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South Florida Natural Resources Center

Independent Technical Review of the Twin Pines Permit Application Hydrologic Modeling

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Executive Summary

The Fish and Wildlife Service (FWS) requested National Park Service (NPS) South Florida Natural Resources Center (SFNRC) hydrology experts to conduct an independent technical review of hydrologic modeling performed as part of the Twin Pines Permit Application Materials for the Saunders Demonstration Mine. The NPS team reviewed the documents for the Twin Pines (TP) mining permit application posted on the Georgia Environmental Protection Division (GA-EPD) website in January 2023 as well as the updated new modeling conducted in 2022 by Dr. Sorab Panday and GSI Environmental for the Twin Pines application, obtained directly from GA-EPD.

The hydrologic modelers at the SFNRC have specialized expertise in multidimensional hydrologic modeling and in the hydrologic modeling tools used as well as many years of experience in freshwater wetlands research and surface water/groundwater interactions. We were tasked to review the modeling performed as part of the TP mining permit application to determine if the modeling was sufficient to conclude that there would be no harm caused to the Okefenokee National Wildlife Refuge (ONWR).

We reviewed the input data accuracy, applicability of the models and completeness, the model assumptions, the model scenarios, the final results and conclusions. Our analysis revealed a series of critical shortcomings in the modeling used for prediction of impacts to ONWR. Several inadequate assumptions in the model collectively compromised the modeling capability to accurately predict the impacts on ONWR.

The area modeled did not include the complete watershed that connects the mining site to the ONWR downstream. The limited geologic data collected was not sufficient to determine the spatial distribution of the low-permeability black sand deposits which can have a large influence on subsurface flow direction and magnitude. The model used fixed-head boundary conditions that were too close to the regions of interest, which can bias the model results. The model boundary conditions in the model were setup in such a way that it eliminated the ability to predict the impacts on ONWR particularly in dry and wet periods.

The modeling did not capture the seasonal and interannual variability in the system, using only average conditions. Modeling of dry periods is especially critical to ensure damage to the refuge will not be caused when small changes in water flows can have the largest effects. The choice to use a steady-state model that approximates average conditions instead of a transient model that captures the seasonal and interannual variability in the system is a critical shortfall.

Interpretation of model results relative to impacts on ONWR was not possible because the model grouped data from multiple watersheds, including those *not* influenced by the mine, diluting the magnitude of changes seen in the watershed where the mine itself would be located. Model results also included data from the model boundaries (which are prescribed inputs, not outputs) which adds additional bias to the results. The modeling stated that 93% of the water flows in the model were surface water, but the developed model is mainly a groundwater one and cannot explicitly model surface water. The use of a specialized package to approximate the surface water flows had critical drawbacks, such as the fact that groundwater can move into the surface water domain, but surface water is not permitted to infiltrate back into the groundwater. Surface water is not permitted to flow overland from one cell to another in these models.

The modeling also did not quantify the combined impacts of the mining processes (dewatering, pumping, and mixing of soils), but instead modeled each process separately. The effects of pit dewatering on the amount of water received by ONWR was not correctly modeled or analyzed. Our review of the calculated volume of water removed from the system reveals it is a significant fraction (16%) of the water budget in the area.

Our ultimate determination is that the modeling used to predict the magnitude, extent, and types of impacts from the mining processes and proposed reclamation were not adequate to ensure that no harmful impacts will be made to the ONWR. An expanded modeling effort would be needed to address the insufficiencies stated above.

Introduction

National Park Service (NPS) staff at the South Florida Natural Resources Center (SFNRC) were tasked with an Independent Technical Review of hydrological modeling and supporting information for Twin Pines' Saunders Demonstration Mine permit application. The purpose of this review was to determine if the modeling was sufficient to conclude that there would be no harm caused to the Okefenokee National Wildlife Refuge (ONWR).

The authors of this report are hydrologists at the NPS with specialized experience in coupled surface water-groundwater modeling and in wetlands hydrology. Kiren Bahm has 10 years of experience working with MODFLOW models and has been a hydrologist at the SFNRC for 15 years. Her master's degree is in physics. Dr. Rajendra Paudel has more than 15 years of experience in hydrologic modeling including the applications of groundwater flow models. He has his Ph.D. in Soil and Water Science, focused on hydrologic and water quality modeling.

The NPS reviewed the documents for the Twin Pines (TP) mining permit application posted on the GA-EPD website 1/19/2023 for public comment and review. Additional documents related to the application were provided to NPS by ONWR staff, and the latest new model files conducted by Dr. Sorab Panday and GSI Environmental in 2022 to support the TP application were obtained directly from the Georgia Environmental Protection Division (GA-EPD). The materials were reviewed between October 2022 and January 2023. NPS staff coordinated with ONWR staff but performed this review independently.

Our review included modeling input data accuracy, applicability, completeness, conceptual and analytical model assumptions, scenario implementation, model output and interpretation of results, and conclusions made form the modeling analysis.

The models reviewed were used to evaluate the effects of three different mining processes: disturbance of soils along Trail Ridge, dewatering of the mine pit, and pumping from the Floridan Aquifer. The concerns related to ONWR are:

- Soil disturbance: Filling of spoils back to the mine pit could result in permanent redirection of subsurface water flows, and potentially compromise a confining layer that could be holding water in the swamp.
- Dewatering: Dewatering of mine pit during active mining operations could reduce the amount of water directed to ONWR.
- Pumping: Pumping from the Floridian Aquifer could increase water losses from swamp.

Several issues were found with the modeling that should be addressed. This report documents the findings from our review.

Important Findings

Please note that these findings are *not* listed in order of priority.

Areal extent of the model domain omits the most direct flow path between mine and ONWR.

Combined inappropriate modeling assumptions compromise its predictive capability with respect to the impacts on ONWR:

- Assumptions for hydrogeologic properties in modeling of mining area are not appropriate based on available datasets.
- All simulations were performed assuming steady-state conditions using average values. Such simulations do not take into account seasonal and interannual response to freshwater recharge and therefore do not simulate the dry season and periods correctly. Flows in dry periods are critical for swamp's ecological health and frequency of wildfire.
- Modeling did not simulate effects in the dry season when water levels are lower, and there is less precipitation.
- There is a seasonal variability in observed groundwater head along the boundary of the modeled area. A constant head boundary and a specified head "drain" boundary conditions in the model do not take into account this variability.
- Methodology of simulating surface water flow using the “Drain Package” needs more justification before conclusions can be considered valid. The MODFLOW model is primarily a groundwater model, yet more than 90% of the water modeled is on the surface.

Modeling did not adequately prove that dewatering of mine pit won’t adversely affect ONWR. Dewatering of the mine pit has a significant impact on the water budget along Trail Ridge, removing an average of 16% of the water budget. Inappropriate modeling assumptions eliminated the ability to accurately predict the dewatering impacts on ONWR.

Model scenarios do not simultaneously simulate dewatering, pumping, and mining, to predict the collective effects on ONWR.

Modeling and analysis did not consider re-mining of bentonite layer in dragline overlap areas, which could cause bentonite to be mixed throughout the soil column with all the tailings placed back in the mine pit.

Quantification of impacts to ONWR incorrectly included the boundaries, which would obfuscate any actual impacts of the mine.

Use of the Theis solution to predict drawdown of the Upper Floridan due to pumping is too simplistic to accurately predict effects on ONWR.

Detailed Findings

The detailed findings below are organized into three sections: the model setups, the steady-state modeling assumptions, and the assessment of impacts. Each problem identified is grouped into one of these sections, and the findings are *not* listed in order of priority.

Model setups have critical problems

Pumping model is oversimplified

TP proposes to withdraw water from the Upper Floridan Aquifer (UFA) to process the mine spoils. The UFA is a confined aquifer that extends beneath the proposed mining site as well as underneath the ONWR. TP will install 2 pumps at about 650-foot depth that will be permitted to remove 500 gallons per minute (gpm) each from the UFA, for a total of 1000 gpm (Twin Pines Minerals LLC and Wood, 2023). TP used the Theis Equation to quantify the impacts of pumping on ONWR (Twin Pines Minerals LLC, 2022).

The Theis Equation was used to predict the drawdown at ONWR that would be caused by pumping from the UFA. The mathematical expression uses a linear solution for prediction of drawdown, but this system is nonlinear so the approach that captures nonlinearity is required. Nonlinearities include the subsurface geology (layer thickness, permeability, soil type, rebound time). Also, the Theis Equation assumes constant aquifer and radial flows which is not applicable in the site's real field conditions because the hydrogeologic system in this area is heterogenous and the groundwater flow dynamics are complex.

The Theis Equation used to predict the drawdown in this permit application doesn't capture the real field conditions. It is too simplistic to accurately predict the effects of pumping on ONWR.

Model validation/verification was not completed

The calibrated model was used to evaluate the impacts of post-mining conditions without proper verification. Hydrologic models are routinely calibrated on a set of data and then validated on an independent set of data. The process should take into account the dynamic nature of the system being modeled. If the model is not taken through the validation process, its fidelity would remain in question. At this point, it is unknown whether the calibrated parameters are suitable to use for different conditions (such as post-mining conditions) than used in the calibration (pre-mining conditions). It is important to note that active mining operations and post-mining operations are different from pre-mining conditions due to excavating the soil, backfilling of tailings and homogenization of black sand. So, it is essential to verify the model to ensure the reliability in output it produces.

Hydraulic conductivity is insufficient to characterize the groundwater system

Initial hydraulic conductivity values in the models were estimated from a very limited set of observation sites mostly around the proposed mining site. There are no sites within one mile of ONWR, and most sites are 2 miles or more away (Holt R. , Tanner, Smith, Patton, & Lepchitz, 2020). TP estimated spatial hydraulic conductivity values using indicator kriging from this limited set of sites that are far from ONWR. From the geologic cores it is evident that the model domain exhibits heterogeneity in subsurface characteristics and extrapolating the hydraulic conductivity values doesn't accurately represent the subsurface conditions in the model and therefore doesn't accurately simulate the groundwater flows. The piezometers or monitoring wells used to obtain hydraulic conductivity values were not sufficient to fully characterize the site, making the datasets describing the properties of the groundwater system questionable. Hydraulic conductivity is one of the key parameters in the model and affects the radius of influence of the mining in the model results. In reality, the radius of influence shown in the model results could be different. Therefore, it is critical to constrain hydraulic conductivity values with adequate observation data to accurately model the groundwater flows and the zone of influence.

