams. Higher leakance values were required for streams on the eastern side of the model domain.

The hydraulic conductivity values for the model were calibrated using PEST. Overall, the calibration procedure led to a good match between the observed and modeled heads (Figure 31). The mean of the residuals was small (0.79 ft) compared to the range of observed heads (over 80 ft), and the normalized root mean squared error was 3.32%.

The calibrated horizontal hydraulic conductivity fields for each model layer are shown in Figures 32-46. Similar hydraulic conductivity patterns are found in all model layers, indicating that the hydraulic heads are not sensitive to vertical variations in hydraulic conductivity. In general, higher hydraulic conductivities were produced on the west and east model boundaries to accommodate the flux of water through a thinner aquifer. Higher hydraulic conductivities along the center of Trail Ridge flatten the water table. North-to-south oriented bands of lower hydraulic conductivity occur along the western and eastern flanks of Trail Ridge, maintaining the water table within a few feet of the land surface.

The modeled pre-mining water table (Figure 47) resembles the potentiometric surface of the Surficial Aquifer on July 26, 2019 (Figure 5). The modeled water-table does not reproduce all of the topographic variability shown in the interpreted potentiometric surface map but does retain the overall pattern and shows the influence of the streams on the eastern side of the model domain.

Groundwater Flow Model Post Mining Results

After the mining is completed, the mined volume will be filled with homogenized sand spoil. The elevation of the base of the proposed mining zone ranges from ~136 ft in the northwest part of the mined area to 111 ft in the southeast part of the mined area (Figure 48). For the purpose of this model, it is assumed that the final elevation of the bottom of the mine is 119 ft. Experiments conducted on homogenized sands from the Twin Pines Mine study area reveal that the hydraulic conductivity of the pit filling will be approximately 1.0E-03 cm/s (Holt et al., 2019f). The calibrated hydraulic conductivity values in all grid blocks above 119 ft within the mine footprint were replaced with a horizontal and vertical conductivity of 1.0E-03 cm/s. The resulting horizontal hydraulic conductivity values are shown in Figures 49 - 63. Within the mine footprint some of the horizontal hydraulic conductivity values are reduced; however, nearly all the vertical hydraulic conductivity values were increased.

Comparison of the Pre-Mining and Post-Mining Model Results

The changes of hydraulic conductivity within the mine footprint produced only minor variations in the position of the water table (Figure 64). The differences are best revealed by subtracting the post-mining water table from the pre-mining water table (Figure 65). Across much of the model domain, water table changes are very small. In the vicinity of the proposed mine pit, water table elevations both increased and decreased as a result of mining activities. The water table rose over 2 ft in the western part of the mining area, and locally decreased by over 1 ft near the central part of the mining area. Within the eastern part of the mining area water level increases and decreases due to mining were less than one (1) ft. These variations result from the groundwater flow system adjusting to a homogeneous block of sand spoil placed within the mine pit. Where the Okefenokee National Wildlife Refuge is closest to the mine footprint, the water table is reduced by 0.0004 ft due to mining activities.

Table 3 presents a comparison of the water budgets for the pre-mining and post-mining models. Mining leads to a decrease of stream outflow (drains) across the entire model of 35 cubic feet per day (ft^3/d) or 4.1E-04 cubic feet per second (cfs) and an equivalent increase in groundwater discharge at the constant head boundaries.

Both models were subdivided into two zones following the topographic divide on Trail Ridge (Figure 66). Separate water budgets were determined for each zone in each model. For the eastern zone (Zone 1), Table 4 presents the water budget. The eastern zone experienced a decrease of 40 ft^3/d of stream discharge and 300 ft^3/d of discharge to the constant head boundaries due to mining. The western zone (Table 5), however, showed an increase of 4 ft^3/d in stream discharge and 340 ft^3/d of groundwater discharge due to mining. Based on these model results, the swamps to the west of the study area, including the Okefenokee Swamp, will receive a fractional increase in both stream and groundwater discharge due to the proposed mine.

IMPACT OF A MOVING MINE

At the Twin Pines Mine, heavy mineral sands will be excavated from a moving pit that has a length of 500 ft, a width of 100 ft, and an average depth of 50 ft. The pit will advance at a rate of 100 ft/day, and the oldest part of the pit will be filled at the same rate, so the pit dimensions will change minimally over time. Some water contained within the excavated sands will be removed from the pit by the drag line. Much of the water within the excavated sands will, however, quickly drain from the excavated sand and infiltrate back into the aquifer. Furthermore, the sand spoil that is returned to the mine pit will also contain a significant amount of water. Some water will be lost to evaporation as the sand is transported on mobile conveyors to and from the processing facility, but the net loss of water from the pit area and the aquifer will be small. Below, we will consider the impact of an extreme case, where all the water in the excavated sands are removed from the aquifer.

The extent of that drawdown in the Surficial Aquifer due to the removal of all water within the excavated sands can be quantified using an analytical solution for a moving, rectangular source of heat (e.g., Ling, 1973 and Tichy 1991). This solution can be adapted to simulate the drawdown effects from a moving mine pit, as the equations for heat flow and groundwater flow are identical.

If we move with the center point of the mine pit, the heads will quickly drawdown, and the pattern of the drawdown will eventually stabilize or reach a steady state. The time required for the moving pit to reach steady state is given by (Hou and Komanduri, 2000)

$$t_{SS} = 20\frac{T}{SV^2} \qquad (2)$$

where S is the storage coefficient, V is the velocity of the pit, and T is the aquifer transmissivity. If we assume that

V = 100 ft/d
T = 1,500 ft/d
S = 0.3

the drawdown due to the moving mine pit will reach a steady state in 10 days.

The governing equation and boundary conditions for a moving rectangular sink of groundwater is

$$\nabla^2 h = \frac{S\,V}{T}\frac{\partial h}{\partial x} \qquad (2)$$

with boundary conditions

$$z = 0,\ |x| \le L,\ |y| \le W,\ q = -K\frac{\partial h}{\partial z} \qquad (3)$$

$$z = 0,\ |x| > L,\ |y| > W,\ -K\frac{\partial h}{\partial z} = 0 \qquad (4)$$

$$z \ge 0,\ \sqrt{x^2 + y^2 + z^2} \to \infty,\ h \to 0 \qquad (5)$$

where y and z spatial coordinates; x is a Lagrangian spatial coordinate that moves in the x-direction at V; L is the length of the pit; and W is the width of the pit. Figure 67 depicts the half-space geometry of the moving pit. Using the following non-dimensional terms

$$x^* = \frac{x}{L},\ \mathrm{y}^* = \frac{y}{L},\ \mathrm{z}^* = \frac{z}{L},\ \mathrm{h}^* = \frac{hK}{qL}, Pe = \frac{SVL}{T} \qquad (6)$$

the solution is (e.g., Ling, 1973)

$$h^* = -\frac{1}{\pi}\int_{-1}^{+1}\int_{-W/L}^{W/L} \frac{\exp\left\{-Pe\left[r^* - (x^* - x^{*'})\right]/2\right\}}{r^*} dy^{*`} dx^{*`} \qquad (7)$$

with

$$r^* = \sqrt{(x^* - x^{*'})^2 + (y^* - y^{*'})^2 + (z^*)^2} \qquad (8)$$

For our pit, L = 250 ft, W = 50 ft, and K = 13 ft/d. If we assume that a volume of 100 ft × 100 ft × 50 ft of sand is excavated per day, the porosity of the sand is 0.3, and all of the water contained within that pore space is removed with the sand, the volumetric discharge from the pit (Q) will be 150,000 ft^3/d, and the Darcy flux (q) is equal to the volumetric discharge/area of the pit or q = 3 ft/d. Using these parameters in equations 6, 7, and 8, the steady-state drawdown to removing all of the water in the excavated sand is shown in Figure 67. In Figure 67, the origin is fixed at x = 0 and moving to the left at 100 ft/d. In this case, the x-coordinate of the moving origin can be related to time. The pit, and moving origin, moves to the left at a velocity of 100 ft/d; therefore, the drawdown at an x-coordinate of 1,000 ft represents the drawdown 10 days after the moving mine pit has passed that location. In this unrealistic case, the drawdown recovers to about 4 ft of the original water table position after 10 days and between 1 ft and 2 ft after 20 days.

It is clear from this unrealistic example (the removal of all water within the excavated sand), that the water table around the moving mine pit will quickly recover to close to its original position and that mining activities will not dewater the Okefenokee Swamp. When superimposed on the existing water table, groundwater divides will continue to separate the moving pit from the Okefenokee to the west and the streams to the east. The Trail Ridge hydrologic divide separating the Okefenokee Swamp to west from the Saint Mary's River to the east will always be maintained.

SUMMARY AND CONCLUSIONS

The objective of this report is to document numerical and analytical groundwater flow models developed to evaluate the impact of the proposed Twin Pines Mine on the hydrologic system of Trail Ridge and areas on its flanks, including the Okefenokee Wildlife Refuge. A conceptual model of the flow system present at Trail Ridge was created. Two numerical models of the Trail Ridge area were developed using MODFLOW-2005. The first model, representing a pre-mining condition, was parameterized using a geostatistical approach and calibrated to heads observed in observation wells. Using the calibrated model, a second numerical model was developed to represent post-mining conditions. In this model, the horizontal and vertical hydraulic conductivity of all model grid blocks within the proposed mine footprint and above an elevation of 119 ft were set to a single value (1.0E-03 cm/s) to replicate homogeneous sand spoil returned to the mine pit. Groundwater discharge to constant head boundaries and streams and modeled water table position were compared. An analytical model was developed for examining the impact of the moving mine pit on drawdown within the Surficial Aquifer. In this model, we considered an extreme case where all the water within excavated sand would be removed from the mine pit. The aquifer drawdown in this extreme case was determined.

We draw the following conclusions from these modeling efforts:

- **Trail Ridge is a classic example of topographically-driven groundwater flow.** It acts as a hydrologic divide that separates the Okefenokee Swamp to the west from the Saint Mary's River to the east. Rainfall on Trail Ridge provides water to the Surficial Aquifer. This groundwater recharge causes the water table to rise within a few feet of the ground surface along Trail Ridge, forming a hydrologic divide that mimics the topography. Because groundwater flow follows the elevation of the water table, Trail Ridge groundwater flows to the west, supplying water to the Okefenokee Swamp, and flows to the east, supplying water to springs and creeks.
- **Proposed mining activities will have an insignificant impact the groundwater and stream flow to the Okefenokee Swamp and the creeks and groundwater system to the east of Trail Ridge.** A comparison of groundwater models of the pre-mining conditions and post-mining conditions show that changes to the groundwater discharge and stream discharge are minimal and insignificant.

- Mining activities will cause insignificant changes in the water table across most of the study area. Within the mine pit, the water table position will both increase and decrease due to the placement of homogenized sand spoil in the mine pit. At the Okefenokee Wildlife Refuge, the models predict that the water table will decrease by 0.0004 ft due to mining.
- Mining activities will not dewater the Okefenokee Swamp. The Okefenokee Swamp is 2.7 miles away from the closest part of the proposed mine footprint. The active mine pit will be small and filled within five days. Analytical groundwater models of the moving mine pit show that water levels will recover to within four feet of their original position within 10 days following excavation and 2 ft of their original position within about 30 days. The perturbation of the water table caused by the moving mine pit will not affect the Okefenokee Swamp. The Trail Ridge hydrologic divide separating the Okefenokee Swamp to west from the Saint Mary's River to the east will always be maintained.

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FIGURES

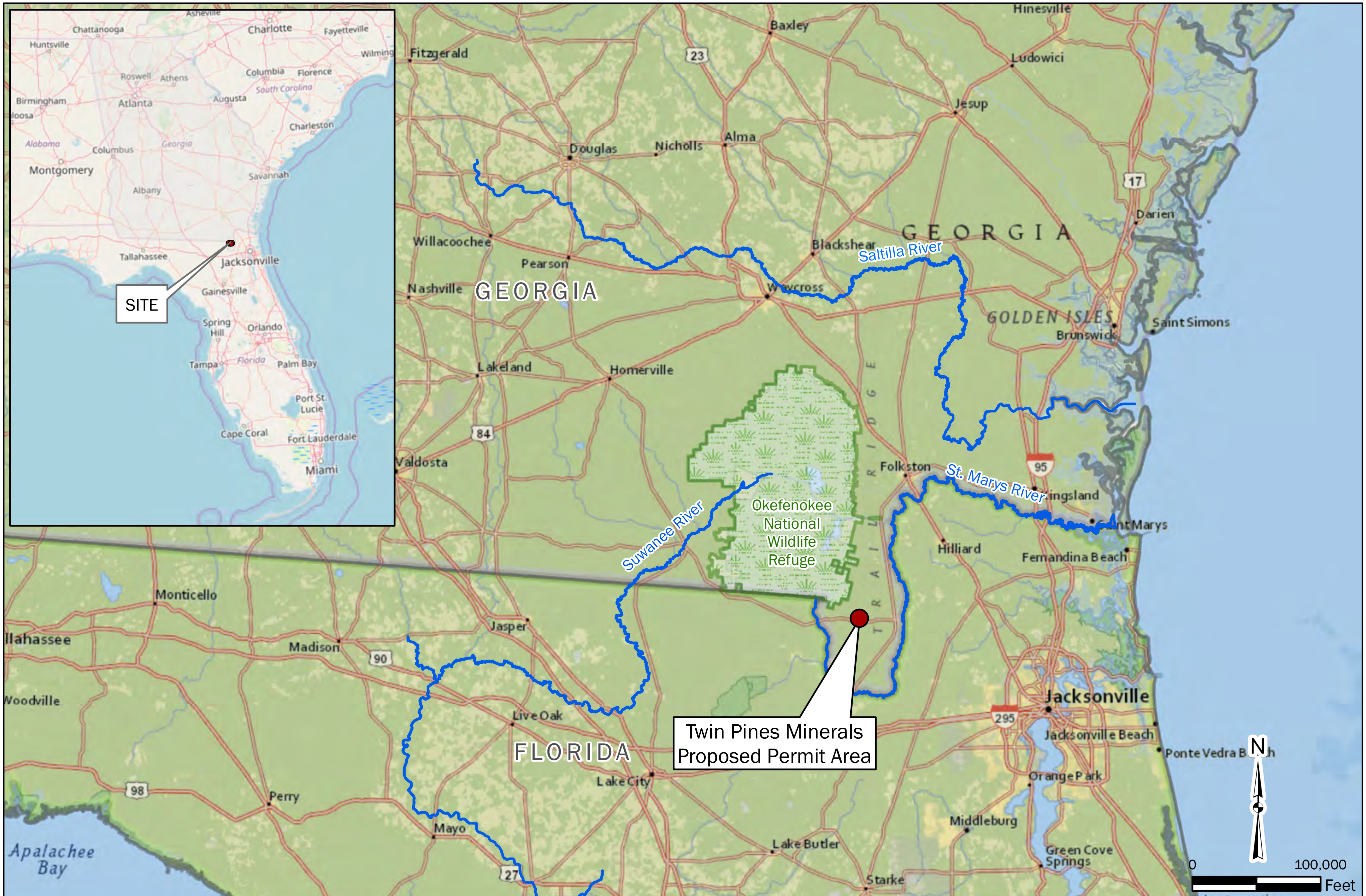

FIGURE 1: LOCATION OF THE PROPOSED TWIN PINES MINE

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

INSET BASEMAP: Open Street Map. BASEMAP: National Geographic World Map.

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CHECKED BY: RMH	
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REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 100,000 ft

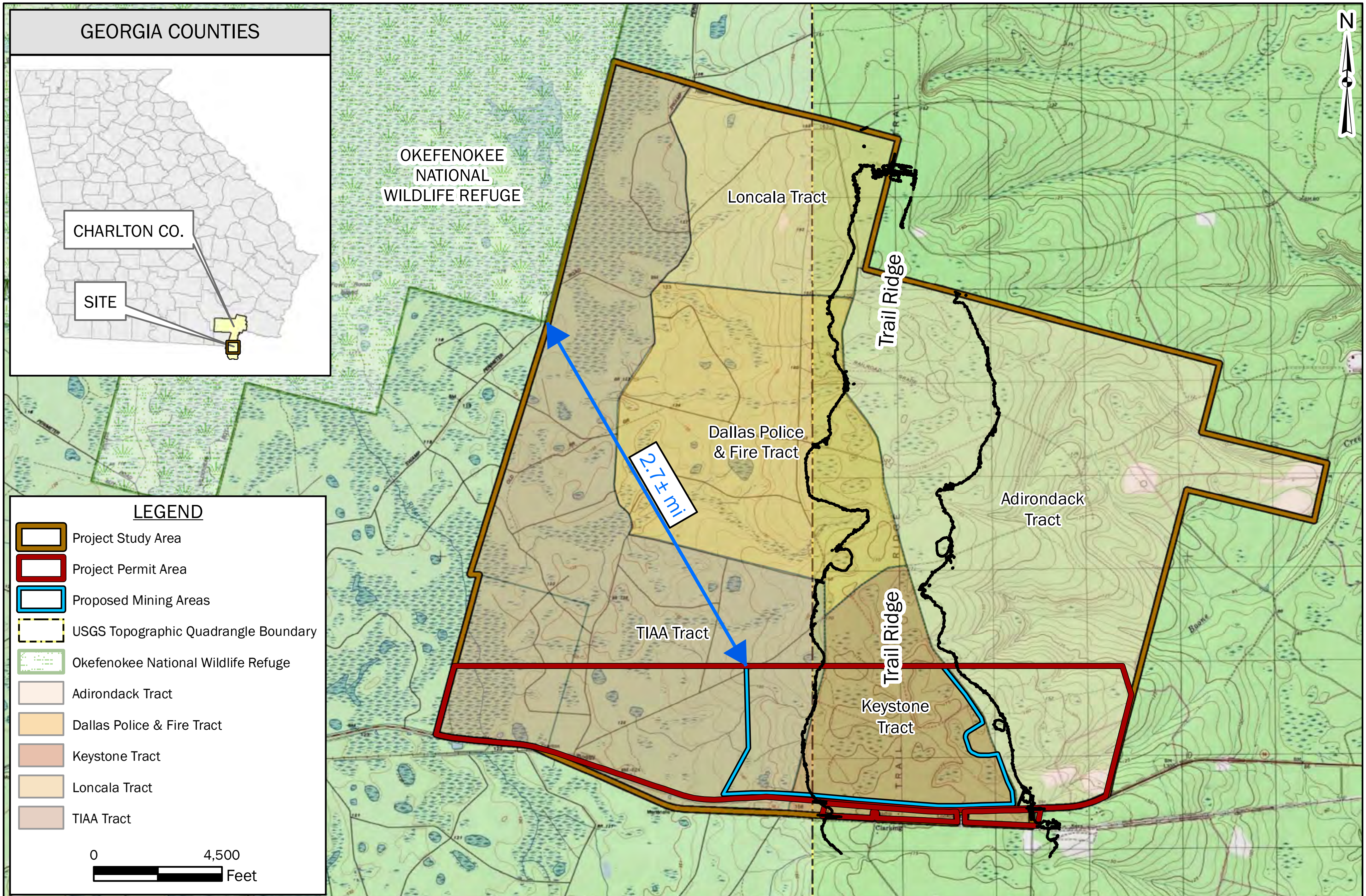

FIGURE 2: PROJECT STUDY & PROPOSED PERMIT AREA

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

BASEMAP: USGS 7.5 Minute Quadrangle Map, Florida & Georgia, (West) Moniac 1968 (10-ft Contour Interval), (East) Saint George 1982 (5-ft Contour Interval).

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APPROX. SCALE:	1 in = 4,500 ft

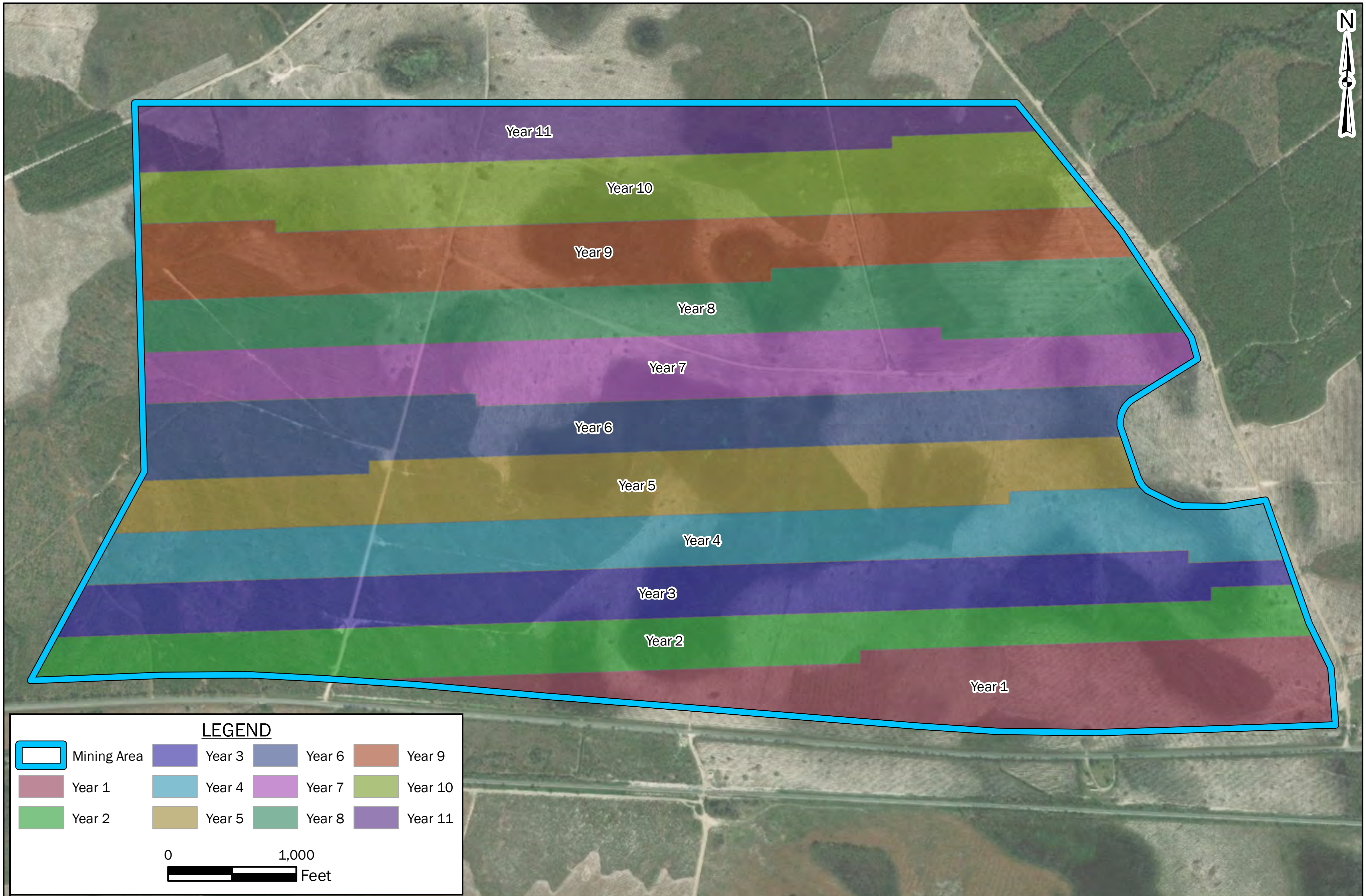

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FIGURE 3: MINING SCHEDULE

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

BASEMAP: DigitalGlobe, 3/24/2018 (0.46 m Resolution).

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APPROX. SCALE: 1 in = 1,000 ft

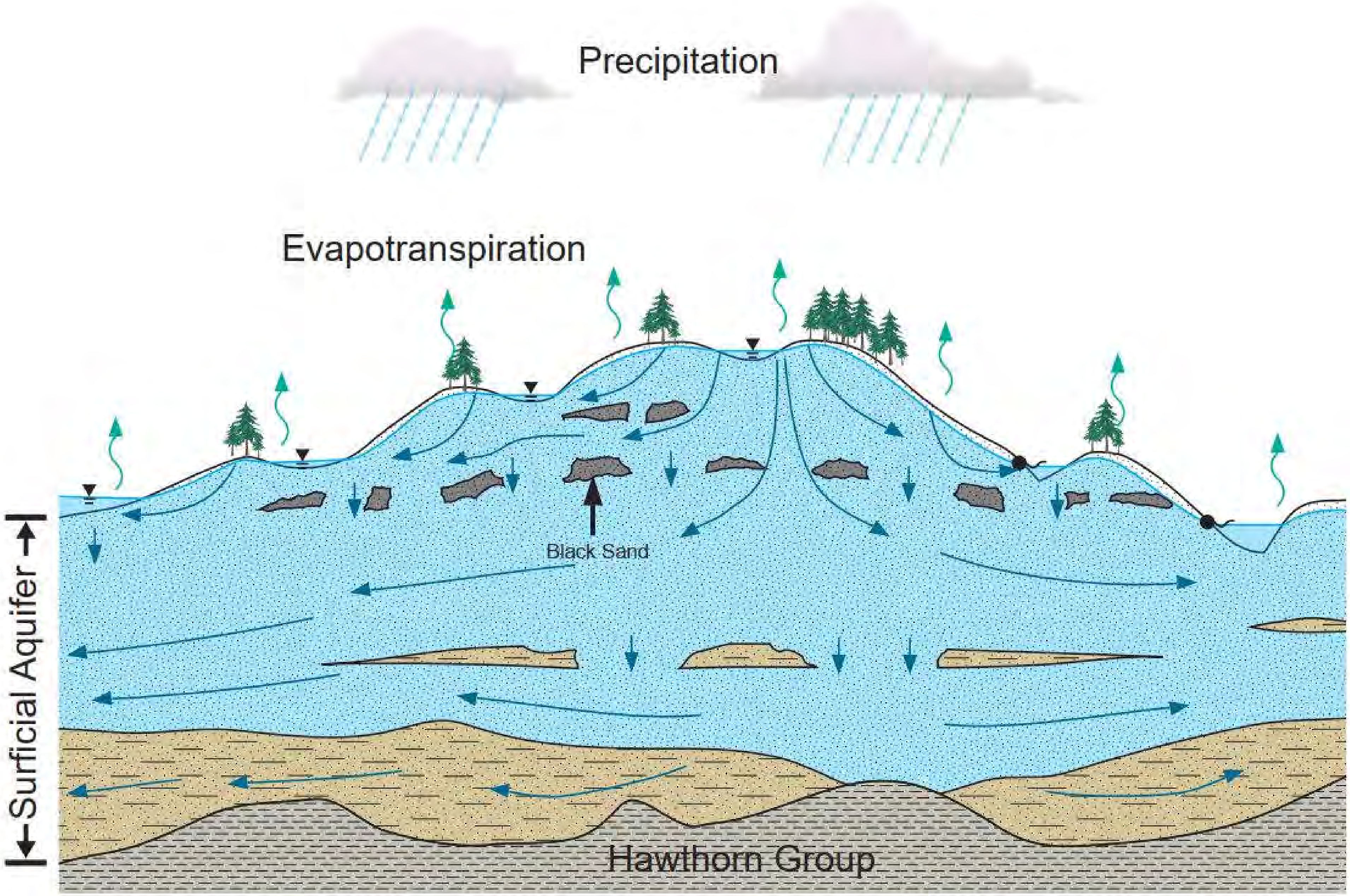

FIGURE 4: CONCEPTUAL HYDROGEOLOGIC MODEL

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

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REVISION DATE: N/A
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APPROX. SCALE:

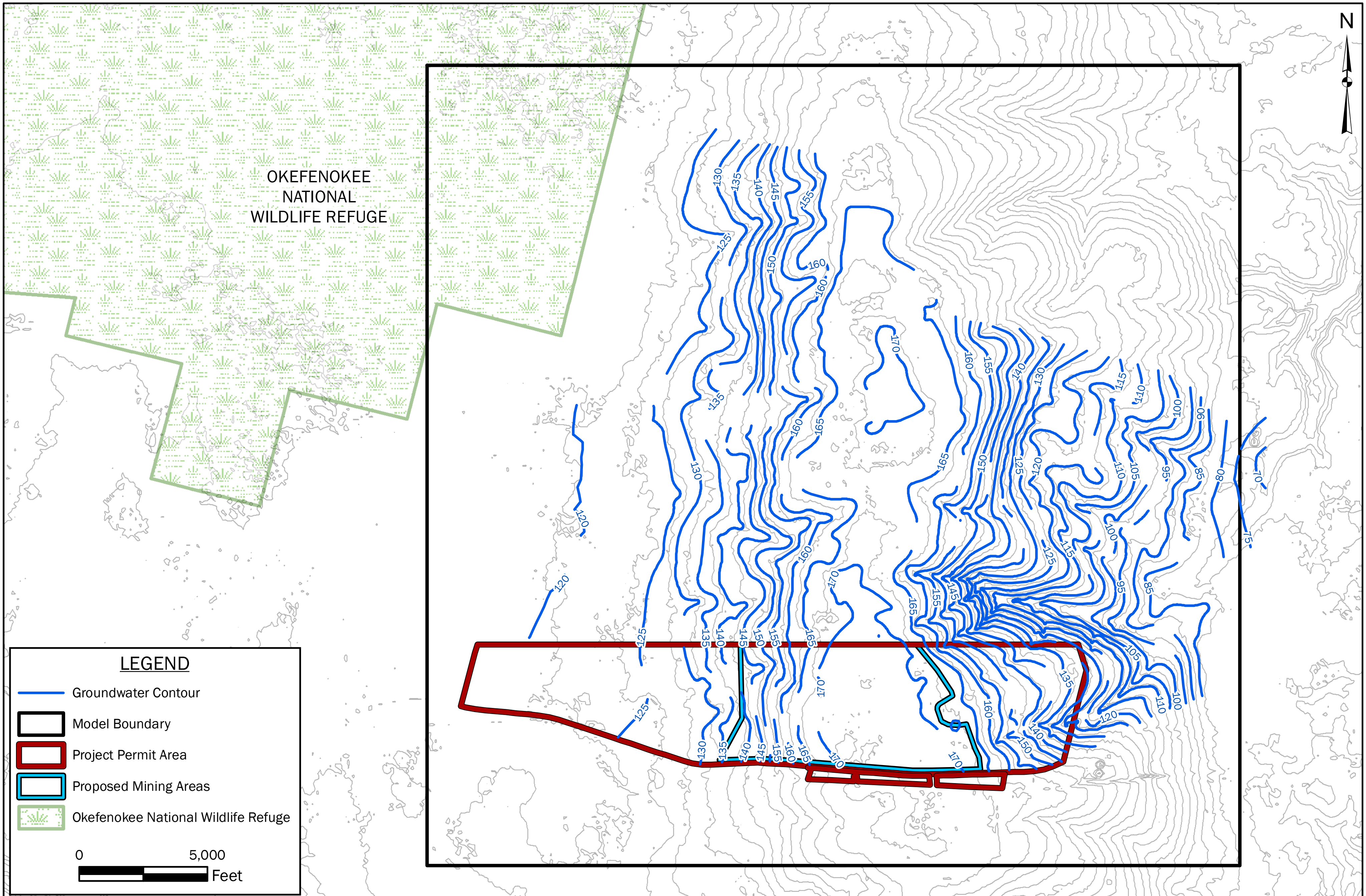
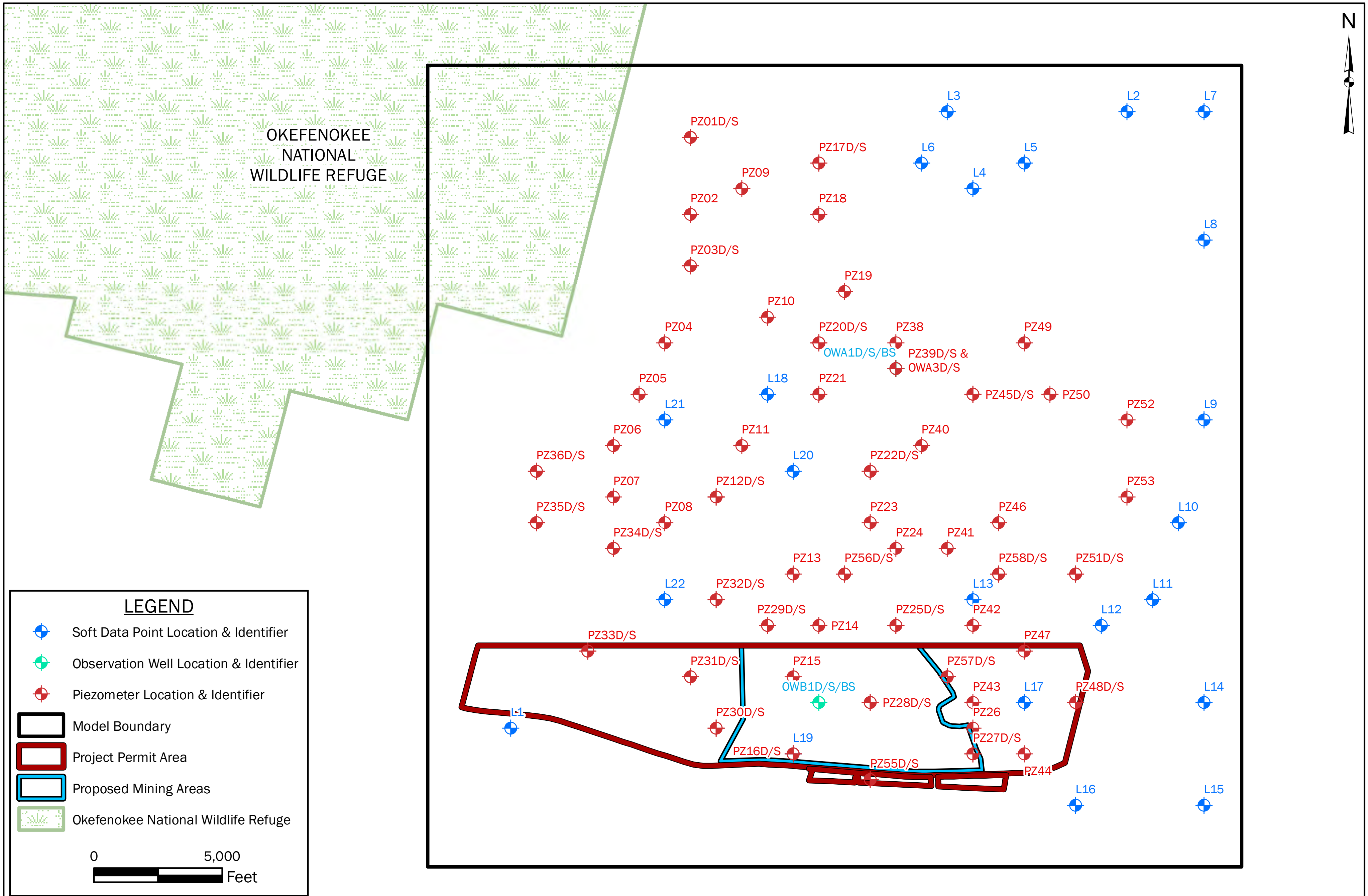


FIGURE 5: POTENTIOMETRIC SURFACE MAP - JULY 26, 2019

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft



TTL

FIGURE 6: PIEZOMETER & WELL LOCATION MAP

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
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DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

