GSI ENVIRONMENTAL

MEMORANDUM

TO: Wei Zeng, Georgia Environmental Protection Division

FROM: Sorab Panday, GSI Environmental

RE: Responses to Georgia EPD Modeling Questions

EXECUTIVE SUMMARY

This memorandum addresses questions that have been raised by Georgia EPD regarding: (1) the distribution of consolidated black sands (CBS) within the study domain, (2) the distribution and continuity of CBS within the mining area, and (3) the hydrogeologic impact of holes in the bentonite layer where the CBS may be absent.

RESPONSES

Question 1: What is the distribution of CBS within the study domain?

Response: The CBS cover approximately 70% of the study area based on cross-sections evaluated by GA EPD (Kennedy, 2020b). My evaluation confirmed GA EPD's calculations: **Figure 1** (reproduced from Figure 4 of GSI, 2021) shows the locations where CBS were present in the soil boring logs. As noted in GSI (2021), there are distinct zones (demarcated visually on the figure) where CBS do and do not exist in the logs. There is also an area just to the west of Trail Ridge near the southern portions of the model domain, which may be a transition zone where boring logs may or may not show CBS presence. Note that this is the location of the highest density of data. The CBS are present in 65% of the borings and cover approximately 77% of the study area, as interpolated in the figure.

Question 2: What is the distribution of CBS within the proposed mining area? Are the CBS continuous in the proposed mining area?

Response: With the exception of two borings along the southeast corner, the CBS were found in all borings within the proposed mining area. The thickness of the CBS is variable where present. For the base case pre-mining condition, the groundwater flow model used boring logs with greater than 1 foot thickness of CBS to interpolate the values across the domain, as shown on **Figure 2** (reproduced from Figure 9 of GSI, 2021). The model was calibrated using water levels and water level differences across the CBS and therefore also evaluates connectivity information across the CBS, which may also indicate absence (or discontinuity) in the CBS. The calibrated hydraulic conductivity of the CBS unit in the model is shown on **Figure 3** (reproduced from Figure 27 of GSI, 2021). As indicated on the figure, the proposed mining area is covered by lower hydraulic conductivity materials, except within its southeastern portion (where **Figure 1** shows a lack of CBS in the boreholes).

Question 3: In the model runs showing the post-mining condition with the soil amendment layer, was the bentonite layer placed throughout the proposed mining area during reclamation, and what would be the impact of "holes" in the bentonite layer where CBS does not exist?

Response: The post-mining case model with the soil amendment included a continuous bentonite layer throughout the proposed mining area. The modeling study also performed a sensitivity analysis on the amount of bentonite that would give the least drawdown from pre-mining conditions, which included a simulation with no bentonite layer. **Figure 4** (reproduced from Figure 39 of GSI, 2021) shows the impact on the water table between pre- and post-mining conditions with no bentonite amendments in the reclaimed sands, indicating that the impacts are restricted only to the proposed mining area and immediate vicinity, with largest drawdowns ranging from 2.01 to 6.65 feet and water level increases of up to 1.76 feet. **Figure 5** (reproduced from Figure 41 of GSI, 2021) shows the impact of a continuous 10.9% bentonite amendment layer on the water table, indicating that the impacts are restricted only to the proposed mining area and immediate vicinity, with largest drawdowns of up to 2.03 feet near the periphery of the mined area and water level increases of up to 5.31 feet in the middle of the mined area.

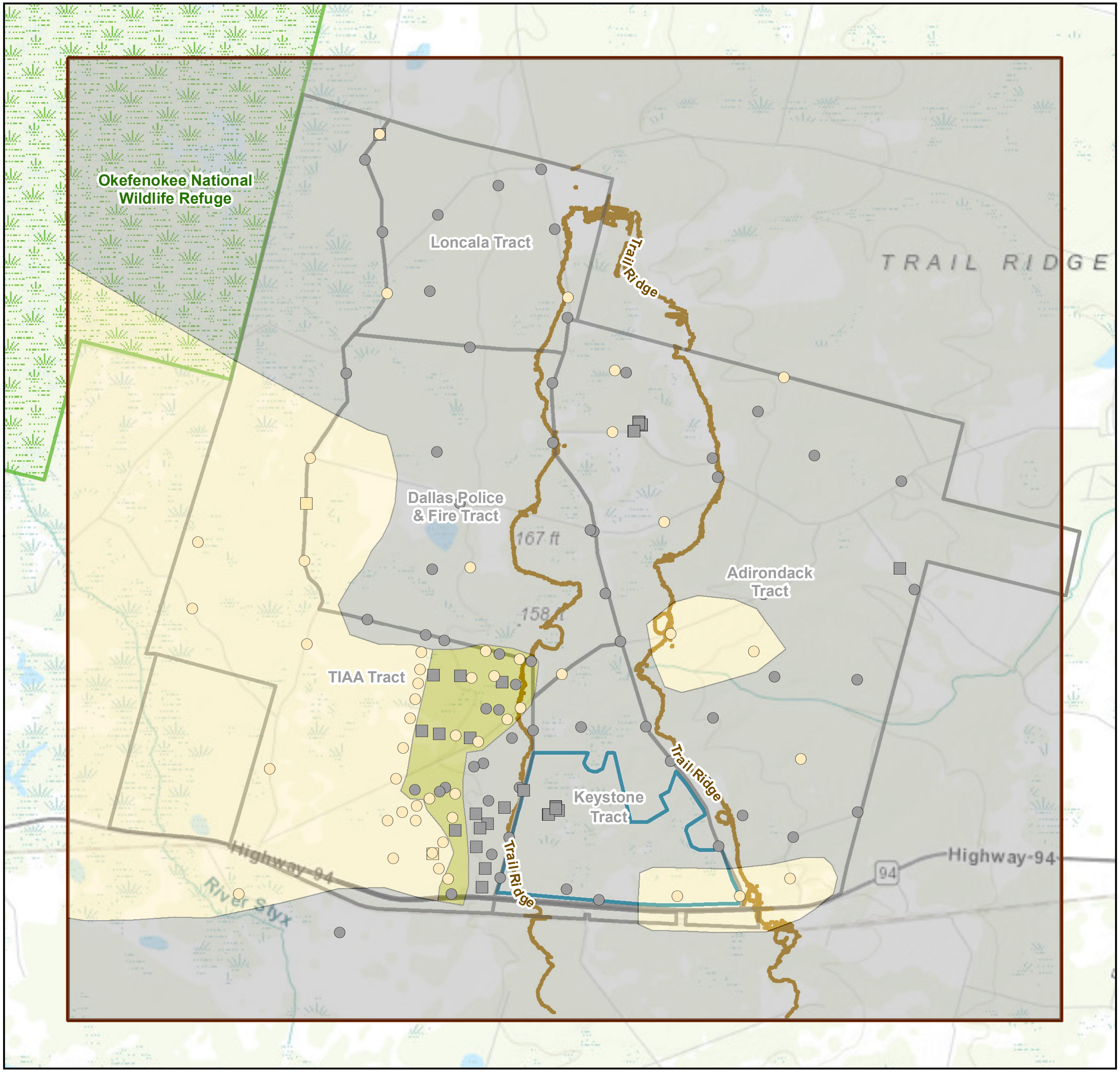
The simulation shown in **Figure 5** includes a continuous 10.9% bentonite amendment layer throughout the post-mined area. However, the connectivity across the CBS may vary depending on its thickness, composition, and possible discontinuities away from the borings. Therefore, a sensitivity study was conducted to examine the effect of “holes” in the bentonite where the CBS was possibly missing or discontinuous. The calibrated model was examined to determine where its hydraulic conductivity is high, and the post-mine model hydraulic conductivity within the bentonite layer was altered to create “holes” in the bentonite where the pre-mine hydraulic conductivity of the CBS was higher than a cut-off limit. A cutoff value of 7.8×10^{-4} ft/d was selected, because that value created holes in the bentonite both east and west of the apex of Trail Ridge (the CBS had values less than 1.0×10^{-3} ft/d on the West side of Trail Ridge, so using that cutoff value would not have put holes in the bentonite to the west).