Justification for use of the steady-state model is flawed

The use of a steady-state model configuration for modeling the effects of mining and re-filling of the pit was allowed by Kennedy (GA-EPD) and justified by using an analysis he completed with a transient model used by the GA-EPD (Kennedy, 2020). In his analysis he set Layer 1 to variable head and compared groundwater stage maps for two dates (6 months apart) that represented high and low recharge periods. In his report he showed two images from this model with dates of January 1st 2020 (Figure 1) and July 1st, 2020 (Figure 2). He concluded that since the groundwater surfaces across the domain were similar on these two dates, a steady-state model *could* be used by TP (Kennedy, 2020).

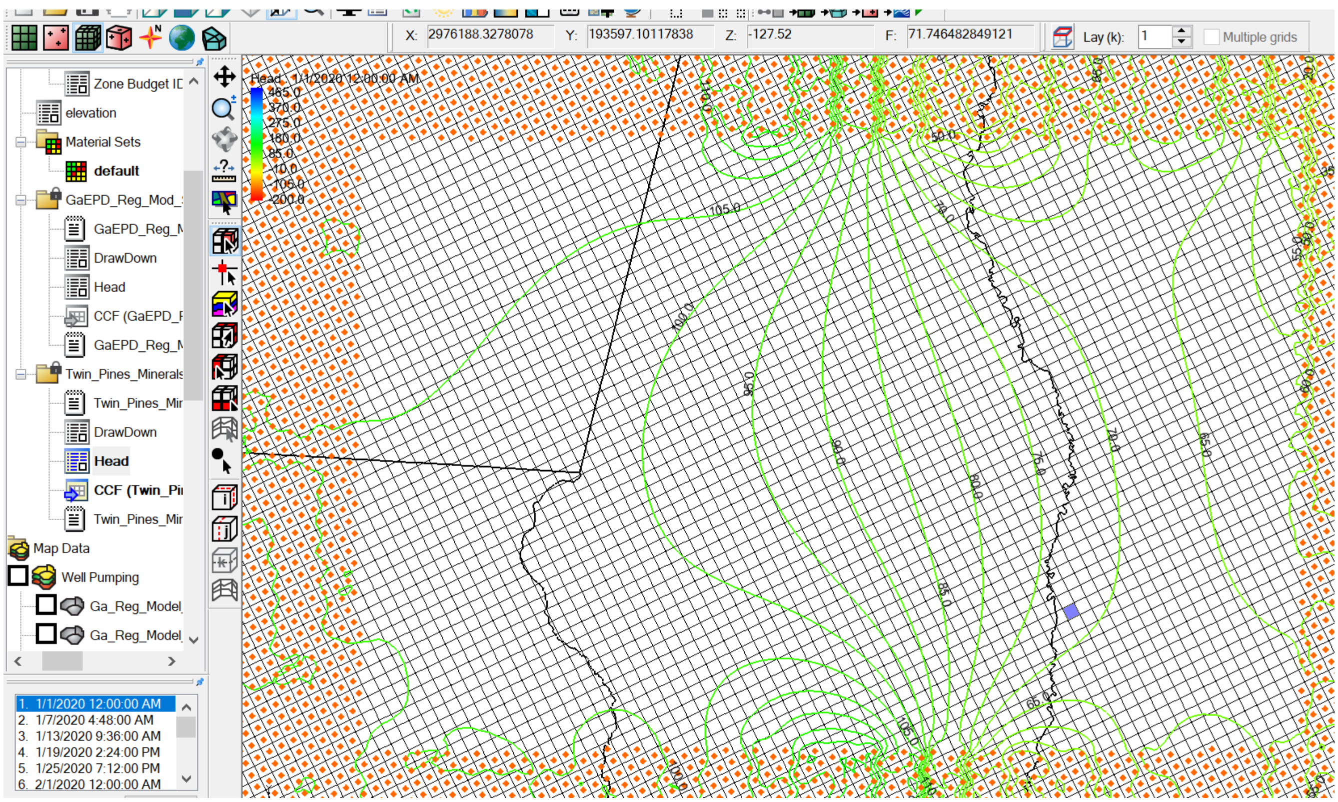

Figure 1. January groundwater heads from GA-EPD's letter to Twin Pines (Kennedy, 2020)

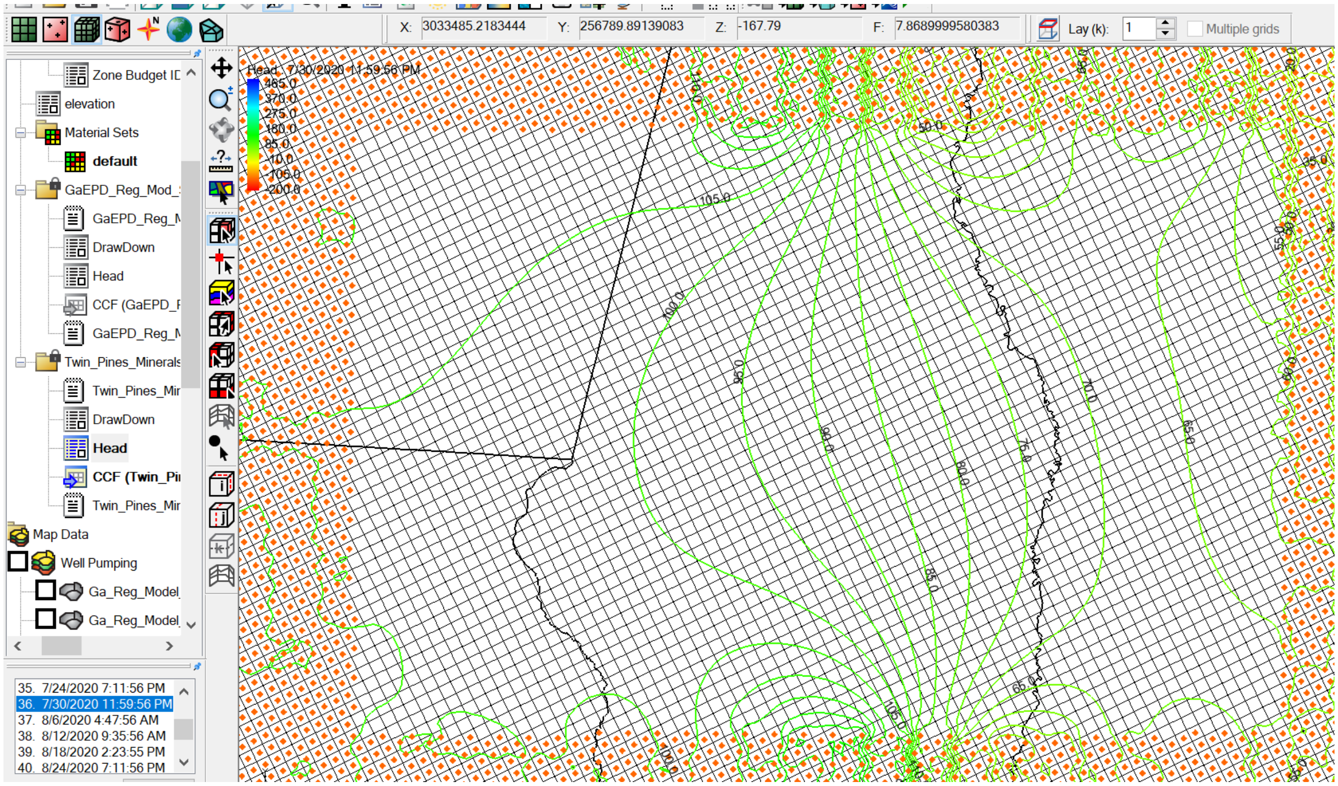

Figure 2. July groundwater heads from GA-EPD's letter to Twin Pines (Kennedy, 2020)

We investigated this result with a review of variability in groundwater levels at stations within the region (Figure 3). As an example, in 2019, groundwater stages measured from groundwater wells varied about 4 feet from minimum to maximum for station PZ-28 within the proposed mining area (Figure 4), and 4 feet for station PZ-01 near ONWR and the northern model boundary (Figure 5).

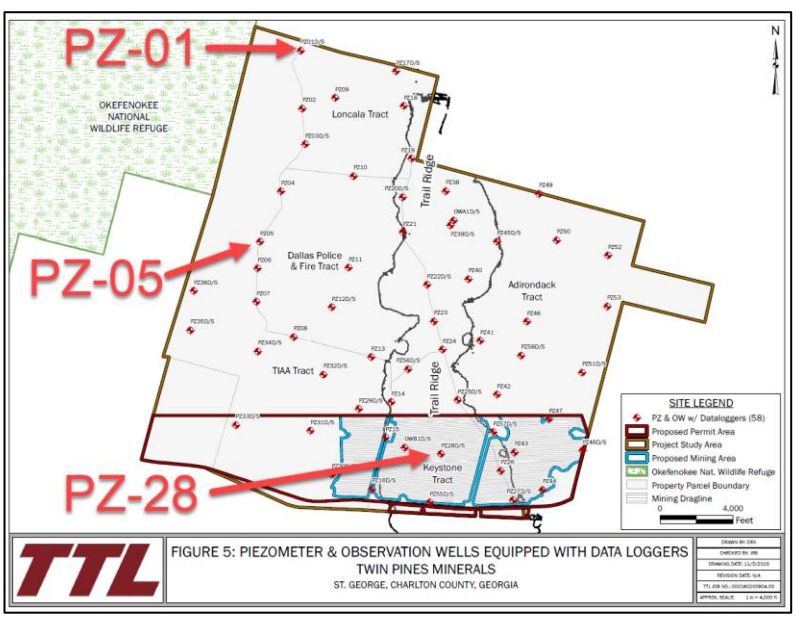

Figure 3. Well location map (Holt R. M., Tanner, Smith, Patton, & Lepchitz, 2019)