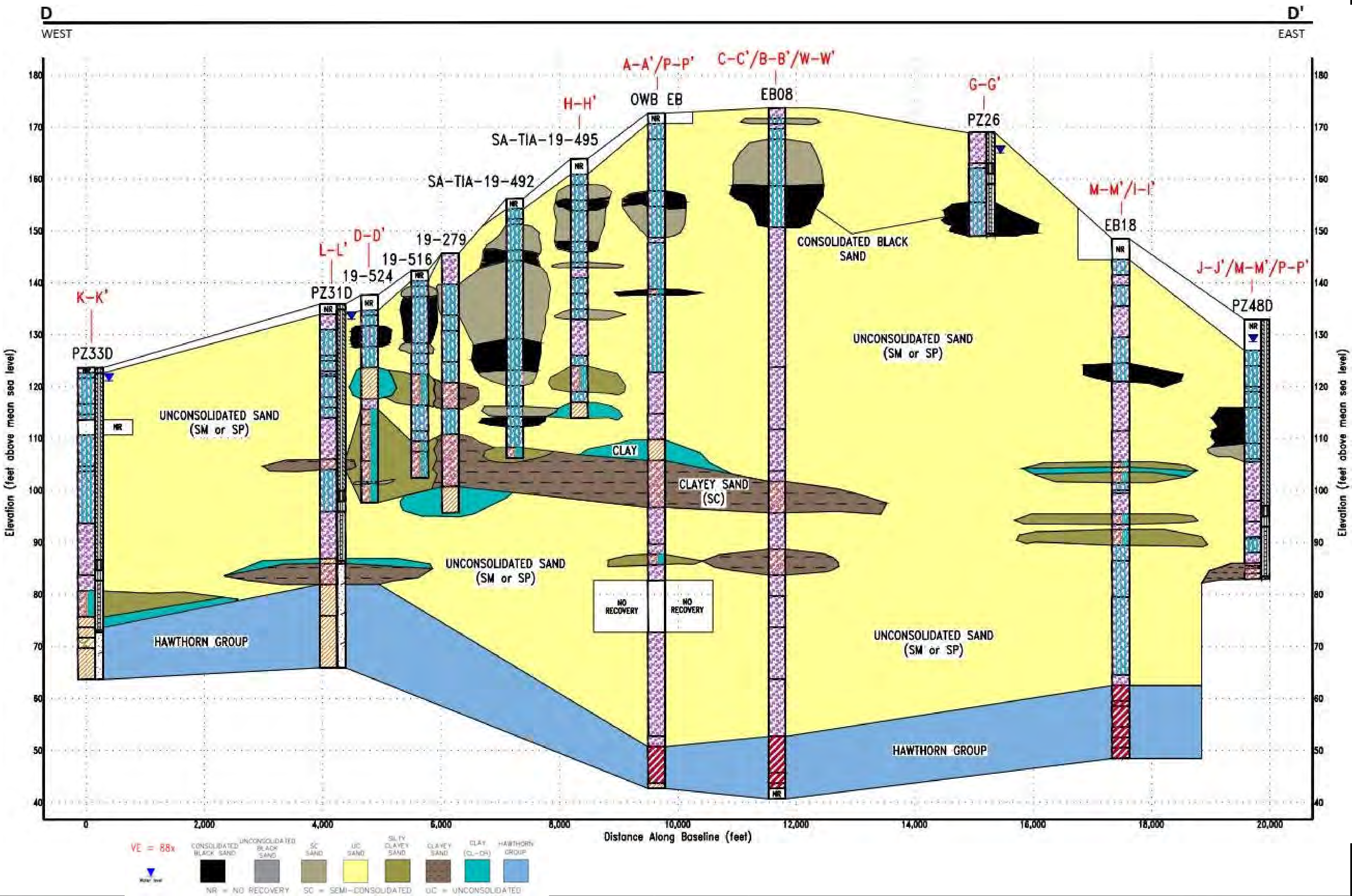

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FIGURE 7: EXAMPLE WEST-TO-EAST PROFILE

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

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CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE:

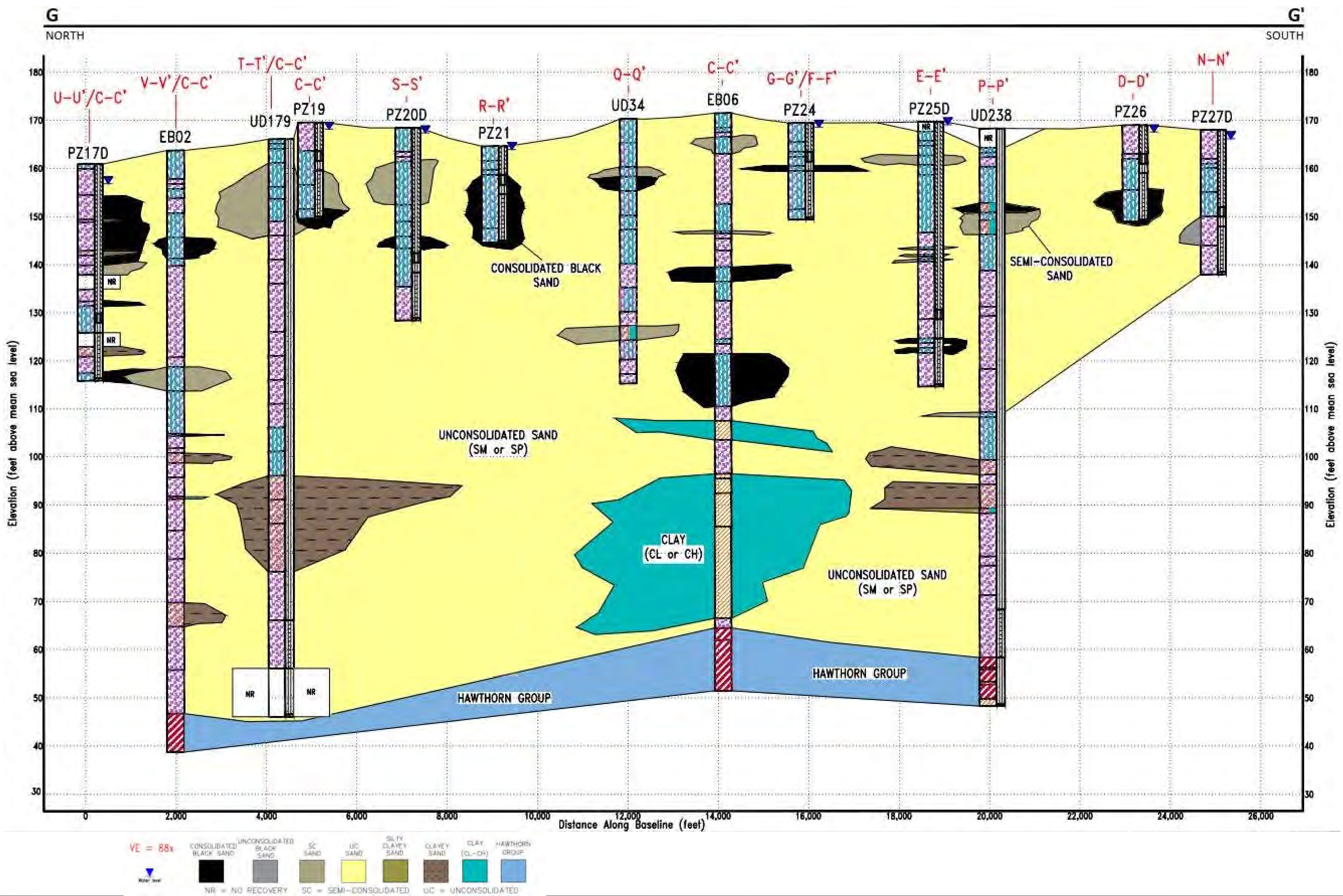

FIGURE 8: EXAMPLE NORTH-TO-SOUTH PROFILE

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE:

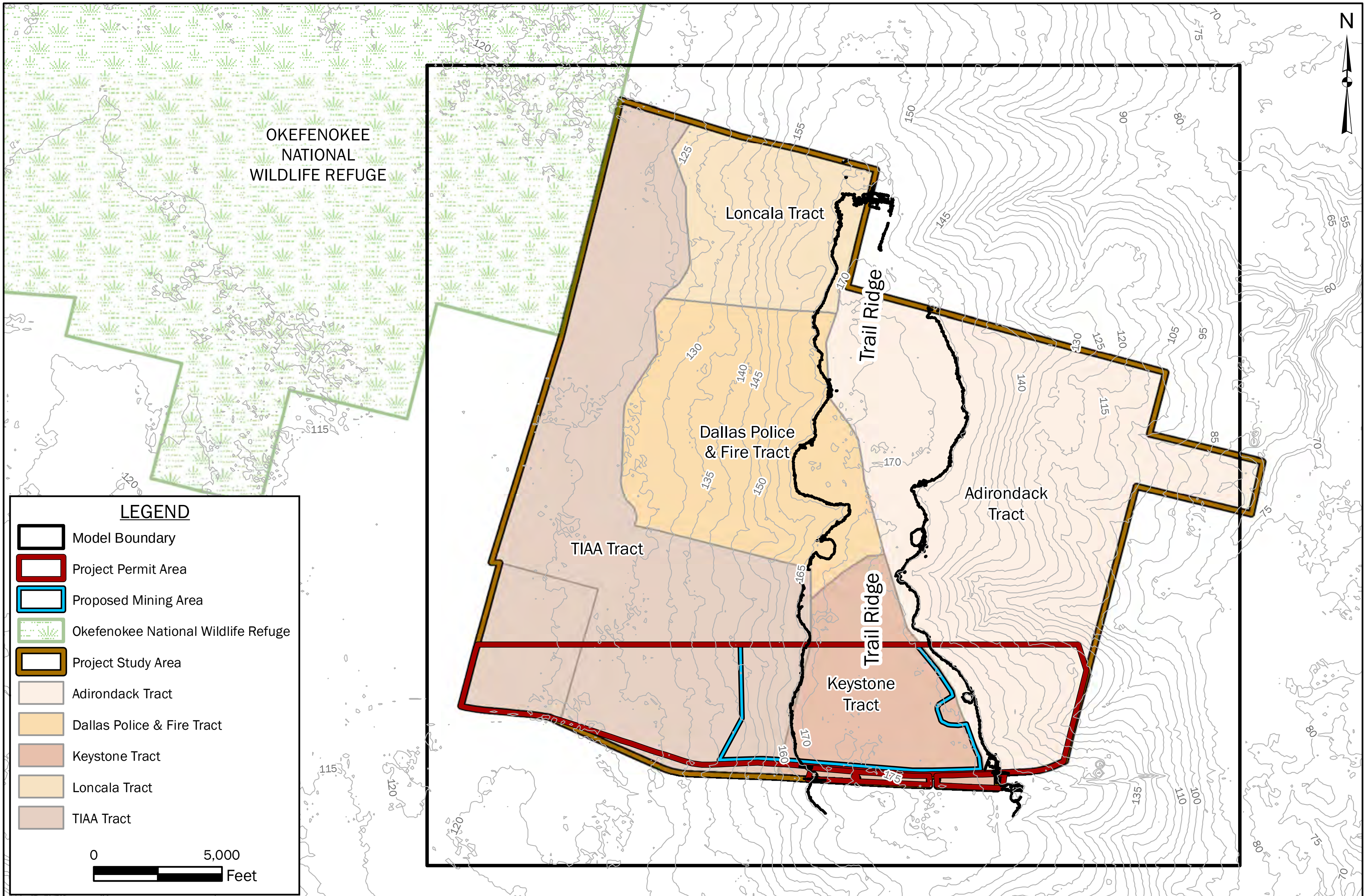

FIGURE 9: MODEL AREA MAP

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

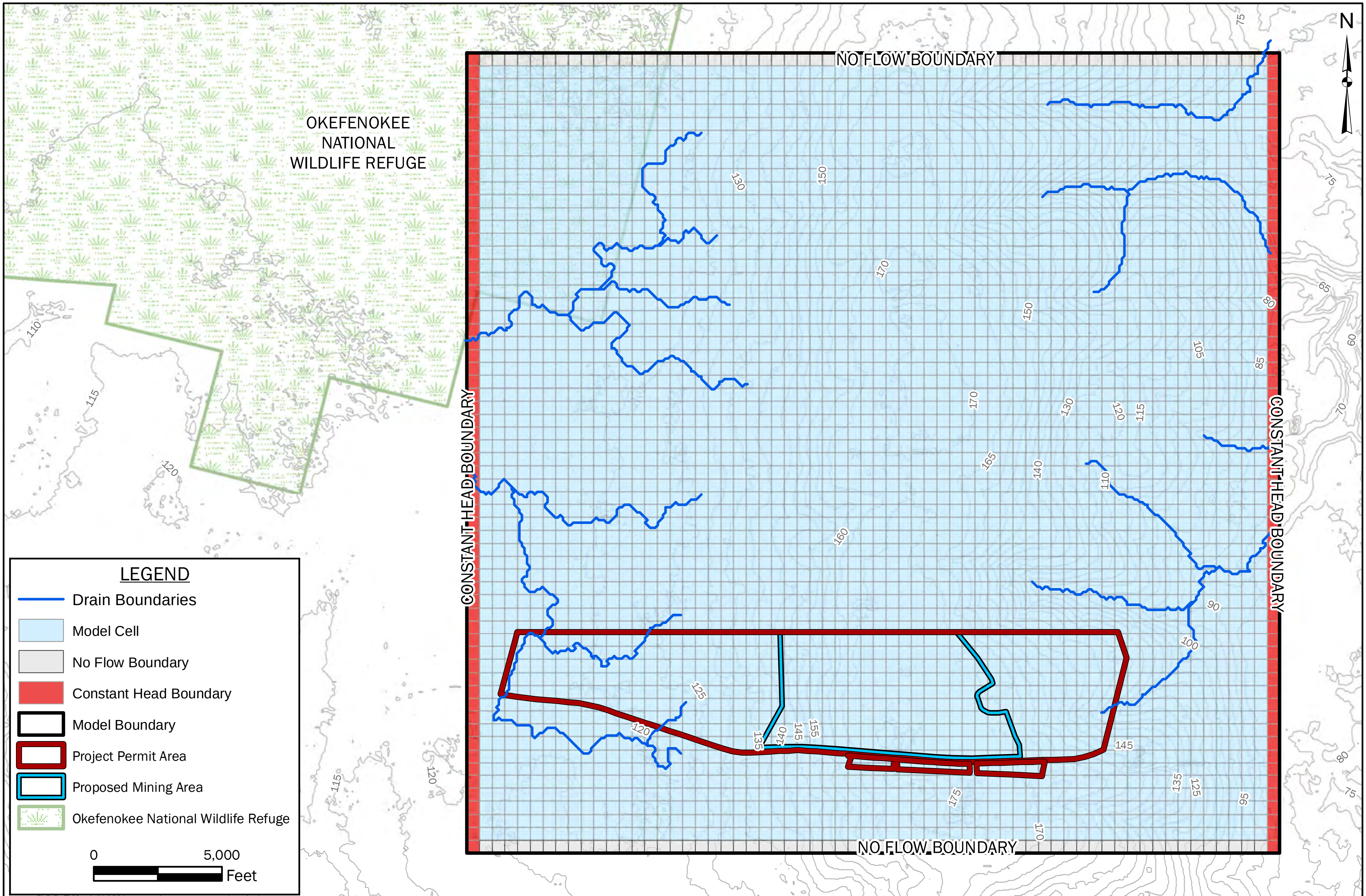

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FIGURE 10: MODEL GRID & BOUNDARY CONDITIONS

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

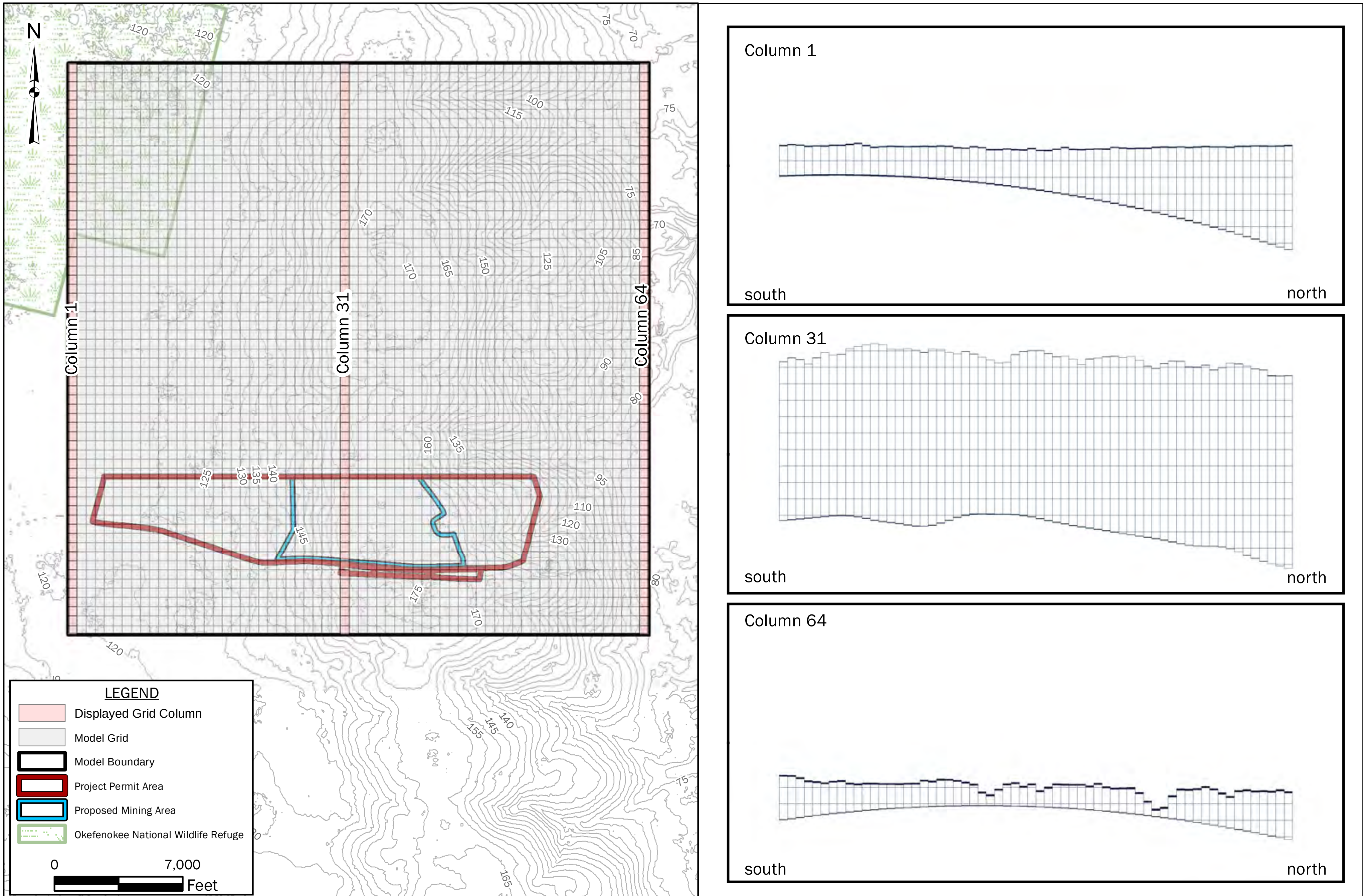

FIGURE 11: VERTICAL MODEL GRID NORTH TO SOUTH

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 7,000 ft

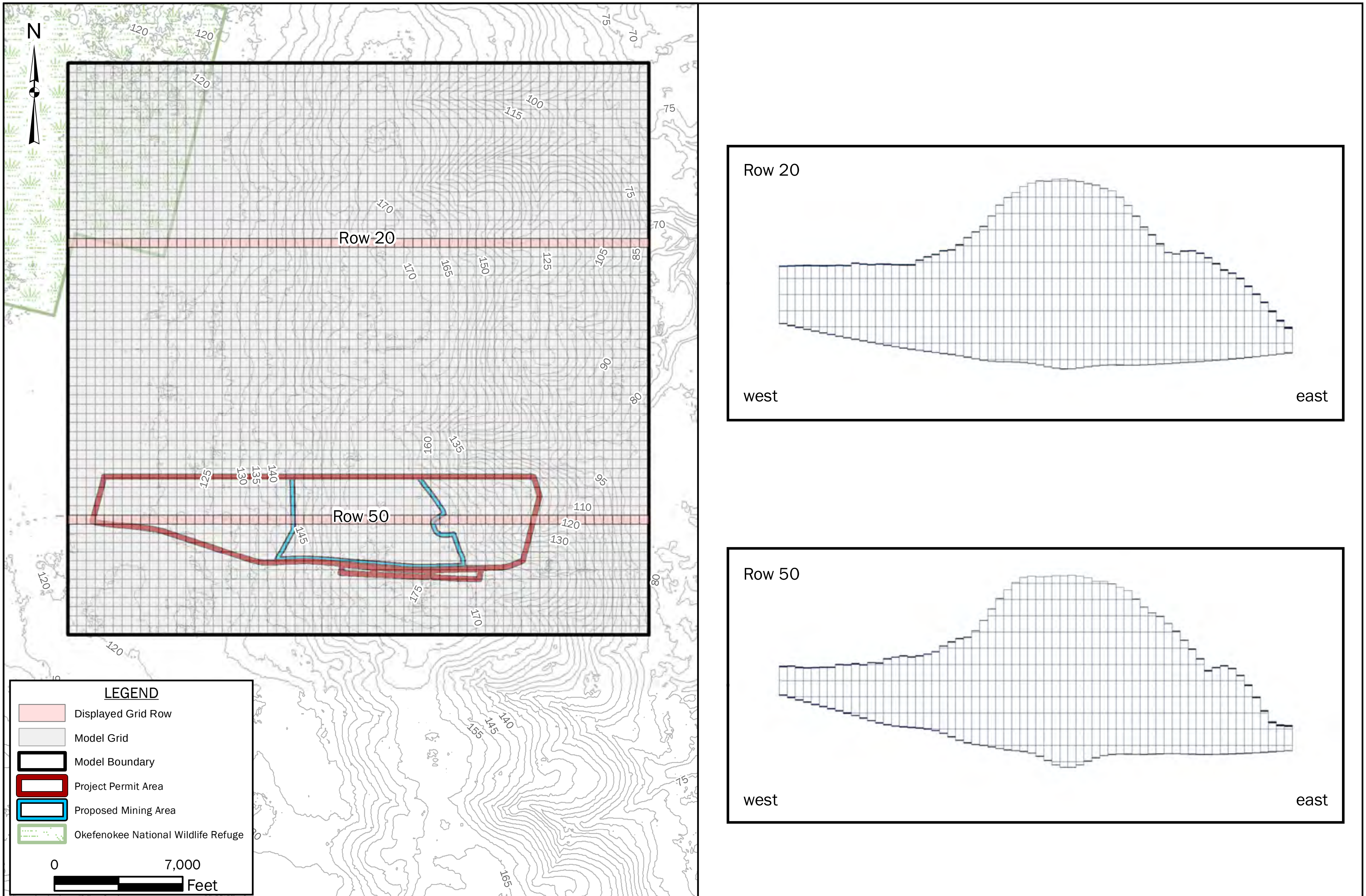

FIGURE 12: VERTICAL MODEL GRID WEST TO EAST

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 7,000 ft

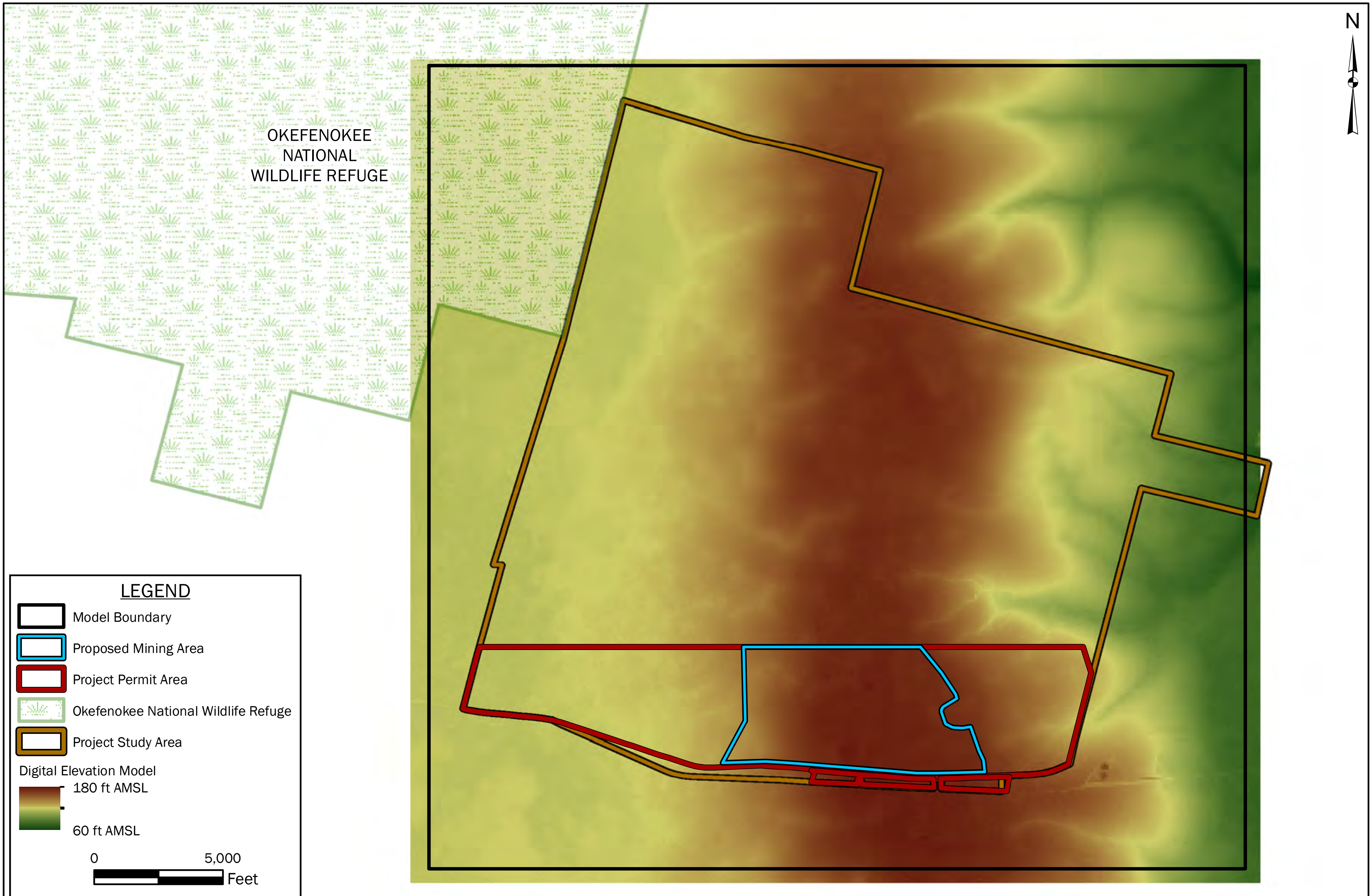

FIGURE 13: SURFACE DIGITAL ELEVATION MODEL

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
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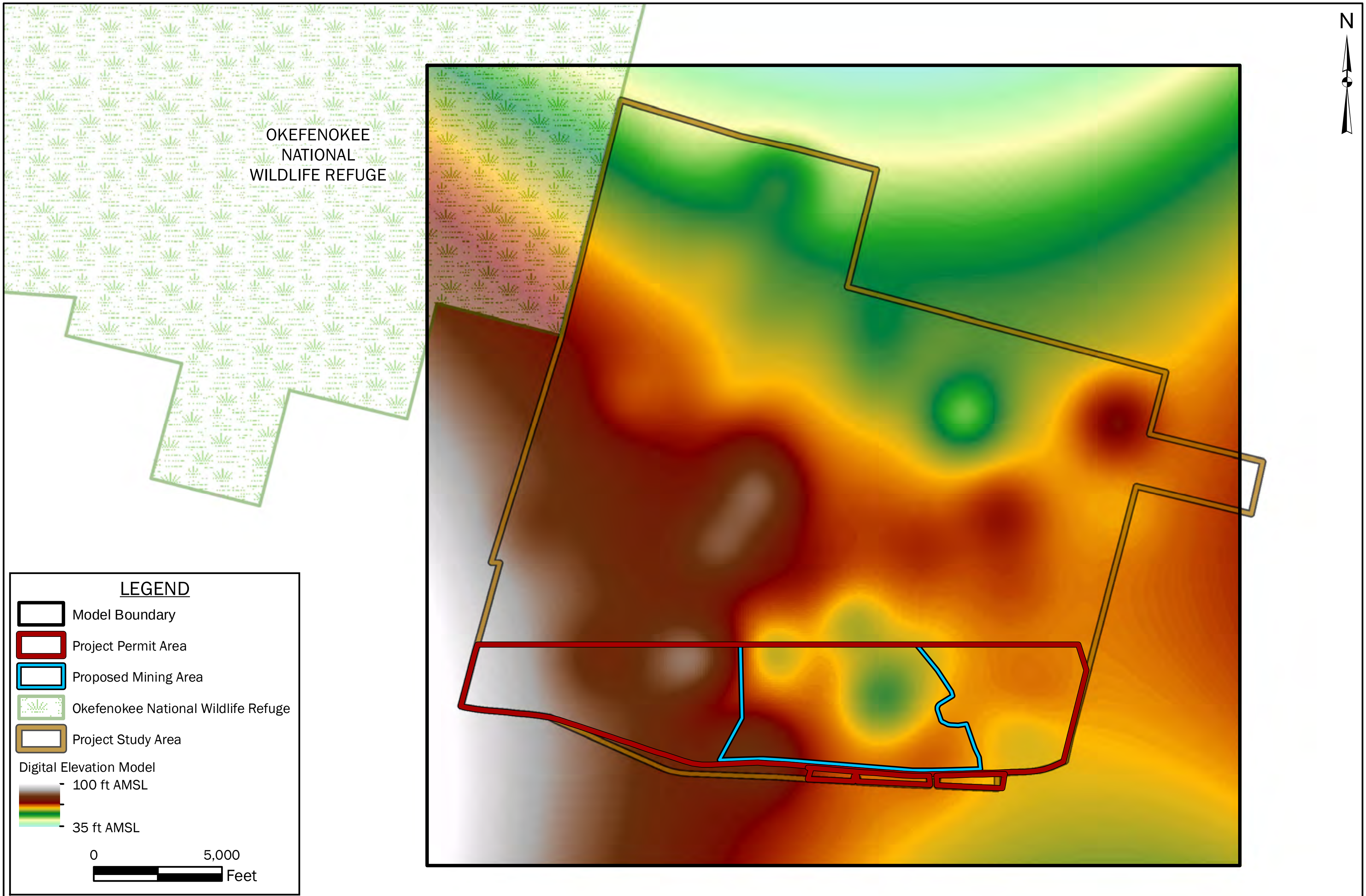