A sensitivity study was conducted on the 10.9 % bentonite amendment model. **Figure 6** shows the layout of the holes in the bentonite layer (i.e., in locations where the calibrated model CBS hydraulic conductivity value was larger than the cutoff value of 7.8×10^{-4} ft/d). The hydraulic conductivity within these holes was set to 2.8 ft/d, which is the estimated value for the reclaimed sands. About 63% of the mined area is covered with bentonite while the remaining portion of the mined area was modeled with holes in the bentonite. **Figure 7** shows the water level contours for this case, indicating that water flows to the west, west of Trail Ridge, and to the east, east of Trail Ridge. **Figure 8** shows the water table difference for this sensitivity case compared to the pre-mining condition, indicating generally minimal water level changes (between approximately a 0.2 foot water level increase and a 0.99 foot water level decrease) across the majority of the site. Two locations, which coincide with the hole locations depicted on **Figure 6**, exhibited water level decreases of approximately 2.0 feet. **Figure 9** shows the water table difference between the sensitivity case (approximately 63% coverage of a 10.9% bentonite layer) compared to the simulation with a continuous 10.9% bentonite layer depicted in **Figure 5**. As can be seen, the holes provide a water level drop of between 2.01 and 6.08 feet across the mining area. This difference is primarily attributable to water level increases relative to the pre-mining condition caused by the continuous bentonite layer.

Overall, the analysis shows that the placement and distribution of the bentonite layer has a negligible effect on wetlands west of the mine site. **Table 1** shows the water balance for the various cases. As can be seen, there are negligible changes in discharge to the wetlands compared to the pre-mining case, regardless of the bentonite layer structure.

REFERENCES

GSI Environmental, 2021. Modeling The Groundwater Flow System at the Proposed Twin Pines Mine on Trail Ridge. September 14, 2021.



N

LEGEND

- Well With Consolidated Black Sands Absent - Cross Sections
- Well With Consolidated Black Sands Absent - Additional Wells
- Well With Consolidated Black Sands Present - Cross Sections
- Well With Consolidated Black Sands Present - Additional Wells

Consolidated Black Sands (CBS) Classification

- Interpreted Area of Present CBS
- Interpreted Area of Absent
- Interpreted CBS Transition Zone
- Modeling Study Area
- Okefenokee National Wildlife Refuge
- Proposed Mining Area
- Trail Ridge (Elevation > 165 feet)

Notes:
1. Projection: North American Datum 1983 Georgia State Plane East (Feet)
2. Cross Sections refer to those included in Holt et al. (2019g). Additional wells refers to well log information not included in the 2019 cross sections.

Scale in Miles

0 0.5 1

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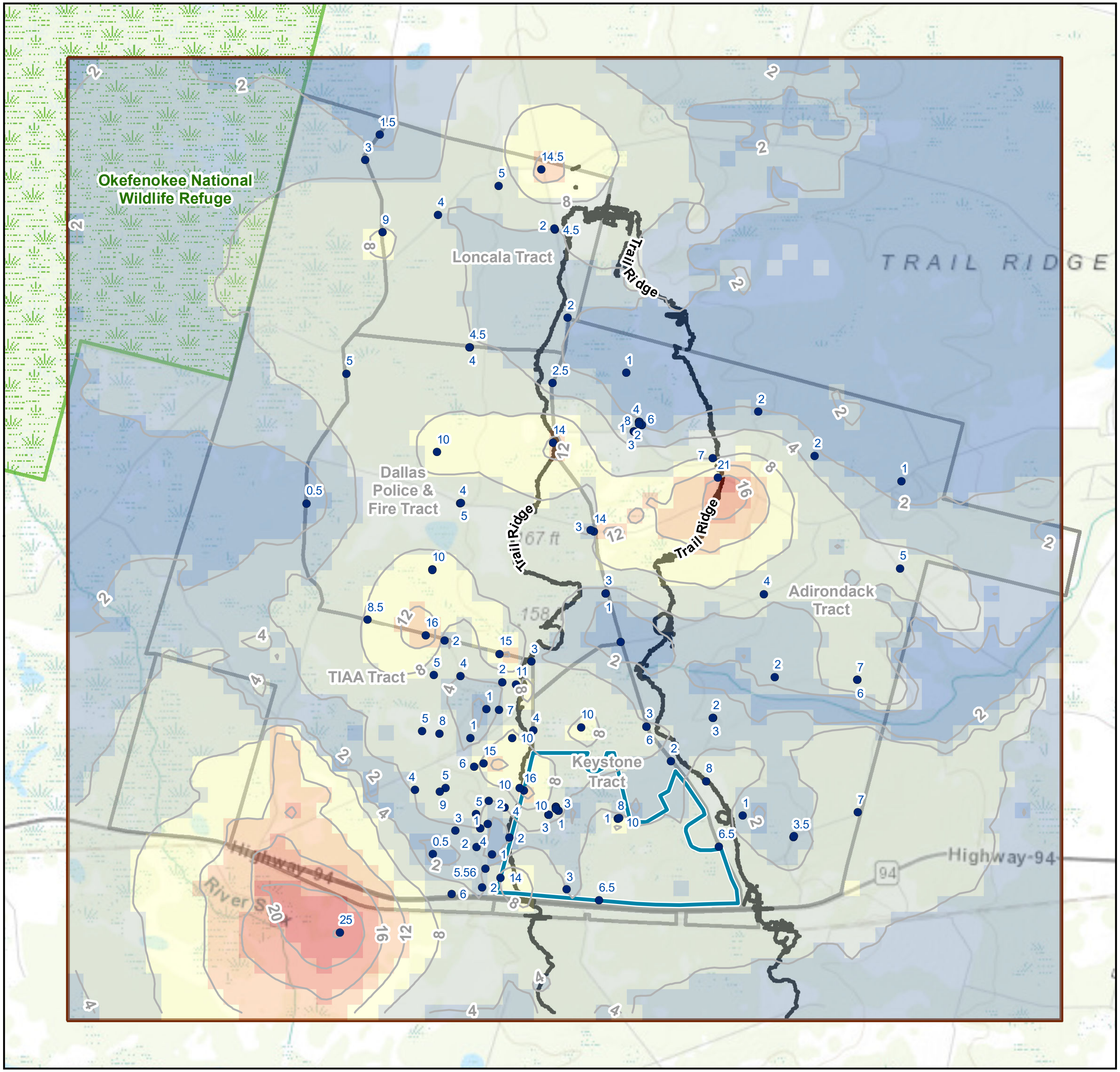
Figure 1
Aerial Distribution of Consolidated Black Sands

Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

GSI Job No. 5844	Drawn By: RLW
Issued: 20-Jul-2021	Chk'd By: SP
Map ID: Figure01	Appv'd By: SP

FIGURE 1



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LEGEND

- Well Log Consolidated Black Sand Thickness (Feet)
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Hydrostratigraphic Unit 2 Thickness Contours (Feet)

Hydrostratigraphic Unit 2 Thickness (Feet)

- 0.50 - 2.00
- 2.01 - 4.00
- 4.01 - 8.00
- 8.01 - 12.00
- 12.01 - 16.00
- 16.01 - 20.00
- 20.01 - 24.52
- Modeling Study Area
- Okefenokee National Wildlife Refuge

Notes:

1. Projection: North American Datum 1983 Georgia State Plane East (Feet)

Scale in Miles

0 0.5 1

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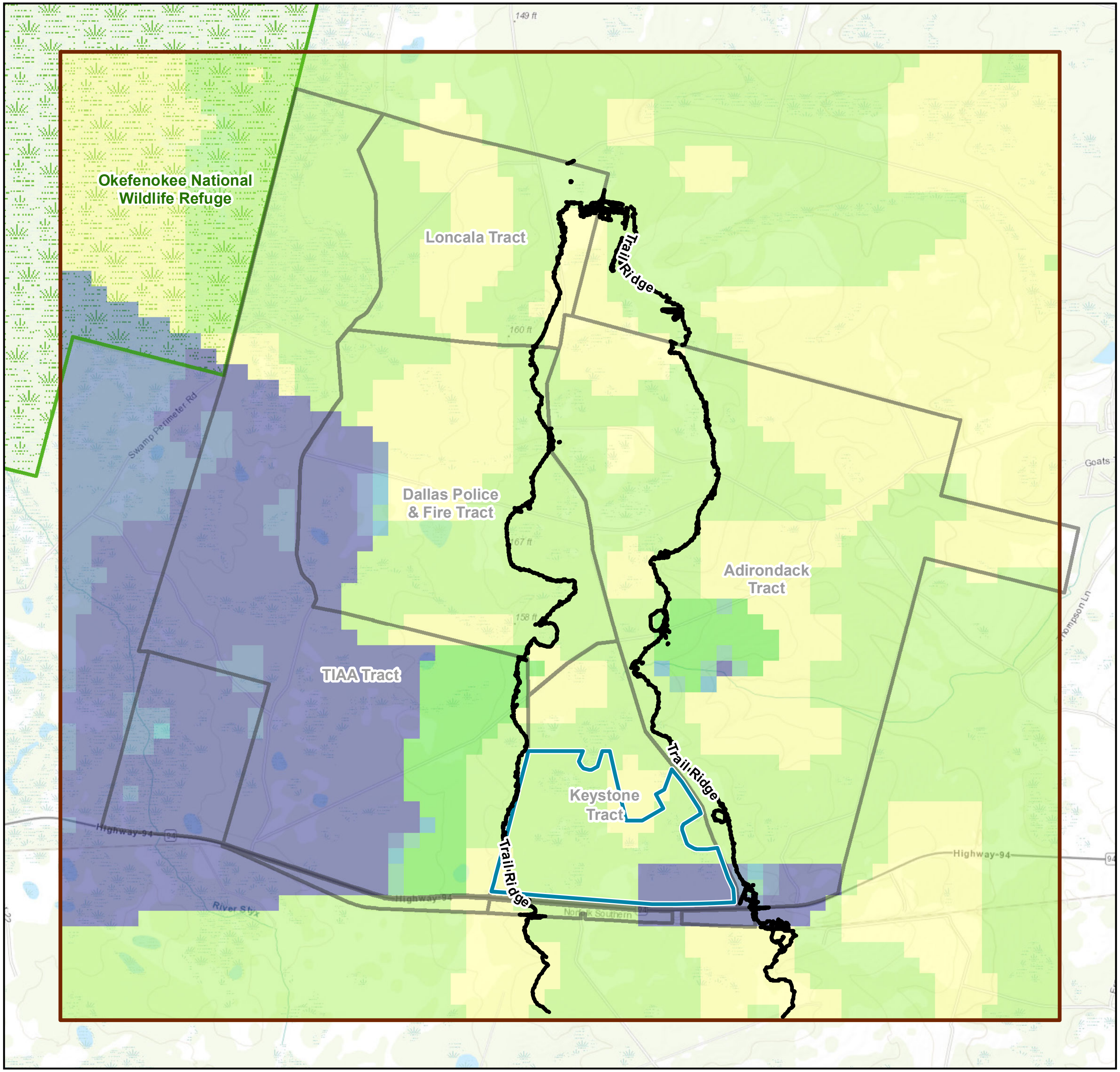
Figure 2
Consolidated Black Sands Sand (Hydrostratigraphic Unit 2) Thickness
Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