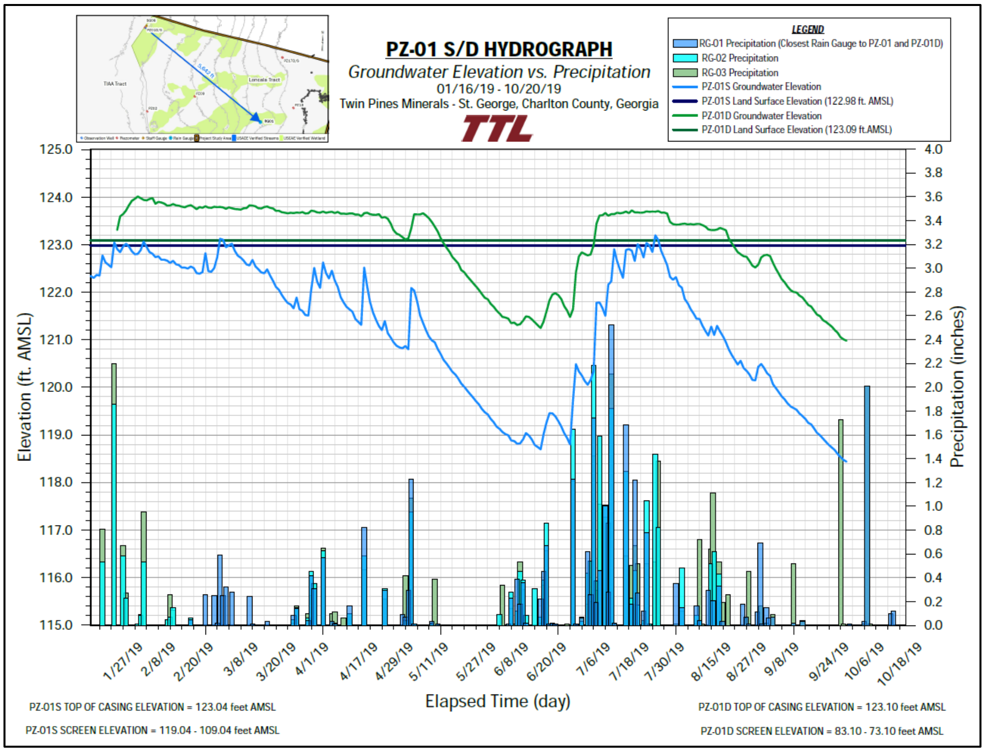

Figure 4. Groundwater elevation vs. precipitation for station PZ-01 (Holt R. M., Tanner, Smith, Patton, & Lepchitz, 2019)

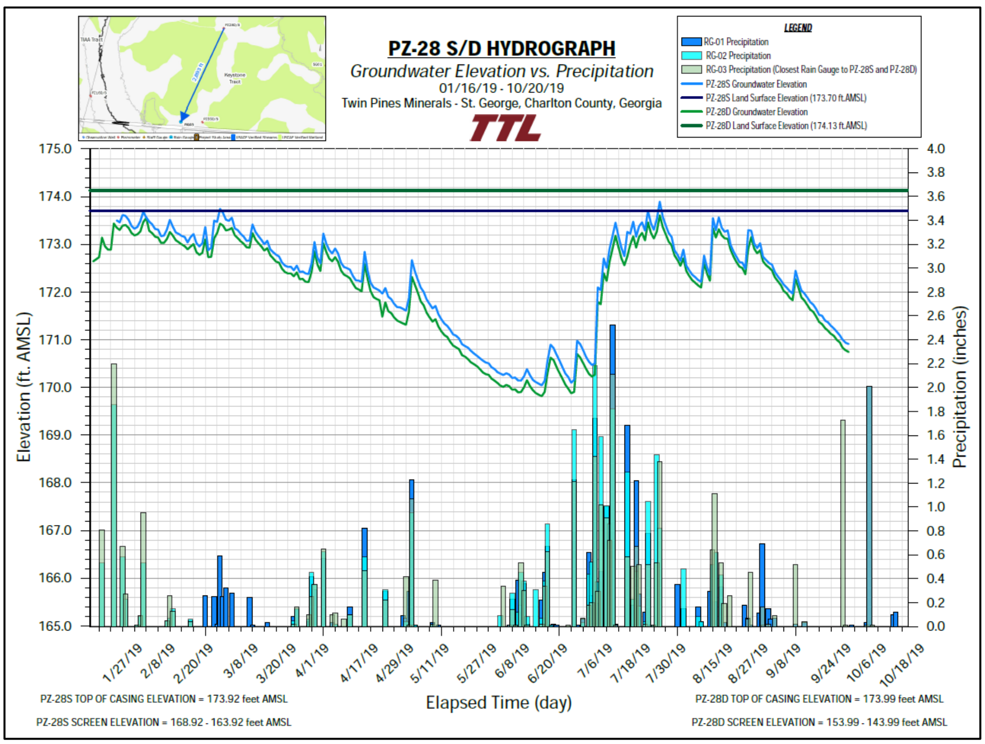

Figure 5. Groundwater elevation vs. precipitation for station PZ-28 (Holt R. M., Tanner, Smith, Patton, & Lepchitz, 2019)

Kennedy's transient model only showed groundwater stage in two timesteps (two days) that were six months apart but did not show any temporal variability in stage. Observed data at groundwater wells show 4 feet of variability (Holt R. M., Tanner, Smith, Patton, & Lepchitz, 2019). Kennedy's plots for January and July are in fact *exactly* the same (see Figure 1 and Figure 2), which also calls into question the sensitivity of the transient model.

The model omits a direct flow path between the mine and ONWR

The National Hydrography Dataset for Wetlands, used to construct the soil disturbance and dewatering models, shows stream channels and wetlands in the area of the proposed mine (Figure 6). The darker blue lines in the figure depict stream channels within the chosen model domain.

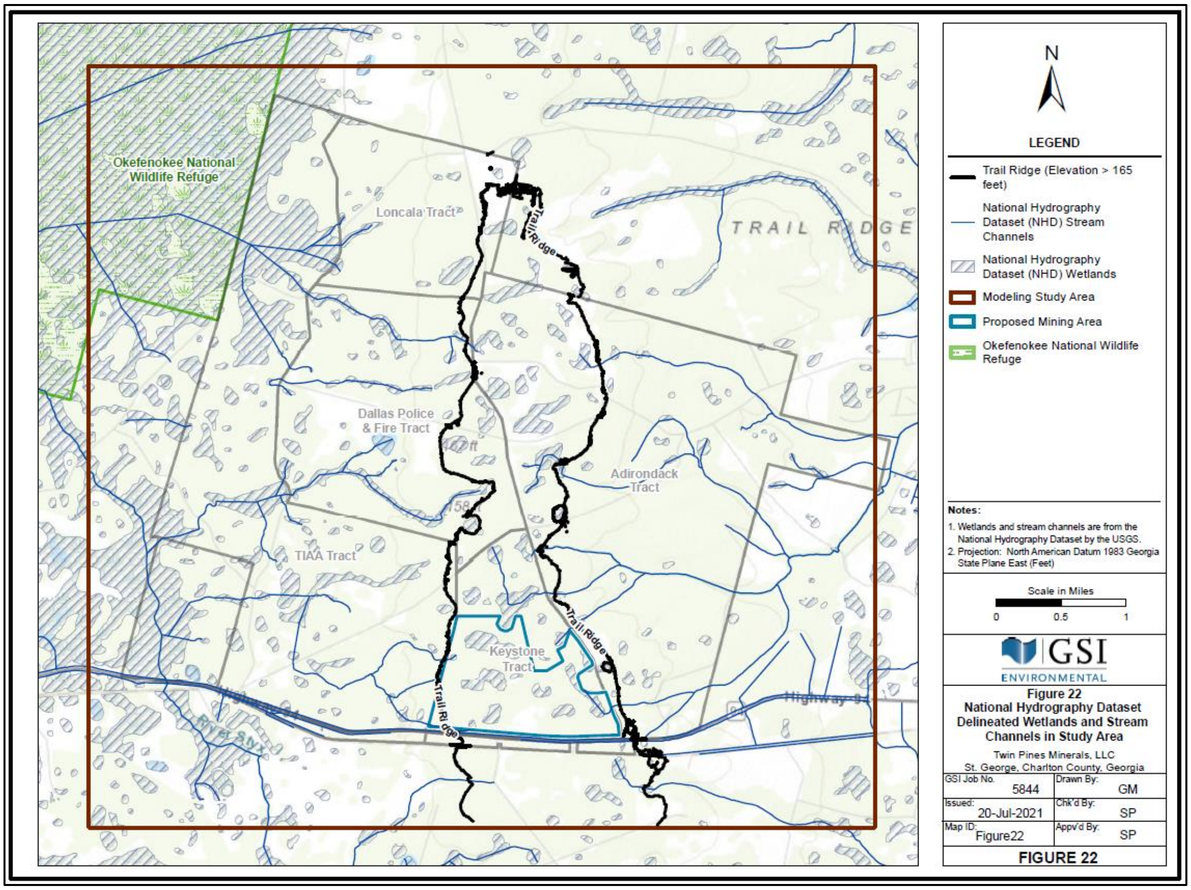

Figure 6. Wetlands and stream channels from the USGS National Hydrography Dataset (Panday, Wyckoff, & Martell, 2021).

The model domain, however, omits the direct flow path connection between the proposed mine site and its final destination, the ONWR (see Figure 7). Ideally, it would be appropriate to set model boundaries to the natural divides in the watershed, to meaningfully capture all downstream effects of perturbation of the environment.