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FIGURE 14: TOP OF HAWTHORN DIGITAL ELEVATION MODEL

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

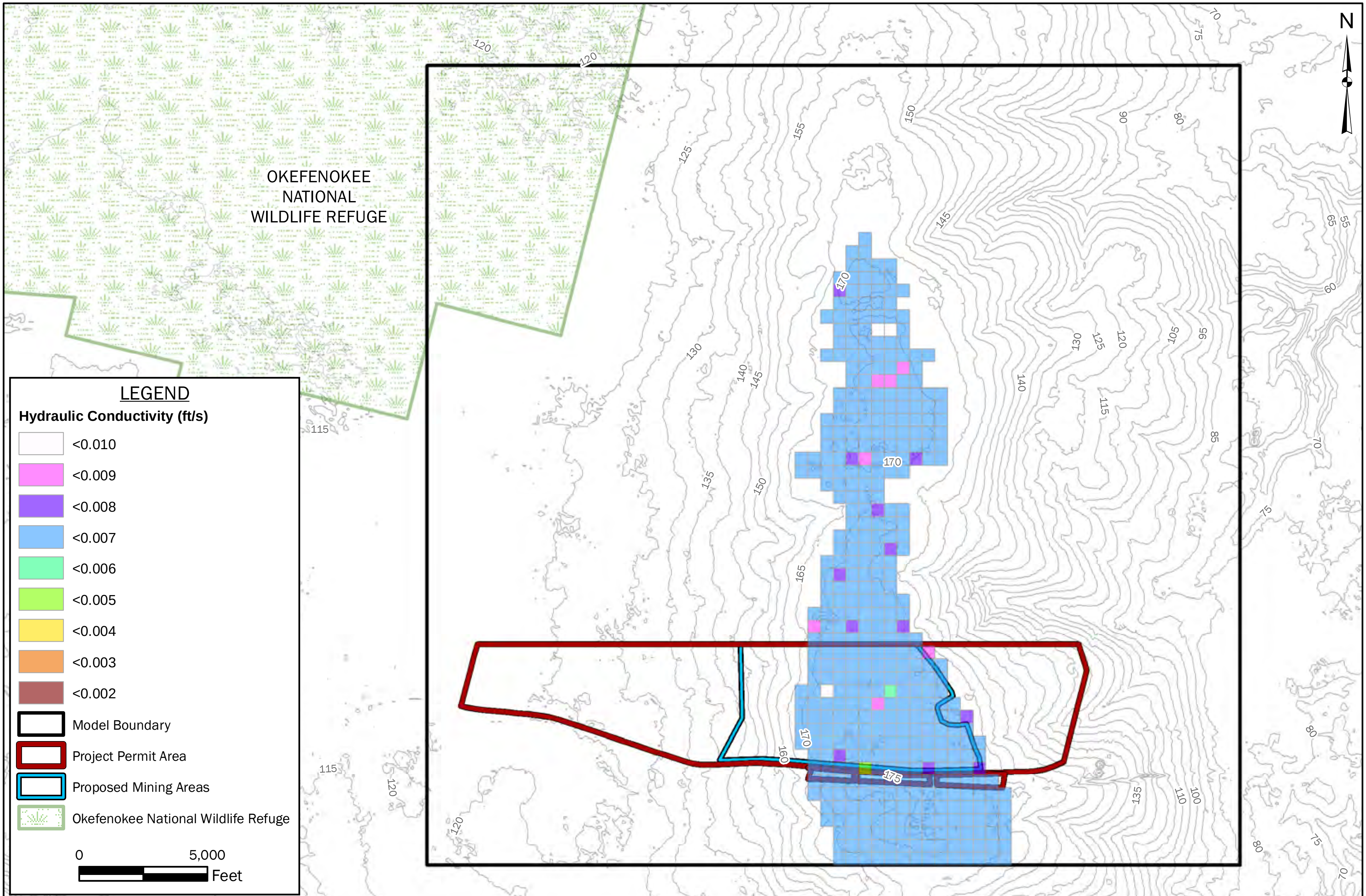

FIGURE 15: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 1

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

TTL

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

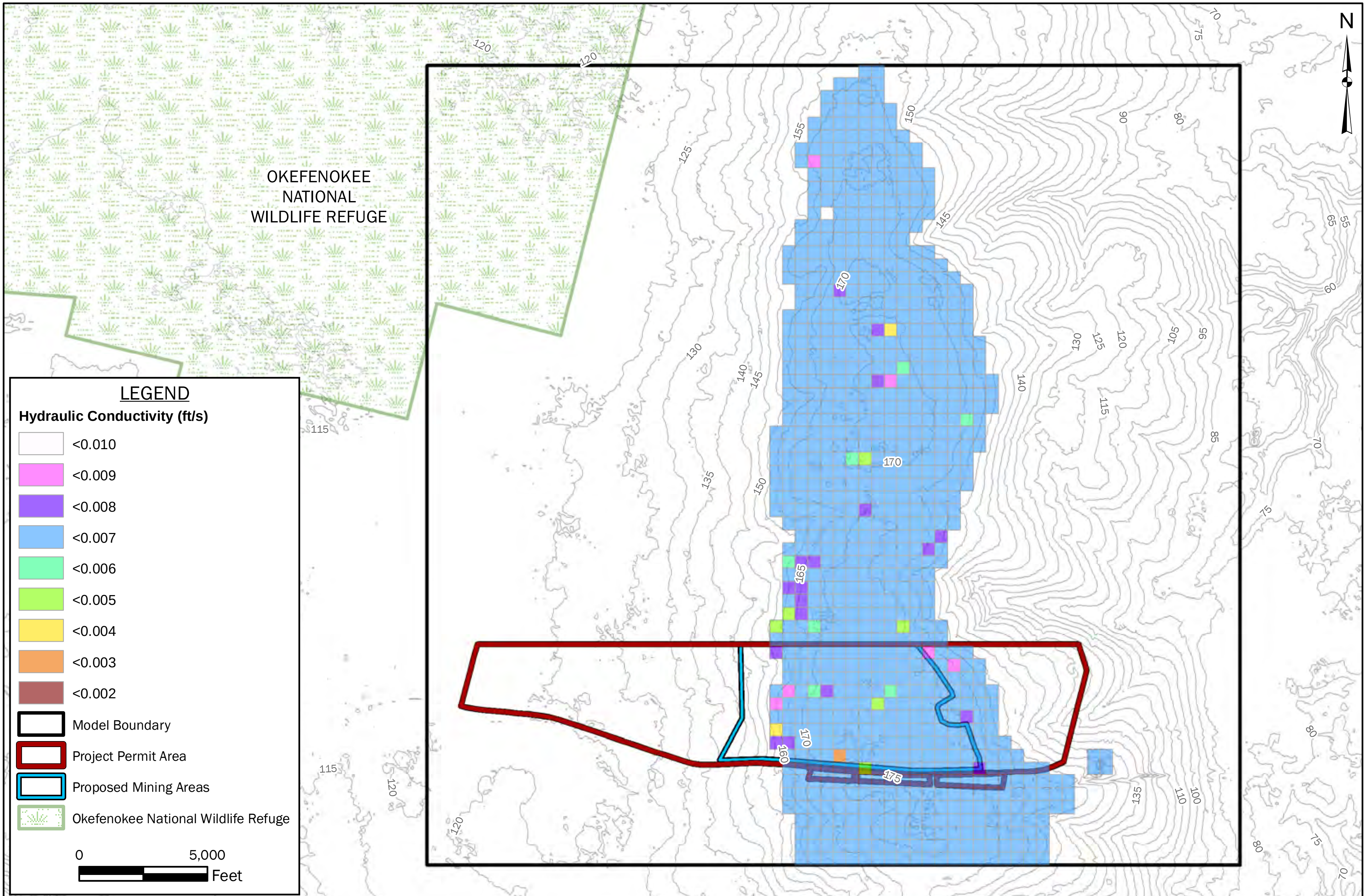

FIGURE 16: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 2

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

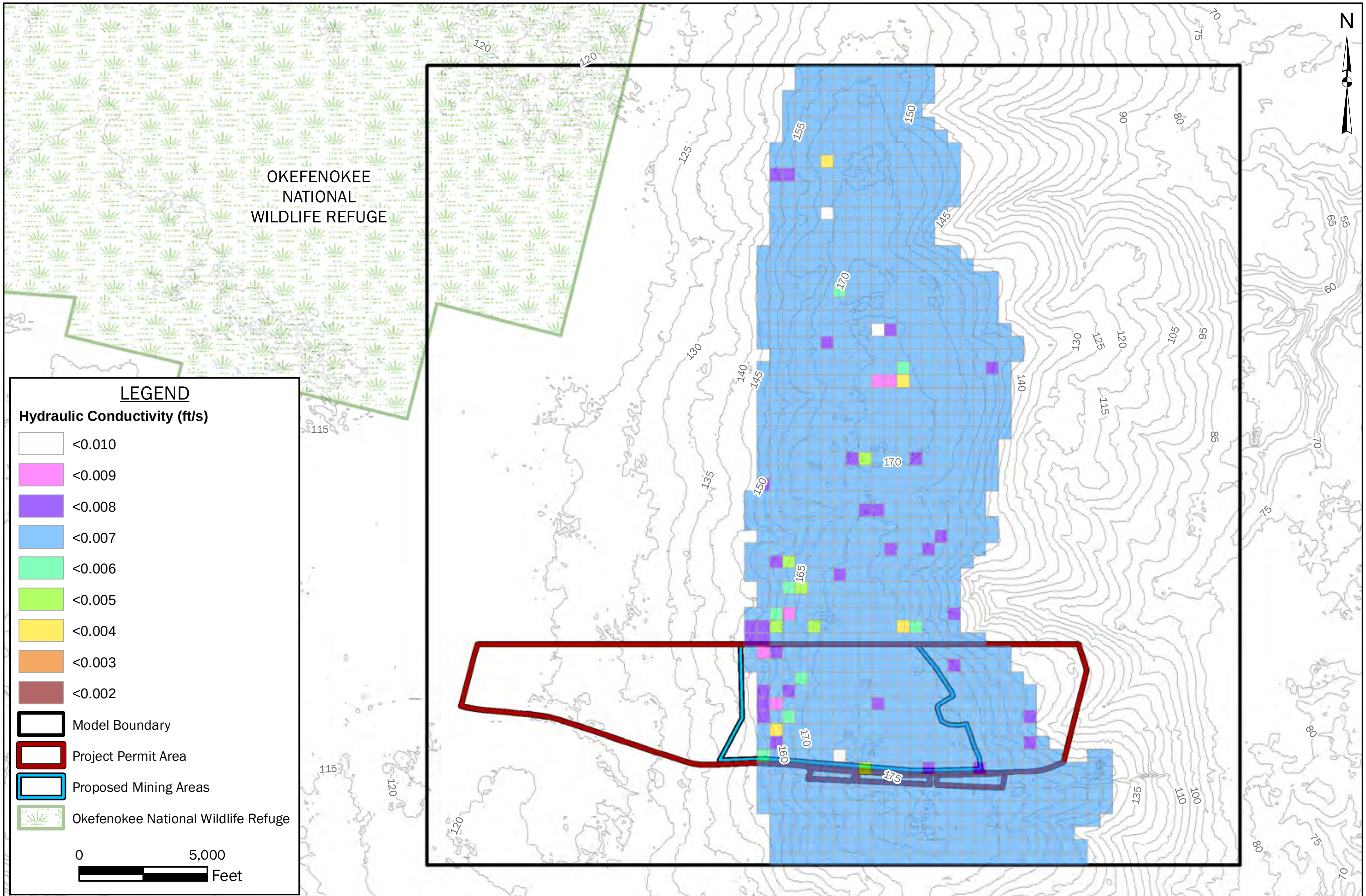

FIGURE 17: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 3

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
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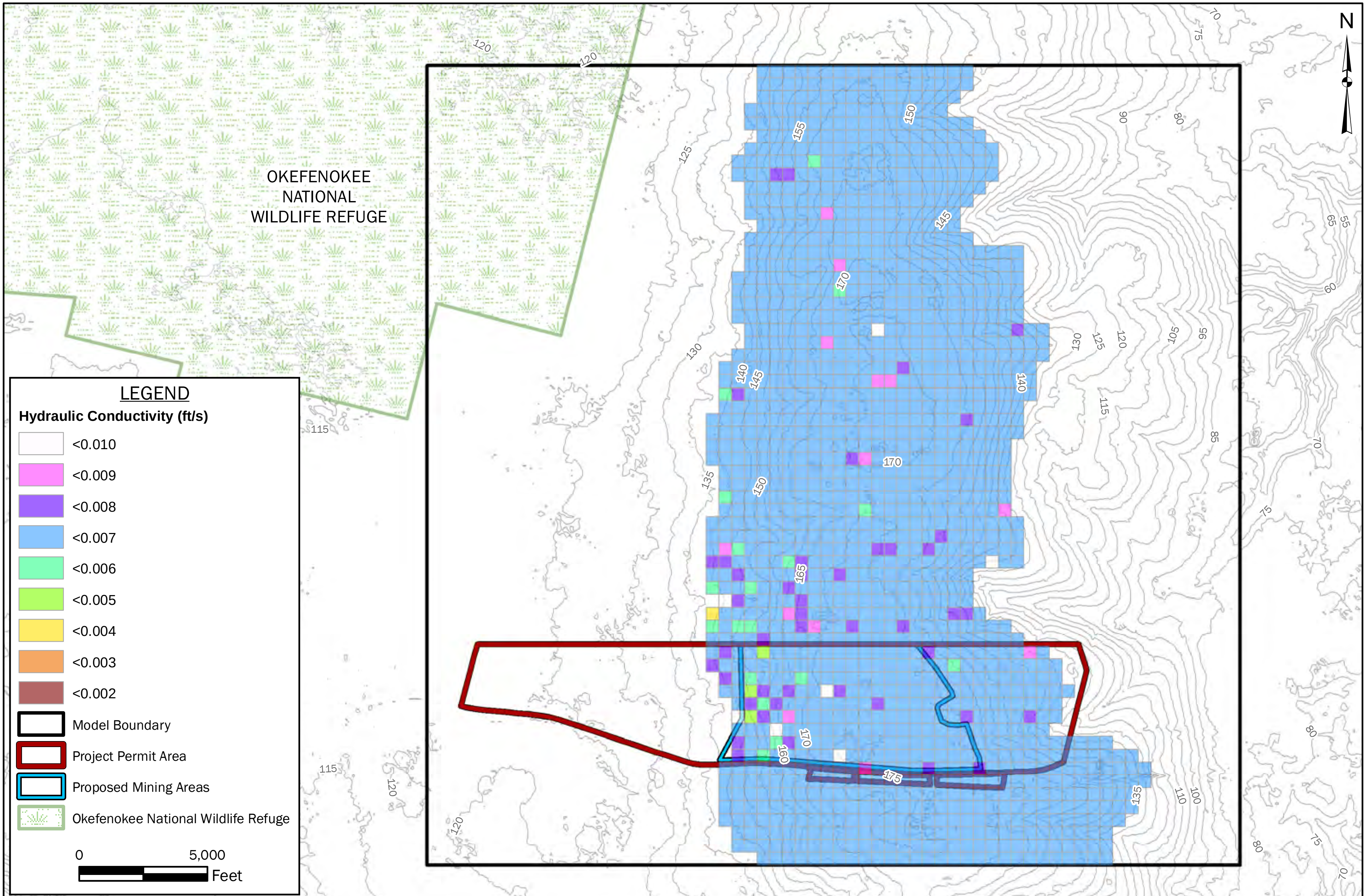

FIGURE 18: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 4

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

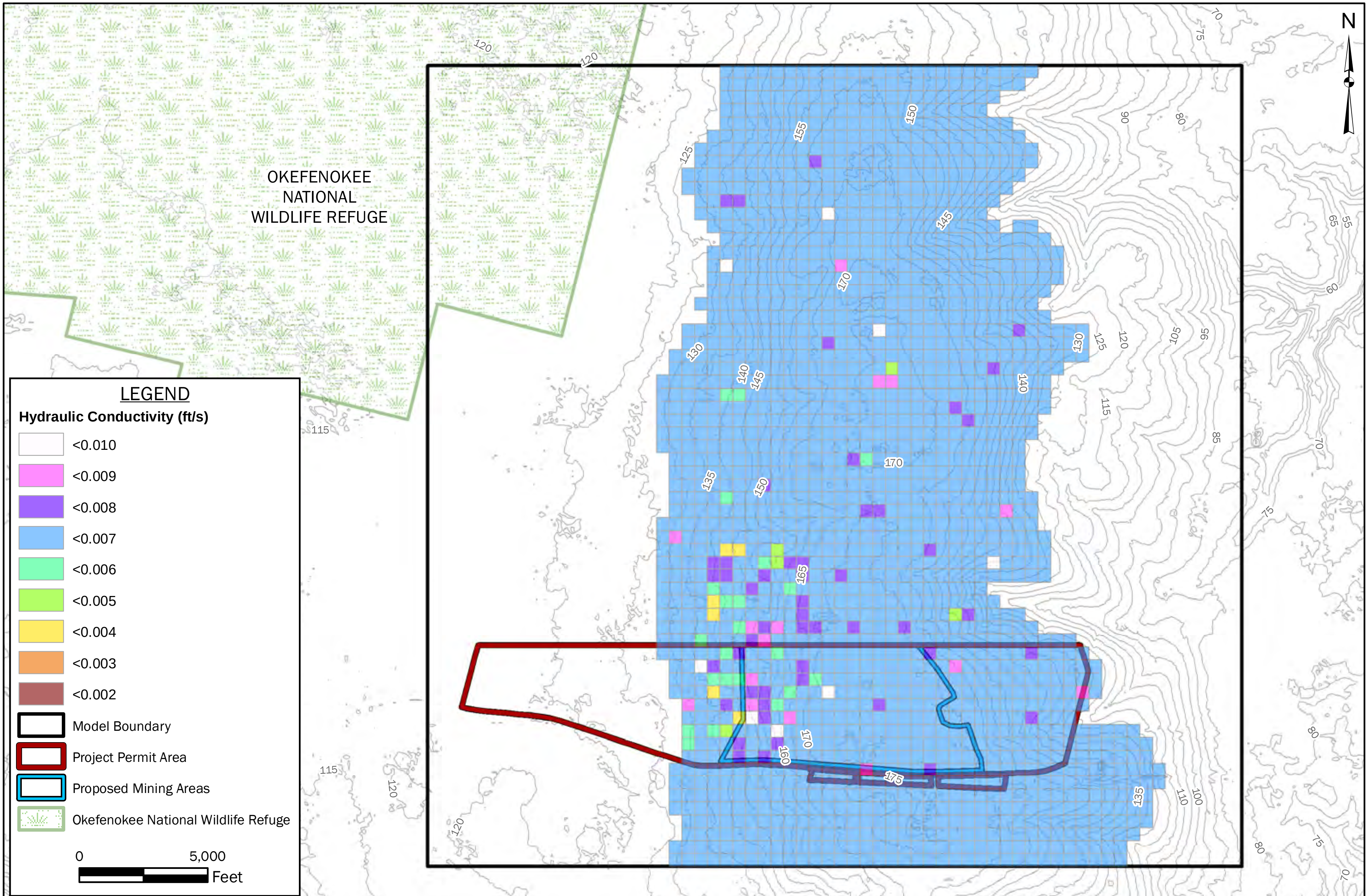

FIGURE 19: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 5

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
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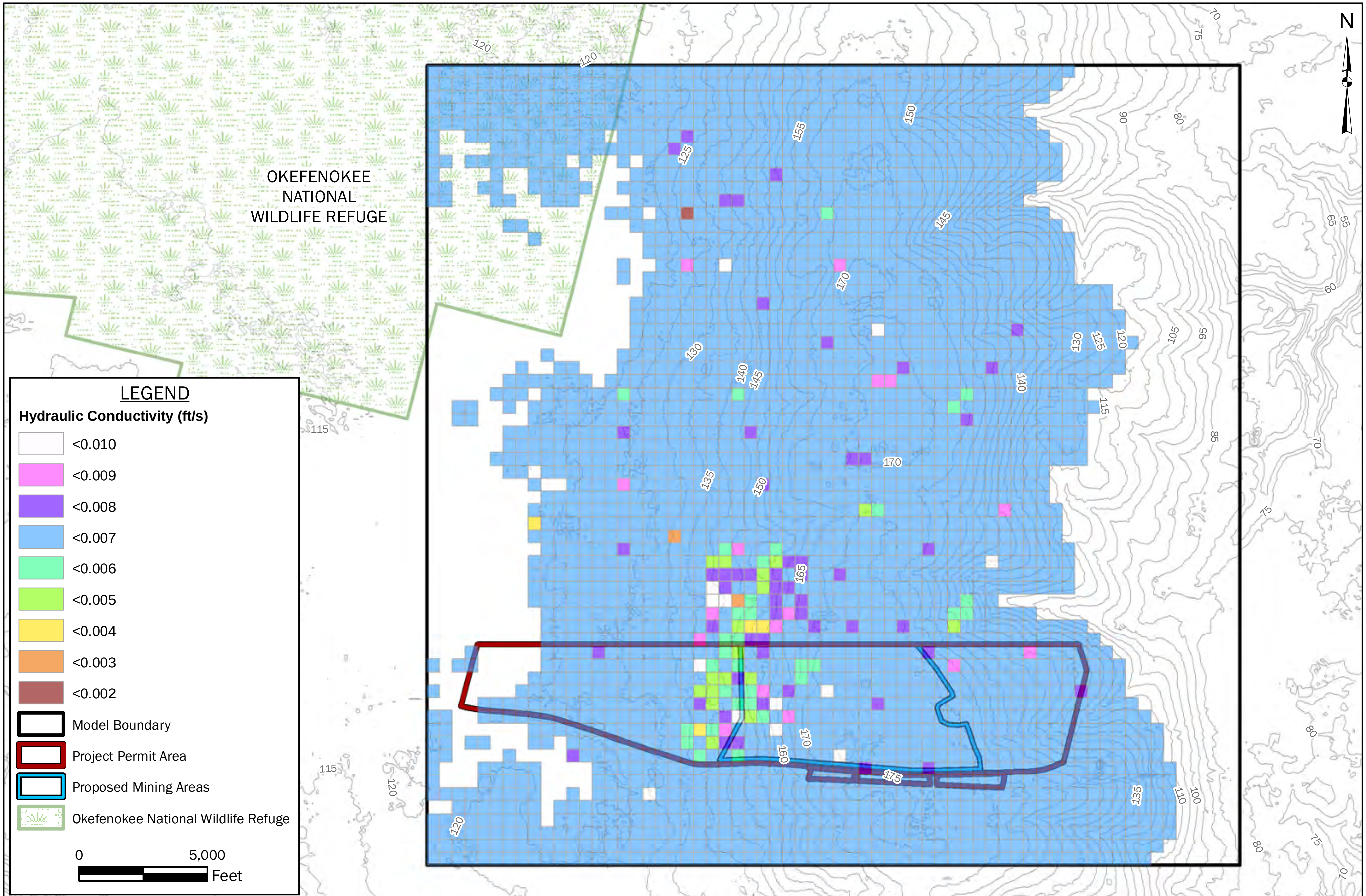

FIGURE 20: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 6

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
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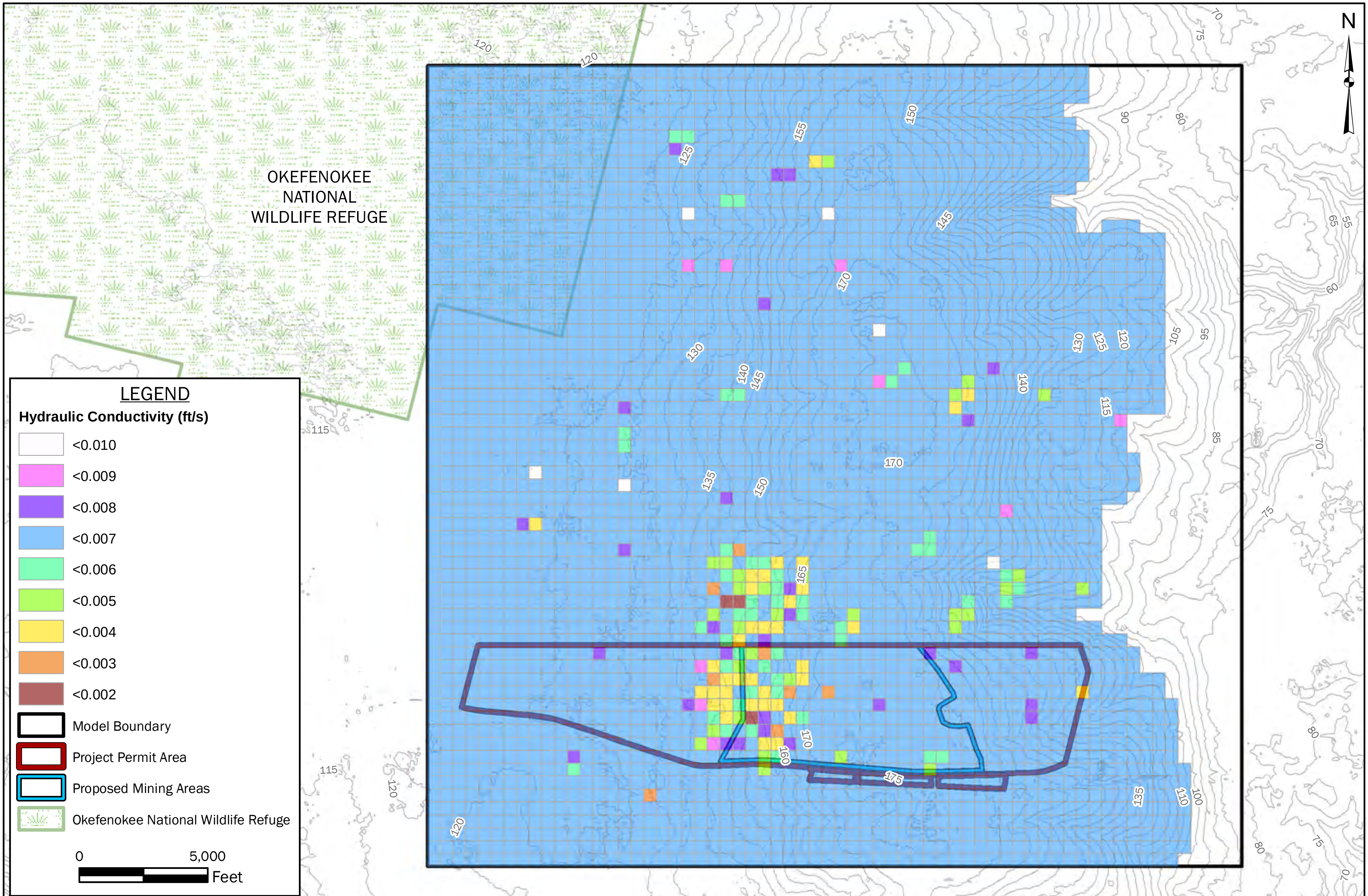

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FIGURE 21: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 7

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
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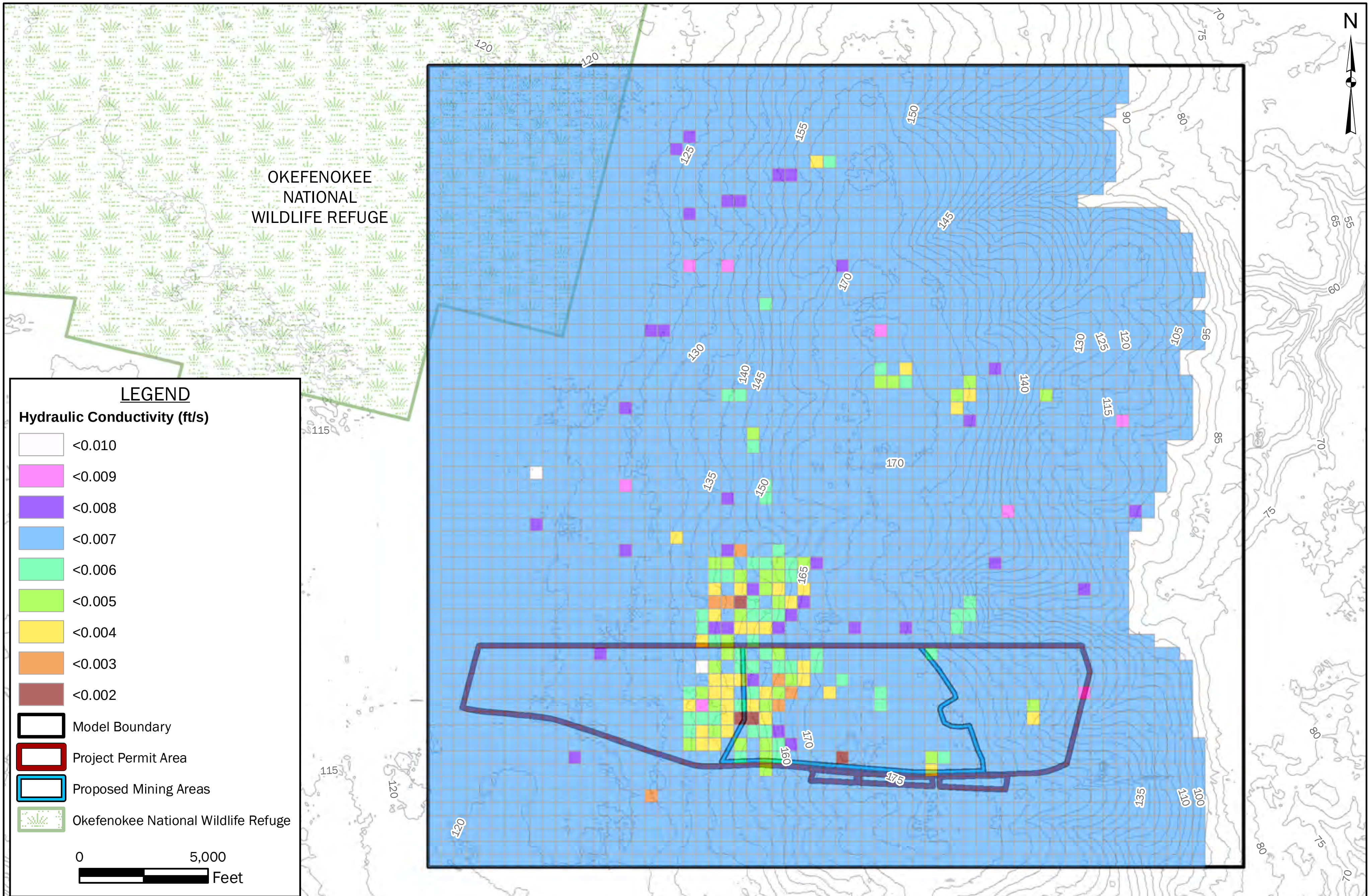

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FIGURE 22: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 8

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
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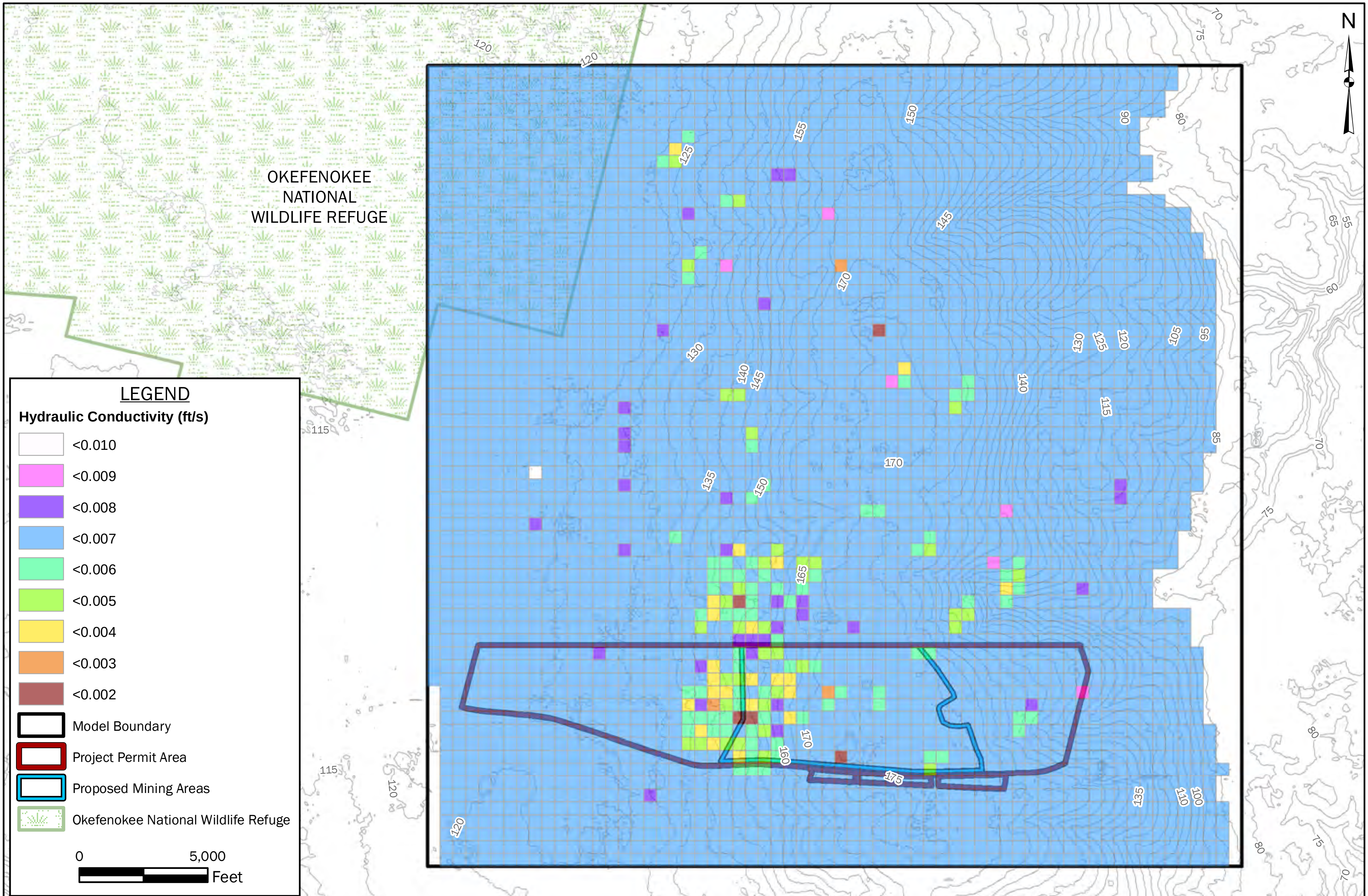

FIGURE 23: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 9

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
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DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
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APPROX. SCALE:	1 in = 5,000 ft

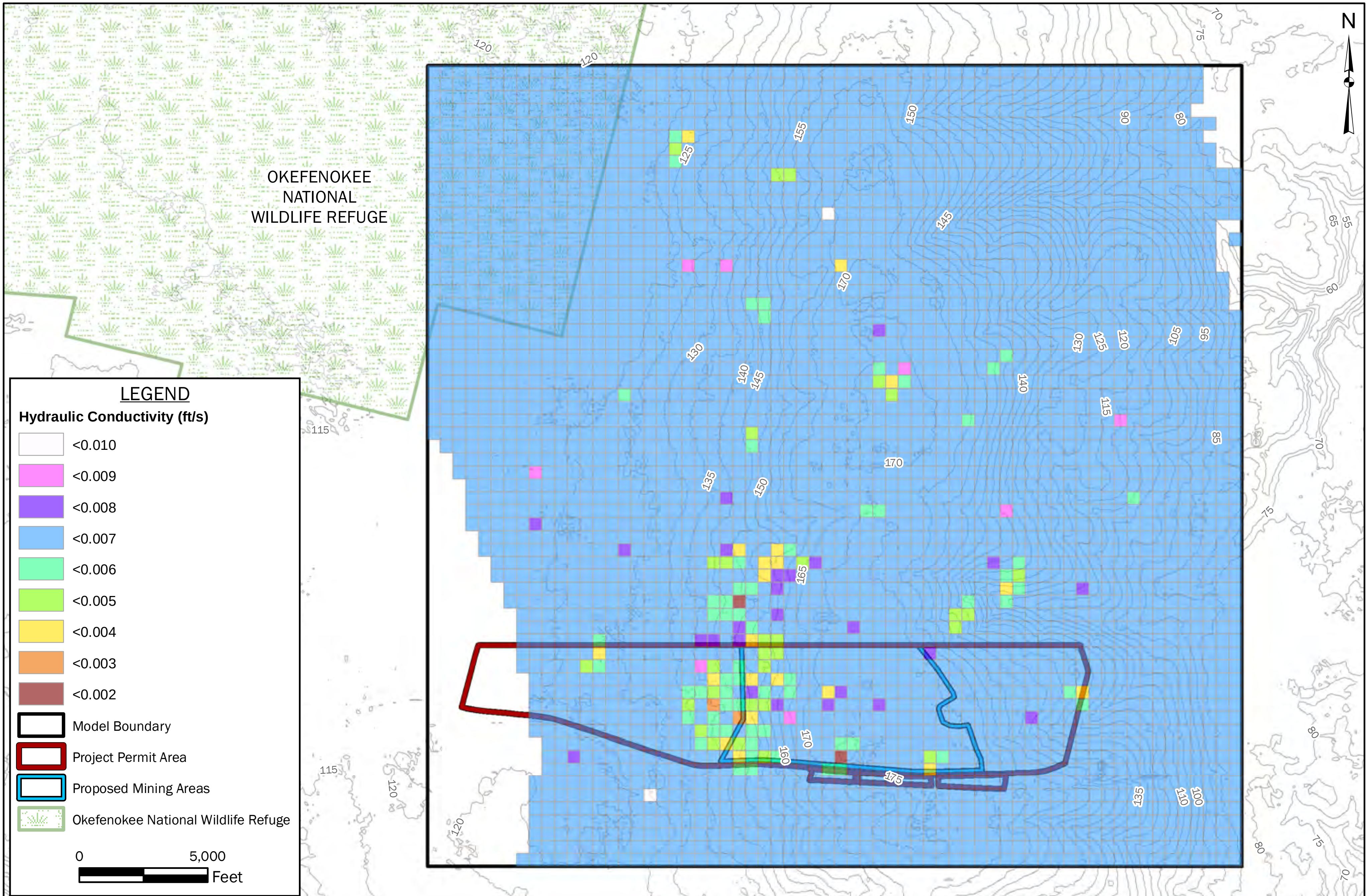

FIGURE 24: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 10

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

TTL

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

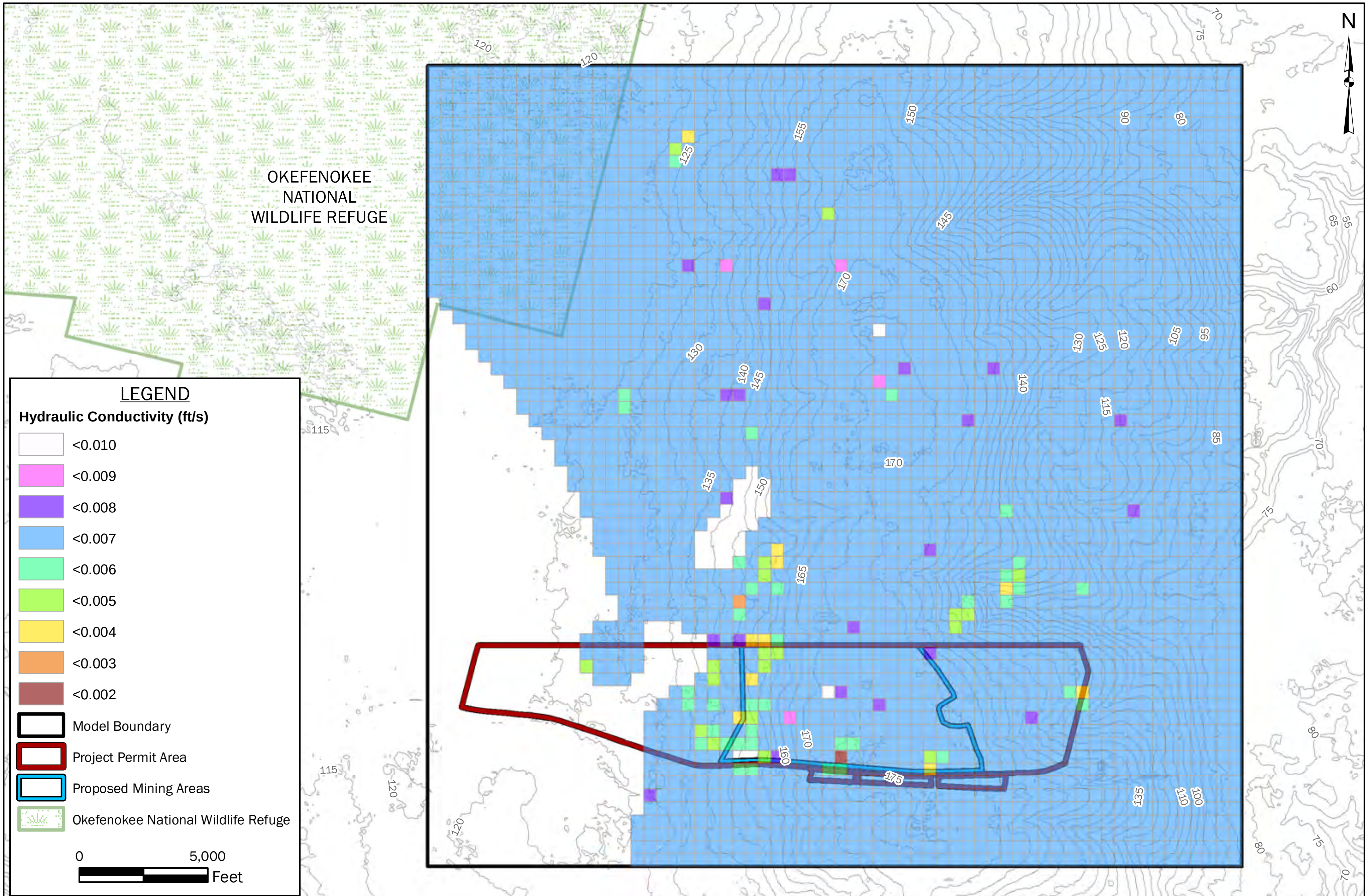

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FIGURE 25: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 11