GSI Job No. 5844	Drawn By: RLW
Issued: 20-Jul-2021	Chk'd By: SP
Map ID: Figure02	Appv'd By: SP

FIGURE 2



N

LEGEND

- Trail Ridge (Elevation > 165 feet)

Horizontal Hydraulic Conductivity (Feet/Day)

- 0.000040 (1e-8 cm/s) - 0.00028 (1e-7 cm/s)
- 0.00029 (1e-7 cm/s) - 0.0028 (1e-6 cm/s)
- 0.0029 (1e-6 cm/s) - 0.50 (1.8e-4 cm/s)
- 0.51 - 1.0
- 1.1 - 2.0
- 2.1 - 4.0
- 4.1 - 9.3
- Modeling Study Area
- Proposed Mining Area
- Okefenokee National Wildlife Refuge

Notes:

1. HSU = hydrostratigraphic unit
2. Projection: North American Datum 1983 Georgia State Plane East (Feet)

Scale in Miles

0 0.5 1

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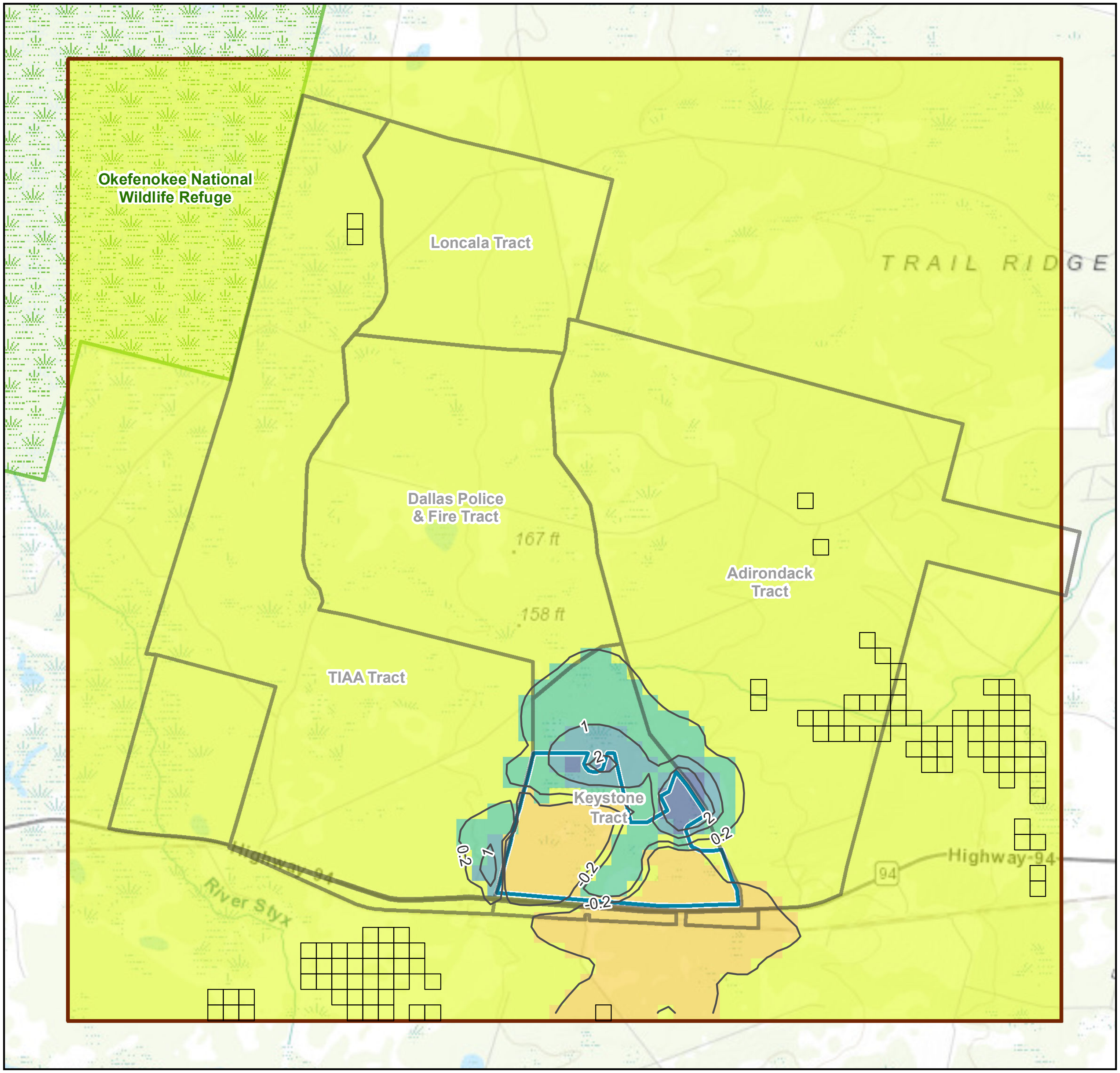
Figure 3
Calibrated Horizontal Hydraulic Conductivity Consolidated Black Sands (HSU 2)
Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

GSI Job No. 5844	Drawn By: GM
Issued: 20-Jul-2021	Chk'd By: SP
Map ID: Figure03	Appv'd By: SP

FIGURE 3



N

LEGEND

Simulated Head Difference (Feet) - Negative (Positive) Values Indicate Water Level Rise (Decrease)

Simulated Water Levels > 5 feet Above Ground Surface

Proposed Mining Area

Modeling Study Area

Simulated Head Difference (Feet) - Negative (Positive) Values Indicate Water Level Rise (Decrease)

- -1.76 - -0.20
- -0.19 - 0.20
- 0.21 - 1.00
- 1.01 - 2.00
- 2.01 - 6.65

Okefenokee National Wildlife Refuge

Notes:
1. Projection: North American Datum 1983 Georgia State Plane East (Feet)