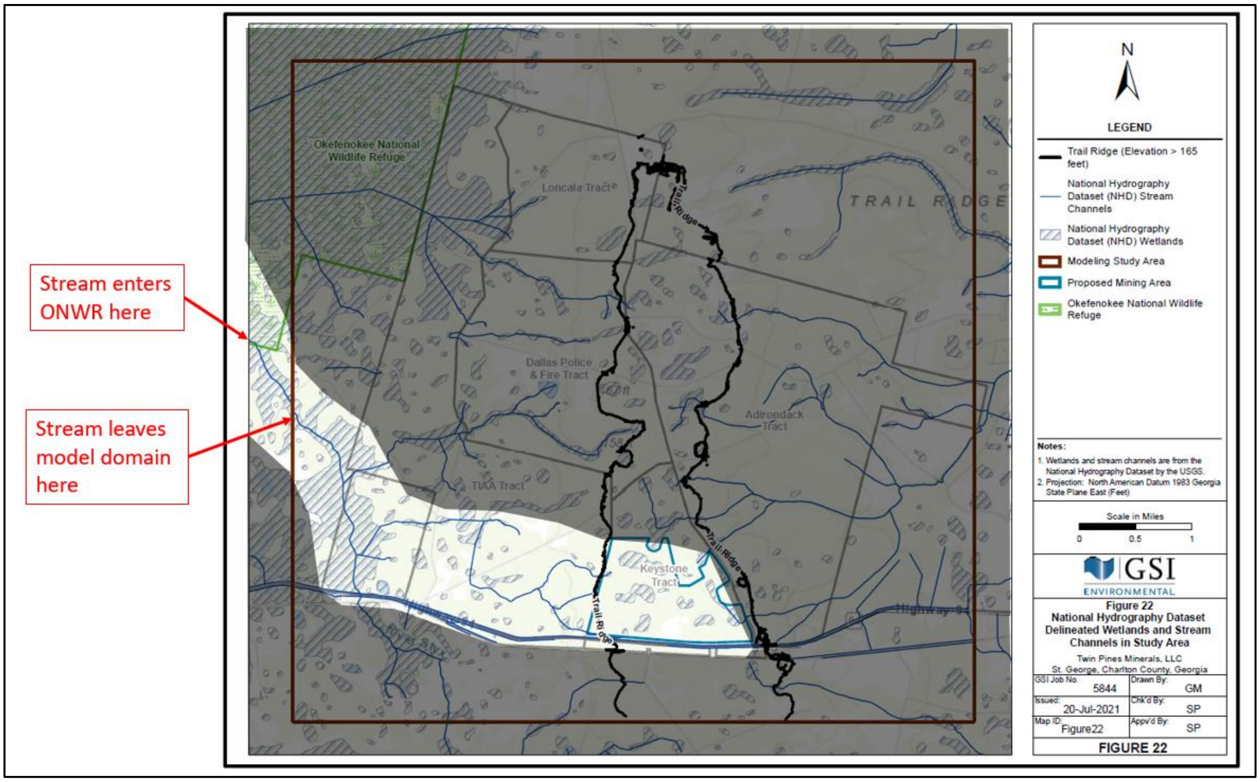

Figure 7. Stream channels extending between the proposed mine site and ONWR. The model domain does not include the area where the stream channel enters ONWR. Base map is from (Panday, Wyckoff, & Martell, 2021), with shading and red annotations added by the authors of this report.

The model domain is not large enough to accurately assess the impacts on ONWR. Also, averaging in results from watersheds that do *not* connect the mine site and ONWR obfuscates the true impacts from mining on the refuge.

Drain cell elevations in model do not match description in report

The drain elevations in the soil disturbance and dewatering models were set to the streambed elevation or the elevation of the wetland, according to Panday (Panday, Wyckoff, & Martell, 2021), for all of the drain cells in the model (shown in yellow in Figure 8).

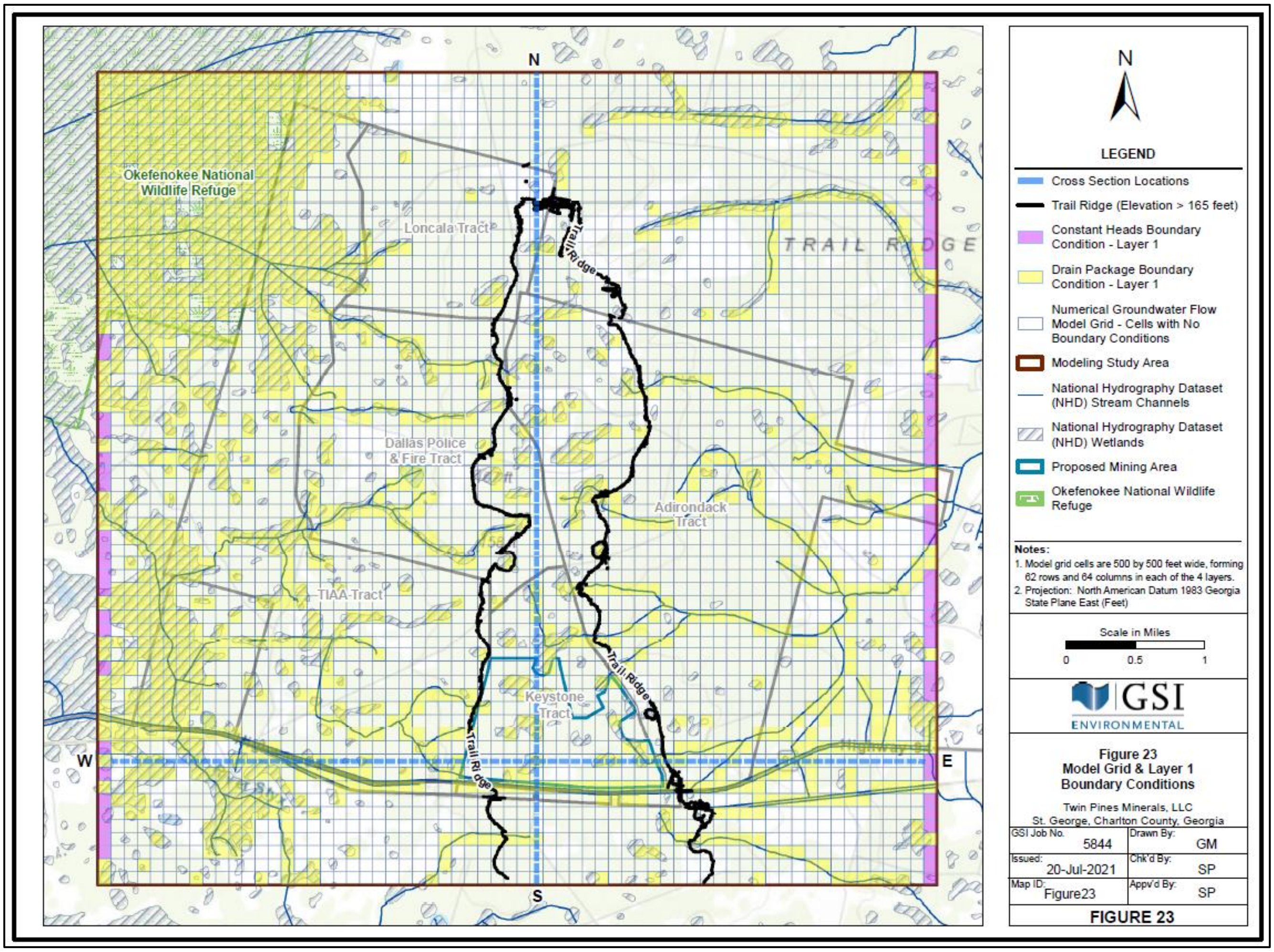

Figure 8. Model grid, showing boundary conditions. Drain cells are in yellow, and constant head boundary cells are in pink (Panday, Wyckoff, & Martell, 2021)

In the models provided by GA-EPD to NPS, however, many of the drain cells were found to be 0.5 feet *below* the land surface elevation (shown in red in Figure 9). For example, in the "v01a_TPM_GwFlow_Cal_OF_NWR_Bal model", the land surface elevation of the cell in row 52 and column 26 (from the DIS file) is 142.39 ft., and the drain elevation in the same cell (from the DRN file) is 141.89 ft., a difference of 0.5 ft. This was found to be true for several models used in the TP analysis. The reasons for this were not explained in the report. Setting cell elevations shown in red in Figure 9 half a foot lower than land surface elevation can significantly affect the water flow dynamics in the model, especially in wetlands and streams. These discrepancies in cell elevations need to be addressed before model results can be considered reliable.

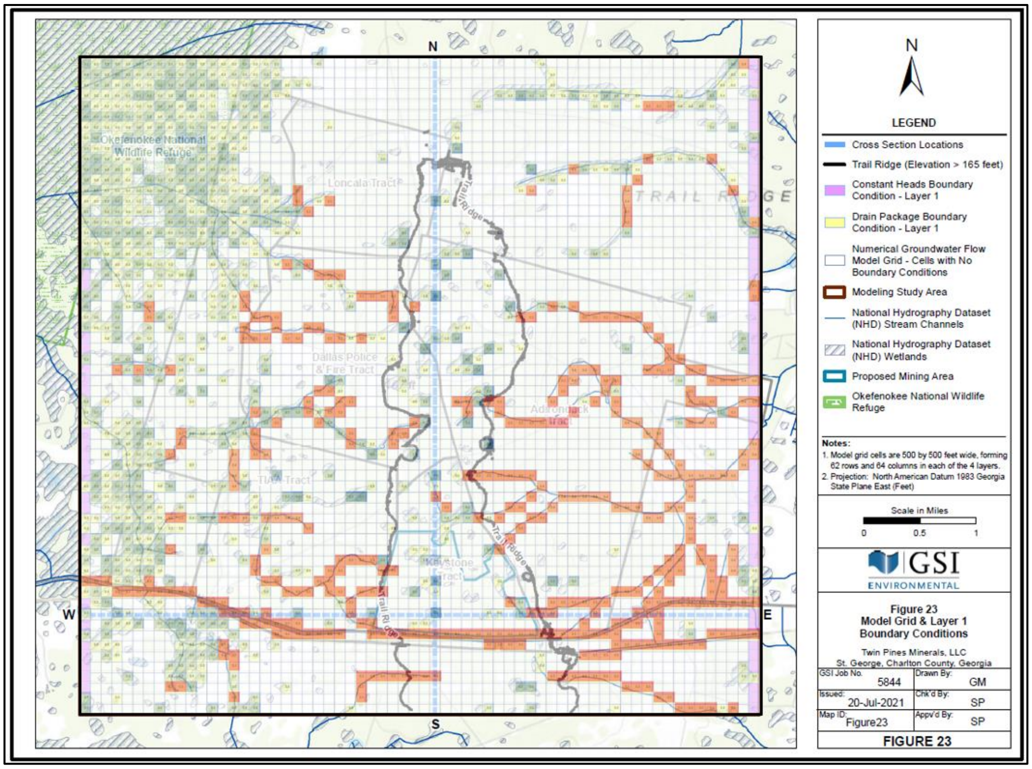

Figure 9. Model domain, showing cells with differences between drain and land elevations. Elevation differences (between drain elevations and cell land surface elevations) greater than 0.5 feet are shown in red. Base map is from (Panday, Wyckoff, & Martell, 2021), with red and blue cell highlighting added by the authors of this report.