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

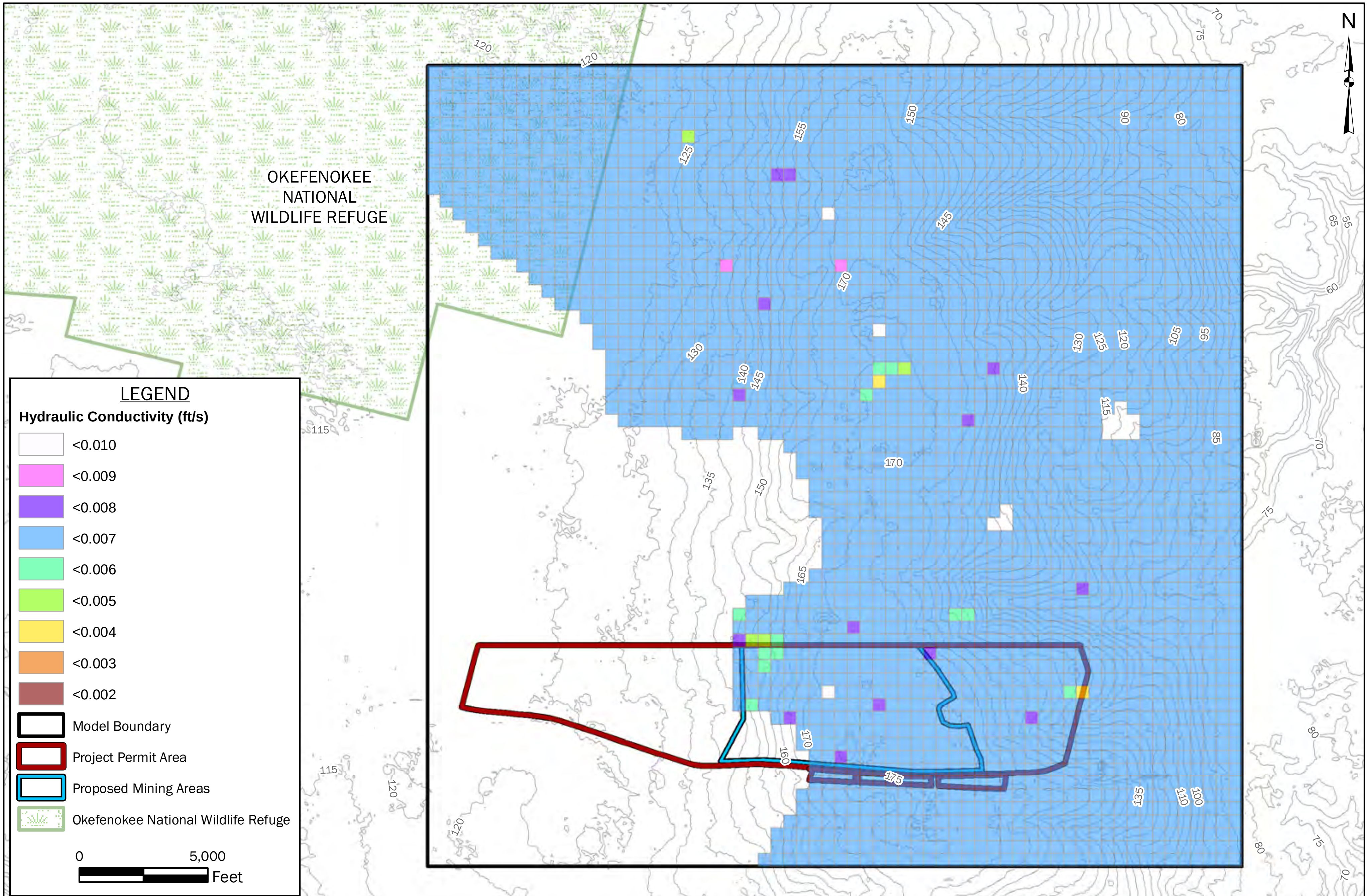

FIGURE 26: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 12

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

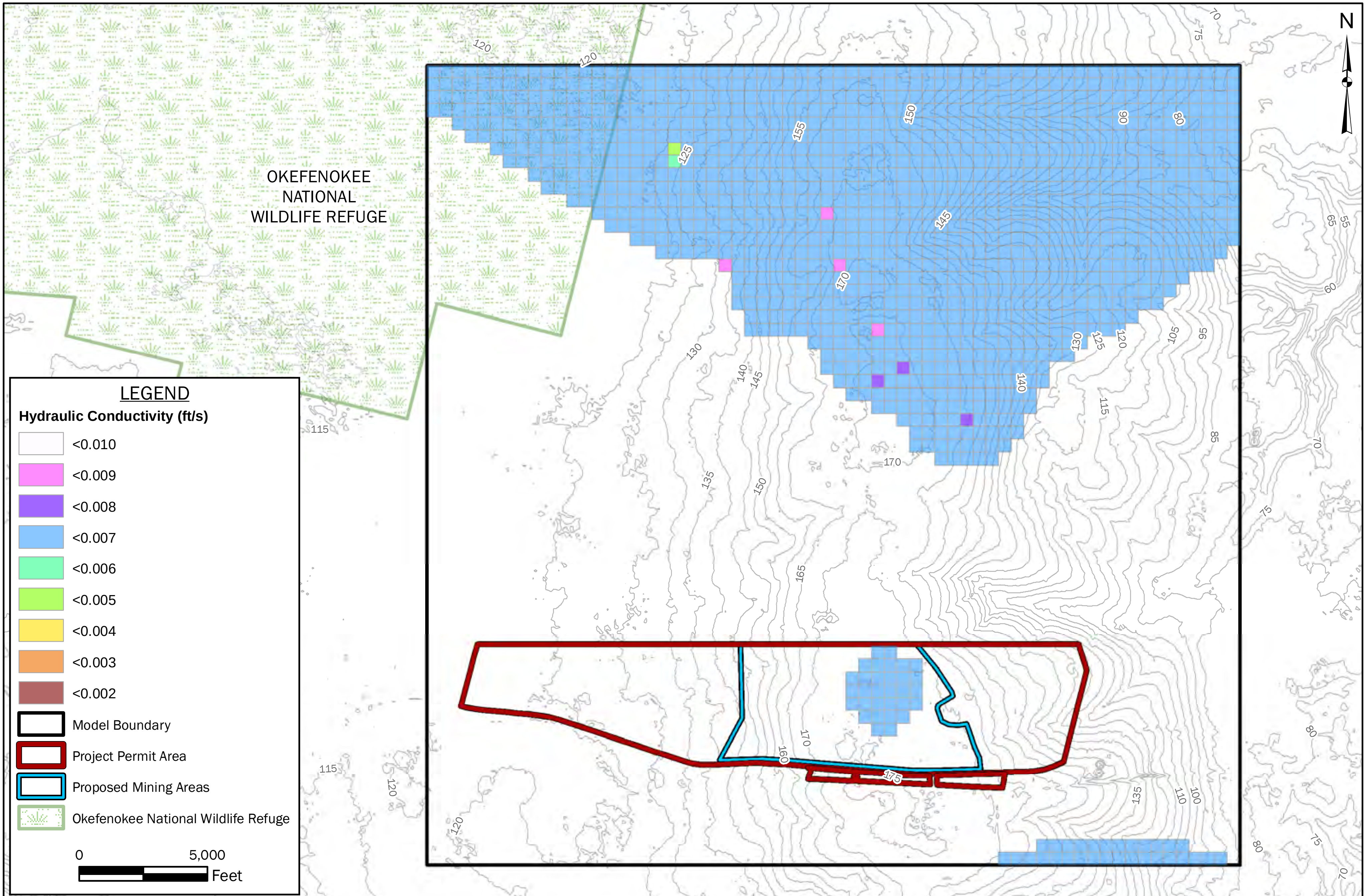

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FIGURE 27: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 13

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
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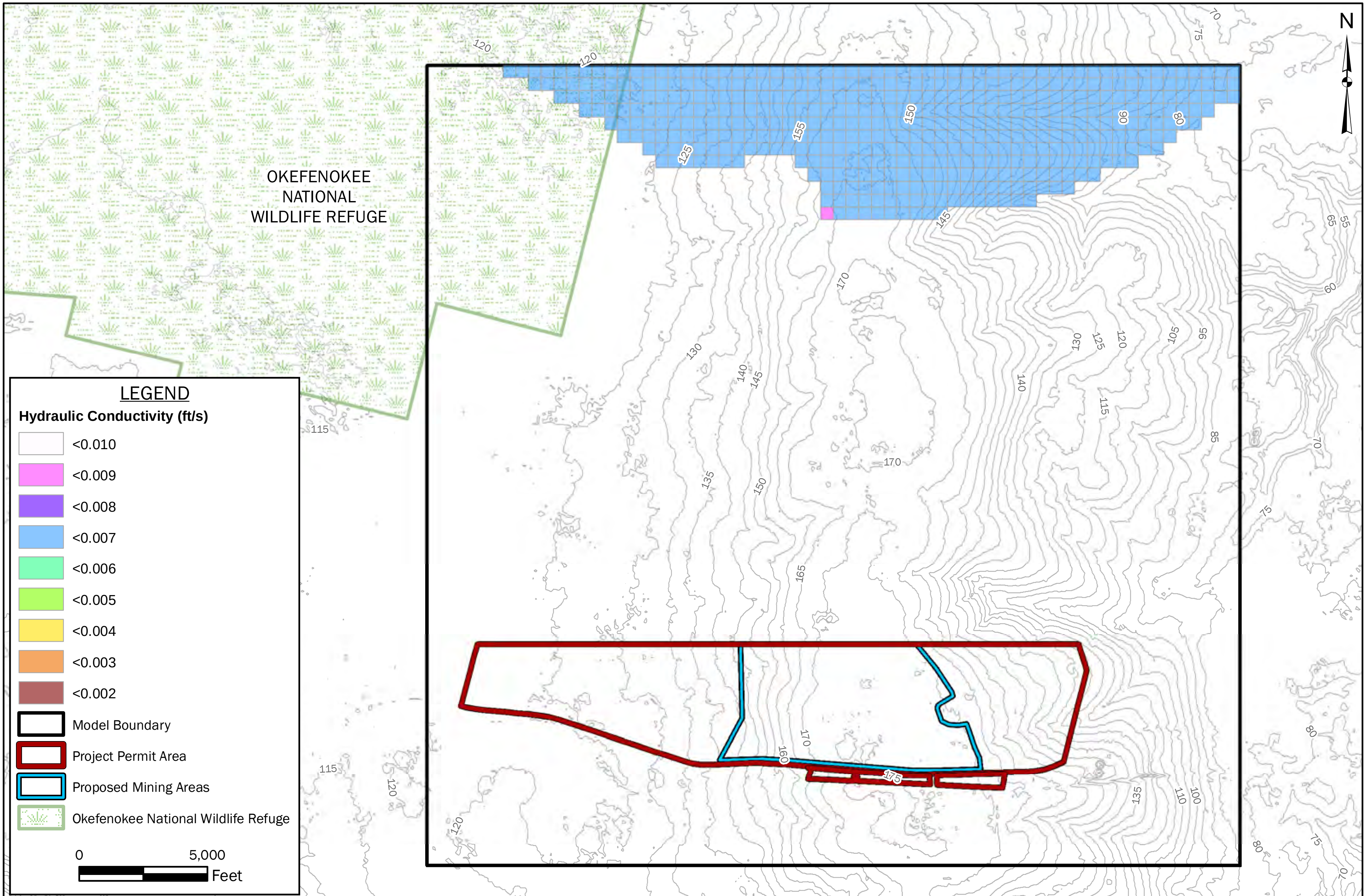


FIGURE 28: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 14

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

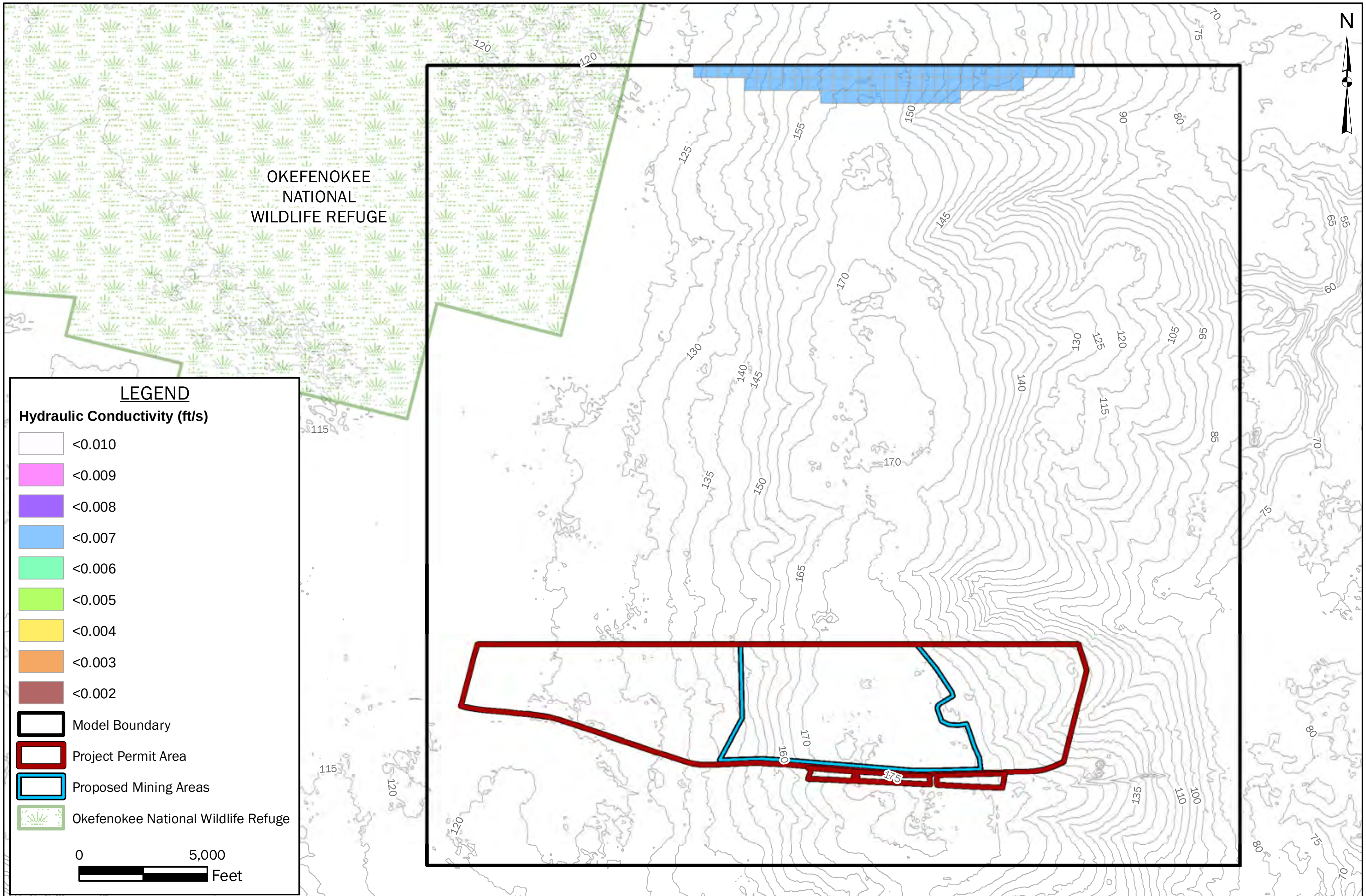


FIGURE 29: INITIAL MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 15

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

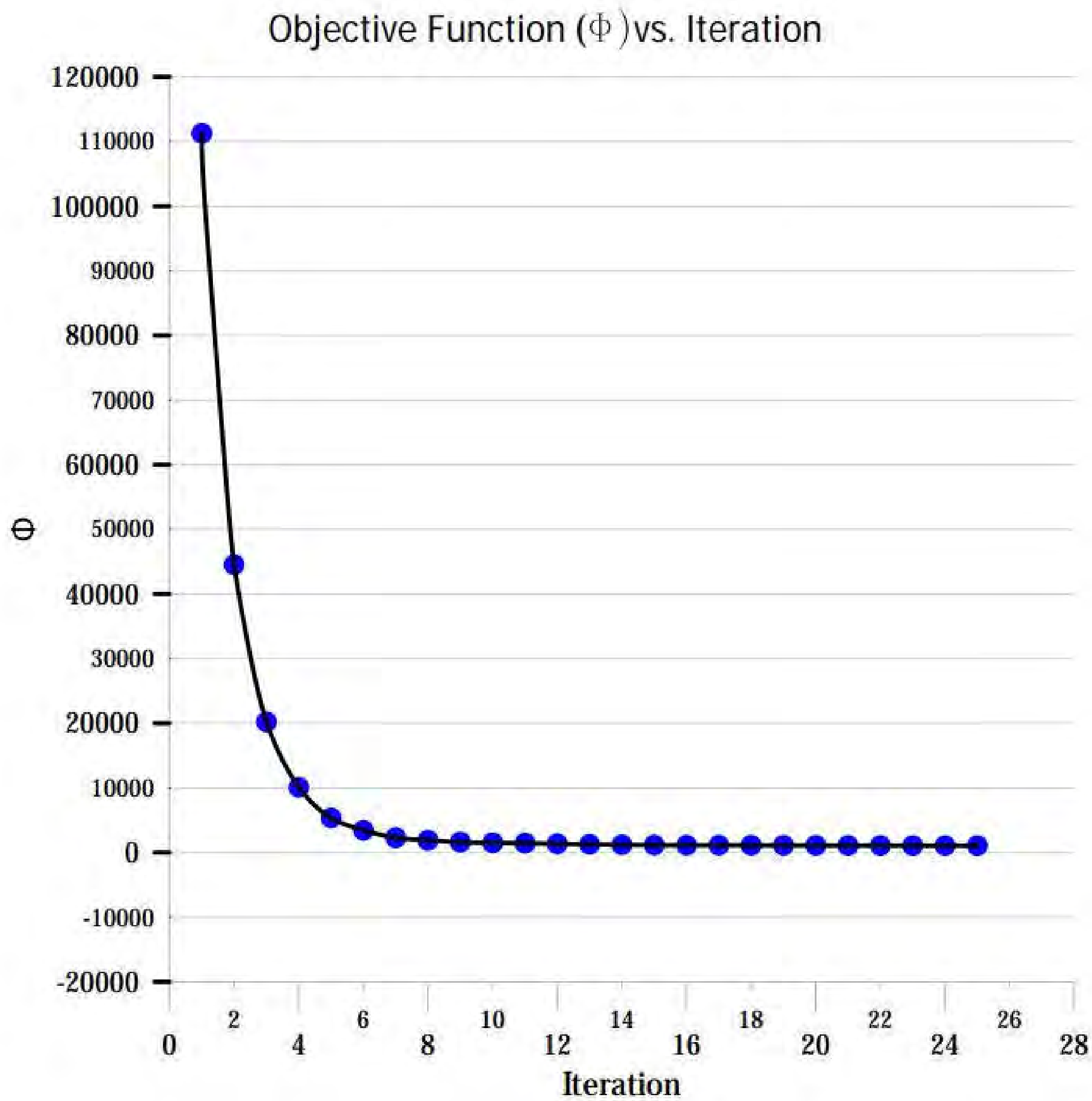
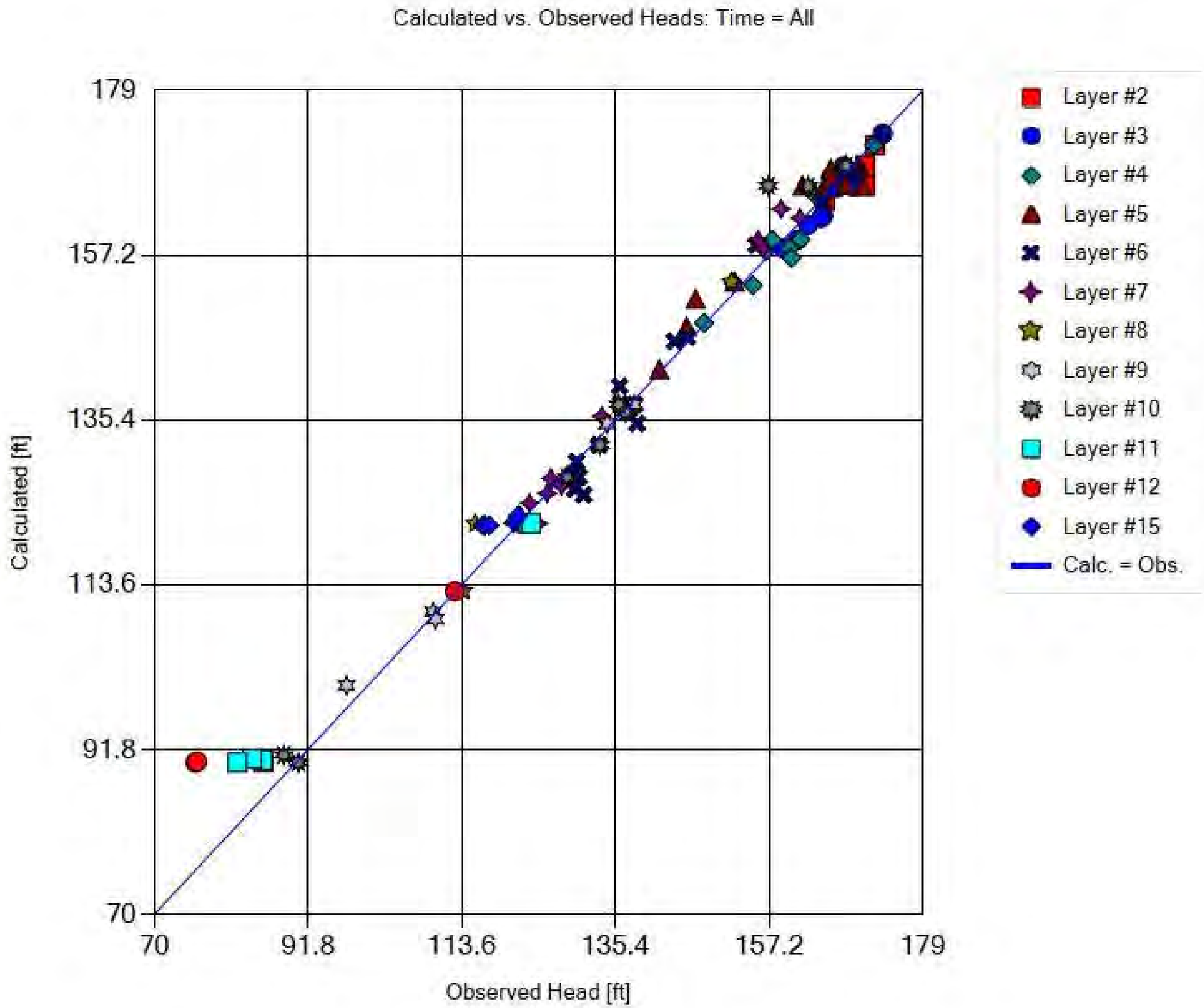


FIGURE 30: OBJECTIVE FUNCTION V. ITERATION

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE:



Min.Residual: -0.0051 (ft) at PZ06/PZ06 Time=0
Max.Residual: 14.27 (ft) at L7/L7 Time=0
Residual Mean: 0.76 (ft)
Abs.Residual Mean: 2.16 (ft)

Standard Error of the Estimate: 0.3 (ft)
Root Mean Squared: 3.23 (ft)
Normalized RMS: 3.31 (%)
Correlation Coefficient: 0.99

TTL

FIGURE 31: CALCULATED V. OBSERVED HEADS - CALIBRATED

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE:

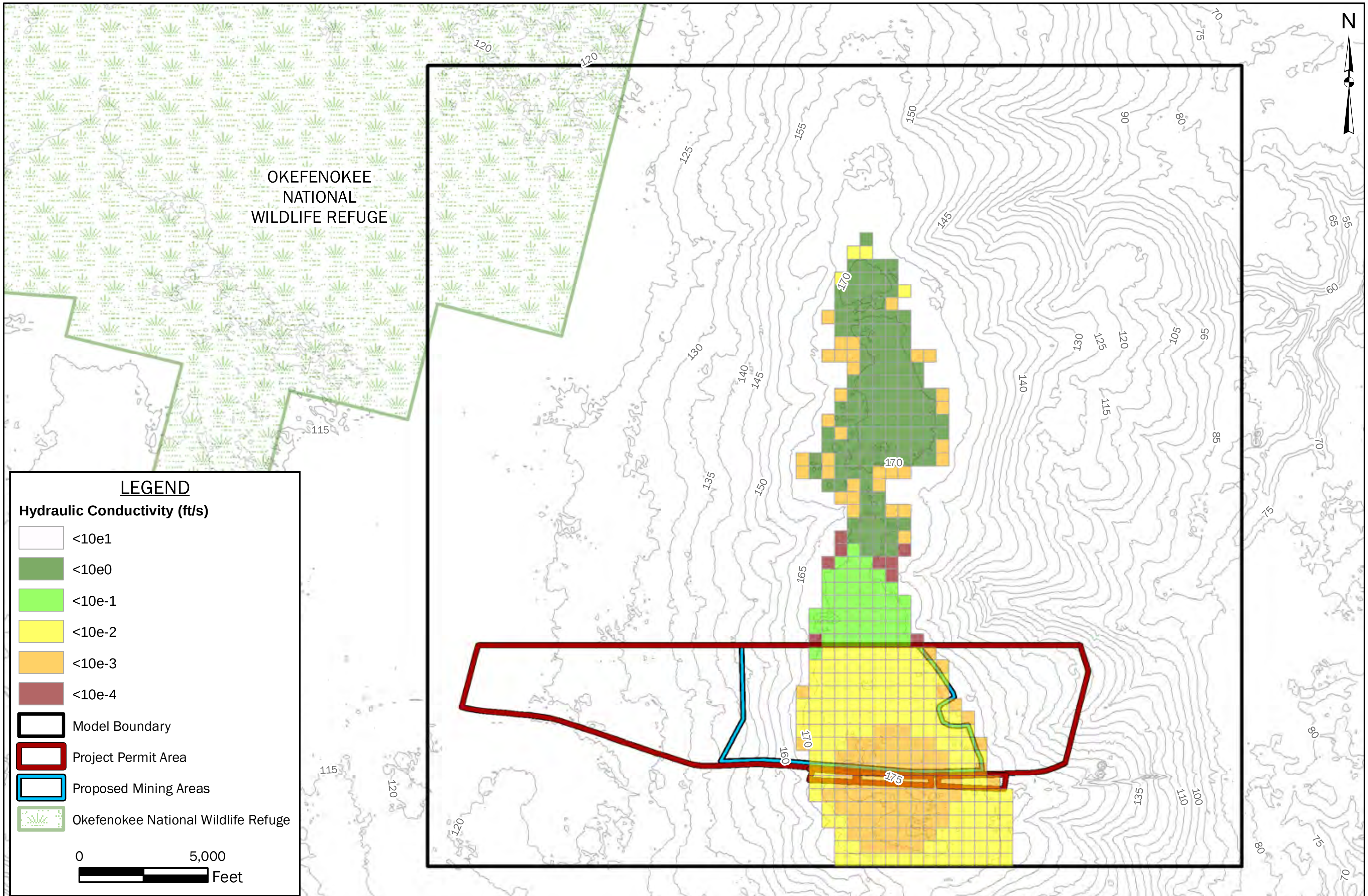


FIGURE 32: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 1

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

TTL

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

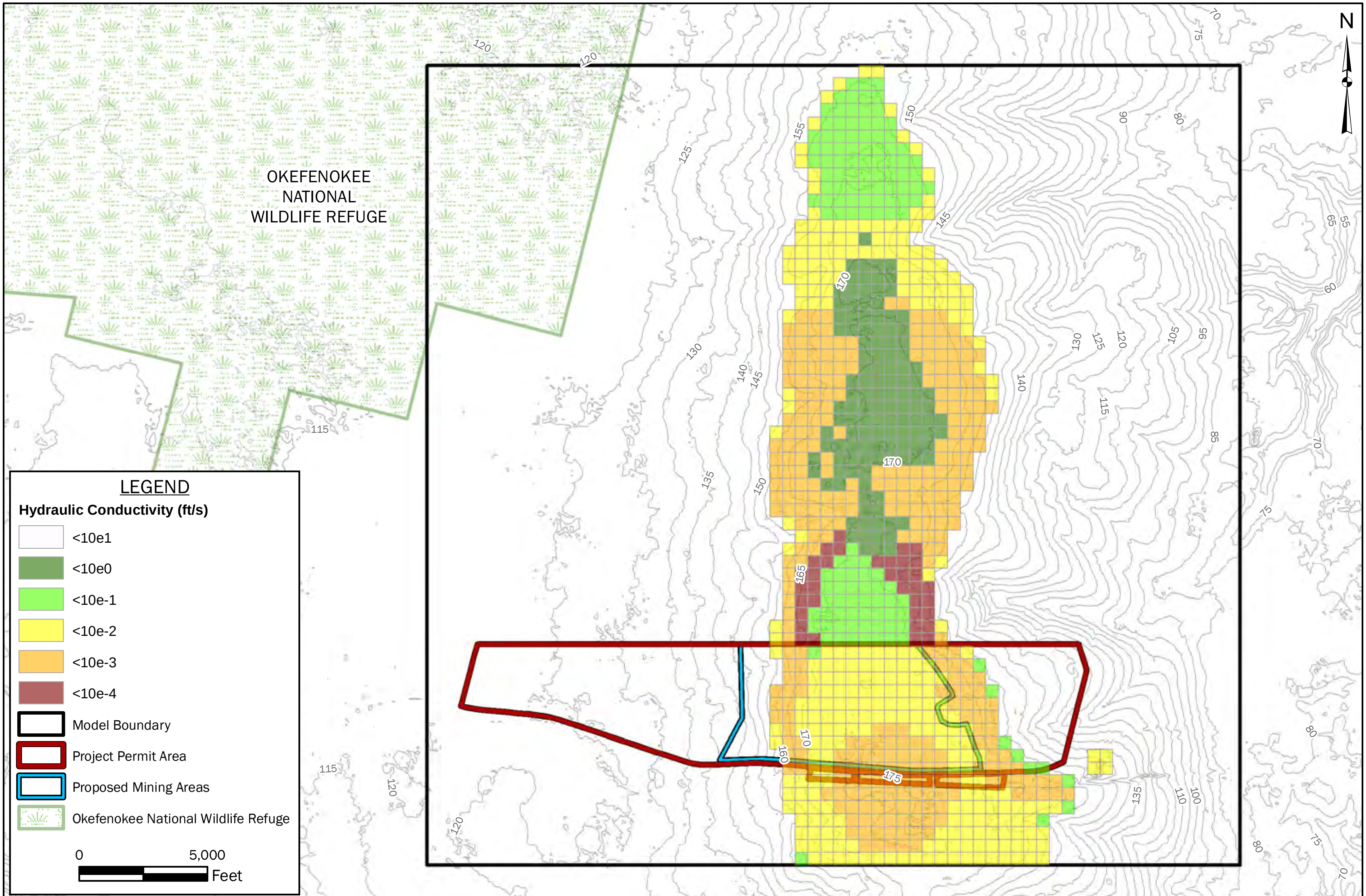
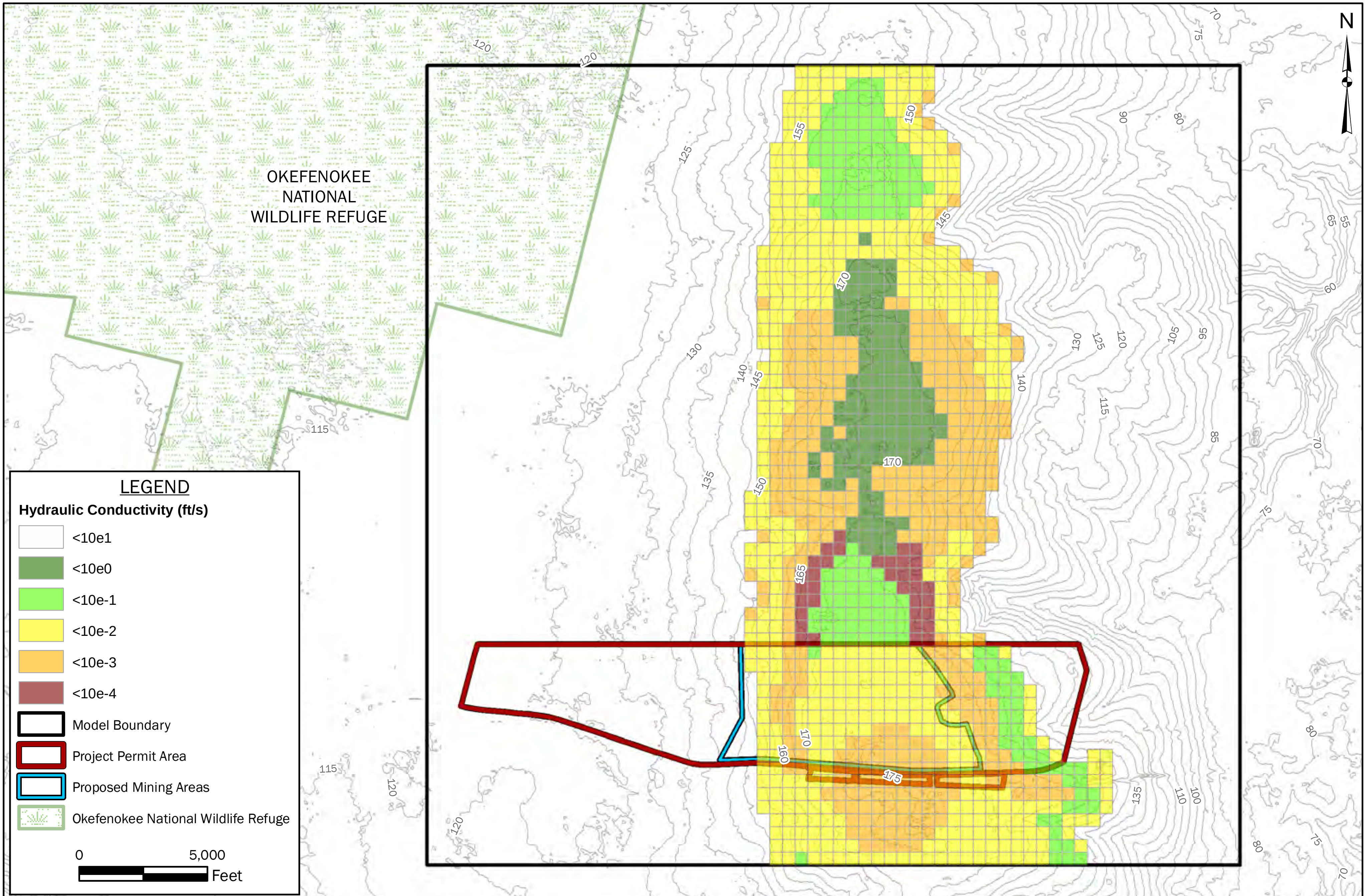