Scale in Miles
0 0.5 1

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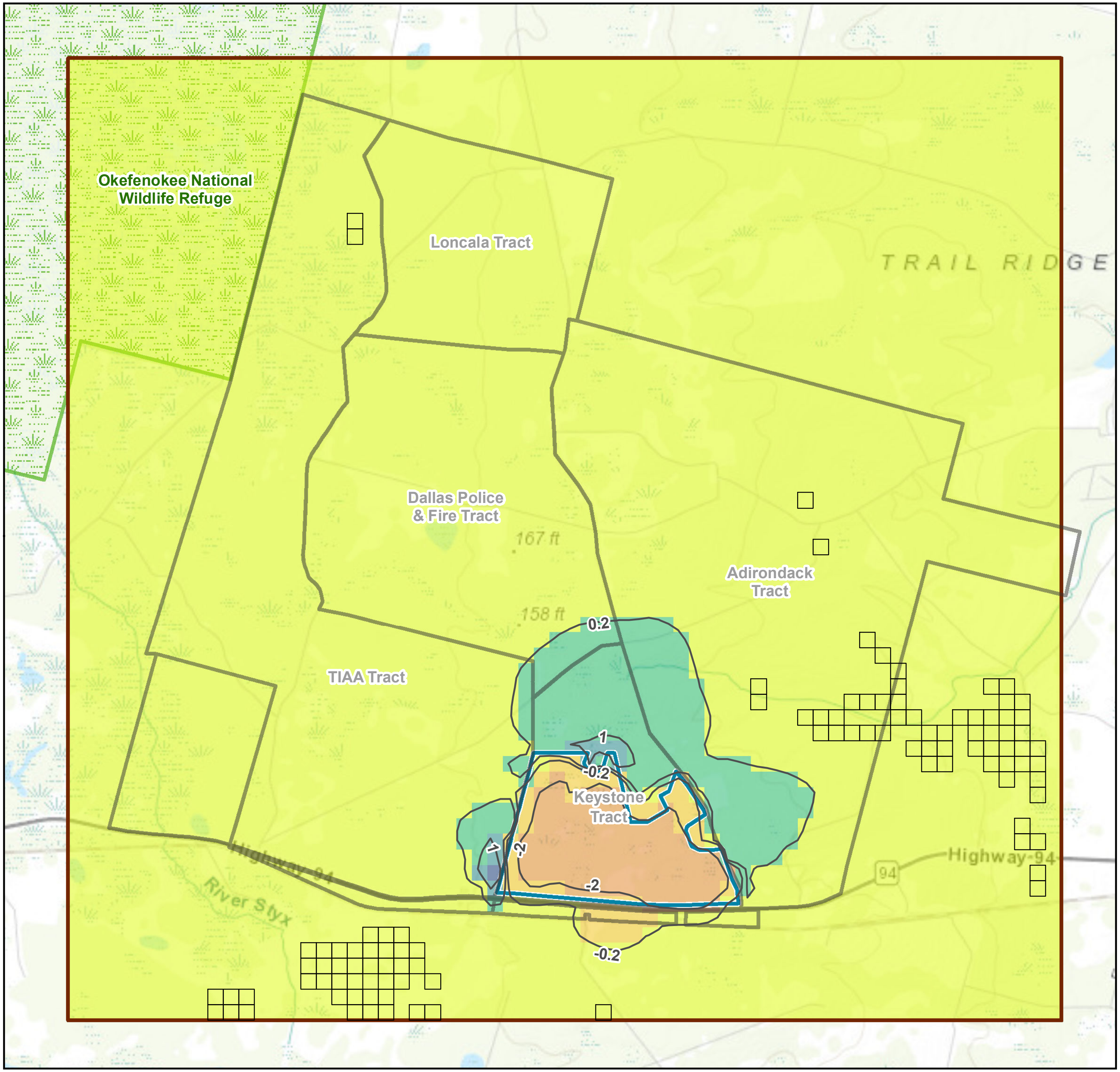
Figure 4
Water Table Difference
No Bentonite Soil Amendment
Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

GSI Job No. 5844	Drawn By: RLW
Issued: 20-Jul-2021	Chk'd By: SP
Map ID: Figure04	Appv'd By: SP

FIGURE 4



N

LEGEND

- Simulated Head Difference (Feet) - Negative (Positive) Values Indicate Water Level Rise (Decrease)
- Simulated Water Levels > 5 feet Above Ground Surface
- Proposed Mining Area
- Modeling Study Area

Simulated Head Difference (Feet) - Negative (Positive) Values Indicate Water Level Rise (Decrease)

- -5.31 - -2.00
- -1.99 - -0.20
- -0.19 - 0.20
- 0.21 - 1.00
- 1.01 - 2.00
- 2.01 - 2.03
- Okefenokee National Wildlife Refuge

Notes:
1. Projection: North American Datum 1983 Georgia State Plane East (Feet)