Steady-state modeling does not capture important variability in the system

Recharge rates need to be spatially and temporally variable

In the soil disturbance and dewatering models, a constant recharge rate of 4.13 inches/year (difference between precipitation and evapotranspiration) was applied to all cells within the model domain (Panday, Wyckoff, & Martell, 2021). The three rainfall stations within the model domain (Figure 10) clearly show that there is significant variability in precipitation in both time and space (Figure 11). Also, there is a large variability in evapotranspiration in time and space due to differences in land-use, hydrologic conditions and seasonal and interannual variability in temperature. Figure 12 shows the location of the station at Folkston, GA. This station illustrates how rainfall and evaporation measured at the site change through the months of the year, and how the *differences between* rainfall and evaporation measured at this site also change through the months (Figure 13). Without spatio-temporal variability representation of recharge rates in the model, it is difficult to evaluate the impacts of mining on ONWR, particularly during the dry periods. Since recharge is the single source of water for the model and has a strong seasonal variability, simulations of the hydrology of this area need to accurately characterize spatiotemporal variations.

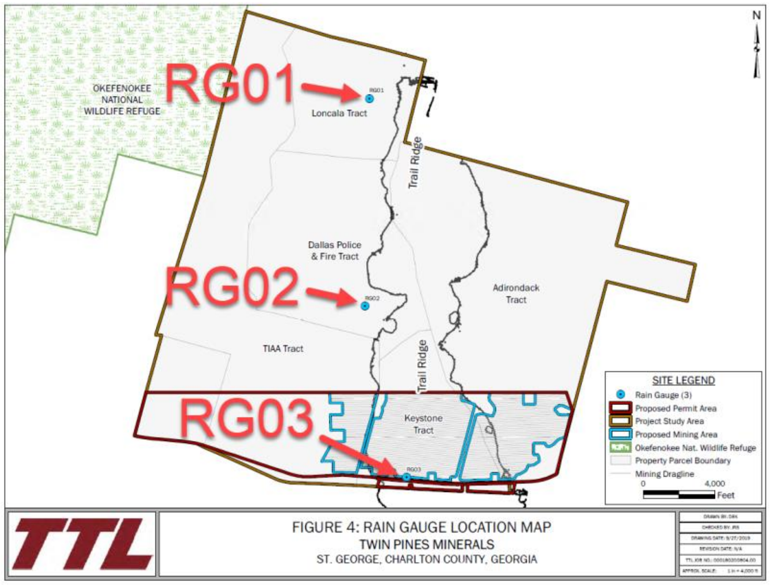

Figure 10. Rain gauge location map. Red text and arrows added by the authors of this report (Holt R. , Tanner, Smith, Patton, & Lepchitz, 2019)

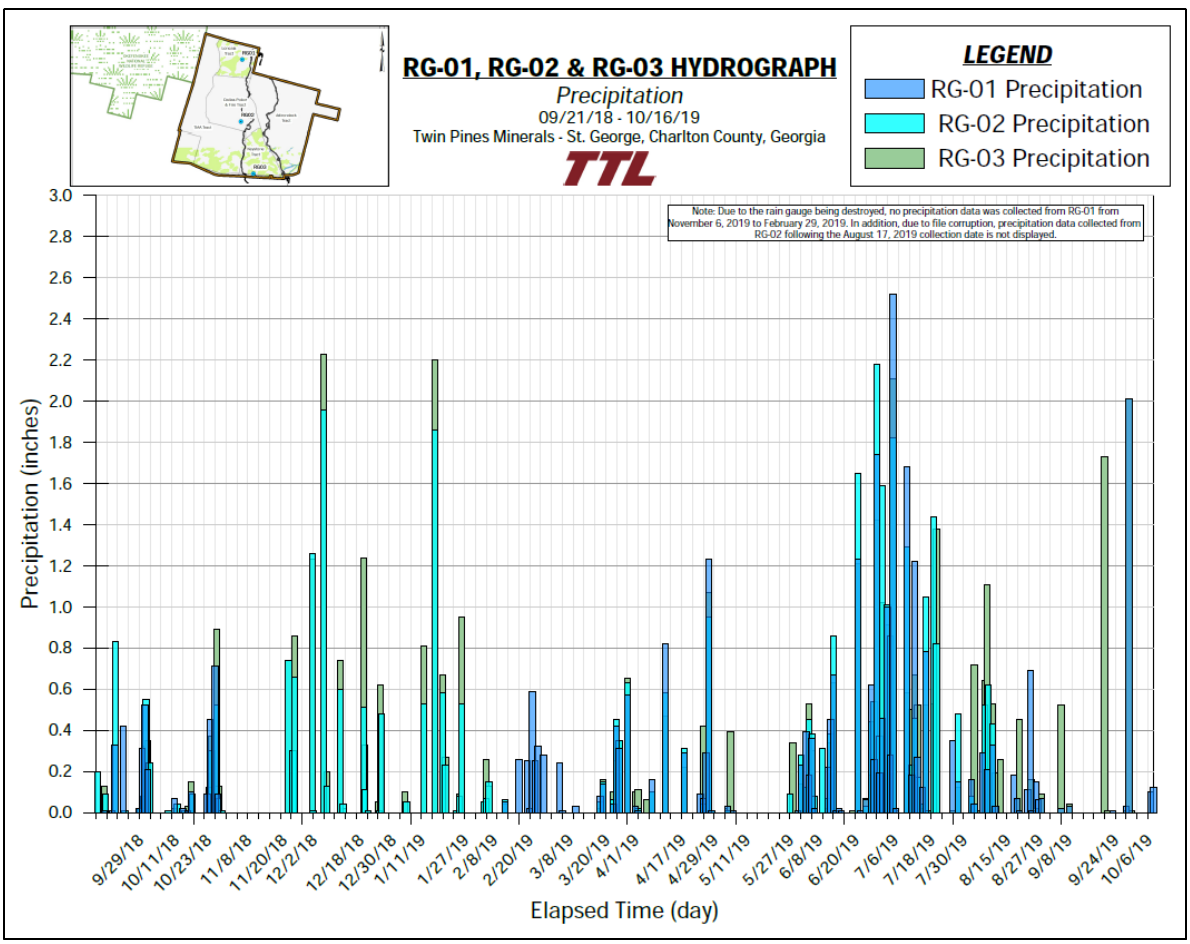

Figure 11. Precipitation data collected 2018-2019 at three locations near the proposed mining location (Holt R. , Tanner, Smith, Patton, & Lepchitz, 2019)

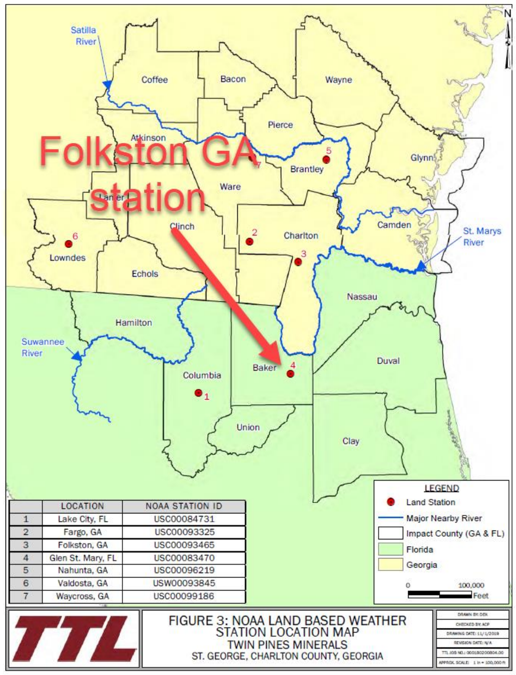

Figure 12. Location of Folkston station (Holt R. , Tanner, Smith, Patton, & Lepchitz, 2019). Red text and arrow have been added by the authors of this report.

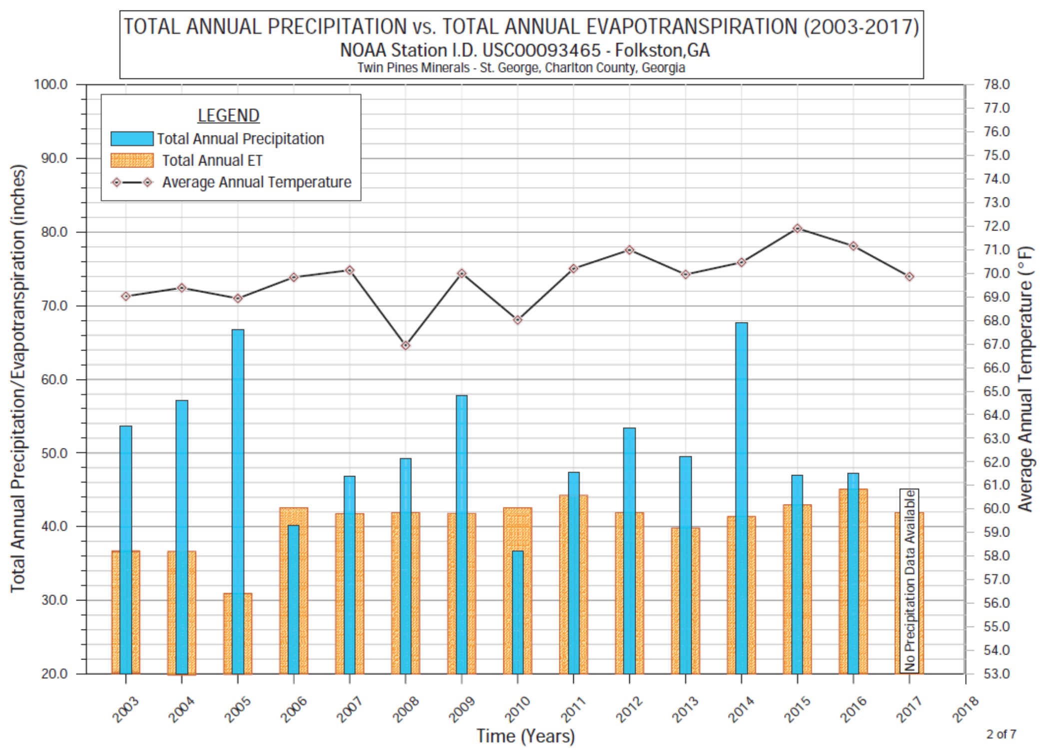

Figure 13. Precipitation and evaporation at Folkston station (Holt R. , Tanner, Smith, Patton, & Lepchitz, 2019)

Constant-head boundary condition is not appropriate

The MODFLOW soil disturbance and dewatering models used to quantify effects of the mine on ONWR are presented in several reports (Holt R. , Tanner, Smith, Patton, & Lepchitz, 2020), (Holt R. , Tanner, Smith, Patton, & Lepchitz, 2020), (Panday, Wyckoff, & Martell, 2021), (Panday, Wyckoff, & Martell, 2021), and (Panday S. , 2023). Steady-state models were used to quantify impacts of the dredging and re-filling of materials in the mine pit on the hydrology of ONWR.

