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September 17, 2021

Transmitted Via: Email (Jamie.Lancaster1@dnr.ga.gov)

Ms. Jamie Lancaster
Surface Mining Unit
Georgia Department of Natural Resources
Environmental Protection Division
4244 International Parkway, Suite 104
Atlanta, Georgia 30354

Subject: *Revised MLUP and Response to EPD Permit Coordination Comments 9.10.21*
Twin Pines Minerals, LLC
Saunders Demonstration Mine
Charlton County, Georgia
EPD Mine ID No. 2073

Dear Ms. Lancaster:

Transmitted herewith is a revised copy of the Mining Land Use Plan (MLUP) and responses to the Georgia Environmental Protection Division's (EPD's) letter dated September 10, 2021, which provided review comments to the Surface Mining Application, Mining Land Use Plan and Exhibits submitted by Twin Pines Minerals, LLC (TPM) on June 25 and July 16, 2021. These documents/responses consist of the following:

- Revised MLUP for the purpose of:
    - Addressing EPD comments.
    - Removing reference to NPDES wastewater permitting. The facility will operate with no discharge of wastewater.
    - Expanding the permit area to 735 acres to account for two additional water management ponds.
- A summary of changes to each sheet of the revised MLUP.
- Line by line responses to EPD's Permit Coordination Comments dated September 10, 2021.
- The Provisions Checklist and Checkist Explanation documents, which have been revised to remove the NPDES wastewater permitting references.
- The Surface Mining Application Form, which has been revised for the change of the permit acreage and removal of the NPDES wastewater permit.

Please contact the undersigned with any questions.

Sincerely,
TTL, Inc.

Sheryle G. Reeves, P.E.
Principal Engineer

James R. Smith, P.G.
Principal Geologist

Summary of Revisions to Sheets 1 through 14 of the Revised MLUP

- Sheet 1 – Revised the shape of the permit boundary. Removed the NPDES outfall segment and added area to account for two storage ponds and extra space if needed in the future.
- Sheet 2 – Revised the shape of the permit boundary & permit acreage in legend.
- Sheet 3 – Revised the shape of the permit boundary & permit acreage in legend; removed NPDES wastewater discharge/outfall and treatment pond references from layout, legend, and notes; added the sand processing area and mine pit water management ponds; removed unnecessary callouts at the proposed minerals separation plant area (outside the permit area).
- Sheet 4 – Revised the shape of the permit boundary & permit acreage in legend.
- Sheet 5 – Updated the Mining Process Flow Diagram to reflect zero wastewater discharge.
- Sheet 6 – Revised the shape of the permit boundary & permit acreage in legend; removed NPDES discharge/outfall and treatment pond references from layout, legend, and notes; added the water management storage ponds and stormwater outfall 007.
- Sheet 7 – Updated Erosion Control Notes subsection NPDES Notes #2 and #3 to remove references to wastewater discharge/outfall (right side of the page).
- Sheet 8 – Added additional text to Soil Amendment Plan - General grammatical revisions to text.
- Sheet 8 – Added additional text to Soil Amendment Plan – Section 1.1: Bullet 5 to address EPD Comment #1 (regarding bentonite placement below the water table).
- Sheet 8 – Added additional text to Soil Amendment Plan – Section 1.2.4: last sentence of first paragraph to address EPD Comment #1 (last sentence of sheet 12 comment – regarding bentonite layer will be continuous).
- Sheet 8 - Added post-mining generalized cross-section of the mine foot print to address EPD Comment #1 (last sentence of sheet 12 comment – added cross section with projected bentonite layer in place).
- Sheet 9 – Revised the shape of the permit boundary & permit acreage in legend. Removed reference for non-jurisdictional wetlands.
- Sheet 10 – Revised text and footnotes in Tables 3.2.1 & 3.2.3 to address EPD Comment #1.
- Sheet 11 – Revised the shape of the permit boundary & permit acreage in legend.
- Sheet 12 – Revised generalized geologic cross-section D-D' to show the black consolidated sand as being continuous near the ~155 ft amsl elevation to address EPD Comment #1 for Sheet 12.
- Sheet 13 – Revised the shape of the permit boundary & permit acreage in legend.
- Sheet 14 – Revised text to the Supplemental Narrative:
  - General grammatical revisions to text.
  - Revised Section 3.1 (updated acreage and the center of site longitude/latitude).
  - Revised Section 5.1.2 second paragraph (indicates the facility will operate with no discharge of wastewater, removes language regarding NPDES permitted outfall, and adds language about new holding water management ponds and water reuse).
  - Revised Section 5.1.2 fifth paragraph (addresses pit dewatering and water management).
  - Revised Section 9 (removed bullet referencing NPDES permit).
  - Revised Section 11 (Revised GSI model report).