FIGURE 33: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 2

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft



TTL

FIGURE 34: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 3

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

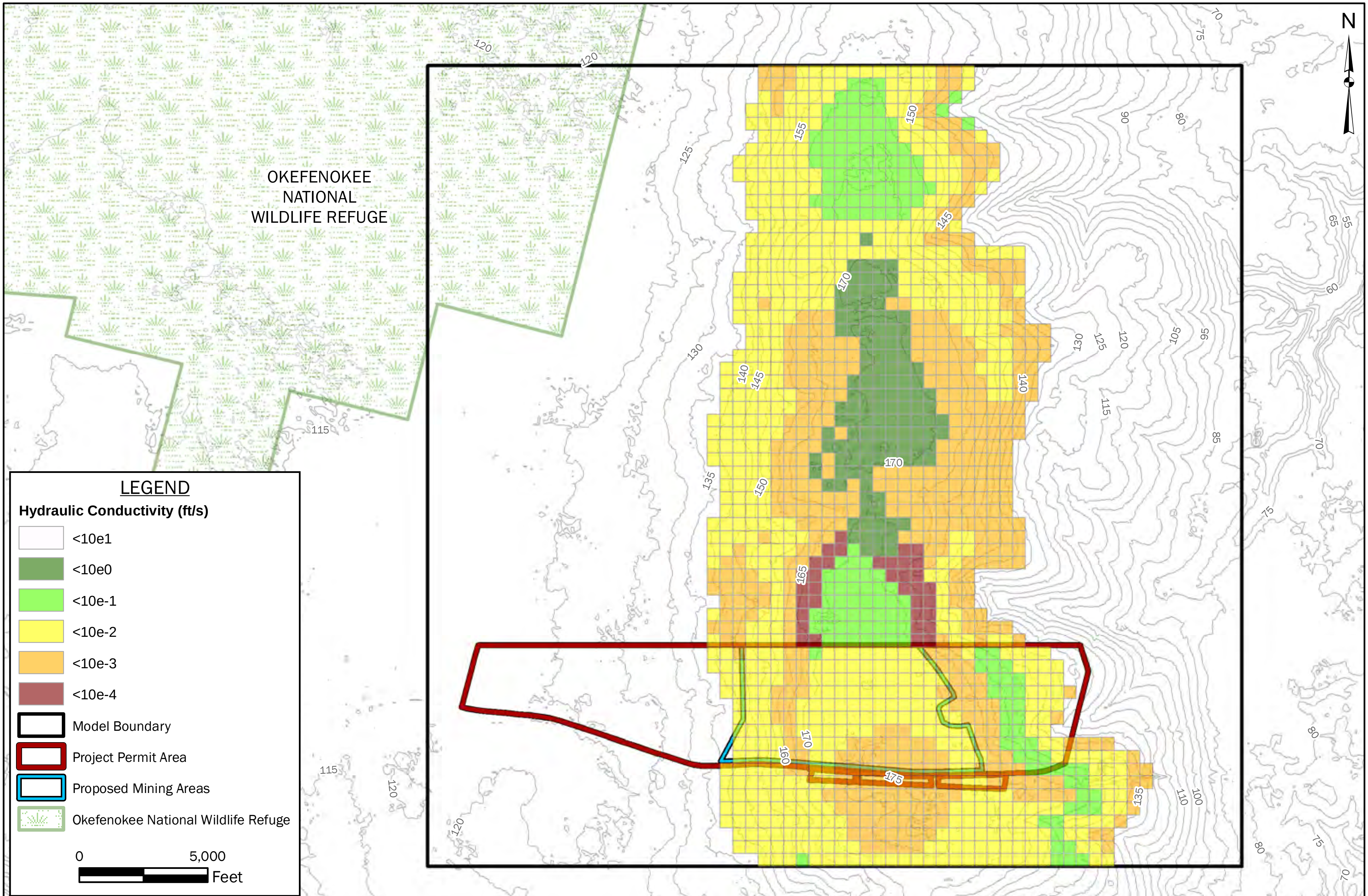


FIGURE 35: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 4

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

TTL

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

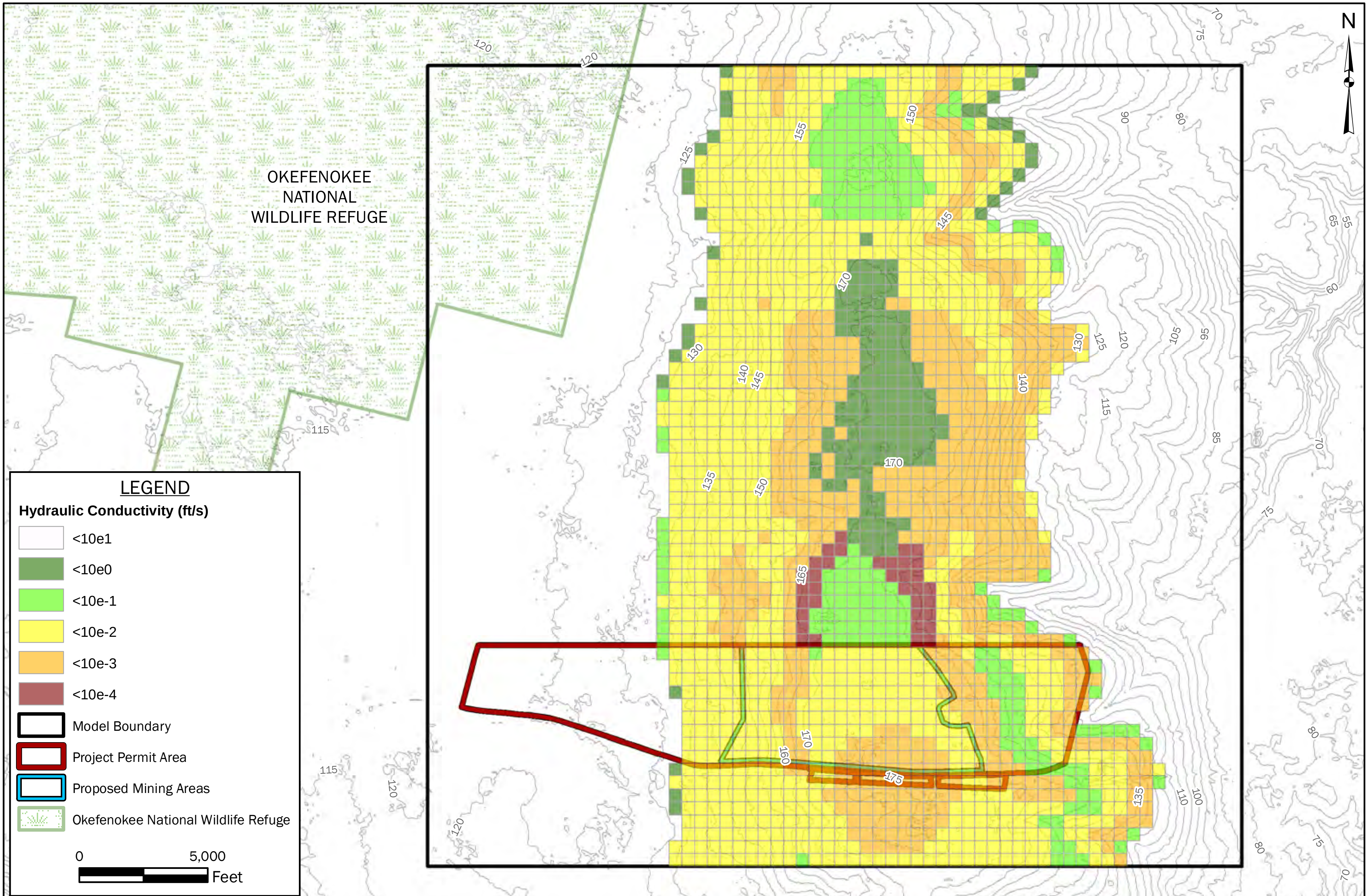


FIGURE 36: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 5

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

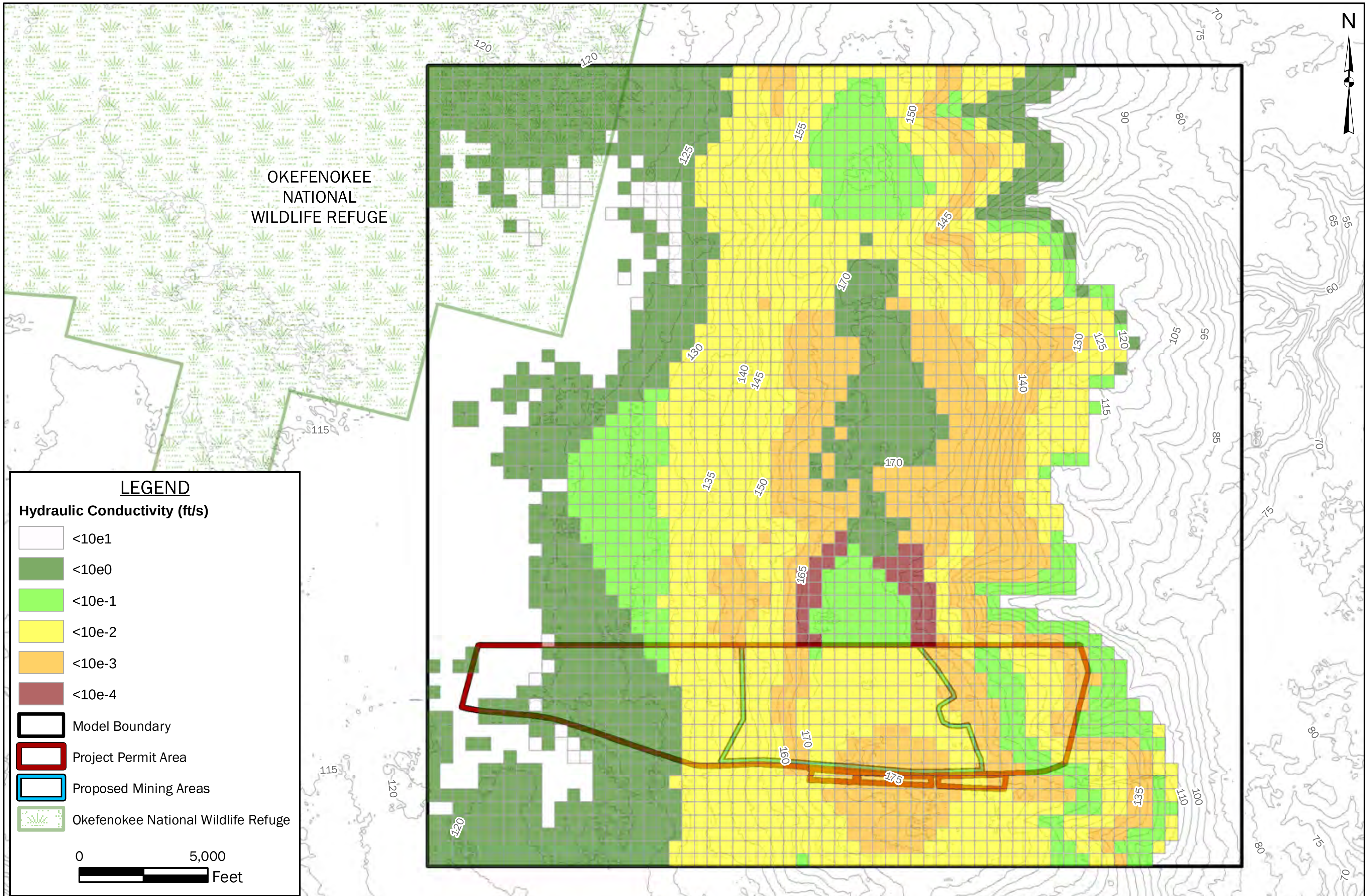


FIGURE 37: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 6

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK

CHECKED BY: RMH

DRAWING DATE: 1/13/2020

REVISION DATE: N/A

TTL JOB NO.: 000180200804.00

APPROX. SCALE: 1 in = 5,000 ft

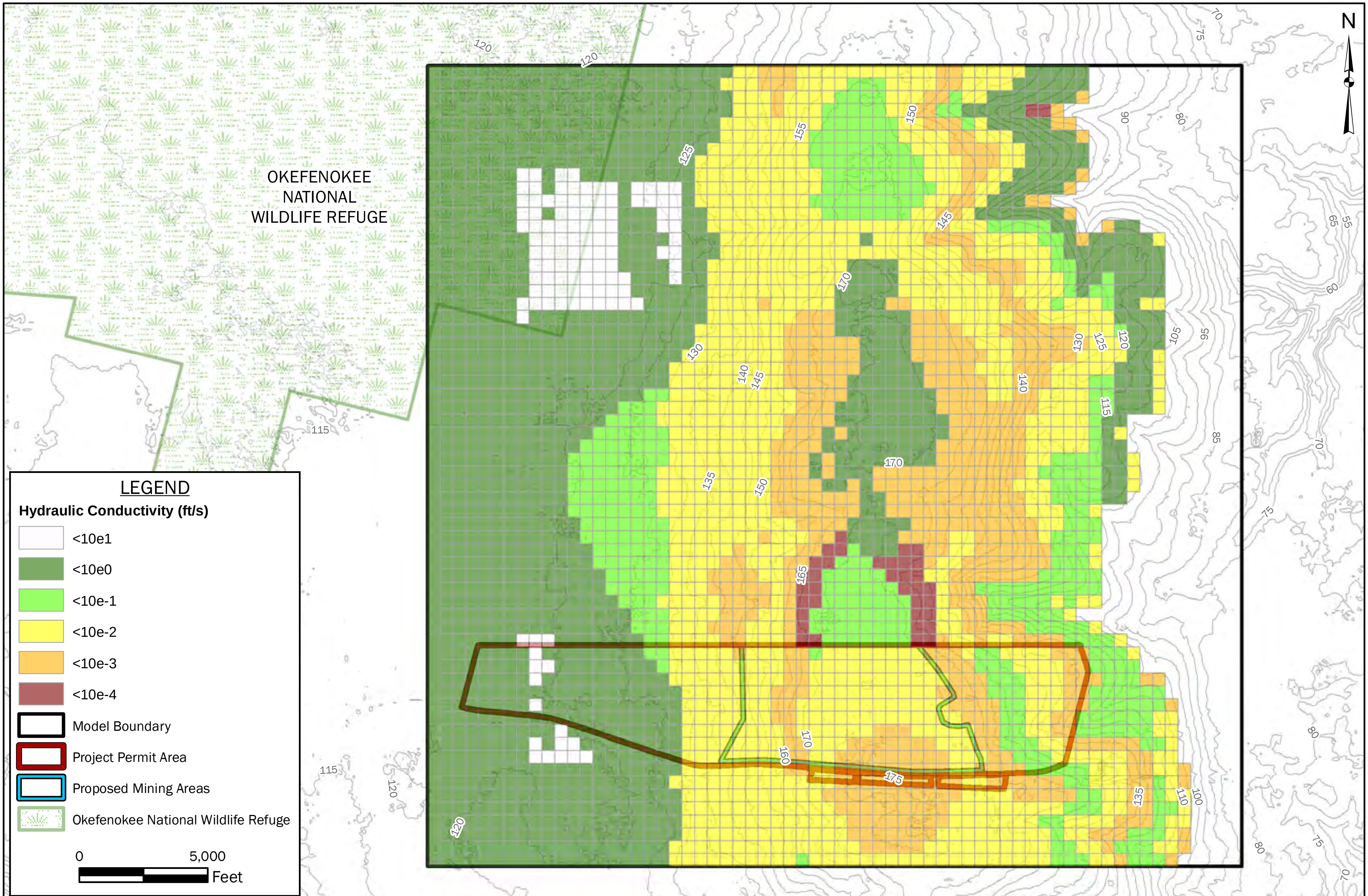


FIGURE 38: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 7

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

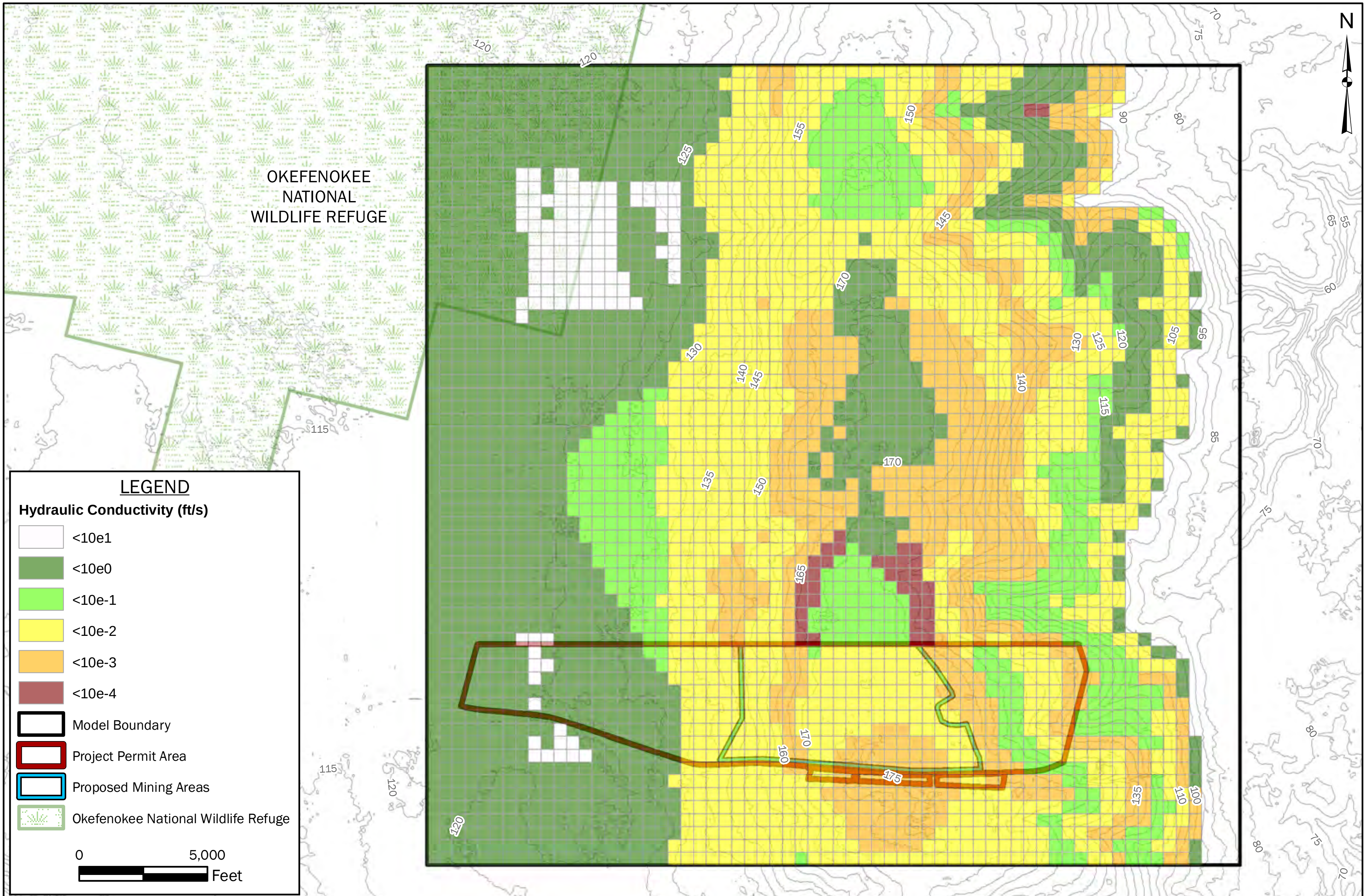


FIGURE 39: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 8

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

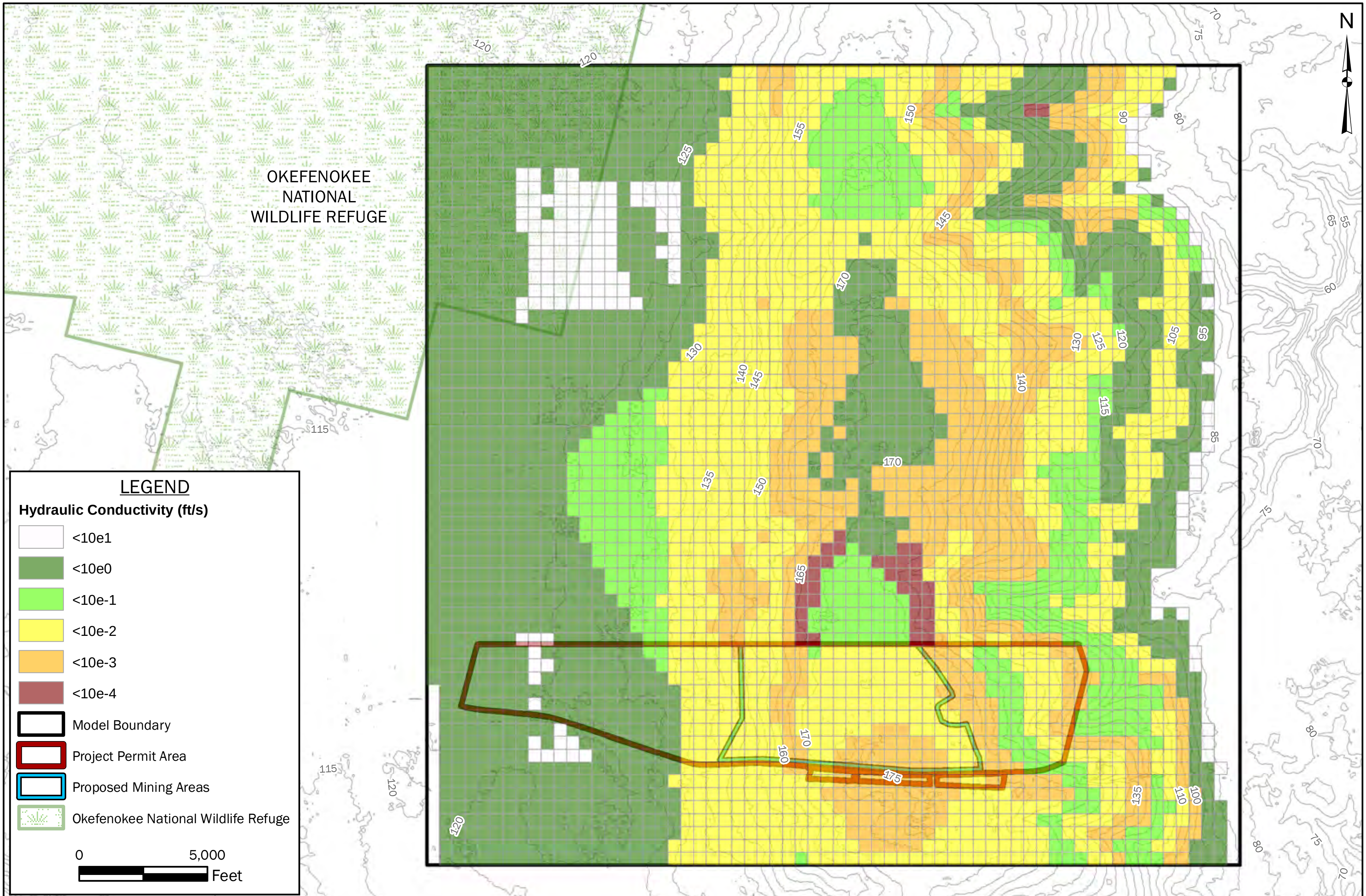


FIGURE 40: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 9

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

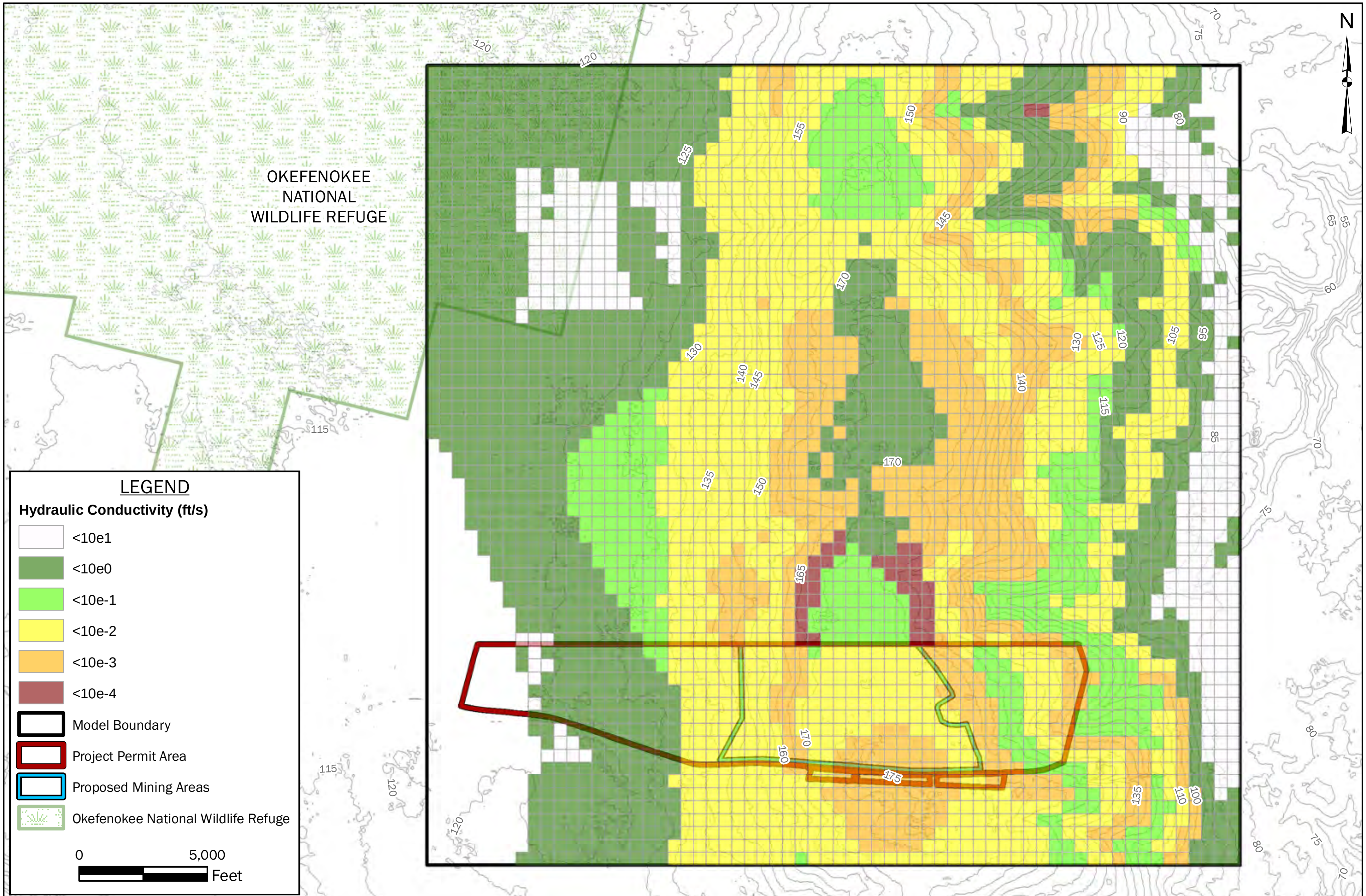


FIGURE 41: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 10

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

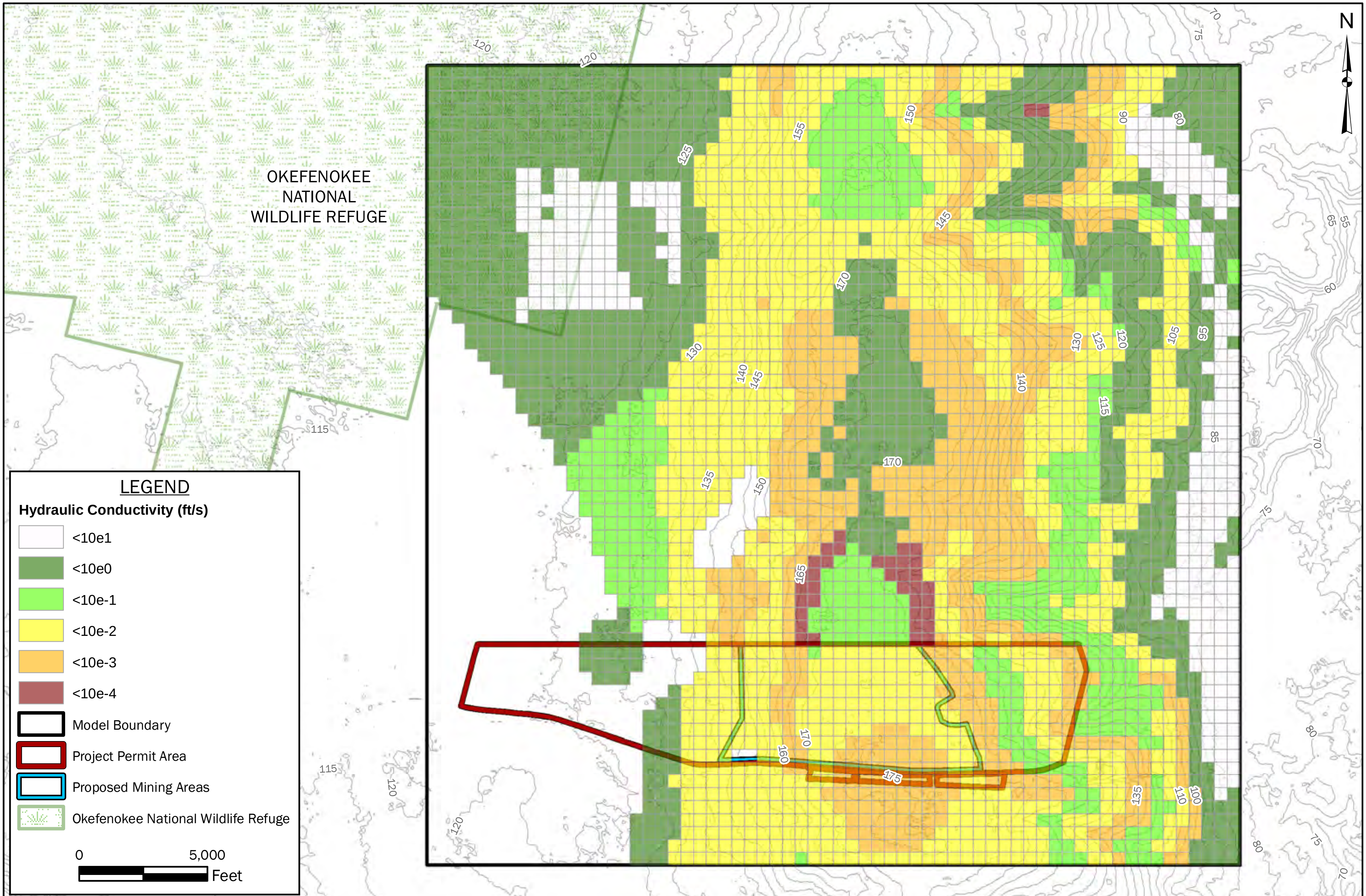


FIGURE 42: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 11

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

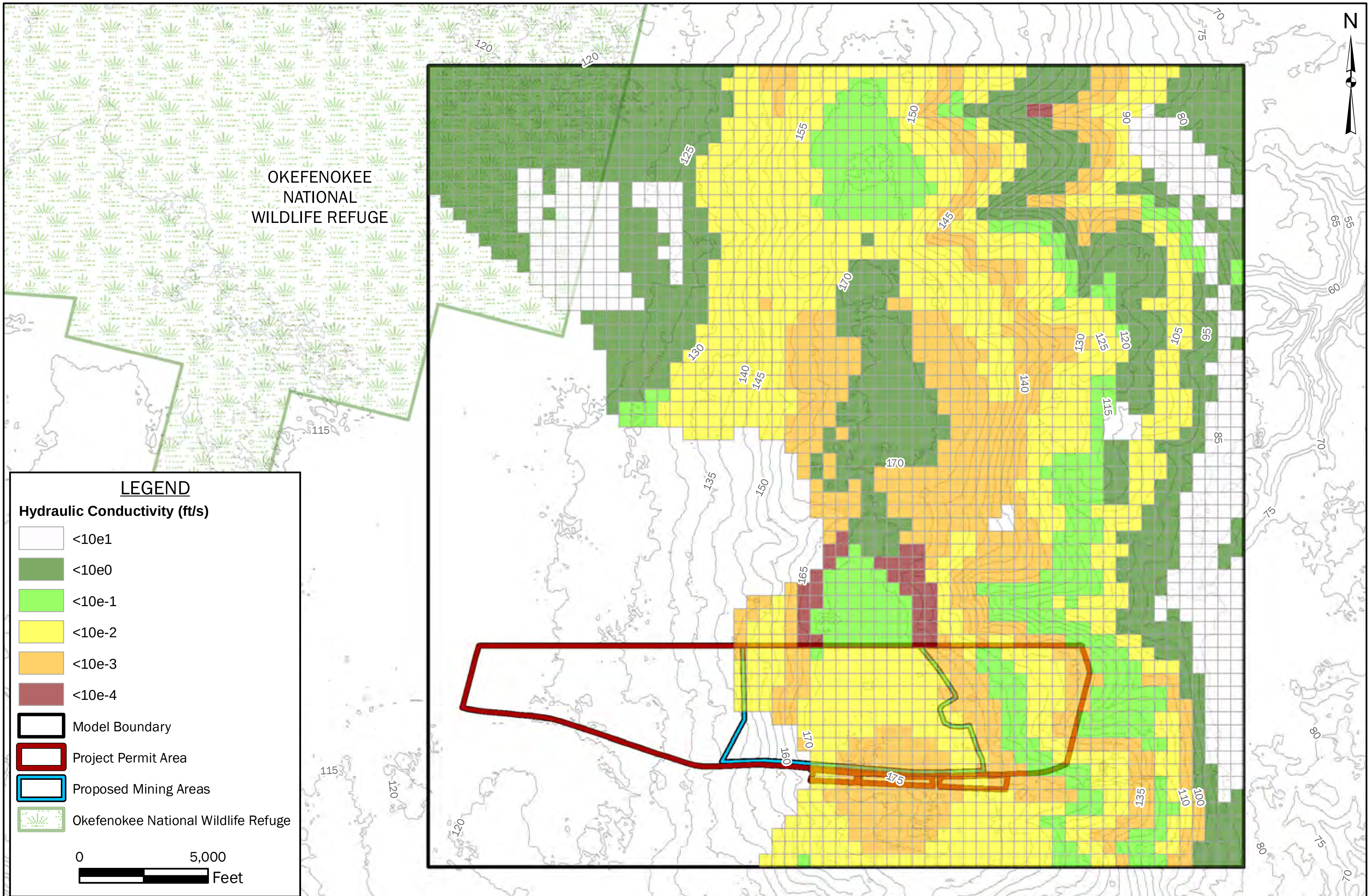