The goal of the simulations performed with these models is to quantify effects of the mine on water levels and flow volumes. When the east and west boundary water levels are set to a fixed value for all simulations, the differences between any two simulations along these boundaries will always be zero. This is especially concerning when we are quantifying effects in a 'before' and 'after' scenario because the difference between the scenarios is *forced* to be zero at the boundaries. This boundary effect also forces differences in cells *near* the boundary to be close to zero. The graph of stage differences between two model runs (Figure 14) illustrates this concept – the isolines showing differences in stage between two runs are forced to curve and then run parallel to the east and west boundaries and will always be zero. Constant head boundary conditions assume a constant water level at the boundary which is only valid where water levels don't change over time. But in this mining site, there are seasonal fluctuations and variable land use, which create a variable water level at the boundary. So, this simplifying assumption doesn't accurately represent the hydrologic conditions near the boundary and is also not suitable to assess the impacts on ONWR which is at the boundary of the model domain.

One cannot conclude that there will not be any effects on water stage in the areas of the model at (or near) the fixed-head boundaries of a steady state model.

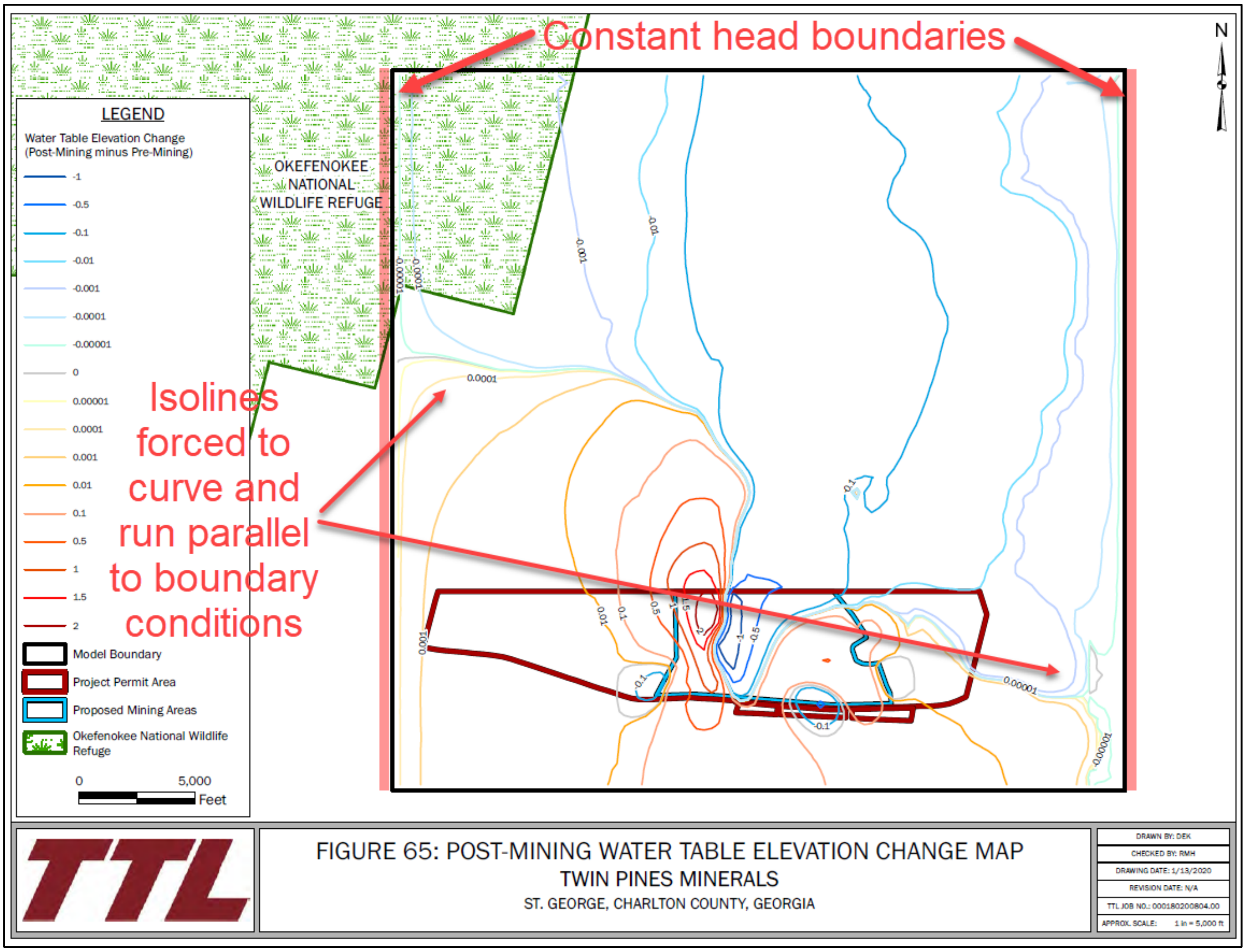

Figure 14. Map showing the change in water levels between two model runs that have constant-head boundaries on the east and west sides (Holt R. , Tanner, Smith, Patton, & Lepchitz, 2020). Red text and arrows are added by the authors of this report. Isolines are forced to run parallel to the boundary on the east and west sides of the domain, indicating that the water table elevation change between model simulations is forced to be zero by the model's fixed-head boundary conditions.

The Drain Package was not appropriate for simulating surface water dynamics

MODFLOW does not have the ability to explicitly model surface water flow and surface water routing. Recharge in the soil disturbance and dewatering models is added directly to the groundwater. In MODFLOW, water can only flow laterally from one cell to a neighboring cell underground - it cannot free-flow from cell to cell over the surface. In an attempt to address this shortcoming of the model, TP used the 'Drain Package', which allows one-way water flow from the groundwater system out of the model in cells specified as drain boundaries (yellow cells in Figure 8 above). This means that groundwater flow to the surface is modeled in these cells, but surface water cannot move into the groundwater system. Any water above the specified 'drain elevation' (specified for each cell) is immediately removed from the model (Harbaugh, 2005). In the MODFLOW models, Panday states that the drain elevations are set to streambed elevation or wetland elevation. These terms are not explicitly defined. Surface water accounts for roughly 90% of the water flows in the MODFLOW models (Panday, Wyckoff, & Martell, 2021).

The use of the ‘Drain Package’ is common to simulate storm drains where water is completely removed from the system, or in agricultural applications to simulate losses of water from evapotranspiration. The broader ‘River Package’ is usually used to simulate streams and rivers but was not used in these simulations. We did not find enough supporting information in the TP reports to justify the use of the ‘Drain Package’ methodology for the application.

This methodology for simulating surface water in the model has critical drawbacks. Wetlands, streams, swamp are assumed to not have any water seeping into the groundwater system. This method does not allow us to directly quantify surface water flows into the refuge, or to predict mining impacts on the flow volumes and stages in the ONWR. Because surface water accounts for 90% of flows in the model, a coupled surface water-groundwater model should be used instead of a groundwater model with a drain package.

No-flow boundary condition is not appropriate

No-flow boundary conditions were used along the northern and southern boundaries of the MODFLOW soil disturbance and dewatering models. Lower groundwater levels exist outside the north and south model boundaries relative to the levels inside the model domain, because groundwater head contours mirror the surface topography in this area (Figure 15). This establishes an energy gradient from south to north across the northern boundary, and a gradient from north to south across the southern boundary of the model domain.

Because gradients exist there will be groundwater flows across these boundaries and “no flow” boundary conditions in the model are not appropriate. Any water that would flow out of the model domain across the southern boundary will be forced to flow out the east or western boundaries instead. Using this type of boundary condition causes water in the model to be redirected to places it would not normally flow.