Response to EPD Comments

Twin Pines Minerals, LLC (TPM) has reviewed the Twin Pines Permit Coordination Document provided by the EPD, dated September 10, 2021, and offers the following responses. Each comment is presented below, followed by TPM's response.

1. Mining Land Use Plan Comments by Surface Mining Unit and James L. Kennedy Ph.D., P.G.

EPD Comment - Sheet 8: 1. Soil Amendment Plan: 1.1 bullet five states that "because the sand/bentonite mixture is very cohesive, it can be cast into the open pit whether it is wet or dry without separating". The model done by GSI simulated a 10.9 percent mixture with bentonite would be sufficient to reproduce the effect of the shallow consolidated black sand layer. A mixture of 89 percent sand and 11 percent bentonite will not have enough cohesion to prevent Stokes Law separation of the sand and clay if it is placed in a mine pit filled with water. Please explain how the blended sand/bentonite material will be placed at the design level/interval below the water table in the mine excavation in a manner that does not allow the bentonite to separate from the sand, or explain how the mine excavation will be temporarily dewatered to allow placement of the blended sand/bentonite material.

> Response: Text has been added to Section 1.1 bullet #5 of Sheet 8 that states "if groundwater rises above the elevation where the sand/bentonite mixture will be placed, the mine pit will temporarily be dewatered to allow placement of the blended sand/bentonite material. Water withdrawn from the active mining pit will be pumped to the water management pond and subsequently reused by the facility.

EPD Comment - Sheet 10: Groundwater & Surface Water Monitoring Plan (1) Section 3.2: For Groundwater and Surface Water Location tables, please modify number 3 on each table with a clearer statement. For example, "Post-mining Monitoring will begin at the end of active mining for a period of approximately 5 years". (This example is based off the projected 5-year mining plan in the MLUP.) Also, please add a number 4 below each table that states "EPD may require an extension of the monitoring plan if necessary".

> Response: Footnotes 3 and 4 of Tables 3.2.1 and 3.2.3 of Sheet 10 have been revised/added to address the comment above.

EPD Comment - The only leaching tests of the mine spoil have been done with groundwater flowing through the mine spoil. Leaching tests must be done with native rain fall and the mine spoil since it is the native rainfall, with a slightly lower pH, which will be the majority of the water which over the long term will interact with and possibly leach metals from the mine spoil and discharge to surface water.

> Response: The memorandum documenting the results of leaching test performed on site soil using native rainwater was submitted on July 16, 2021. Jacobs Memorandum "Addendum to the November 12, 2020 Saunders Demonstration Mine Geochemical Testing and Evaluation" is being resubmitted.

EPD Comment - Sheet 12: Groundwater & Surface Water Monitoring Plan (3): Cross section D-D' shows the upper consolidated black sand layers as discontinuous from wells MPZ-10S/D to MPZ-13S/D at ~155ft above sea level. The black sand layer is ~70% continuous and therefore the cross sections must show horizontality at this elevation. Please include a note on the reclamation page *stating that the bentonite later will be 100% continuous and a projected cross section of the final reclamation with the bentonite in place.*

Response: The generalized geologic cross-section D-D' shown on Sheet 12 has been revised to depict the black consolidated sand as being continuous near the ~155 ft amsl elevation. Text has been added to Section 1.2.4 (last sentence of first paragraph) of the Soil Amendment Plan that states the bentonite layer will be continuous unless TPM receives approval from EPD to discontinue the application of the soil amendment layer. A post-mining generalized geologic cross section with the projected bentonite layer has been added to Sheet 10.

2. Exhibit I Modeling the GW Flow System Comments James L. Kennedy Ph.D., P.G.

EPD Comment - Page 1: The description of the method to be used to place the bentonite-enhanced layer of soil will not work given that the mine pit will not be dewatered. It was noted that placement of the bentonite-enhanced soil layer is not a modeling issue, which is correct, but the description of the process on Page 1 must say placement of the bentonite-enhanced soil layer cannot be simulated by the model.

Response: The GSI modeling report text has been updated as requested in Section 1.0 that provides the Executive Summary (page 1) as well as in Section 7.0 on Post-Mining Analysis section (page 11).

EPD Comment - Page 8: Explicitly explain what use of the drains versus rivers means in the model. In MODFLOW drains can receive water from the modeled aquifer but cannot recharge the modeled aquifer. A river can both receive water from the modeled aquifer and discharge water to the modeled aquifer. Explain that the drains were modeled based on the surface water courses shown on Figures 22 and 23. Explain that no rivers were modeled because there are no rivers within the model domain.

Response: The GSI modeling report text (Section 4.3 Model Boundary Conditions – page 9) has been updated as requested.

EPD Comment - Page 8: Say how many grids there are in the mining area (there are enough grids).

Response: The GSI modeling report text has been updated as requested, in Section 4.1 on Model Discretization (page 8).