Scale in Miles

0 0.5 1

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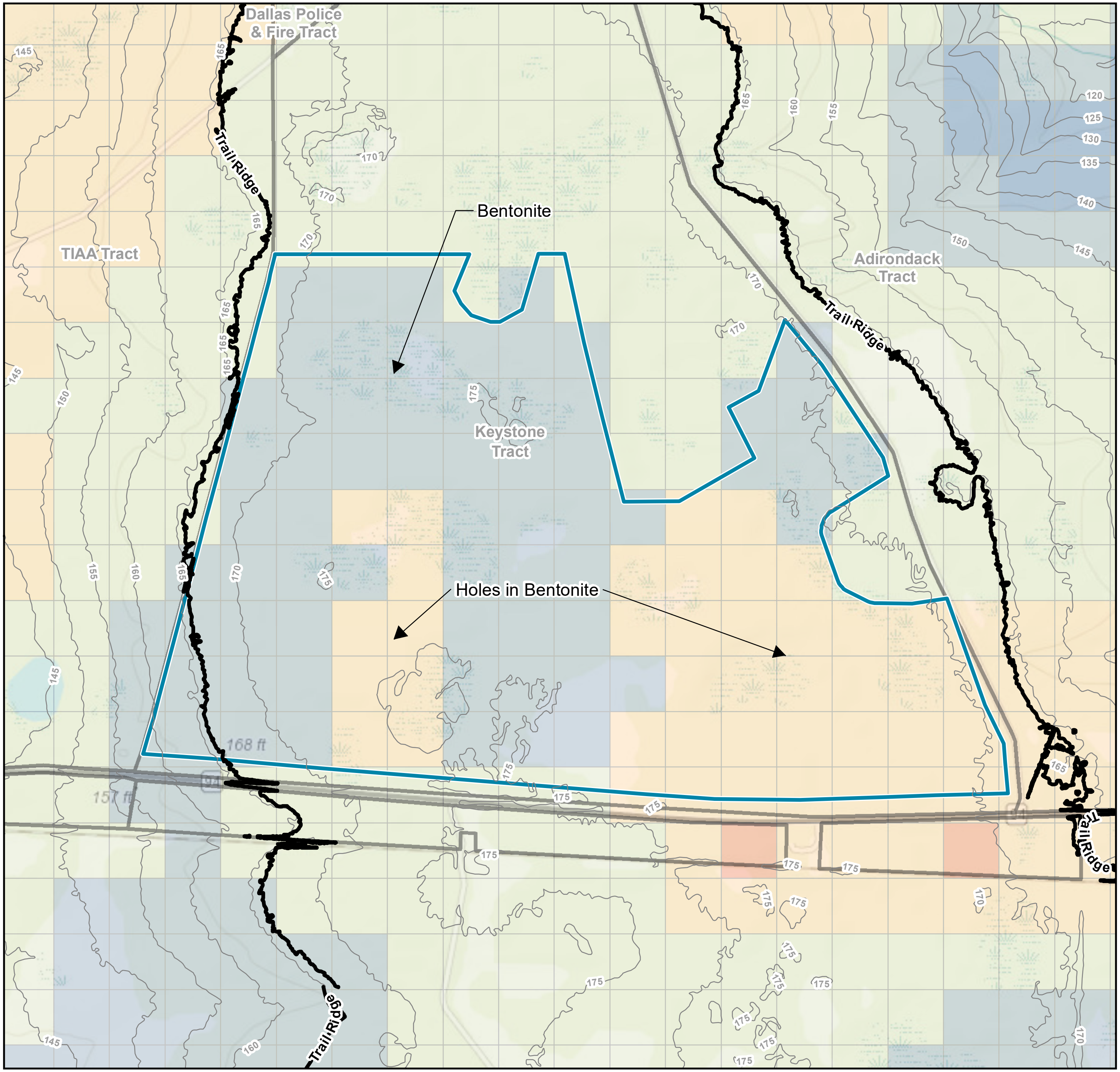
Figure 5
Water Table Difference
10.9% Bentonite Soil Amendment

Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

GSI Job No. 5844	Drawn By: RLW
Issued: 20-Jul-2021	Chk'd By: SP
Map ID: Figure05	Appv'd By: SP

FIGURE 5



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- USGS 10 Feet Elevation Contours
- Proposed Mining Area
- Project Study Tracts

Hydraulic Conductivity (ft/day)

- 0.00003 - 0.000048
- 0.000049 - 0.00028
- 0.000281 - 0.01
- 0.01 - 5.00
- 5.00 - 10.00

Notes

1) Projection: North American Datum 1983 Georgia State Plane East (Feet)

Scale in Miles

0 0.2 0.4

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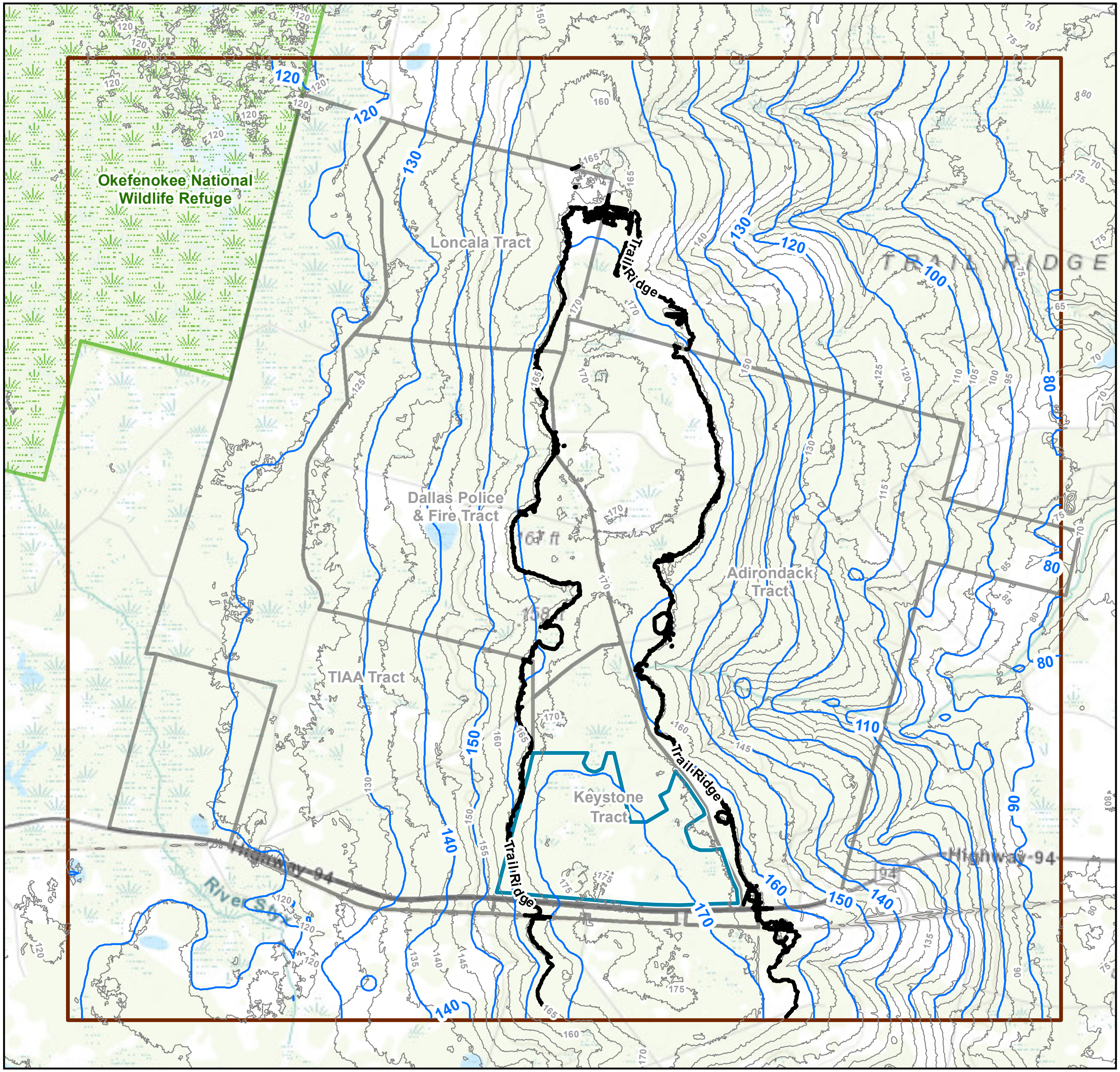
HYDRAULIC CONDUCTIVITY VALUES INDICATING LOCATION OF SIMULATED HOLES IN BENTONITE LAYER FOR SENSITIVITY ANALYSIS

Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

GSI Job No. 6365	Drawn By: RTC
Issued: 5-Sep-2023	Chk'd By: --
Map ID: Figure6	Appv'd By: SP

FIGURE 6



LEGEND

- Trail Ridge (Elevation > 165 feet)
- Simulated Water Level Contours (feet above mean sea level)
- USGS 10 Feet Elevation Contours
- Project Study Tracts
- Modeling Study
- Proposed Mining
- Okefenokee National Wildlife Refuge

Notes

1) Projection: North American Datum 1983 Georgia State Plane East (Feet)

Scale in Miles

0 0.5 1

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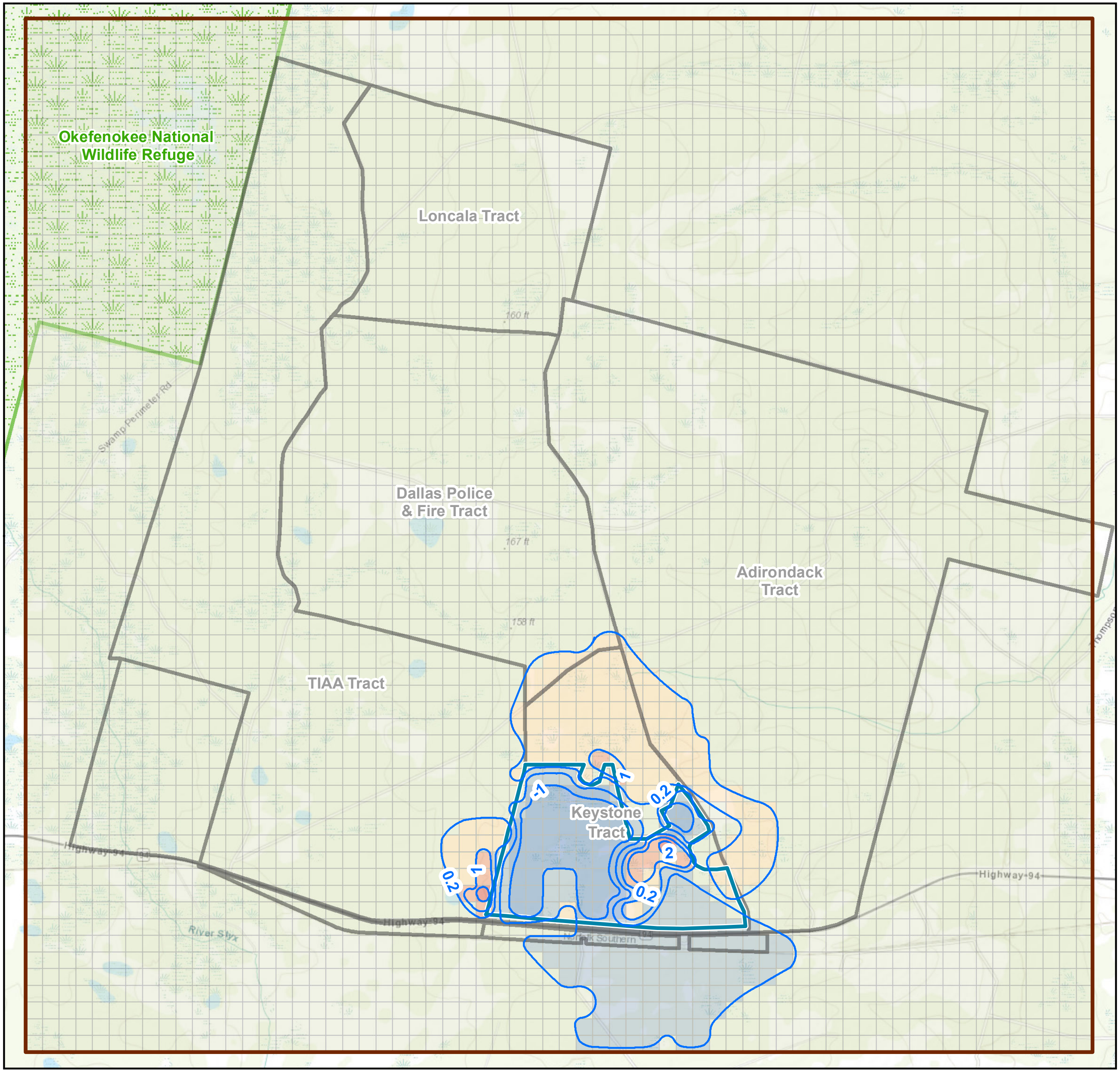
SIMULATED POST-MINING WATER LEVEL CONTOURS FOR SENSITIVITY STUDY WITH HOLES IN BENTONITE LAYER

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia

GSI Job No. 6365	Drawn By: RTC
Issued: 28-Aug-2023	Chk'd By: --
Map ID: Figure7	Appv'd By: SP

FIGURE 7



LEGEND

Simulated Head Difference (feet) - Negative (Positive) Values Indicate Water Level Rise (Decrease)

Modeling Study Area

Proposed Mining Area

Project Study Tracts

Simulated Head Difference (feet) - Negative (Positive) Values Indicate Water Level Rise (Decrease)

-4.26 - -1.00

-0.99 - -0.20

-0.19 - 0.20

0.21 - 1.00

1.01 - 2.00

2.01 - 3.00

Okefenokee National Wildlife Refuge

Notes

1) Projection: North American Datum 1983 Georgia State Plane East (Feet)