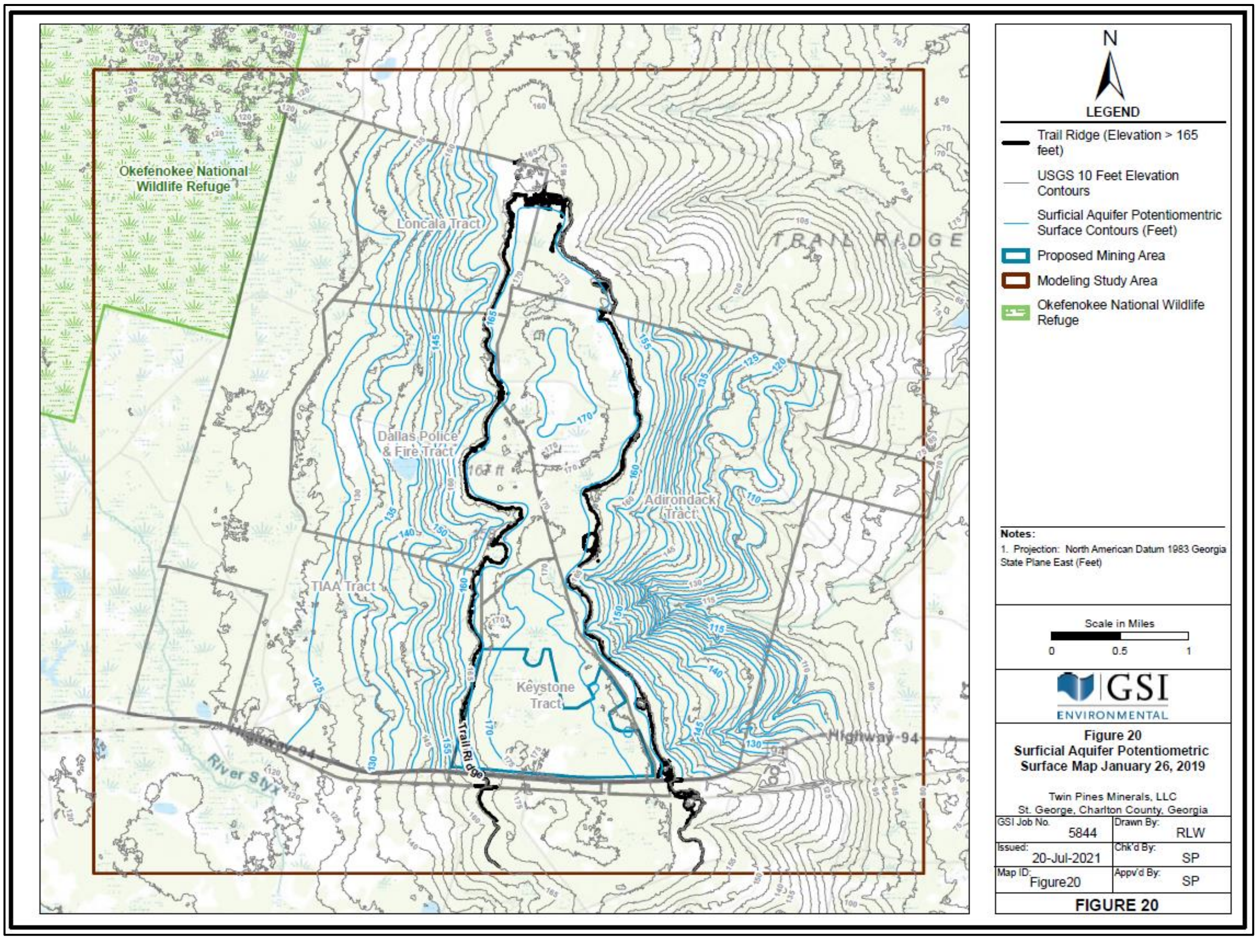

Figure 15. Surficial aquifer potentiometric surface, showing how stage contours generally mirror land surface topography (Panday, Wyckoff, & Martell, 2021)

Model is not set up to mimic the system's natural variability

The soil disturbance and dewatering model simulations were performed assuming steady-state conditions using constant recharge rates and boundary conditions (head and drain). Steady-state simulations assume there is no change in time. But the real field conditions are different from model assumptions. For example, there is a strong seasonal variability in water levels with more than 4 ft difference in water levels between wet and dry seasons (see Figure 4 and Figure 5). Steady state simulations do not take into account seasonal response to recharge and therefore do not simulate the seasonal variability.

From the modeling results it is not possible to evaluate the effects of mining on ONWR during the dry periods, which are particularly critical to maintain the ecological health and reduce the frequency of wildfires. Even a small amount of flow to the swamp during the dry periods is important to reduce the likelihood of wildfire and improve ecological health. TP claimed that there were no impacts of the mine on ONWR during the dry condition using a sensitivity run that reduced constant head boundary conditions by 10 ft. In the model, the constant head boundary conditions only account for 6.5% of the outflow but the drain boundary conditions account for 93.5% of the outflow. The drain boundary conditions were not considered in the sensitivity run. Such results cannot be used to evaluate the impacts on ONWR dry conditions.

In addition, the average of 10-month groundwater levels used to calibrate the model is not sufficient to capture the seasonal and interannual variability (Figure 16). Datasets in nearby sites show a significant interannual variability in precipitation, evaporation, and recharge (see Figure 13). The response of this variability on groundwater levels is not captured with average values and steady-state simulations.

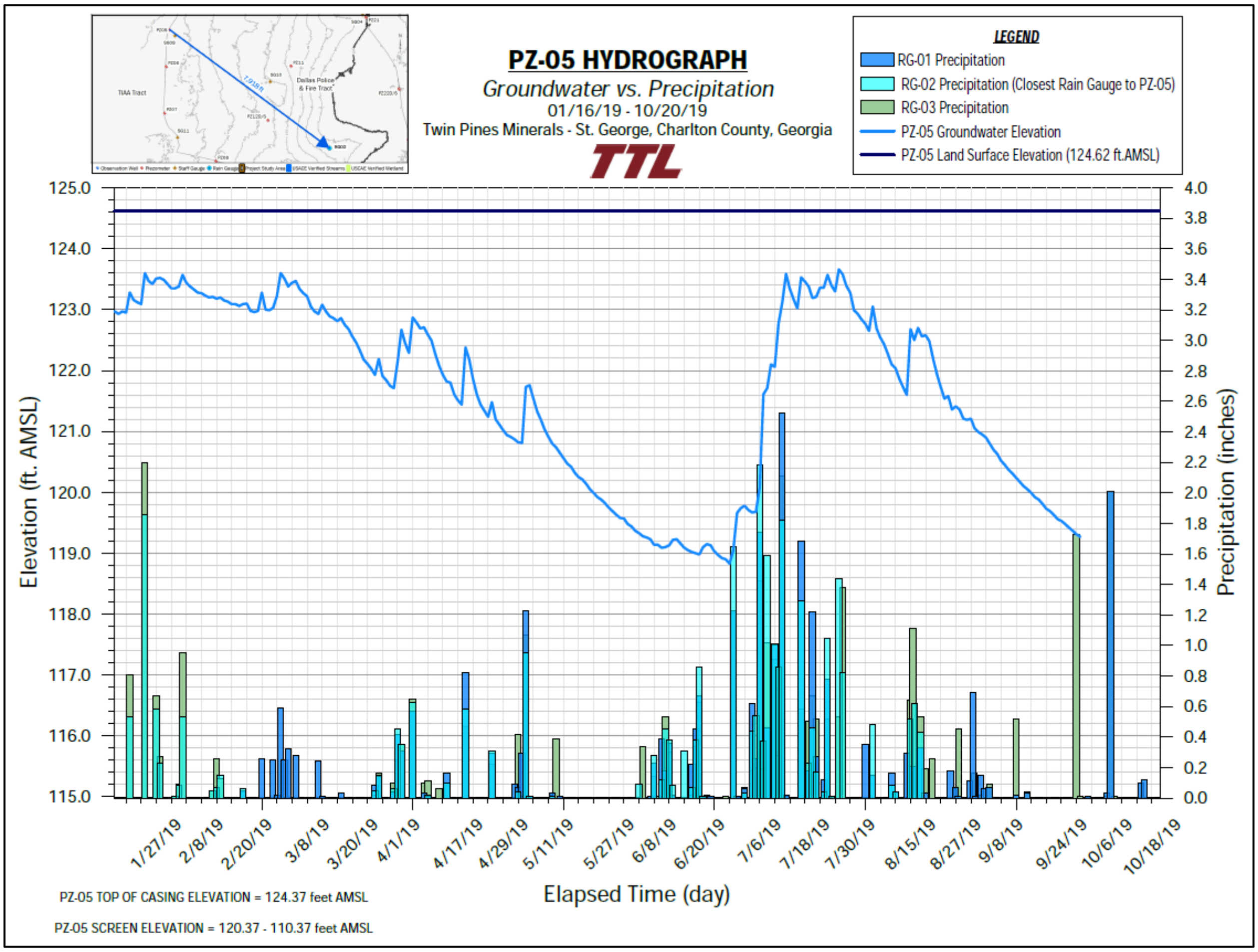

Figure 16. Groundwater elevation vs. precipitation for station PZ-05, with precipitation measurements from stations RG-01, RG-02, and RG-03 (Holt R. , Tanner, Smith, Patton, & Lepchitz, 2019).

The accuracy of steady-state models generally limits their application to very specific conditions where the variable of interest is not a function of time. This system exhibits significant temporal variability (seasonal cycles), and this variability is critical for the health of the ecosystem. For example, water levels in dry periods are vital for wetland ecosystems and a small change in water levels can considerably affect the ONWR ecosystems.

Given the high temporal variability in groundwater levels and precipitation in the study, the steady state model is not an appropriate tool to simulate the dynamic behavior of groundwater in this system.

Assessment of impacts was flawed

Effects on ONWR from mine dewatering were not properly quantified

Modeling determined that dewatering of the mine pit would extract an average of 783 gallons per minute from the surficial aquifer during dewatering operations (Panday S. , 2023). To quantify the effects of this dewatering rate on ONWR, however, Panday quantified *only* the change in groundwater flow across the portion of the ONWR within the model domain. He reported that there would be no change in outflow to drain cells in ONWR. However, because the cells along the ONWR boundary are all classified as drain cells, no surface water is even *allowed* to flow between drain cells in this model. Therefore, by design, the model will never show any surface water exchange across the boundary to ONWR.

Panday did not quantify the change in water flow in *any* of the streams and channels feeding into the ONWR – a serious omission. To give us some perspective on the magnitude of this omission, we can compare the recharge rates to the dewatering rates.

Figure 17 shows the tabulated results for inflows and outflows in the model. Panday's model shows that 4782 gpm of recharge (precipitation minus evaporation) will be added to the area inside the model domain. Because recharge is the main source of water in this system, we can state that this area receives approximately 4782 gallons of water per minute. The pit dewatering will remove an average of 783 gpm from the system, for the four years that mining operations are being conducted, which is 16% of the total recharge rate (4782 gpm).

This estimate is extremely significant because the water budget for the entire model domain is only 4782 gpm. Dewatering of the mine pit will extract an average of 16% of the total recharge received over the entire model domain.

Table 6. Pre-Mining Simulation Water Budget
Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

Water Budget Component		Pre-Mining		
		West[1]	East[2]	Total
Inflows (gallons per minute)	Recharge	2,669	2,113	4,782
Outflows (as % of Total Recharge and gallons per minute)	Lateral Outflows	1.1%	5.4%	6.5%
		28	114	309
	Outflow to Modflow Drain Package[3]	52.0%	41.5%	93.5%
		1,389	877	4,472
Percent Mass Balance Error		0.0%		

Notes:
1. West refers to the west of the Trail Ridge crest as shown on Figure 33.
2. East refers to the east of the Trail Ridge crest as shown on Figure 33.
3. Modflow drain packages represents National Hydrography Dataset wetlands and streams as shown on Figures 22 and 23.
4. GSI (2021) Table 3.

Figure 17. Results for pre-mining model run (Panday, Wyckoff, & Martell, 2021)

It is important to note that the percentage of water lost to mining operations (16%) is an annual average, and also a spatial average over the entire mine site. The mining operation will move east and west, north and south, so the area of influence will also move with the mine. Depending on where the mine is and what geologic formations underlie it, Panday estimates the dewatering to vary between 344 and 1087 gpm (Panday S. , 2023) on average. The amount of recharge over the model domain will also vary seasonally and annually.