FIGURE 43: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 12

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

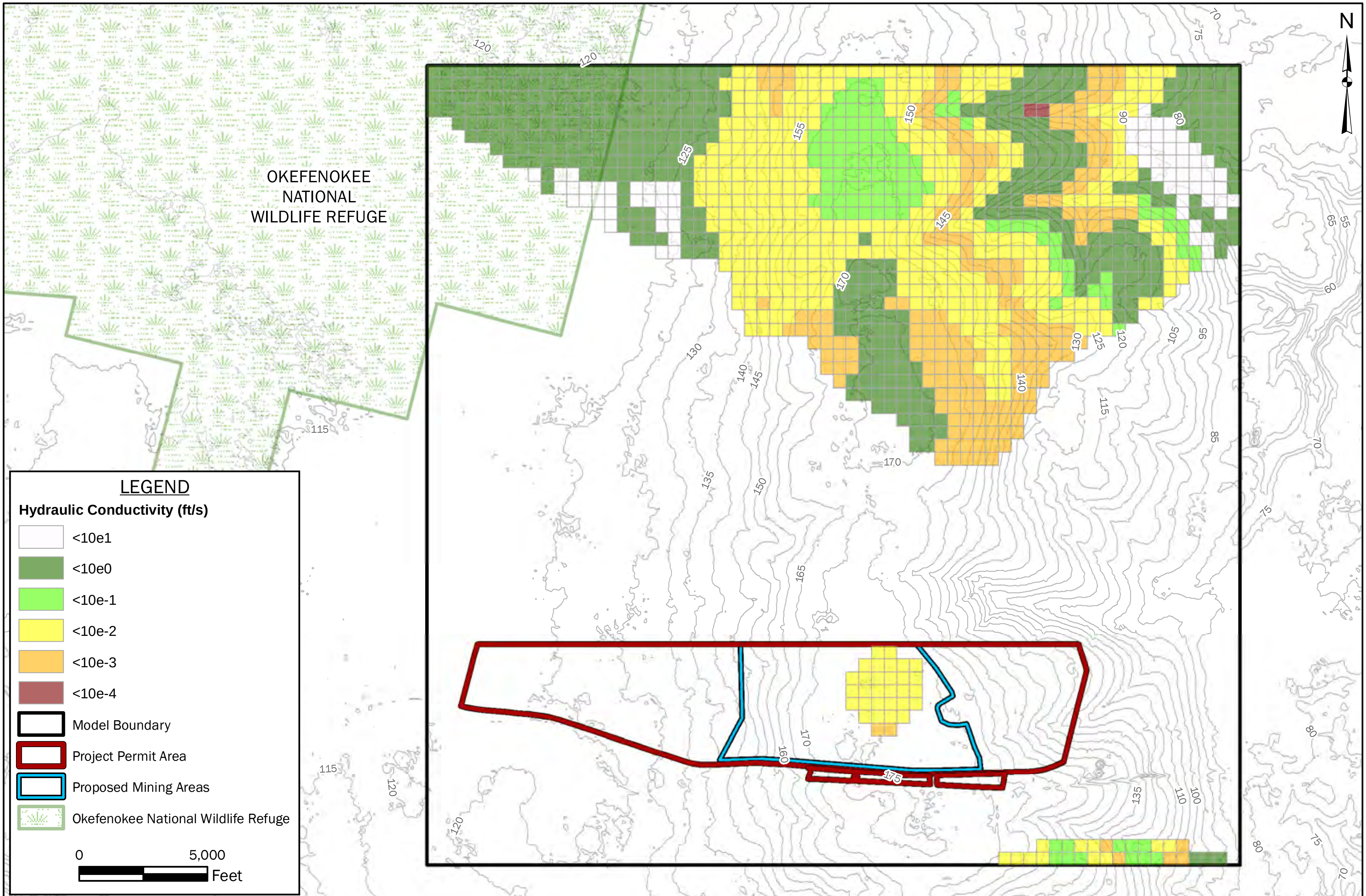


FIGURE 44: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 13

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

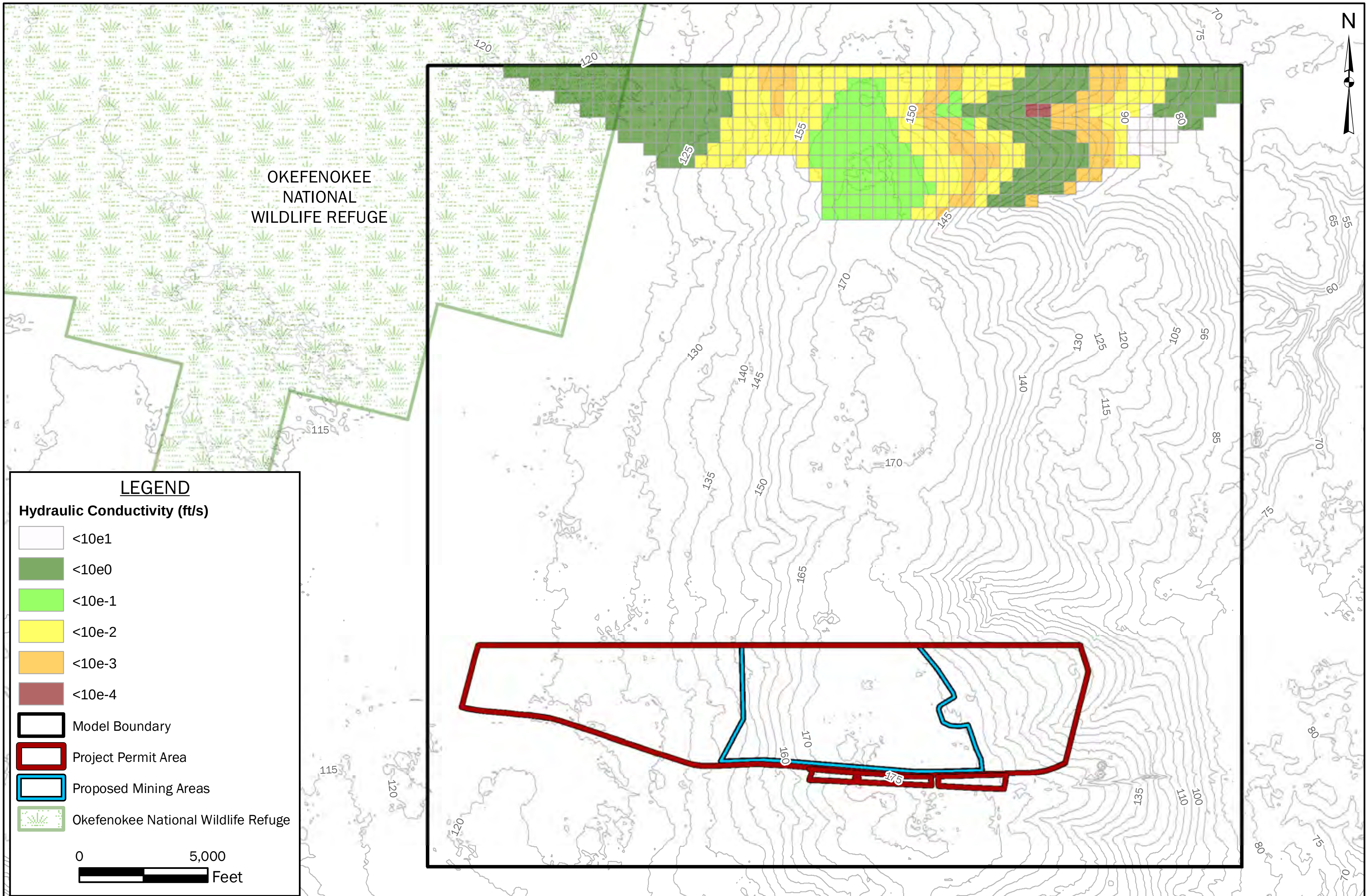


FIGURE 45: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 14

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

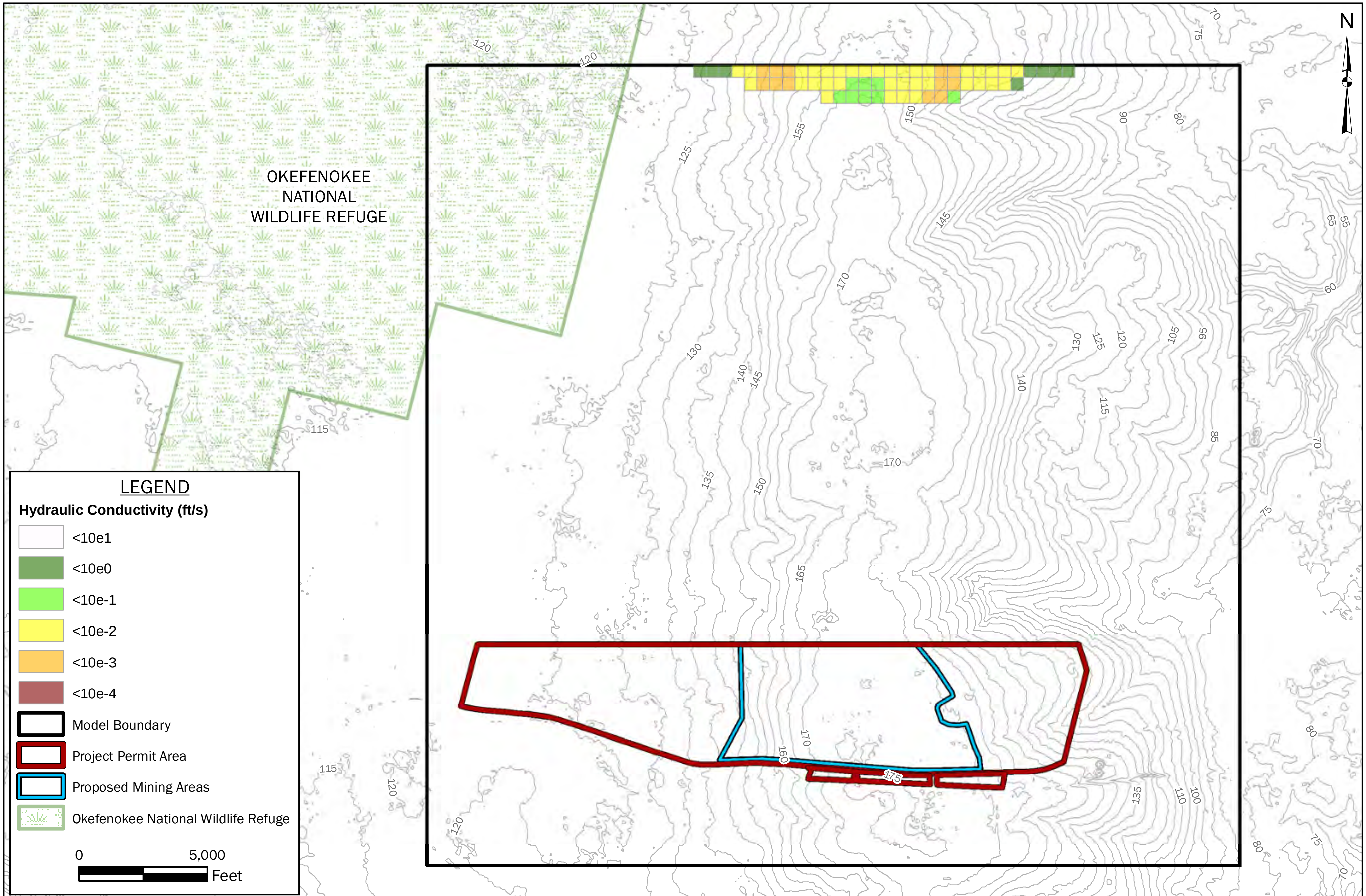


FIGURE 46: CALIBRATED MODEL HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 15

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

TTL

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

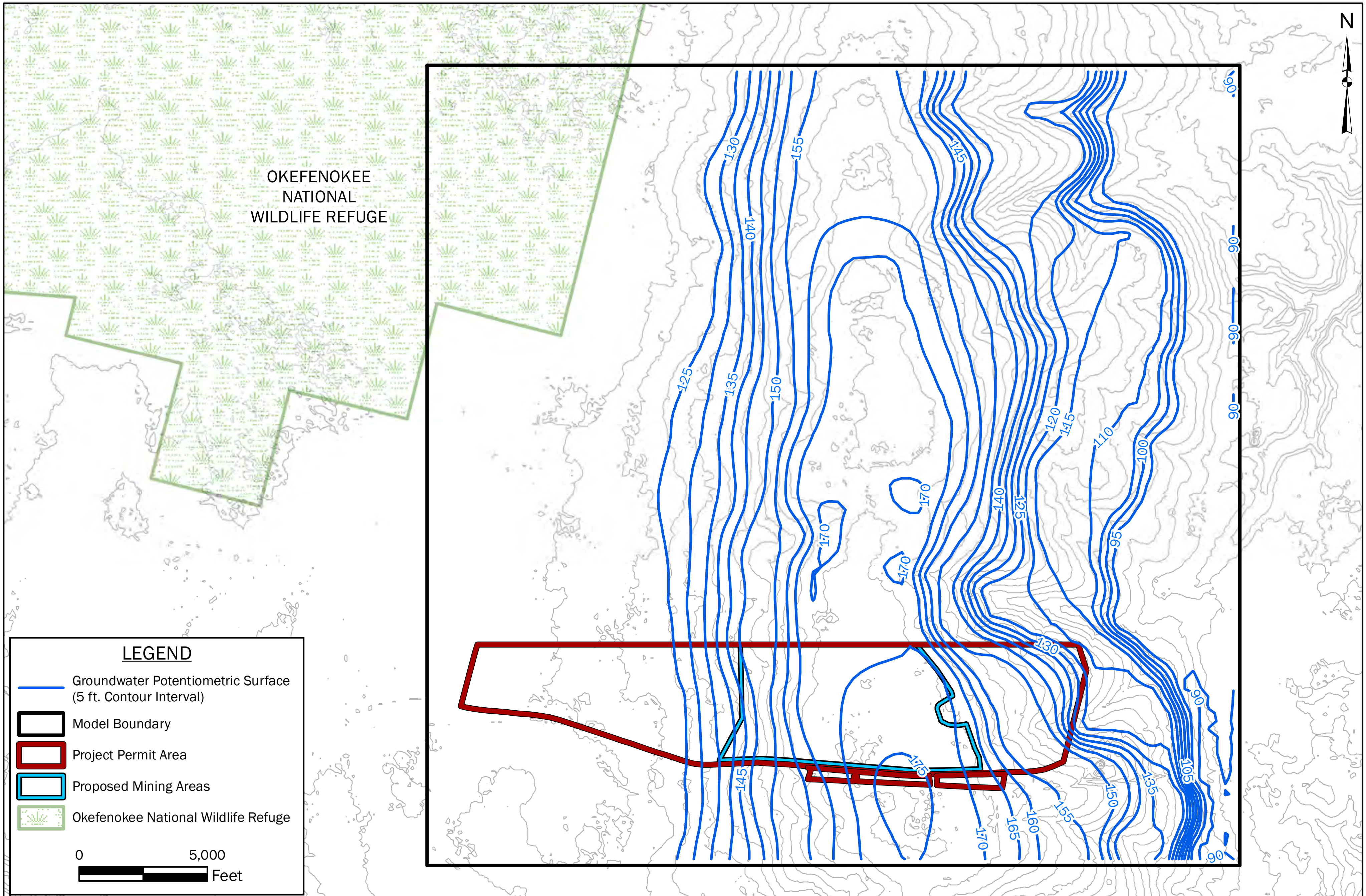


FIGURE 47: PRE-MINING MODEL POTENTIOMETRIC SURFACE MAP

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

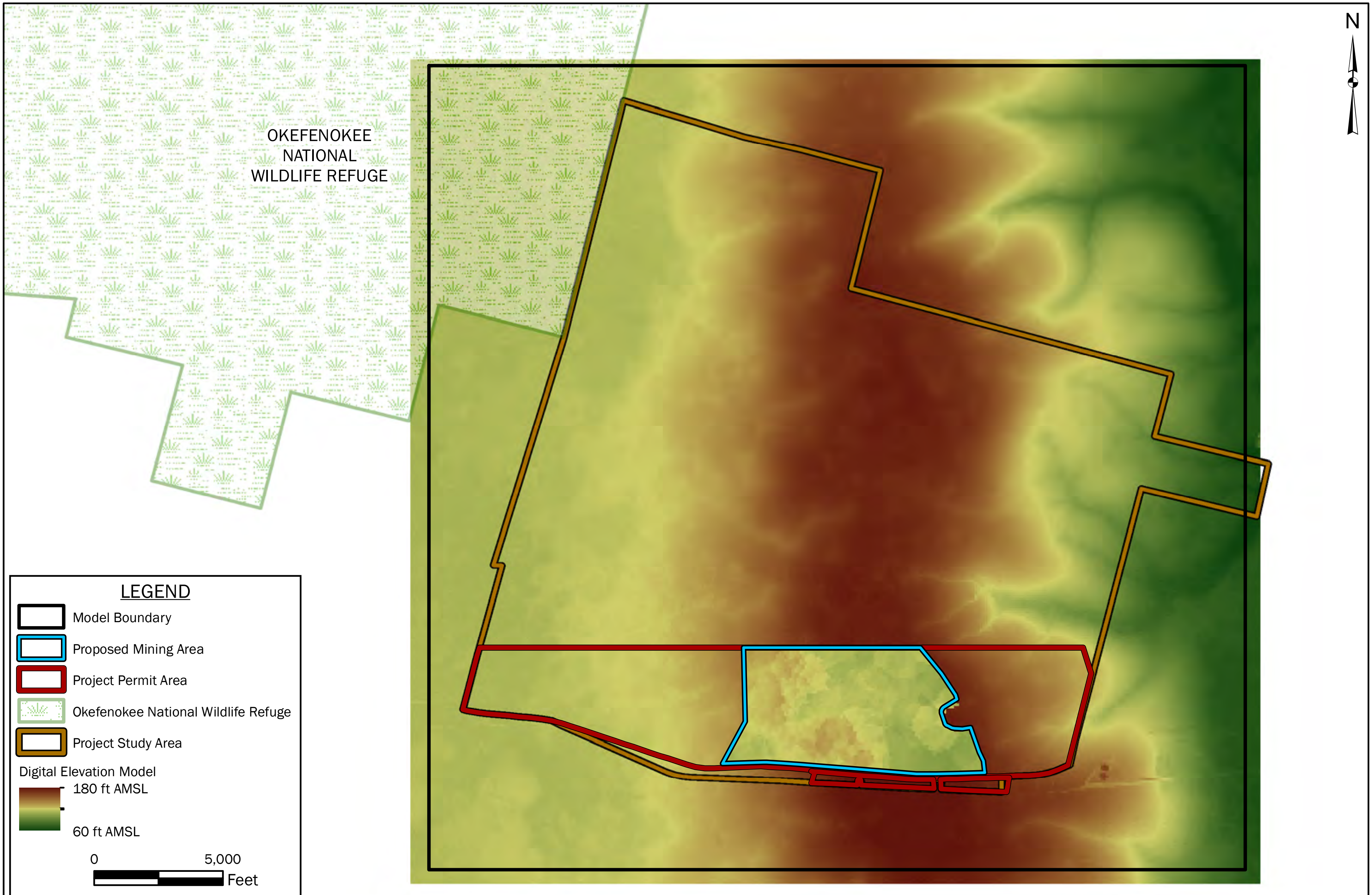
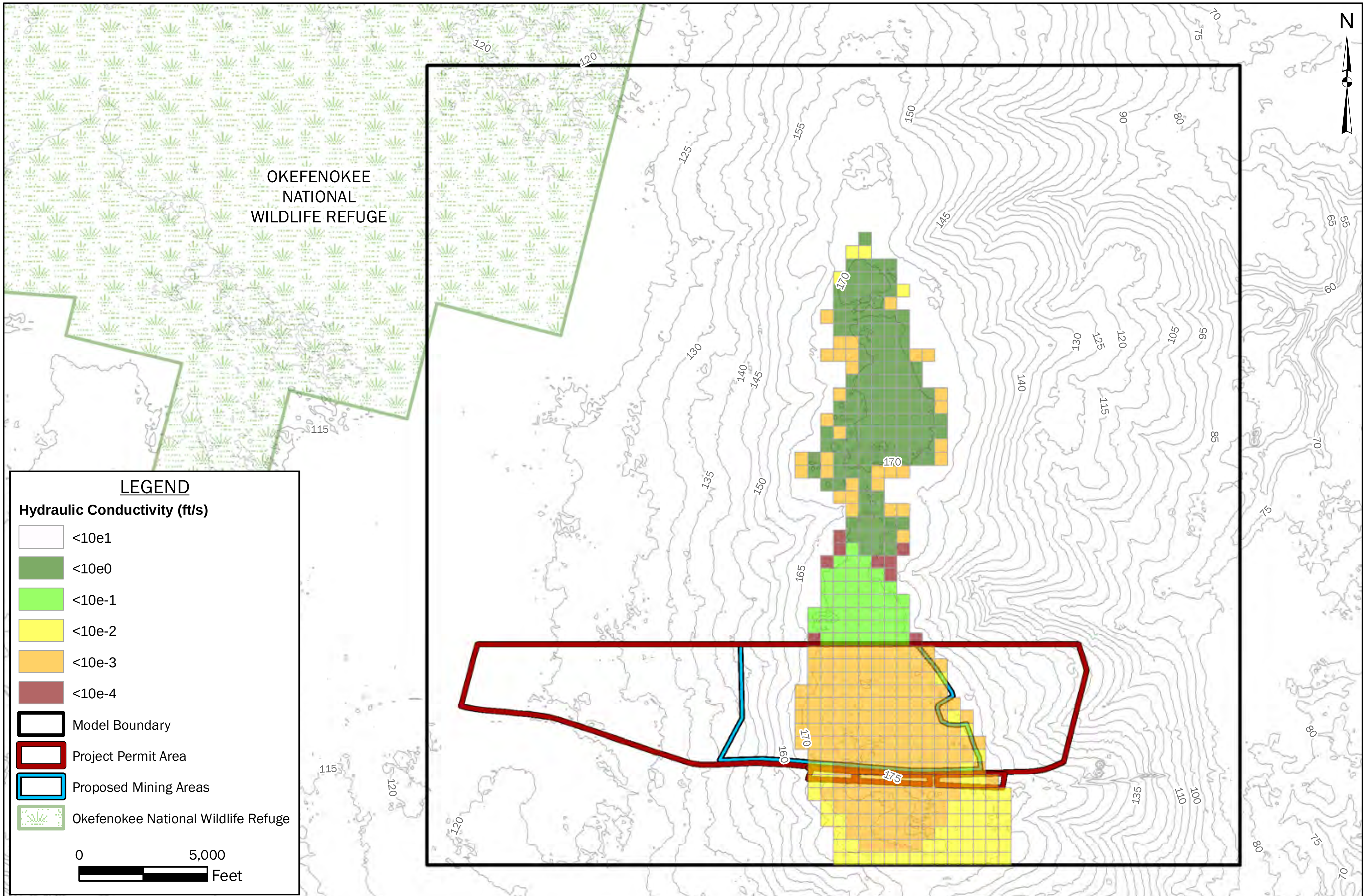


FIGURE 48: SURFACE & MINING BASE DIGITAL ELEVATION MODEL

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft



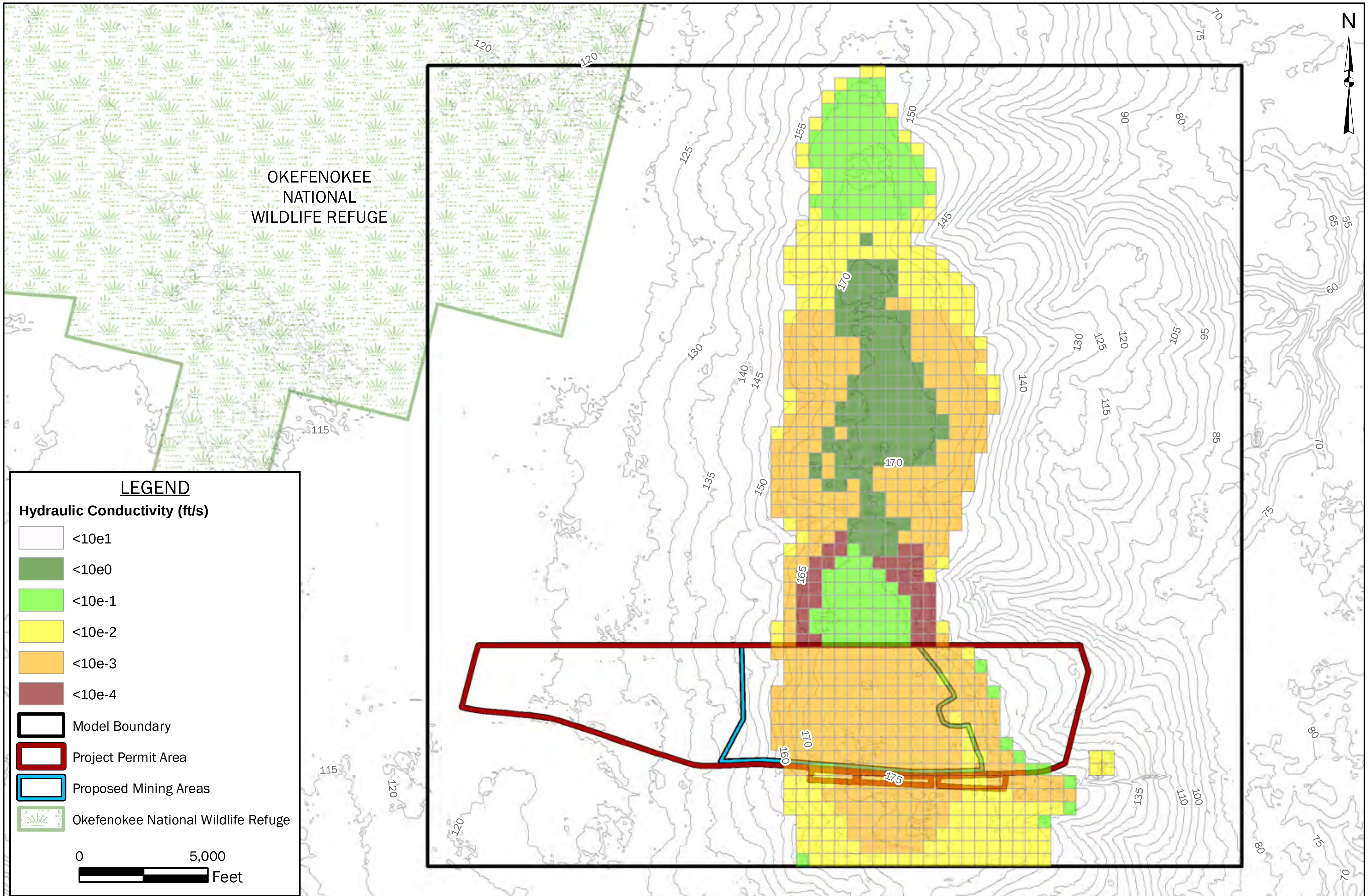
TTL

FIGURE 49: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 1

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft



TTL

FIGURE 50: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 2

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

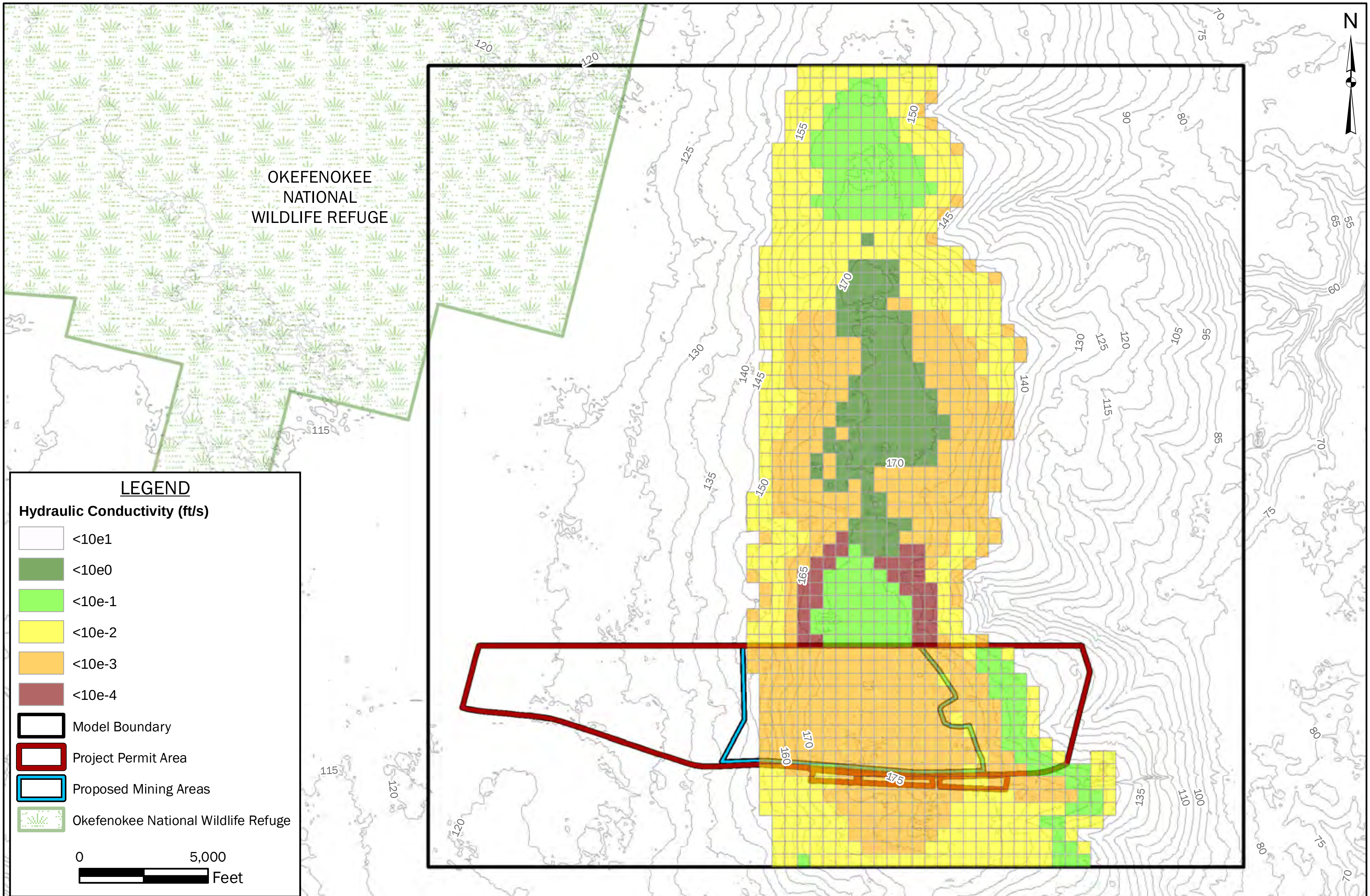


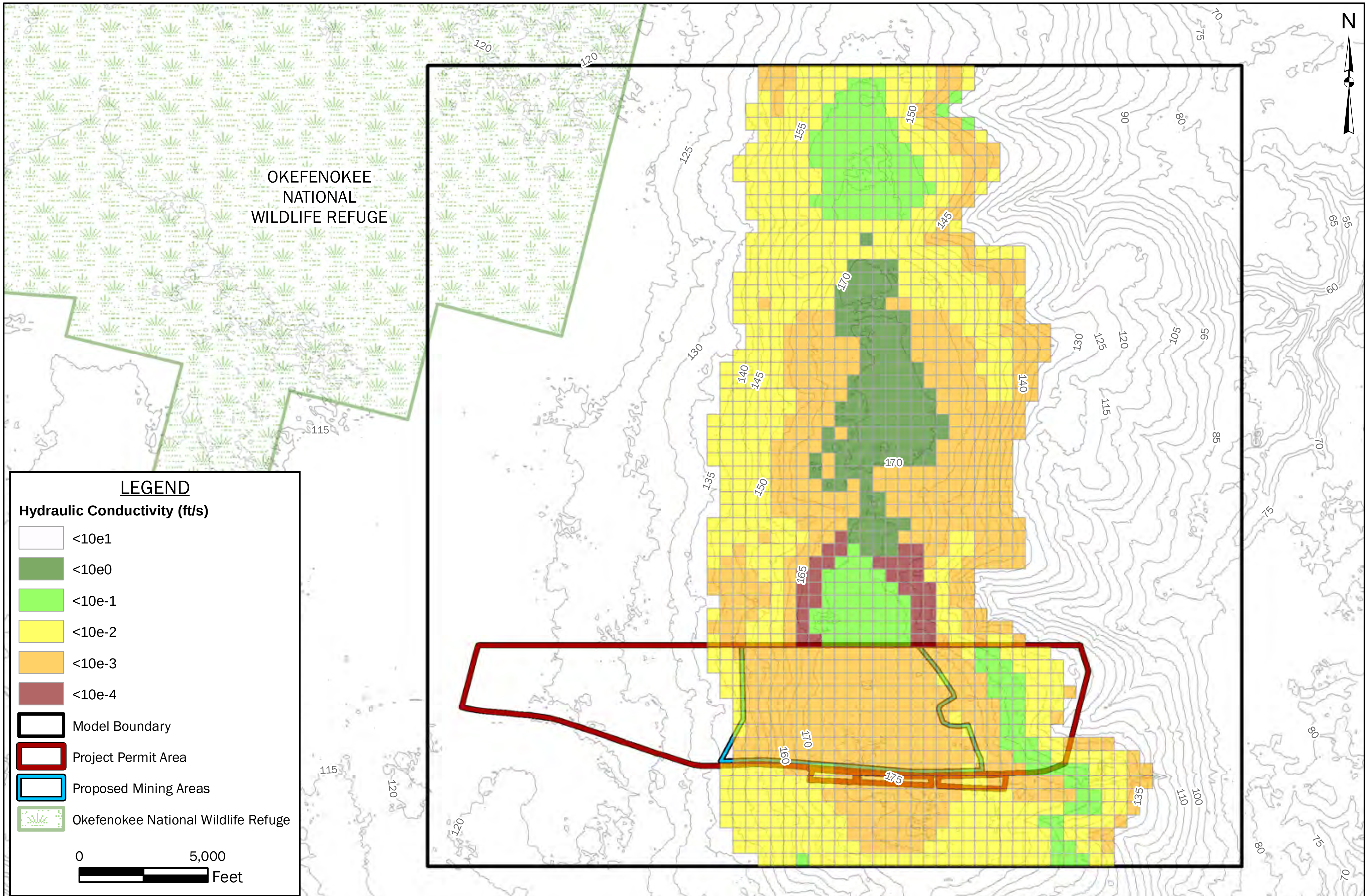
FIGURE 51: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 3

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

TTL

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft



TTL

FIGURE 52: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 4

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

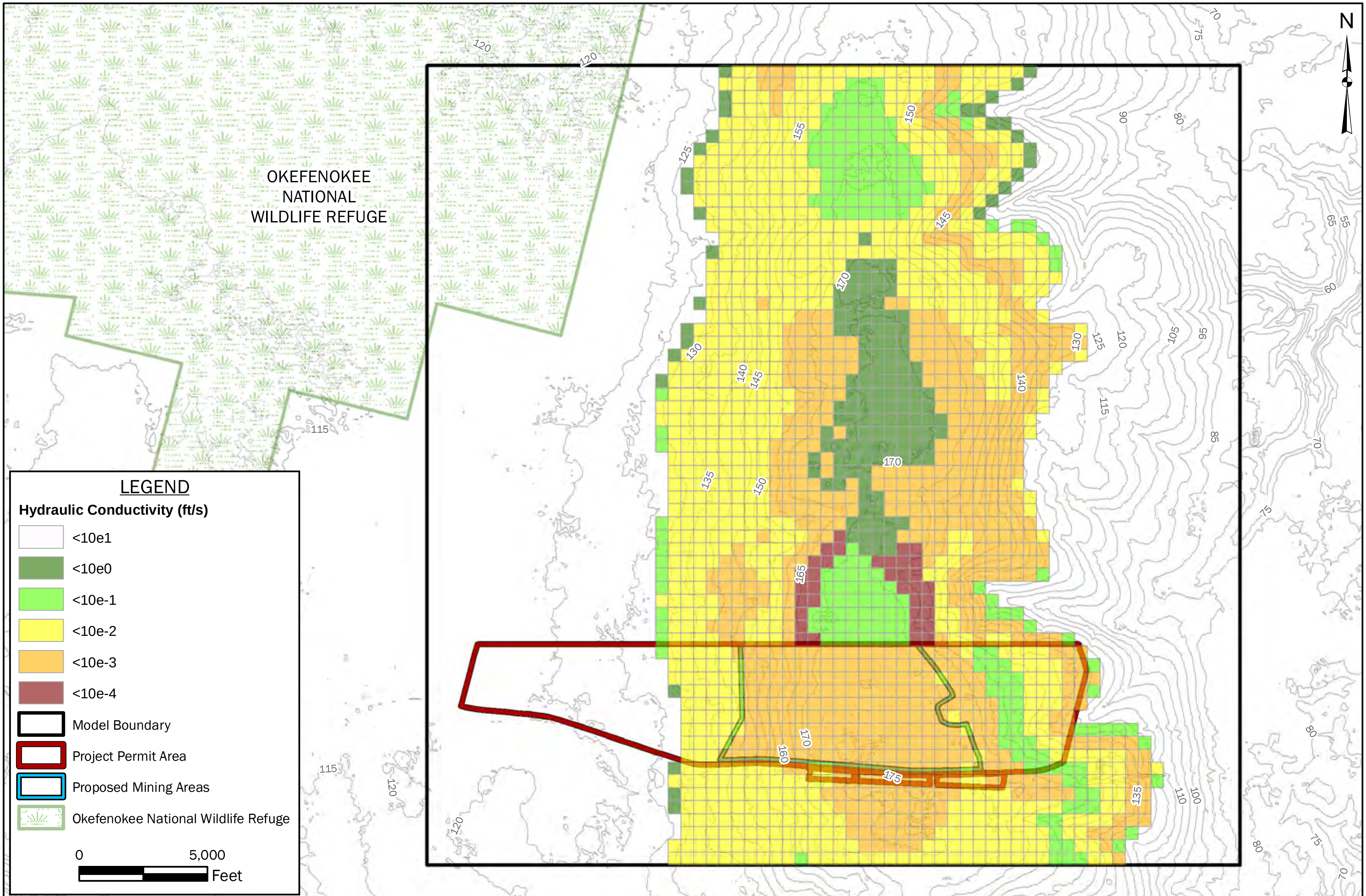
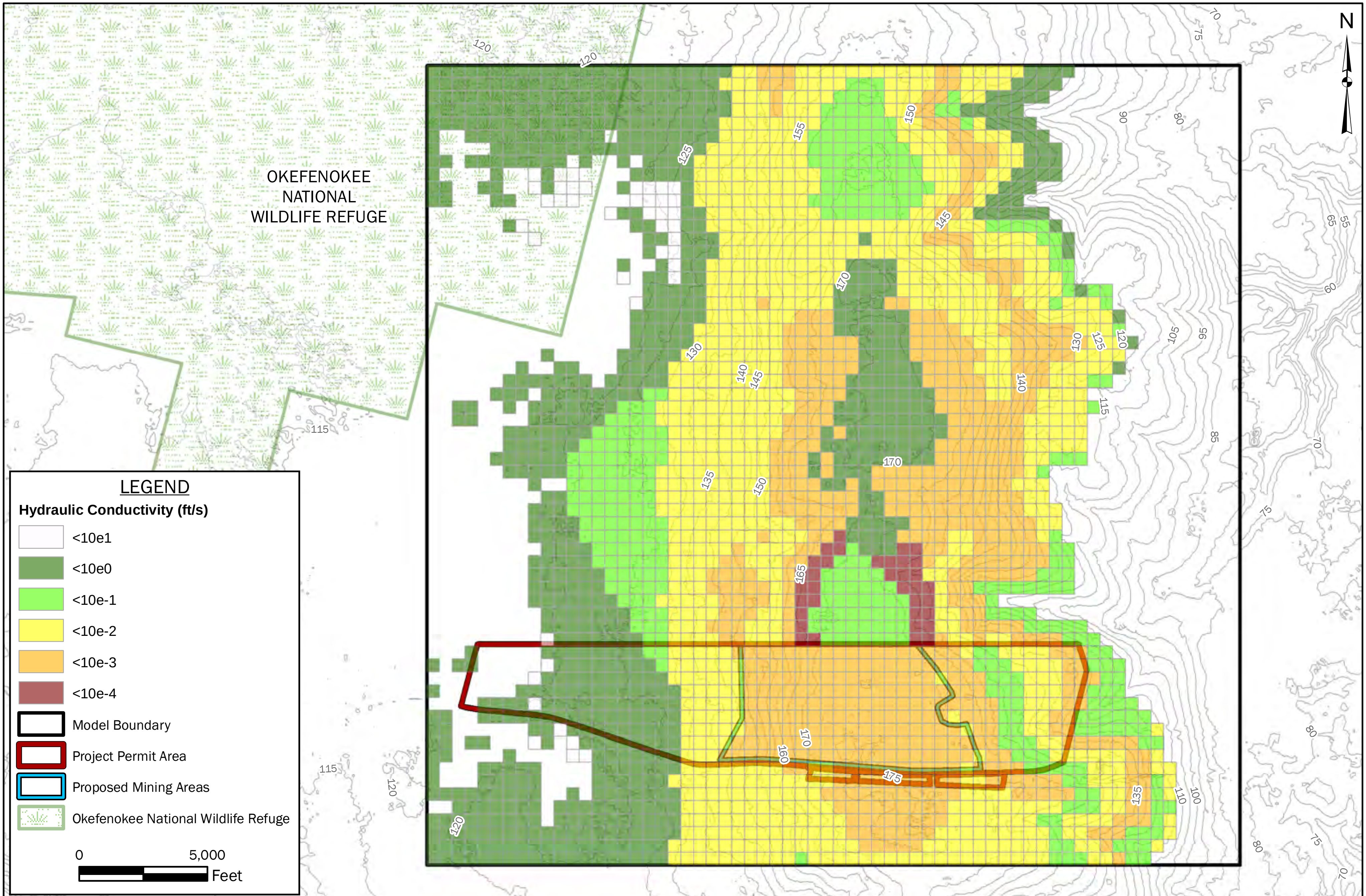