Scale in Miles

0 0.5 1

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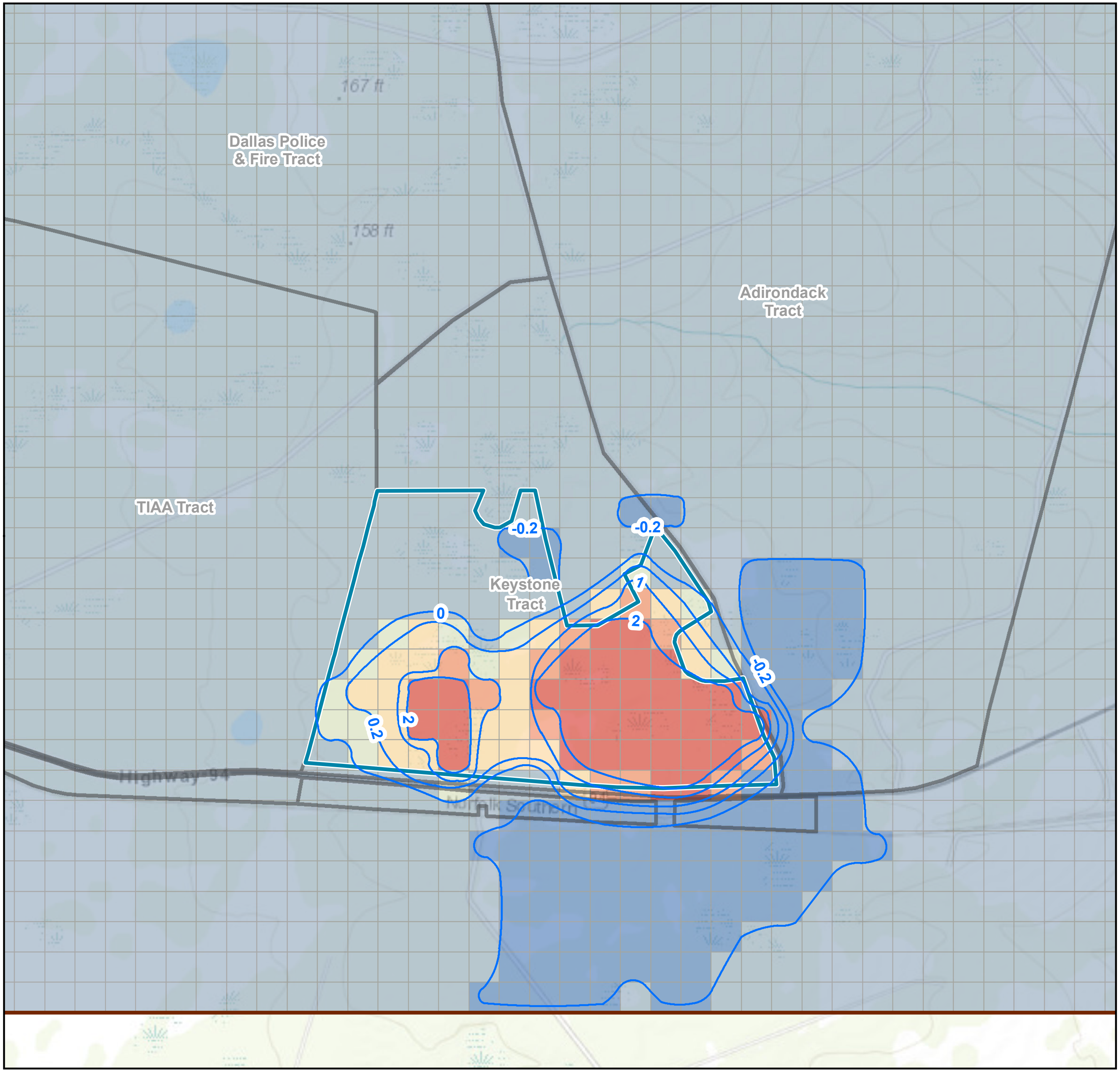
WATER LEVEL DIFFERENCE BETWEEN SENSITIVITY CASE WITH HOLES IN BENTONITE LAYER AND PRE-MINING CONDITION

Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

GSI Job No. 6365	Drawn By: RTC
Issued: 28-Aug-2023	Chk'd By: --
Map ID: Figure8	Appv'd By: SP

FIGURE 8



N

LEGEND

Simulated Head Difference (feet) - Negative (Positive) Values Indicate Water Level Rise (Decrease)

Modeling Study Area

Proposed Mining Area

Project Study Tracts

Simulated Head Difference (feet) - Negative (Positive) Values Indicate Water Level Rise (Decrease)

- -0.75 - -0.20
- -0.19 - 0.00
- 0.01 - 0.20
- 0.21 - 1.00
- 1.01 - 2.00
- 2.01 - 6.08

Notes

1) Projection: North American Datum 1983 Georgia State Plane East (Feet)

Scale in Miles

0 0.25 0.5

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WATER LEVEL DIFFERENCE BETWEEN THE CASE OF HOLES IN BENTONITE LAYER VS. NO HOLES IN BENTONITE LAYER

Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

GSI Job No.: 6365	Drawn By: RTC
Issued: 28-Aug-2023	Chk'd By: --
Map ID: Figure9	Appv'd By: SP

FIGURE 9

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Table 1. Pre- and Post-Mining Water Budget Comparisons for Soil Amendment Bentonite Percentages

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia

Water Budget Component		Pre-Mining			No Bentonite Soil Amendment		
		West[1]	East[2]	Total	West	East	Total
Inflows (gallons per minute)	Recharge	2,669	2,113	4,782	2,669	2,113	4,782
Outflows (as % of Total Recharge and gallons per minute)	Lateral Outflows	1.1%	5.4%	6.5%	1.1%	5.4%	6.5%
		51	258	309	51	258	309
	Outflow to Modflow Drain Package[3]	52.0%	41.5%	93.5%	52.0%	41.6%	93.5%
		2,488	1,984	4,472	2,486	1,987	4,473
Percent Mass Balance Error		0.0%			0.0%		

Water Budget Component		10.9 % Bentonite Soil Amendment			10.9 % Bentonite with Holes Soil Amendment		
		West	East	Total	West	East	Total
Inflows (gallons per minute)	Recharge	2,669	2,113	4,782	2,669	2,113	4,782
Outflows (as % of Total Recharge and gallons per minute)	Lateral Outflows	1.1%	5.4%	6.5%	1.1%	5.4%	6.5%
		51	258	309	51	258	309
	Outflow to Modflow Drain Package	52.1%	41.5%	93.6%	52.1%	41.5%	93.6%
		2,490	1,984	4,474	2,490	1,983	4,473
Percent Mass Balance Error		0.0%			0.0%		

Notes:

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