Re-dredging of the soil amendment layer was not taken into consideration

The Soil Amendment Plan (Twin Pines Minerals LLC, 2022) states that a bentonite amendment layer will be added as part of the reclamation process to re-fill the mine pits, if a black sand layer is found in the area before mining. Figure 18 shows how the dragline will proceed in east-west strips throughout the mining area. The mining pit operation will be preceded by exploratory drilling and followed by refilling of the pit. Re-filling might include the installation of a less-permeable subsurface bentonite layer, if a continuous black sand layer is encountered during the pre-drilling operation. If drilling does not encounter a continuous black sand layer, the re-filling operation will **not** include this less-permeable layer.

As the dragline proceeds, the mine pit will be re-filled with previously mined and mixed materials, along with potential placement of the new bentonite layer. Figure 19 shows how the successive draglines will overlap as the operation moves from south to north. This figure highlights how it will be necessary to re-mine and process overlapping areas for each pass. Some dirt will be dug up, mixed, and replaced during one east-west run, then dug up again, mixed, and replaced in the successive west-east run to the north.

From these drawings, it is clear that re-dredging of previously filled tailings will occur. Modeling assumed that transmissivity values for non-black sand layers would remain constant, but this does not seem possible given the tailings processing plan outlined in the application. If the bentonite layer is placed during one pass, then it must be partially *dug up again* in the next pass, over and over. As the mixing process of the tailings proceeds, any bentonite layer tailings will be mixed with the rest of the materials, and wind up being distributed throughout the entire vertical profile when the pit is re-filled. This could cause problems by altering the hydraulic conductivity of the sand layers above and below the bentonite layer. This will also make it difficult to calculate how much bentonite to add to achieve the desired hydraulic conductivity, because the 10.9% amendment ratio was calculated for sands *not* contaminated with bentonite.

Because this important feedback loop was not accounted for in the Soil Amendment Plan, it needs to be addressed before any permits are approved. It is also important to note that this reclamation process will be a *permanent* change in the system.

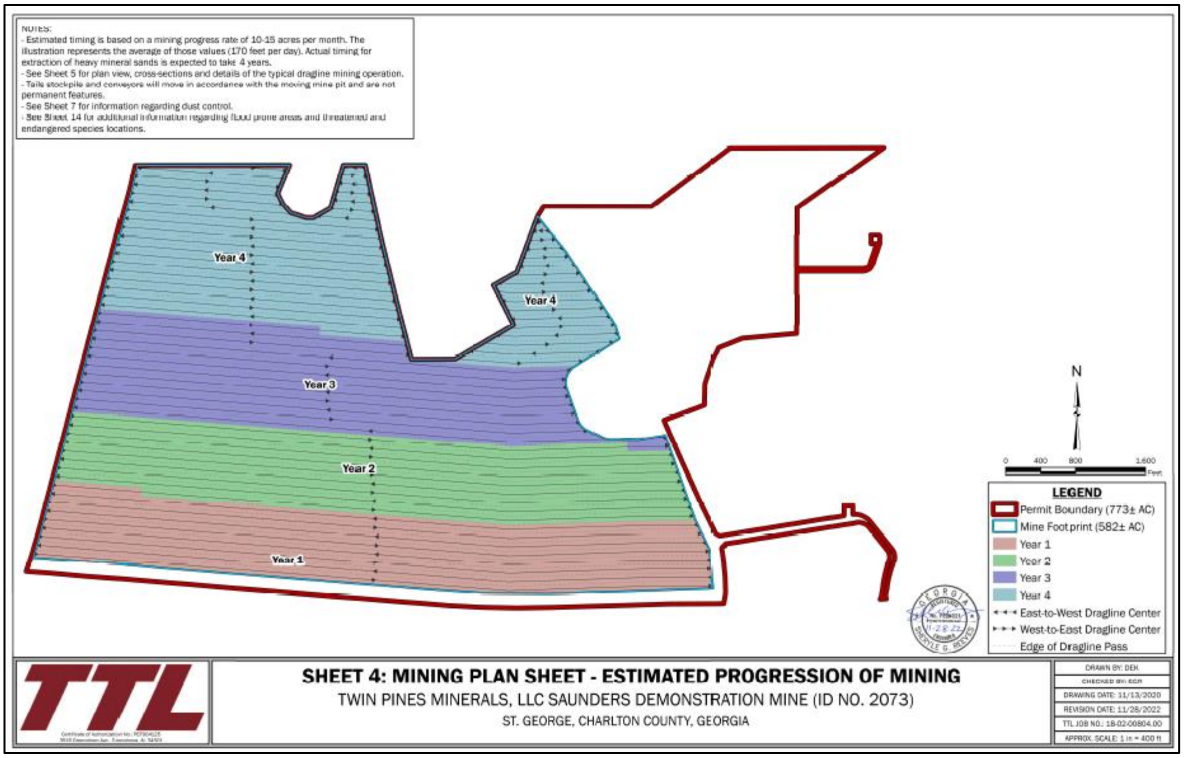

Figure 18. Map showing advancement of dragline in east-west direction (Twin Pines Minerals LLC, 2022).

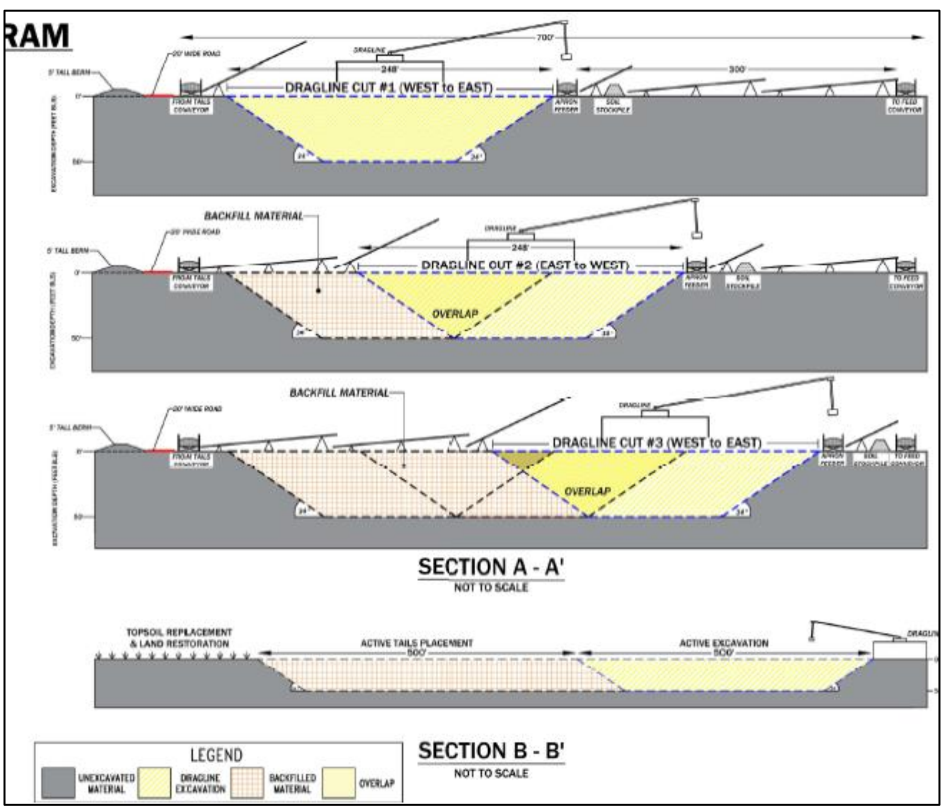

Figure 19. Cross-section showing how successive draglines will overlap with each other, causing overlapping sections to be re-mined (Twin Pines Minerals LLC, 2022).

There are mathematical errors in the report

Model results are presented in the TP report that give volume calculations to quantify effects on the surrounding area (Panday S. , 2023). For example, Figure 17 shows results presented in the report with water volumes shown in gallons per minute.

In this results table, the actual volumes do not add up. For example, the “Lateral Outflows” volumes for West and East should add up to the Total volume, but the values (28 plus 114 gpm) do not add up to the total flow volume presented (309 gpm). These mathematical errors can be found in Tables 6, 7, 8, 9, and 10 of Panday’s report, all of which quantify pre- and post-mining water budgets.

Volume calculations in the modeling that quantify effects of the mine on the surrounding environment are not correct. Conclusions drawn from this data cannot be considered valid.

Modeling and analysis segmentation does not account for combined effects

Each hydrologic process was modeled separately (soil disturbance, dewatering, and aquifer pumping), but not modeled together. These processes will happen simultaneously, and the *combination* of factors needs to be modeled in a non-steady state model. The interaction of these processes could result in unforeseen impacts to ONWR, especially during dry periods.

Project segmentation does not consider potential mining expansion

The intent of a ‘demonstration mine’ is to demonstrate that a larger mining footprint is viable. Approval of the Demonstration Mine application could provide a precedent for future mining, without fully evaluating the cumulative impacts of the full mining footprint and without evaluating the novel impacts from mining other areas.

Conclusions

After reviewing reports posted on the GA-EPD website in January 2023 as well as the updated 2022 modeling conducted by GSI Environmental for the Twin Pines application, the experts within NPS concluded that many of the assumptions (discussed above) used in the dewatering, soil disturbance, and aquifer pumping models are not appropriate to evaluate the impacts of proposed mining on ONWR. These assumptions affect the model's calibration and predictive capabilities for variable conditions, causing the assessment of harm to ONWR to be biased. The use of a steady-state model does not simulate impacts during the sensitive dry periods in ONWR, when any decrease in water can have a large effect on the refuge. The fixed head boundary conditions near ONWR cannot simulate the seasonal and interannual variability in groundwater levels which is evident from the observation data.

Analysis of mine dewatering operations omitted impacts on the portion of ONWR directly downstream of the mine site, and also included model data that should have been discarded. The dewatering estimates show significant impacts on the water budget in the model domain (16% decrease in total water availability) but were not properly tabulated for the portion of ONWR downstream of the mine.

Due to these and other factors, the conclusions made in the Twin Pines permit applications cannot be considered valid until these issues are addressed. The modeling and analysis did not sufficiently prove that ONWR will not be affected by the proposed mining operation.

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