FIGURE 53: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 5

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft



TTL

FIGURE 54: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 6

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

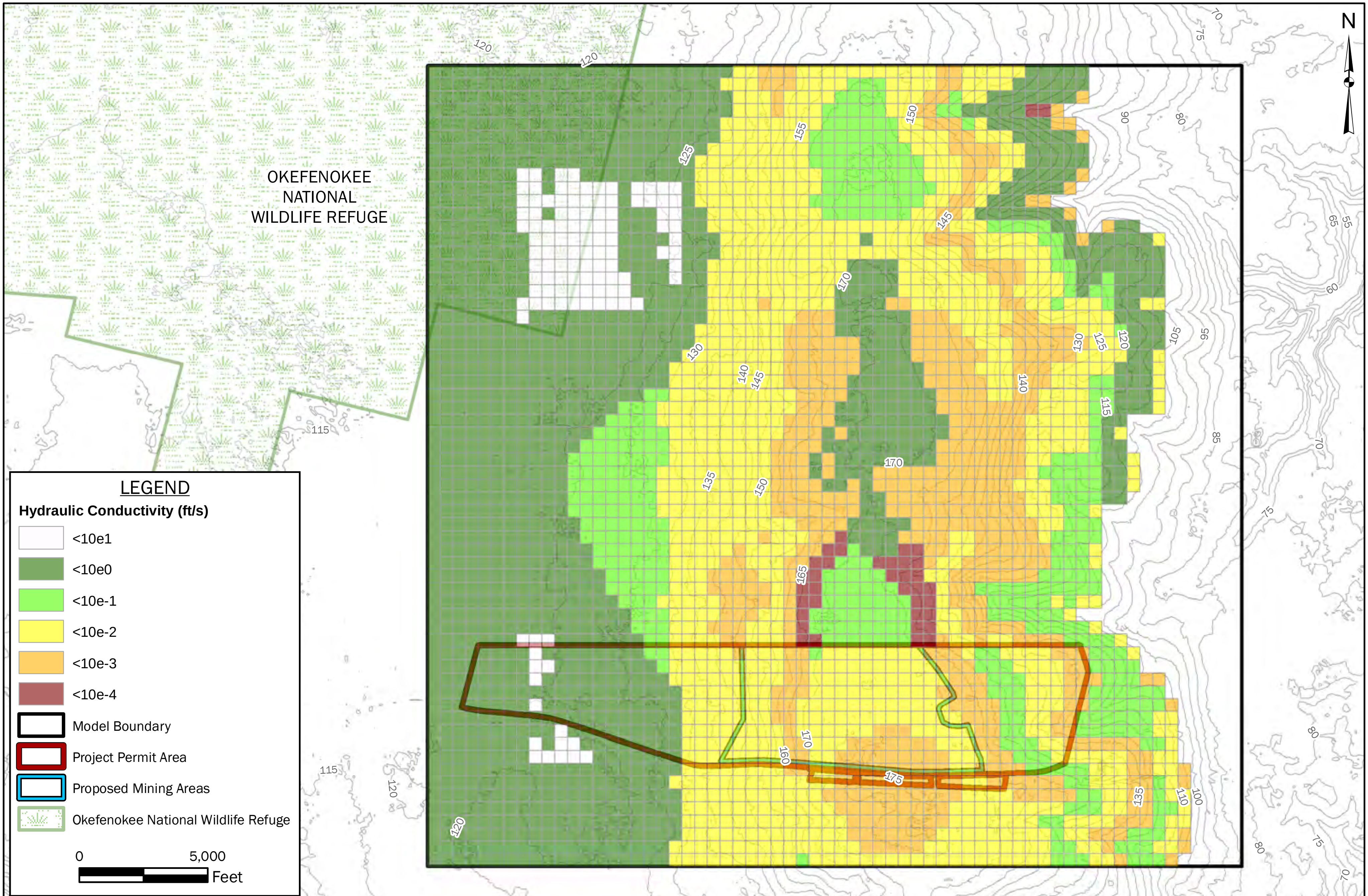
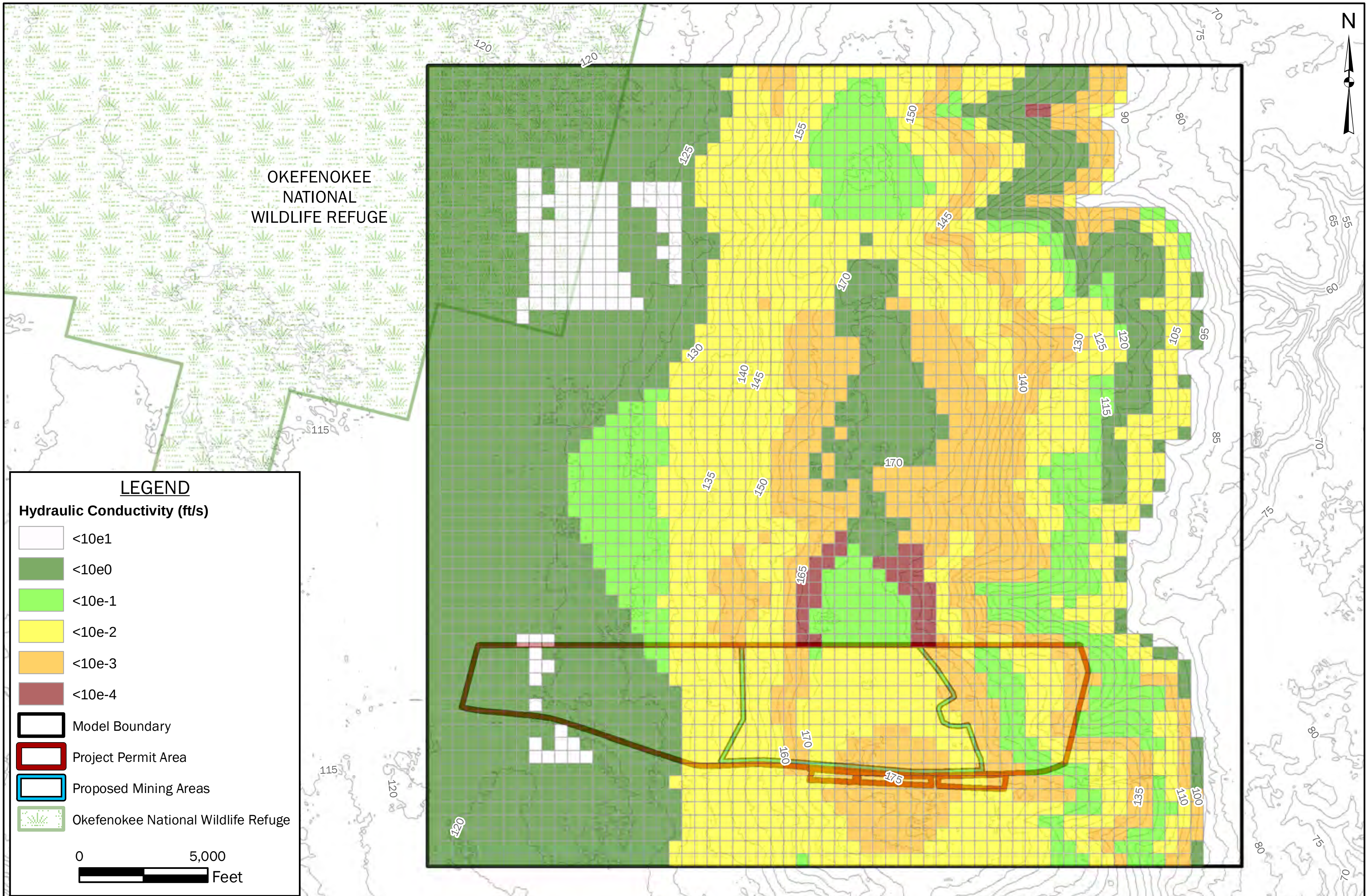


FIGURE 55: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 7

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft



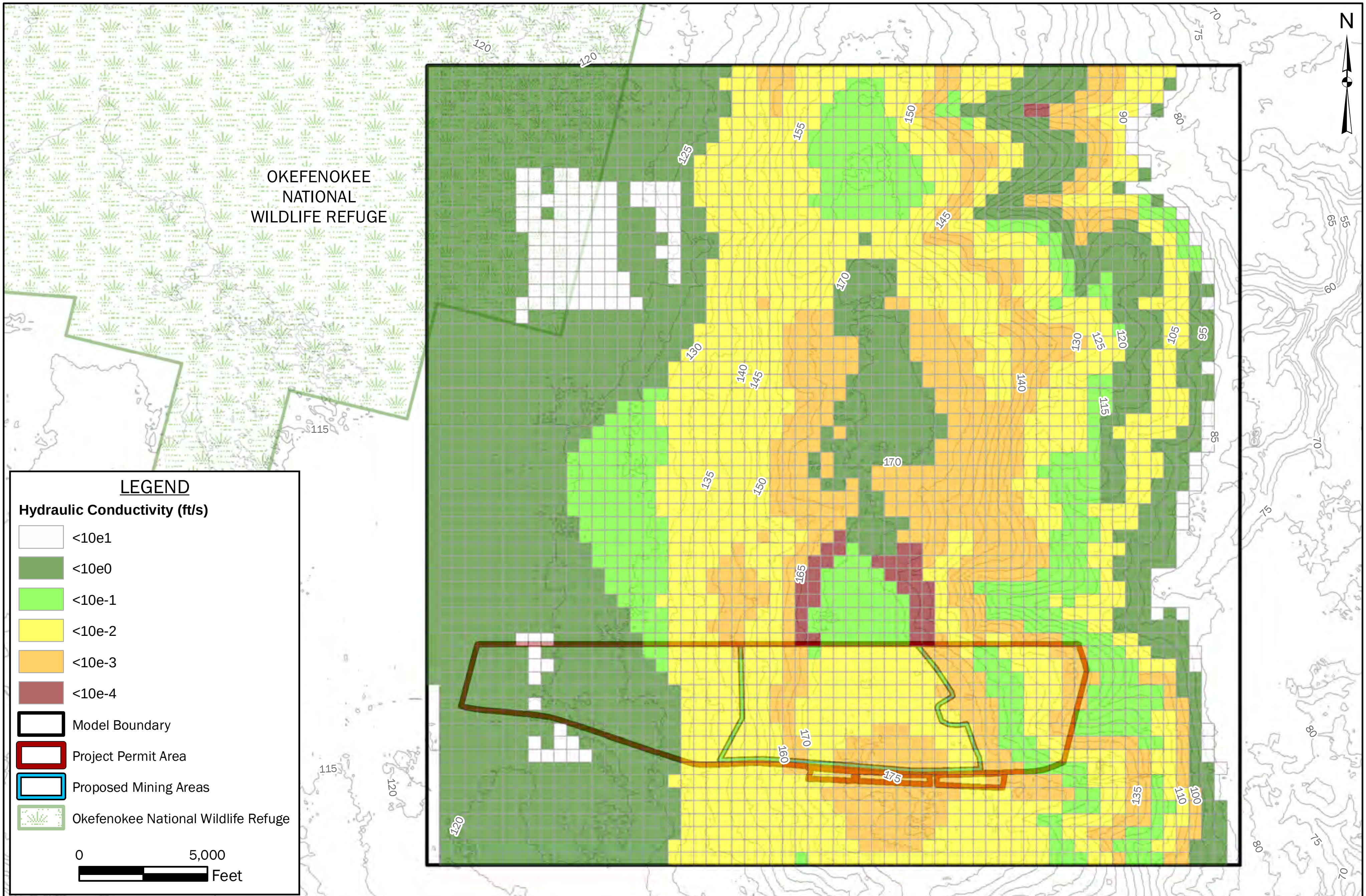
TTL

FIGURE 56: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 8

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft



TTL

FIGURE 57: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 9

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

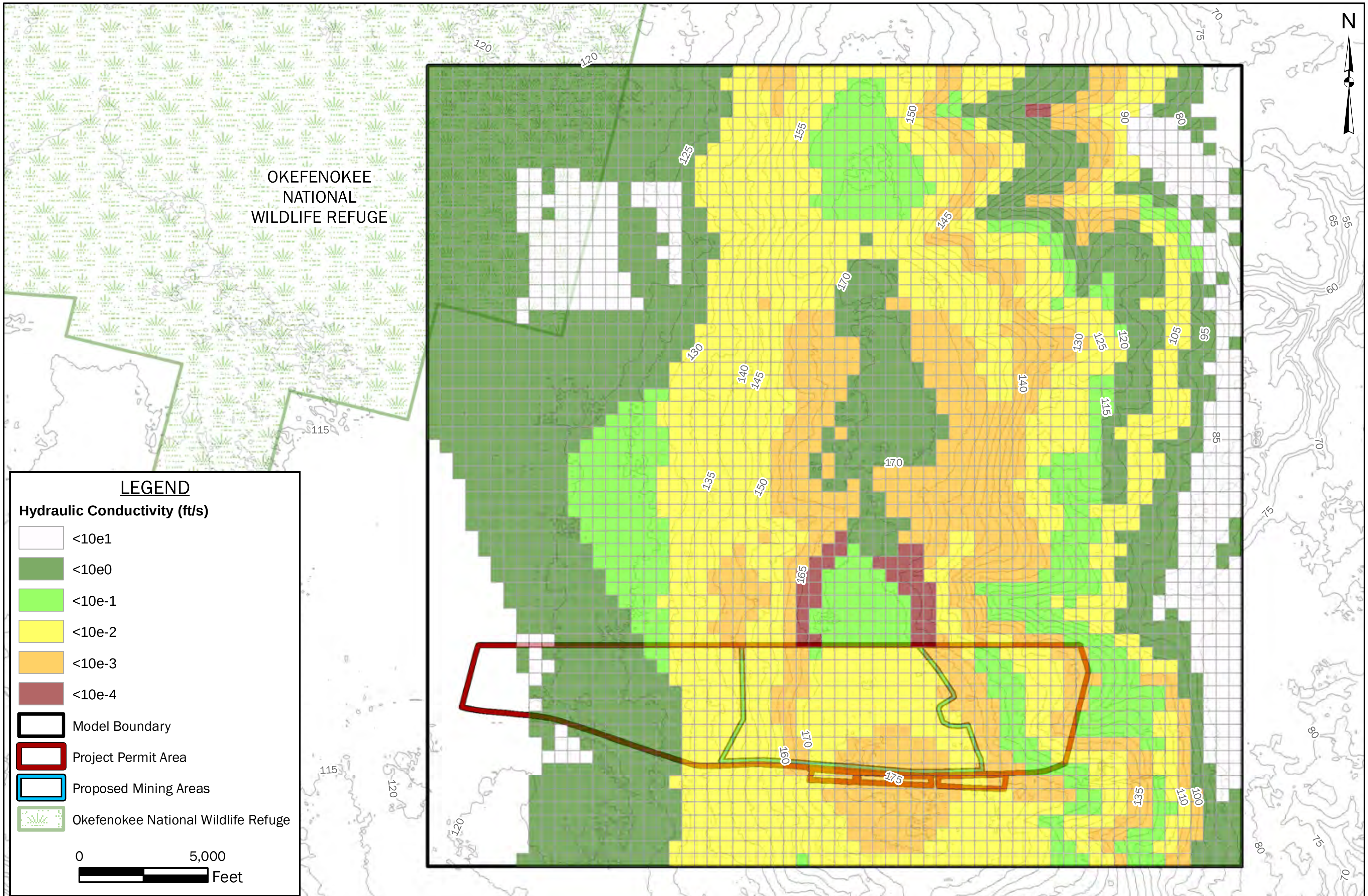


FIGURE 58: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 10

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

TTL

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

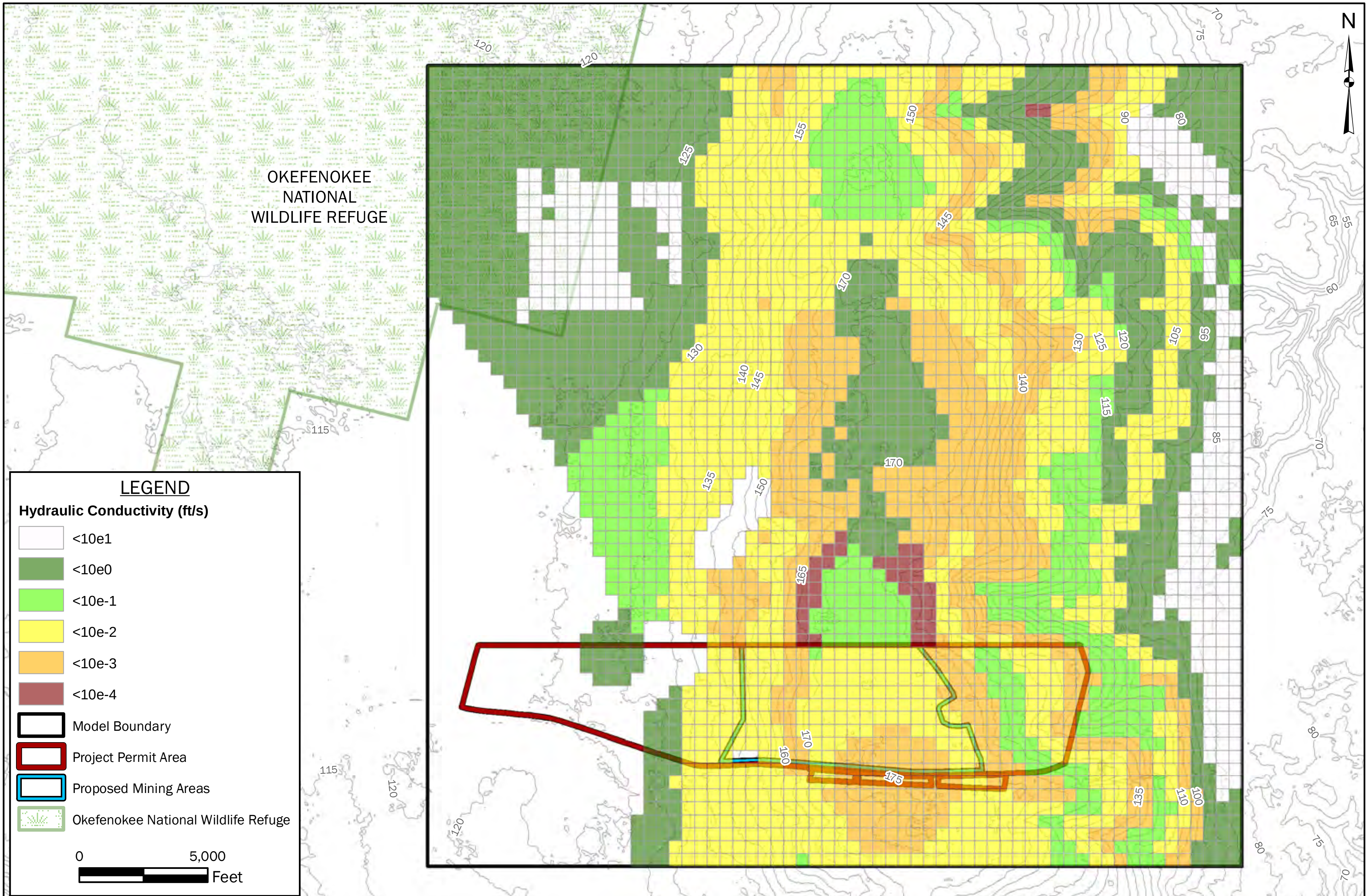


FIGURE 59: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 11

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

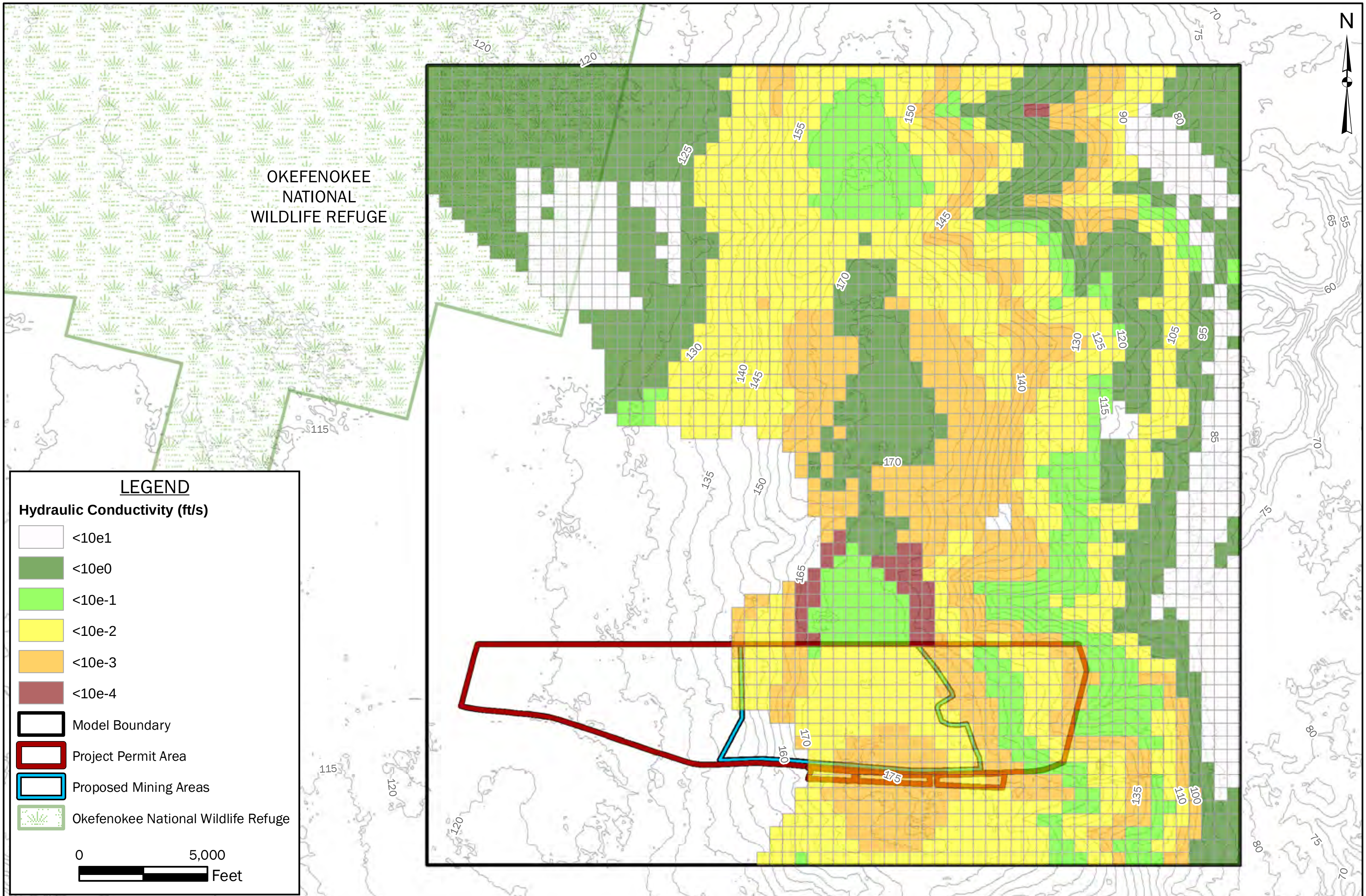


FIGURE 60: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 12

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

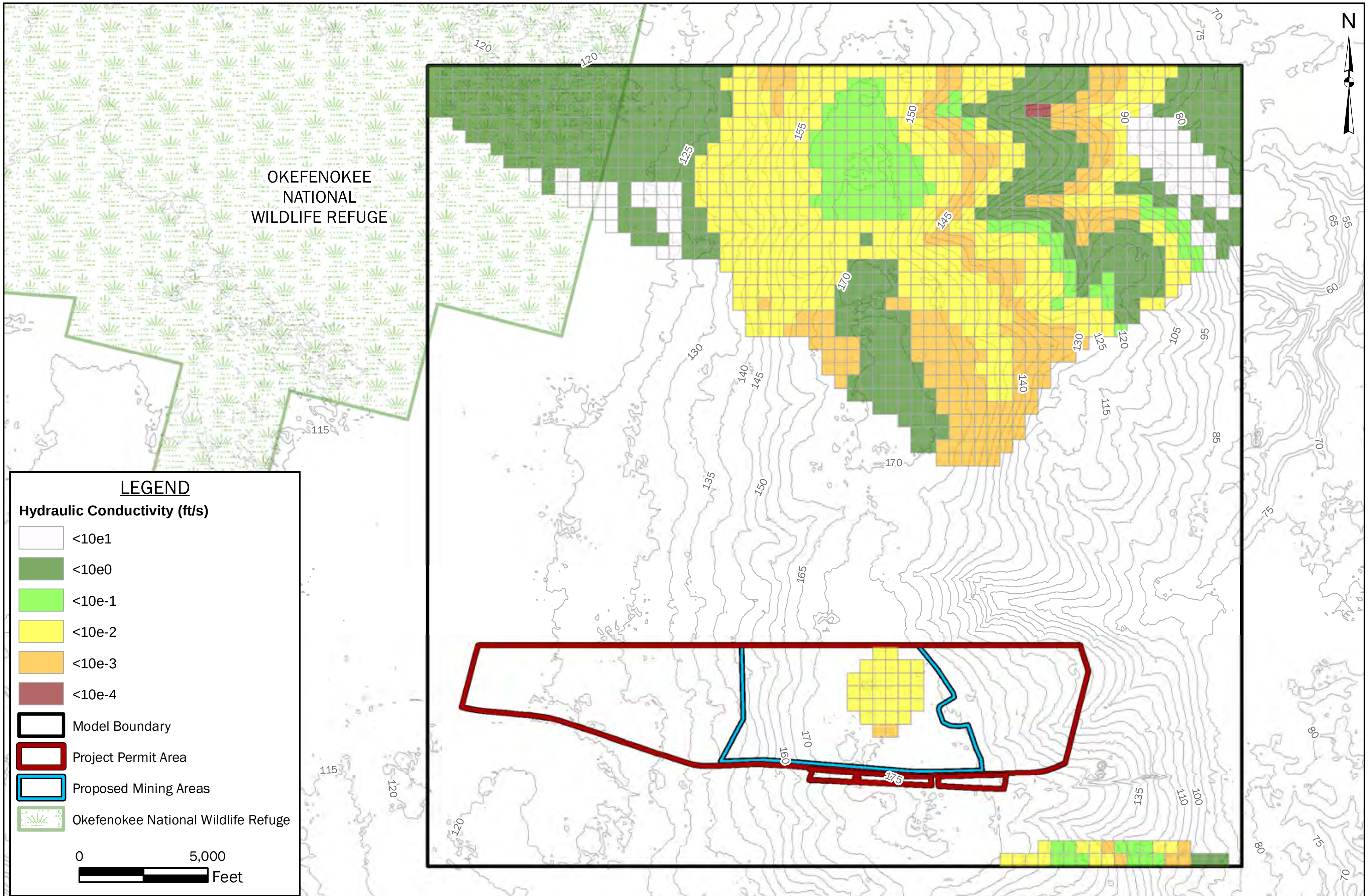


FIGURE 61: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 13

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

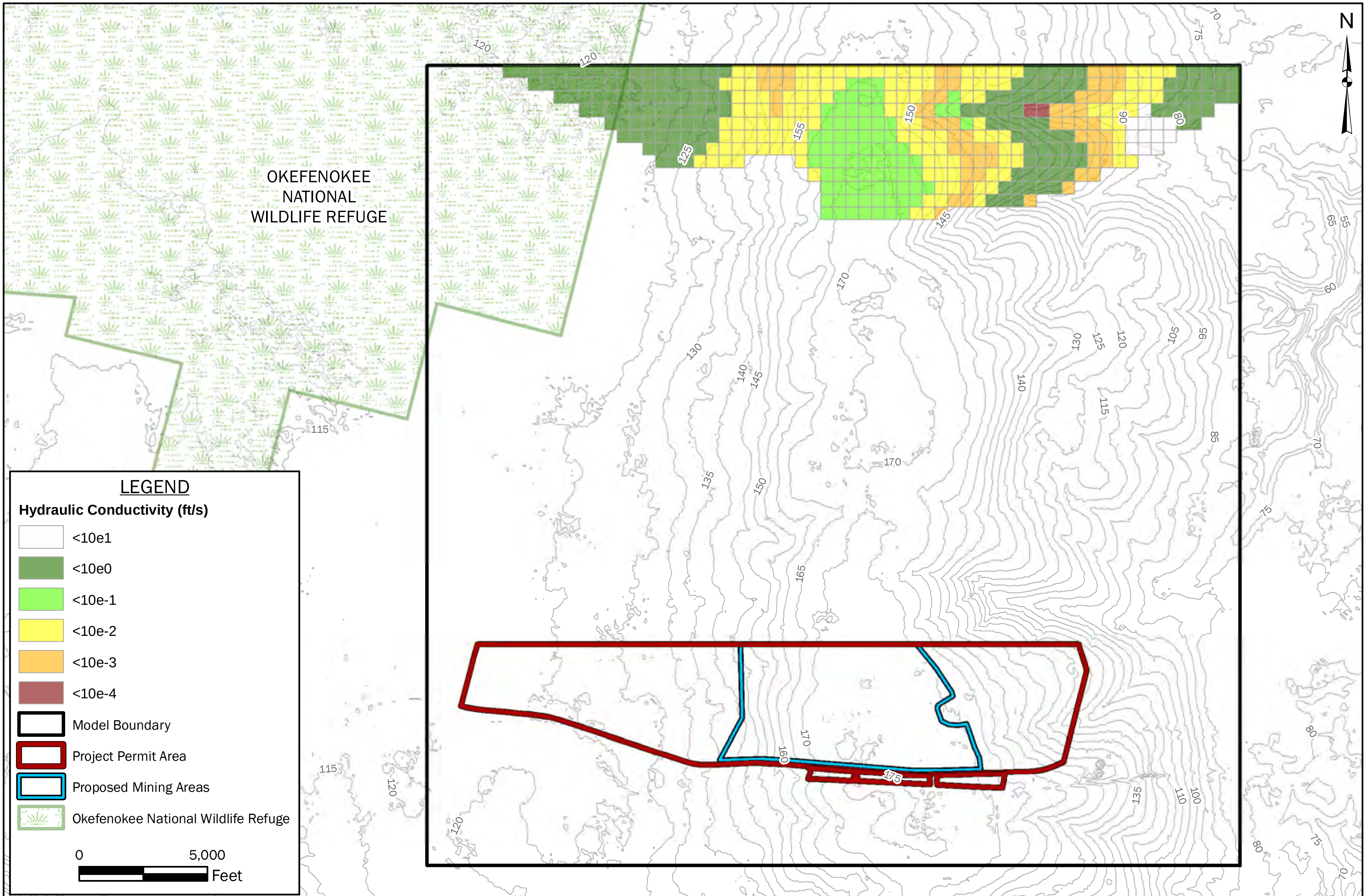


FIGURE 62: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 14

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

TTL

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

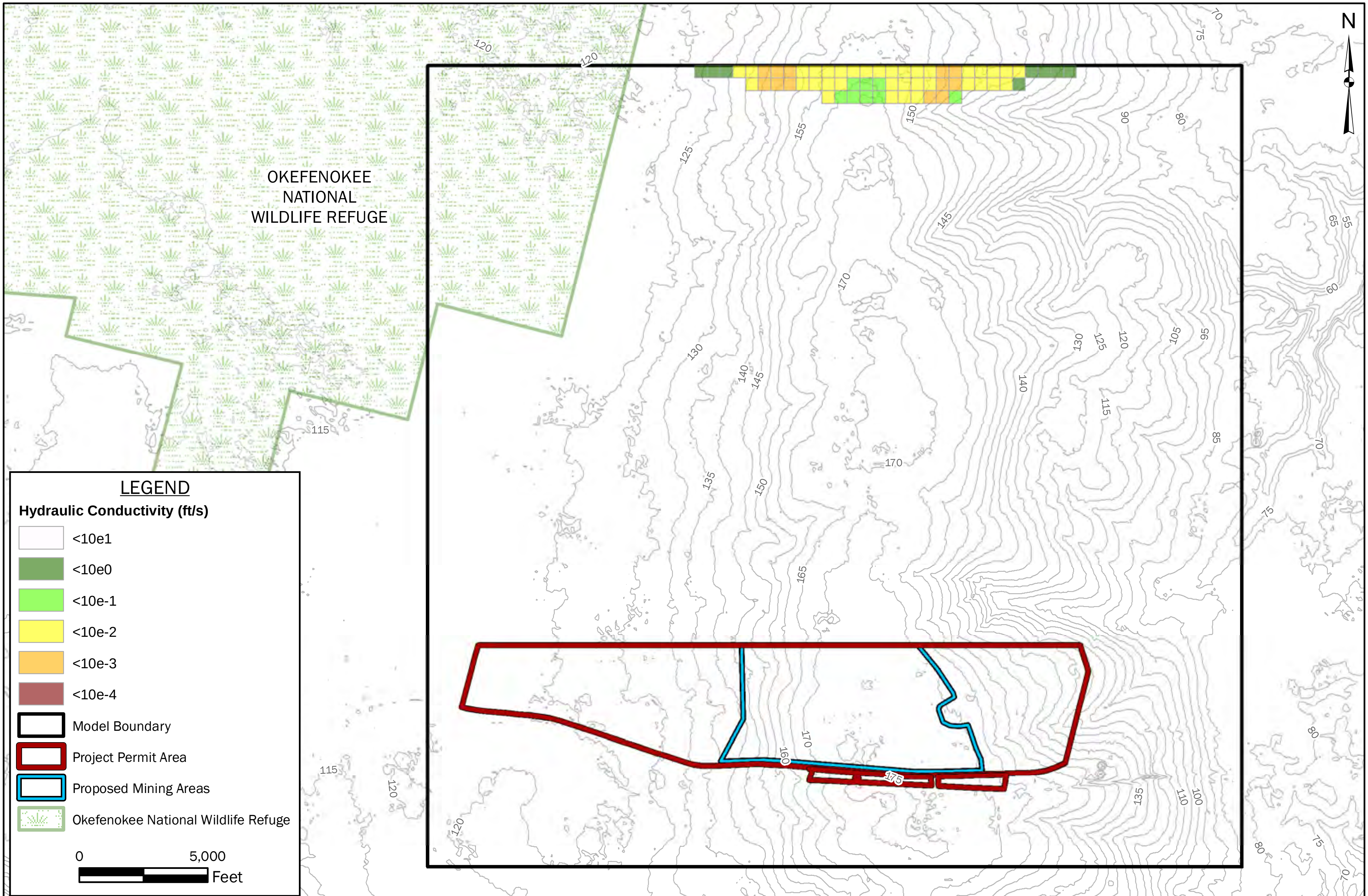


FIGURE 63: POST-MINING HORIZONTAL HYDRAULIC CONDUCTIVITY LAYER 15

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

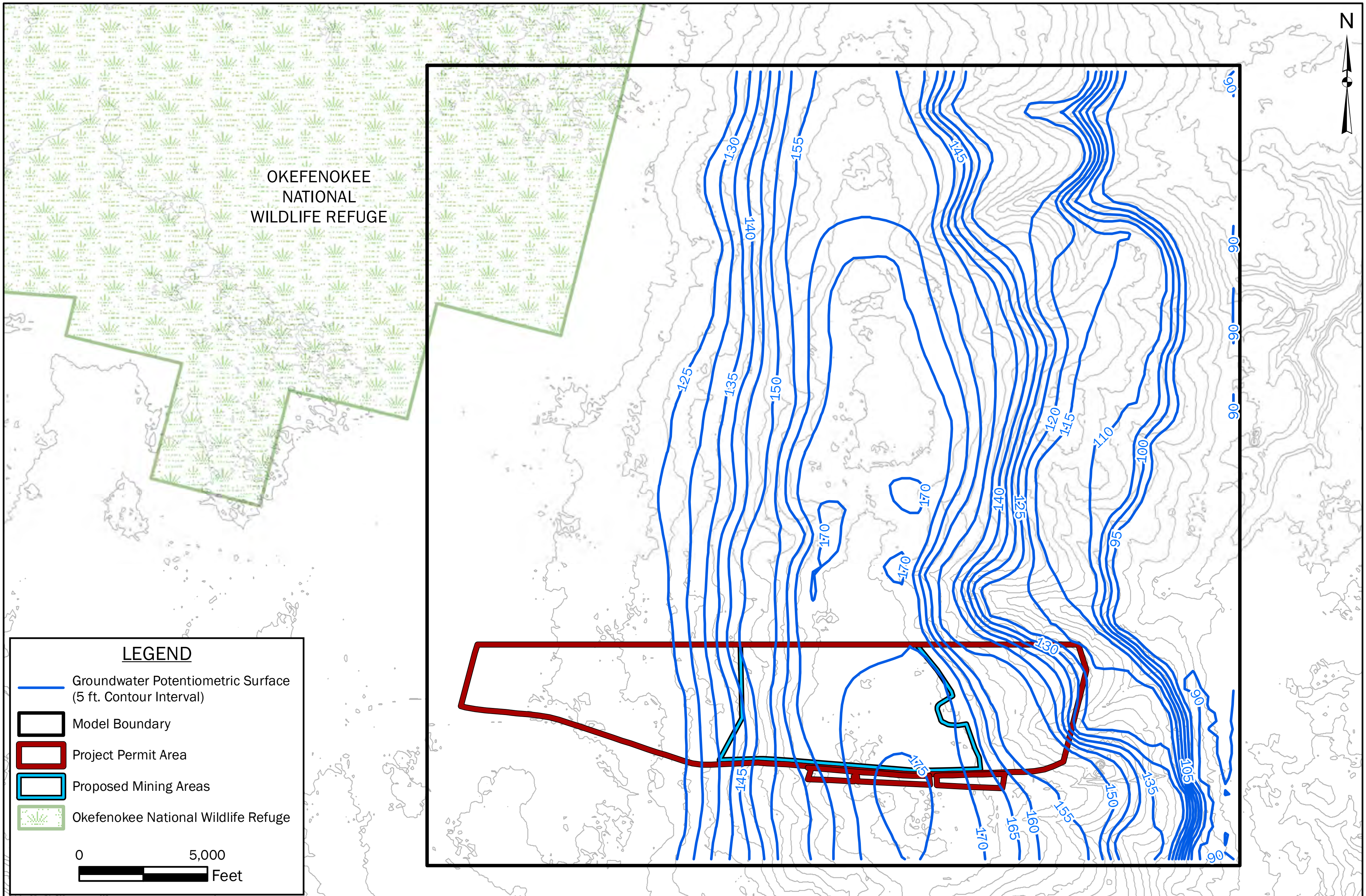


FIGURE 64: POST-MINING MODEL POTENTIOMETRIC SURFACE MAP

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK	
CHECKED BY: RMH	
DRAWING DATE: 1/13/2020	
REVISION DATE: N/A	
TTL JOB NO.: 000180200804.00	
APPROX. SCALE:	1 in = 5,000 ft

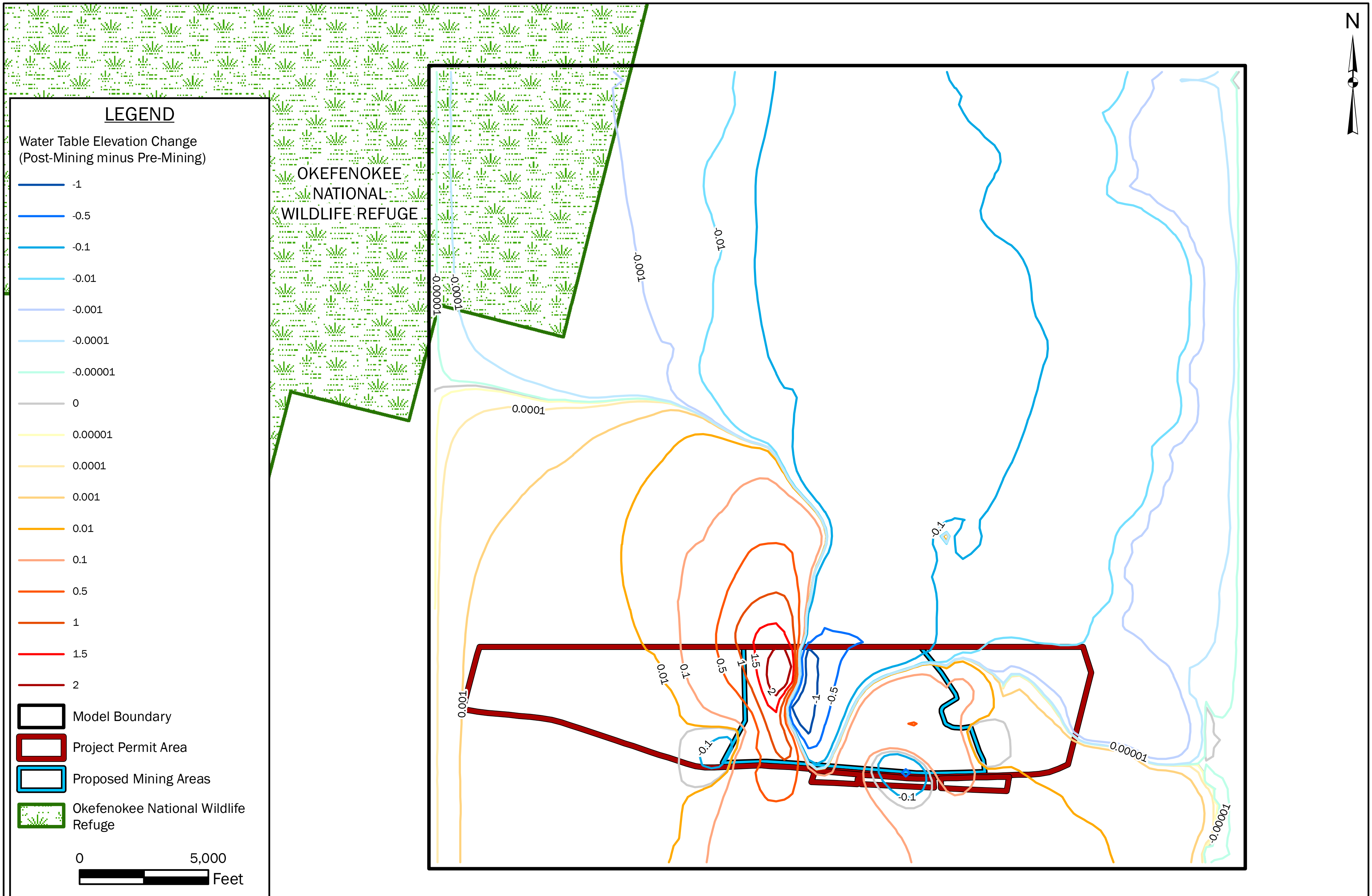
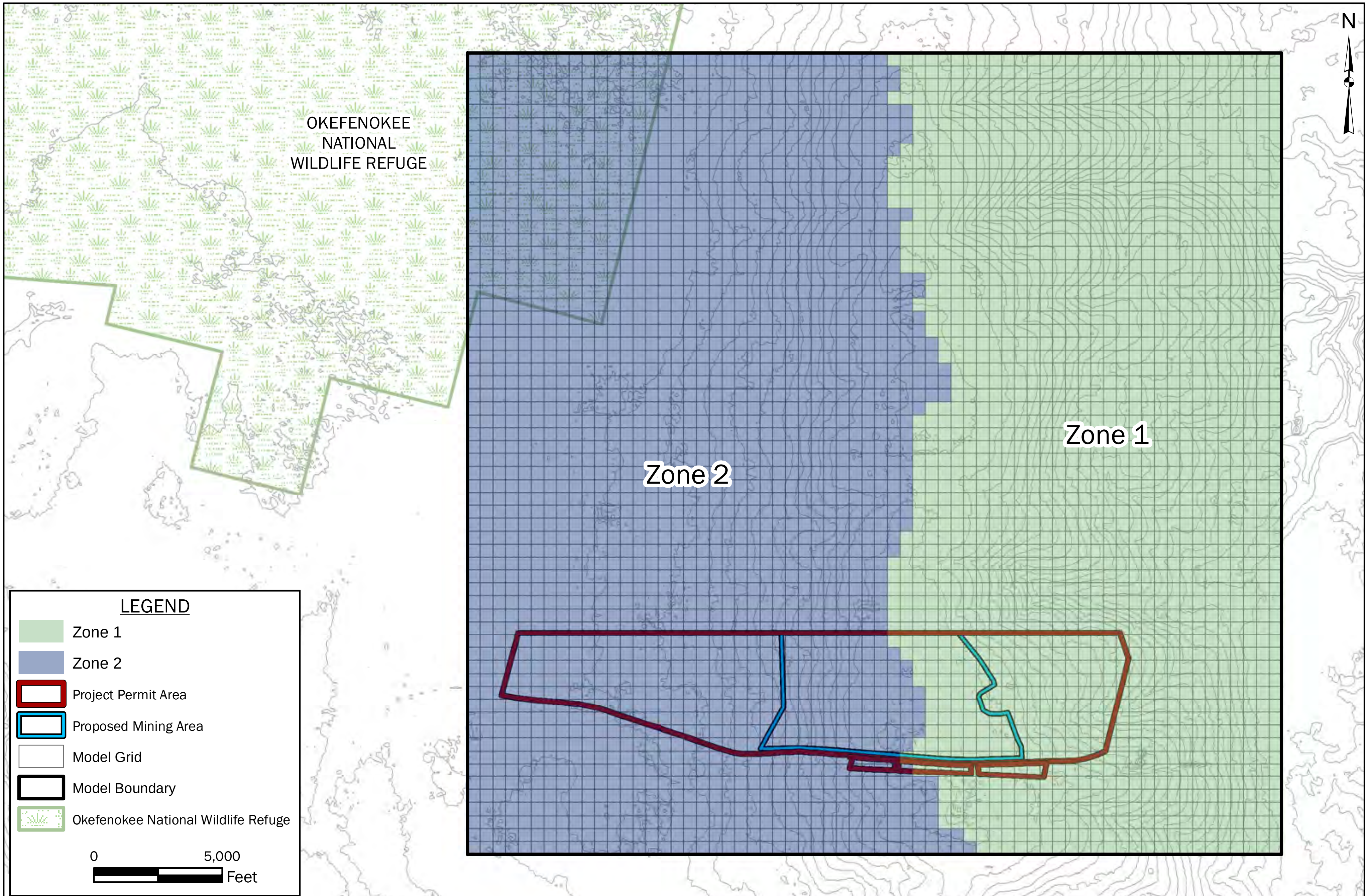


FIGURE 65: POST-MINING WATER TABLE ELEVATION CHANGE MAP

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft



TTL

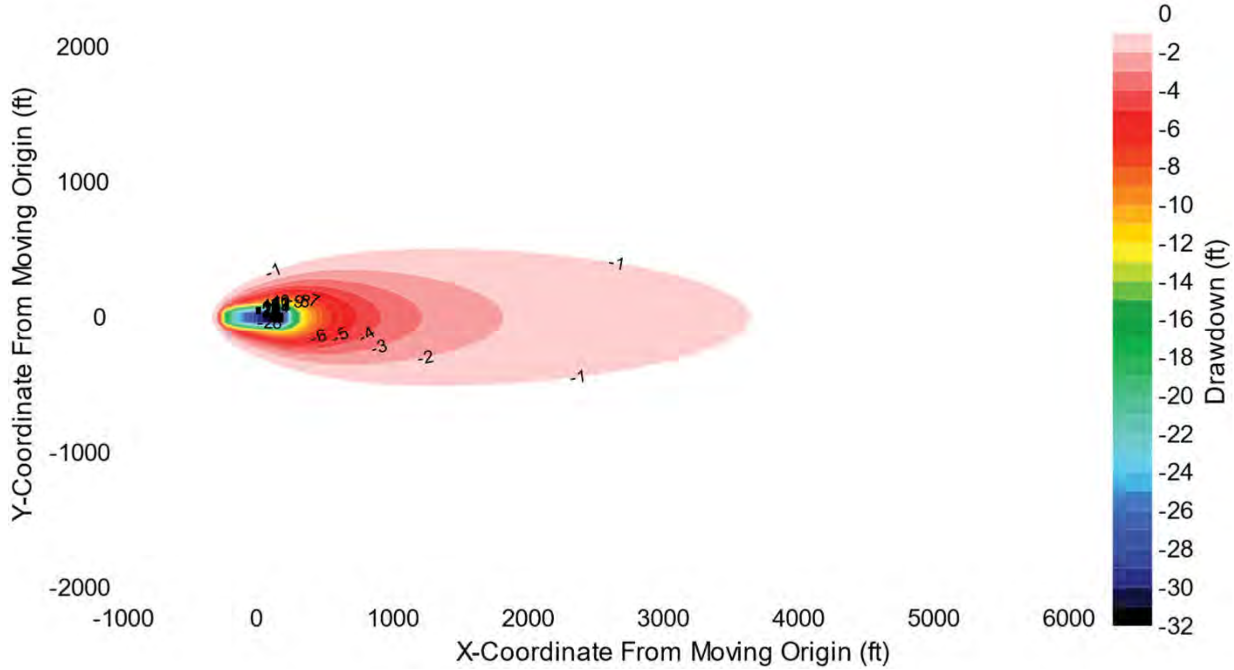
FIGURE 66: MODEL WATER BUDGET ZONE MAP

TWIN PINES MINERALS

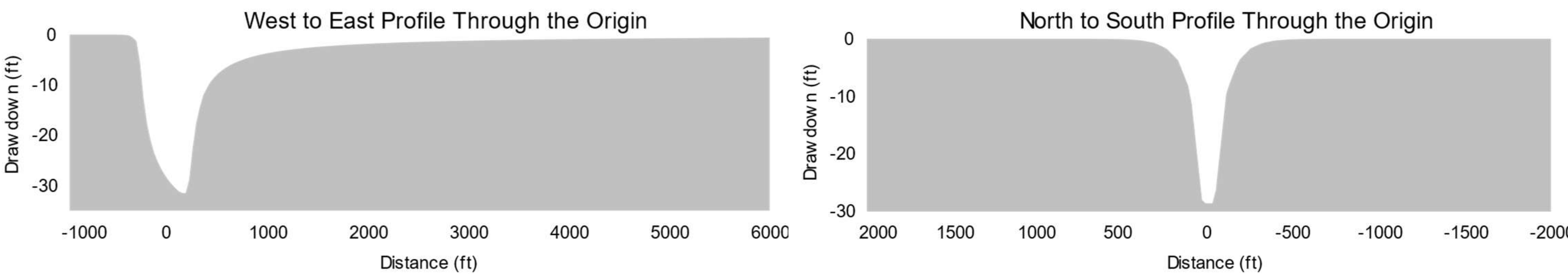
ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 5,000 ft

Drawdown Due to a Moving Rectangular Pit



Drawdown Profiles through the Origin



- *The zone of drawdown moves 100 ft/d in the x-direction*
- *Recovery is fast behind the pit, with drawdown decreasing to > -2 ft in less than 20 days*
- *When superimposed on the existing water table, groundwater divides will separate the moving pit from the Okefenokee to the west and the streams to the east*

TTL

FIGURE 67: DRAWDOWN DUE TO THE MOVING MINE

TWIN PINES MINERALS

ST. GEORGE, CHARLTON COUNTY, GEORGIA

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 1/13/2020
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE:

TABLES

Table 1. Soil Conductivity Values Used to Determine Initial Grid Block Hydraulic Conductivity	
Soil Type	Hydraulic Conductivity (cm/s)
Unconsolidated Sand	1.00E-02
Semi-Consolidated Sand	1.00E-03
Consolidated Sand	5.00E-05
Silty-Clayey Sand	1.00E-04
Clayey Sand	1.00E-04
Clay	5.00E-05

cm/s = centimeters per second

Table 2. Groundwater Observations Including Piezometers and Soft Data Points											
ObsIDname[0]	Easting[1]	Northing[1]	TOC[2]	ScreenT[3]	ScreenM[4]	ScreenB[5]	Layer	Time	Calc.[6]	Obs.[6]	Calc.-Obs.[6]
L1/L1	6.58E+05	1.90E+05	-	-	-	107.51	8	0	121.70	115.51	6.1849
L2/L2	6.82E+05	2.14E+05	-	-	-	80.36	10	0	91.09	88.36	2.7334
L3/L3	6.75E+05	2.14E+05	-	-	-	121.89	6	0	129.98	129.89	0.08297
L4/L4	6.76E+05	2.11E+05	-	-	-	121.35	6	0	128.35	129.35	-1.0039
L5/L5	6.78E+05	2.12E+05	-	-	-	118.27	7	0	127.75	126.27	1.4771
L6/L6	6.74E+05	2.12E+05	-	-	-	148.82	4	0	158.02	156.82	1.203
L7/L7	6.85E+05	2.14E+05	-	-	-	67.82	12	0	90.09	75.82	14.272
L8/L8	6.85E+05	2.09E+05	-	-	-	68.06	12	0	90.19	76.06	14.133
L9/L9	6.85E+05	2.02E+05	-	-	-	77.48	11	0	90.15	85.48	4.672
L10/L10	6.84E+05	1.98E+05	-	-	-	77.37	11	0	90.40	85.37	5.033
L11/L11	6.83E+05	1.95E+05	-	-	-	75.84	11	0	90.61	83.84	6.7703
L12/L12	6.81E+05	1.94E+05	-	-	-	89.27	9	0	100.30	97.27	3.0317
L13/L13	6.76E+05	1.95E+05	-	-	-	115.22	7	0	124.43	123.22	1.2068
L14/L14	6.85E+05	1.91E+05	-	-	-	73.80	11	0	90.09	81.80	8.294
L15/L15	6.85E+05	1.87E+05	-	-	-	82.46	10	0	90.08	90.46	-0.38114
L16/L16	6.80E+05	1.87E+05	-	-	-	146.92	4	0	153.21	154.92	-1.7077
L17/L17	6.78E+05	1.91E+05	-	-	-	138.77	5	0	151.44	146.77	4.6703
L18/L18	6.68E+05	2.03E+05	-	-	-	139.99	4	0	148.31	147.99	0.31858
L19/L19	6.69E+05	1.89E+05	-	-	-	153.24	3	0	158.18	161.24	-3.0584
OWA1BS/OWA1BS	6.73E+05	2.04E+05	172.16	165.16	162.66	160.16	2	0	166.70	170.87	-4.166
OWA1D/OWA1D	6.73E+05	2.04E+05	172.23	92.23	87.73	83.23	10	0	166.67	162.74	3.9259
OWA1S/OWA1S	6.73E+05	2.04E+05	172.12	147.12	142.12	137.12	5	0	166.69	170.53	-3.8441
OWB1BS/OWB1BS	6.70E+05	1.91E+05	172.38	165.38	162.88	160.38	2	0	169.62	170.87	-1.2482
OWB1D/OWB1D	6.70E+05	1.91E+05	172.49	92.49	87.49	82.49	10	0	169.60	168.15	1.448
OWB1S/OWB1S	6.70E+05	1.91E+05	172.43	147.43	142.43	137.43	5	0	169.61	169.85	-0.23541
PZ01D/PZ01D	6.65E+05	2.13E+05	123.10	83.10	78.10	73.10	11	0	121.68	123.04	-1.3591
PZ01S/PZ01S	6.65E+05	2.13E+05	123.04	119.04	114.04	109.04	7	0	121.71	121.93	-0.22498
PZ02/PZ02	6.65E+05	2.10E+05	126.03	122.03	117.03	112.03	7	0	121.71	124.46	-2.7452
PZ03D/PZ03D	6.65E+05	2.08E+05	123.56	83.56	78.56	73.56	11	0	121.72	123.42	-1.6952
PZ03S/PZ03S	6.65E+05	2.08E+05	123.80	119.80	114.80	109.80	7	0	121.75	121.92	-0.17321
PZ04/PZ04	6.64E+05	2.05E+05	123.89	119.89	114.89	109.89	7	0	121.75	120.93	0.81847
PZ05/PZ05	6.63E+05	2.03E+05	124.37	120.37	115.37	110.37	7	0	121.91	121.62	0.28836
PZ06/PZ06	6.62E+05	2.01E+05	124.26	120.26	115.26	110.26	7	0	122.19	122.20	-0.0068085
PZ07/PZ07	6.62E+05	1.99E+05	123.41	119.41	114.41	109.41	7	0	122.75	121.73	1.0238
PZ08/PZ08	6.64E+05	1.98E+05	130.08	126.08	121.08	116.08	7	0	126.64	127.75	-1.1079
PZ09/PZ09	6.67E+05	2.11E+05	135.06	120.06	115.06	110.06	7	0	135.97	133.48	2.4925
PZ10/PZ10	6.68E+05	2.06E+05	145.97	130.97	125.97	120.97	6	0	145.93	143.80	2.1261
PZ11/PZ11	6.67E+05	2.01E+05	148.10	138.10	133.10	128.10	6	0	146.39	145.62	0.76763
PZ12D/PZ12D	6.66E+05	1.99E+05	138.18	98.18	93.18	88.18	10	0	136.34	136.85	-0.51394
PZ12S/PZ12S	6.66E+05	1.99E+05	138.00	128.00	123.00	118.00	7	0	136.35	136.88	-0.52998
PZ13/PZ13	6.69E+05	1.96E+05	157.63	137.63	132.63	127.63	6	0	158.00	155.39	2.6051
PZ14/PZ14	6.70E+05	1.94E+05	167.66	147.66	142.66	137.66	5	0	169.09	165.97	3.1234
PZ15/PZ15	6.69E+05	1.92E+05	166.84	146.84	141.84	136.84	5	0	167.08	164.69	2.3894
PZ16D/PZ16D	6.69E+05	1.89E+05	160.41	120.41	115.41	110.41	7	0	158.17	155.65	2.5156
PZ16S/PZ16S	6.69E+05	1.89E+05	160.42	150.42	145.42	140.42	4	0	158.18	157.69	0.48767
PZ17D/PZ17D	6.70E+05	2.12E+05	161.01	126.01	121.01	116.01	7	0	158.29	156.40	1.8891
PZ17S/PZ17S	6.70E+05	2.12E+05	161.75	157.75	155.25	152.75	3	0	158.31	159.24	-0.92788
PZ18/PZ18	6.70E+05	2.10E+05	164.26	154.26	149.26	144.26	4	0	159.55	161.68	-2.1338
PZ19/PZ19	6.71E+05	2.07E+05	169.87	159.87	154.87	149.87	3	0	166.44	166.85	-0.41136
PZ20D/PZ20D	6.70E+05	2.05E+05	168.46	138.46	133.46	128.46	6	0	164.64	164.87	-0.2271
PZ20S/PZ20S	6.70E+05	2.05E+05	168.33	164.33	161.83	159.33	2	0	164.66	165.13	-0.47467
PZ21/PZ21	6.70E+05	2.03E+05	164.90	154.90	149.90	144.90	4	0	165.34	163.79	1.5547
PZ22D/PZ22D	6.72E+05	2.00E+05	170.48	140.48	135.48	130.48	5	0	166.89	167.99	-1.0996
PZ22S/PZ22S	6.72E+05	2.00E+05	170.18	166.18	163.68	161.18	2	0	166.91	168.33	-1.4178
PZ23/PZ23	6.72E+05	1.98E+05	169.44	165.44	160.44	155.44	3	0	167.37	168.17	-0.80264
PZ24/PZ24	6.73E+05	1.97E+05	169.54	159.54	154.54	149.54	3	0	167.65	168.11	-0.45973
PZ25D/PZ25D	6.73E+05	1.94E+05	169.65	124.65	119.65	114.65	7	0	169.37	167.87	1.5035
PZ25S/PZ25S	6.73E+05	1.94E+05	169.61	159.61	154.61	149.61	3	0	169.39	167.78	1.6115
PZ26/PZ26	6.76E+05	1.90E+05	169.22	159.22	154.22	149.22	3	0	167.63	167.36	0.27374
PZ27D/PZ27D	6.76E+05	1.89E+05	168.06	148.06	143.06	138.06	5	0	167.46	166.07	1.3944
PZ27S/PZ27S	6.76E+05	1.89E+05	168.17	163.17	160.67	158.17	3	0	167.48	165.98	1.4962
PZ28D/PZ28D	6.72E+05	1.91E+05	173.99	153.99	148.99	143.99	4	0	171.41	172.07	-0.66335
PZ28S/PZ28S	6.72E+05	1.91E+05	173.92	168.92	166.42	163.92	2	0	171.43	172.25	-0.82433
PZ29D/PZ29D	6.68E+05	1.94E+05	153.88	113.88	108.88	103.88	8	0	152.00	151.84	0.15718
PZ29S/PZ29S	6.68E+05	1.94E+05	154.04	145.04	140.04	135.04	5	0	152.01	152.34	-0.33496
PZ30D/PZ30D	6.66E+05	1.90E+05	138.02	98.02	93.02	88.02	10	0	137.50	135.87	1.6293
PZ30S/PZ30S	6.66E+05	1.90E+05	137.65	132.65	130.15	127.65	6	0	137.53	136.17	1.3602
PZ31D/PZ31D	6.65E+05	1.92E+05	135.90	95.90	90.90	85.90	10	0	131.83	133.19	-1.3614
PZ31S/PZ31S	6.65E+05	1.92E+05	135.92	128.92	126.42	123.92	6	0	131.83	133.08	-1.2464
PZ32D/PZ32D	6.66E+05	1.95E+05	139.68	99.68	94.68	89.68	9	0	137.07	138.06	-0.98793
PZ32S/PZ32S	6.66E+05	1.95E+05	139.94	131.94	129.44	126.94	6	0	137.10	138.15	-1.0464
PZ33D/PZ33D	6.61E+05	1.93E+05	123.91	82.91	77.91	72.91	15	0	121.96	121.12	0.84202
PZ33S/PZ33S	6.61E+05	1.93E+05	123.73	116.73	114.23	111.73	7	0	121.97	121.45	0.51656
PZ34D/PZ34D	6.62E+05	1.97E+05	124.48	84.48	79.48	74.48	15	0	122.68	121.57	1.1056
PZ34S/PZ34S	6.62E+05	1.97E+05	124.39	114.39	111.89	109.39	7	0	122.69	121.91	0.77533
PZ35D/PZ35D	6.59E+05	1.98E+05	119.17	89.17	84.17	79.17	15	0	121.46	116.63	4.8276
PZ35S/PZ35S	6.59E+05	1.98E+05	119.17	114.17	111.67	109.17	7	0	121.47	116.87	4.5976
PZ36D/PZ36D	6.59E+05	2.00E+05	119.18	89.18	84.18	79.18	15	0	121.44	117.50	3.936
PZ36S/PZ36S	6.59E+05	2.00E+05	118.83	115.83	113.33	110.83	7	0	121.44	116.93	4.5075
PZ38/PZ38	6.73E+05	2.05E+05	171.93	167.93	162.43	156.93	3	0	166.58	169.08	-2.5
PZ39/OWA3D/PZ39/OWA3D	6.73E+05	2.04E+05	171.81	91.81	86.81	81.81	10	0	166.69	157.07	9.6238
PZ39S/OWA3S/PZ39S/OWA3S	6.73E+05	2.04E+05	171.94	146.94	141.94	136.94	5	0	166.71	161.91	4.8042
PZ40/PZ40	6.74E+05	2.01E+05	169.70	165.70	160.70	155.70	3	0	166.83	168.26	-1.4309

Table 2. Groundwater Observations Including Piezometers and Soft Data Points											
ObsIDname[0]	Easting[1]	Northing[1]	TOC[2]	ScreenT[3]	ScreenM[4]	ScreenB[5]	Layer	Time	Calc.[6]	Obs.[6]	Calc.-Obs.[6]
PZ41/PZ41	6.75E+05	1.97E+05	161.19	157.19	152.19	147.19	4	0	158.02	160.12	-2.1036
PZ42/PZ42	6.76E+05	1.94E+05	147.76	143.76	138.76	133.76	5	0	147.79	145.51	2.2838
PZ43/PZ43	6.76E+05	1.91E+05	161.88	157.88	152.88	147.88	4	0	156.79	160.37	-3.5796
PZ44/PZ44	6.78E+05	1.89E+05	154.07	149.07	144.07	139.07	4	0	153.57	152.14	1.4303
PZ45D/PZ45D	6.76E+05	2.03E+05	166.67	127.67	122.67	117.67	7	0	163.58	158.89	4.6936
PZ45S/PZ45S	6.76E+05	2.03E+05	166.72	162.72	157.72	152.72	3	0	162.63	164.85	-2.2178
PZ46/PZ46	6.77E+05	1.98E+05	139.99	134.99	129.99	124.99	6	0	136.93	137.43	-0.50338
PZ47/PZ47	6.78E+05	1.93E+05	138.47	133.47	128.47	123.47	6	0	139.86	136.02	3.8447
PZ48D/PZ48D	6.80E+05	1.91E+05	132.78	92.78	87.78	82.78	10	0	127.85	128.55	-0.70469
PZ48S/PZ48S	6.80E+05	1.91E+05	133.20	129.20	126.70	124.20	6	0	127.86	130.27	-2.4068
PZ49/PZ49	6.78E+05	2.05E+05	143.01	139.01	134.01	129.01	5	0	142.27	141.63	0.64132
PZ50/PZ50	6.79E+05	2.03E+05	127.87	123.87	118.87	113.87	7	0	125.76	125.72	0.039926
PZ51D/PZ51D	6.80E+05	1.96E+05	115.73	75.73	70.73	65.73	12	0	112.76	112.61	0.15068
PZ51S/PZ51S	6.80E+05	1.96E+05	115.84	111.84	109.34	106.84	8	0	112.80	113.80	-1.0033
PZ52/PZ52	6.82E+05	2.02E+05	111.44	107.44	102.44	97.44	9	0	110.07	109.55	0.52296
PZ53/PZ53	6.82E+05	1.99E+05	111.51	106.51	101.51	96.51	9	0	109.09	109.88	-0.78789
PZ55D/PZ55D	6.72E+05	1.88E+05	174.92	135.92	130.92	125.92	6	0	173.22	173.34	-0.11594
PZ55S/PZ55S	6.72E+05	1.88E+05	174.83	164.83	159.83	154.83	3	0	173.24	173.32	-0.083611
PZ56D/PZ56D	6.71E+05	1.96E+05	171.58	131.58	126.58	121.58	6	0	168.40	169.38	-0.98139
PZ56S/PZ56S	6.71E+05	1.96E+05	171.50	166.50	164.00	161.50	2	0	168.42	169.56	-1.1416
PZ57D/PZ57D	6.75E+05	1.92E+05	165.89	126.89	121.89	116.89	7	0	162.06	161.56	0.50229
PZ57S/PZ57S	6.75E+05	1.92E+05	165.68	156.68	154.18	151.68	3	0	162.09	164.57	-2.4795
PZ58D/PZ58D	6.77E+05	1.96E+05	139.98	99.98	94.98	89.98	9	0	134.97	134.25	0.71751
PZ58S/PZ58S	6.77E+05	1.96E+05	140.02	130.02	127.52	125.02	6	0	134.98	138.49	-3.5089
L20/L20	6.69E+05	2.00E+05	-	-	-	154.72	3	1	161.26	162.72	-1.4643
L21/L21	6.64E+05	2.02E+05	-	-	-	122.90	6	2	125.50	130.90	-5.3953
L22/L22	6.64E+05	1.95E+05	-	-	-	121.64	6	3	126.17	129.64	-3.4641

0 All "L" observation point are soft data points; groundwater elevations set to two feet below land surface elevation

1 NAD83-East Georgia State Plane Projection (feet)

2 Top of Casing measured in feet above mean sea level (amsl)

3 Top of screen measured in feet (amsl)

4 Middle of screen measured in feet (amsl)

5 Bottom of screen measured in feet (amsl)

6 Groundwater elevation measured in feet (amsl)

Table 3. Water Budget Comparisons of the Pre-Mining and Post-Mining Models						
Source	Pre-Mining		Post-Mining		Difference	
	In	Out	In	Out	In	Out
Storage*	0.00	0.00	0.00	0.00	0.00	0.00
Constant Head*	0.00	572,079.38	0.00	572,114.56	0.00	-35.19
Drains*	0.00	40,802.34	0.00	40,767.18	0.00	35.17
Recharge**	612,881.69	0.00	612,881.69	0.00	0.00	0.00
Total	**612,881.69**	**612,881.72**	**612,881.69**	**612,881.75**	**0.00**	**-0.02**

* Cumulative Volume (ft^3)

** Rates for time step (ft^3/day)

Table 4. Water Budget Comparison of the Pre-Mining and Post-Mining Models - Zone 1						
Source	Pre-Mining		Post-Mining		Differences	
	In	Out	In	Out	In	Out
Constant Head*	0.00	249,000.00	0.00	248,700.00	0.00	300.00
Drains*	0.00	29,670.00	0.00	29,630.00	0.00	40.00
Recharge**	276,900.00	0.00	276,900.00	0.00	0.00	0.00
Zone 2 to 1	74,254.00	0.00	72,518.00	0.00	1,736.00	0.00
Zone 1 to 2	0.00	72,489.00	0.00	71,092.00	0.00	1,397.00

* Cumulative Volume (ft^3)

** Rates for time step (ft^3/day)

Table 5. Water Budget Comparison of the Pre-Mining and Post-Mining Models - Zone 2						
Source	Pre-Mining		Post-Mining		Differences	
	In	Out	In	Out	In	Out
Constant Head*	0.00	323,080.00	0.00	323,420.00	0.00	-340.00
Drains*	0.00	11,133.00	0.00	11,137.00	0.00	-4.00
Recharge**	335,980.00	0.00	335,980.00	0.00	0.00	0.00
Zone 2 to 1	0.00	74,254.00	0.00	72,518.00	0.00	1,736.00
Zone 1 to 2	72,489.00	0.00	71,092.00	0.00	1,397.00	0.00

* Cumulative Volume (ft^3)

** Rates for time step (ft^3/day)