EPD Comment - Page 12: Please say explicitly if the addition of bentonite was simulated in the mining area shown on Figure 3 (and later figures) or if it was simulated for the entire are (it was simulated in the mining area shown on Figure 3 but that needs to be clarified in the report).

Response: The modeling report text has been updated as requested in Section 7.0 on Post-Mining Analysis section (page 12).

EPD Comment - Does the software used for the model include an LGR (Local Grid Refinement) capability? If it does LGR should be used to model the mine area. LGR could be used to model the mine area at a grid size of 250 ft. x 250 ft. LGR is not needed to make the model acceptable but it would be helpful to see a more detailed numerical analysis of the mining area.

Response: Local grid refinement (LGR) capability can be directly implemented for models built using MODFLOW-2005 but not with the MODFLOW-NWT code that was used for simulation of the proposed Twin Pines Minerals, LLC Saunders Demonstration Mine project.

Revising the code to MODFLOW-USG would allow grid refinement specific to the proposed mine area; however, this would also introduce unnecessary complexity to the modeling effort and, therefore, no changes to the modeling code have been implemented.

ATTACHMENT A

Supporting Document for Response to Comment #1

Jacobs Memorandum - *Addendum to the November 12, 2020 Saunders Demonstration Mine Geochemical Testing and Evaluation* – Dated July 12, 2021

Memorandum Addendum

July 2021 Addendum to the Nov 2020 Geochemical Testing and Evaluation Memorandum

Subject	Addendum to the November 12, 2020 Geochemical Testing and Evaluation Memorandum	**Project Name**	Saunders Demonstration Mine
Attention	TTL, Inc. Twin Pines Minerals, LLC		
From	Robert ("B.T.") C. Thomas, M.S., Ph.D., Jacobs Engineering Group, Inc. (Jacobs)		
Date	July 12, 2021		
Copies to	Galloway & Lyndall LLP King & Spalding LLP		

Dr. James L. Kennedy, the State Geologist with the Georgia Environmental Protection Division (GA EPD) provided review comments of the Technical Response to Review Comments Provided by State Geologist & Supporting Documents (TTL, Inc., 2020). These comments were received as part of the Twin Pines Permit Coordination Document prepared by GA EPD on April 14, 2021. Comment 5.h. is specifically directed at the Geochemical Testing and Evaluation Memorandum prepared by Jacobs in November 2020. This addendum provides the data requested in that comment and during subsequent discussions between Dr. James L. Kennedy and Twin Pines Minerals, LLC. To address Dr James L. Kennedy's requests, Jacobs coordinated further laboratory analysis of samples from the Twin Pines Minerals, LLC Saunders Demonstration Mine site as detailed below.

Response to comment: *Please include a demonstration of Floridan aquifer groundwater chemistry versus local rainwater chemistry in the report.*

The initial SPLP testing conducted in 2020 used two end-member waters: 1) an aliquot of Floridan Aquifer water taken from a municipal well and 2) shallow groundwater collected from well OWB-2S within the proposed mine area. The initial SPLP testing was a blend of these two waters ranging from all Floridan Aquifer to all local shallow groundwater. A comparison of the analytical chemistry of 2020 samples from the Floridan Aquifer and the local shallow groundwater sampled from well OWB-2S, verses rainwater collected from the site in May 2021 is provided in the table below. In general, the three waters vary only in major cations (i.e., Ca, Mg, K, and Na) and anions (i.e., alkalinity, chloride, nitrate, and sulfate); there is no significant difference for almost all trace metals analyzed between the three waters. The one difference is mercury which is non-detect in the Floridan Aquifer, detected in the shallow groundwater at approximately 0.68 ng/L, but not quantifiable, and detected in the rainwater at approximately 4.2 ng/L, but not quantifiable. The other notable difference between the two groundwater samples and the rainwater sample is the pH with both groundwater samples having a slightly alkaline pH (7.5 and 7.3), while the rainwater sample is slightly acidic (pH 5.6). While a slightly more acidic pH can have an impact on the mobility of certain metals (e.g., aluminum), there is no buffering capacity in the rainwater and given the high solids:water ratio of infiltrating rainwater relative to the deposited tailings, the impacts of a slightly acidic pH would be minimal.

As a verification, the SPLP extractions conducted in 2020 using end-member blends of Floridan Aquifer with local shallow groundwater were repeated using rainwater collected from the site on 05/06/2021 (as presented in Table 1). Results from the SPLP extraction are presented in Table 2 and in Figure 1. The data presented in Table 1 is repeated in Table 2 as the "blank" analysis for the SPLP. In general, the rainwater extractions yielded similar or lower metal concentrations in the leachate relative to both the shallow groundwater and Floridan Aquifer leach tests. One exception is aluminum which is leached at a slightly higher concentration in the rainwater SPLP relative to the other two waters tested. This is likely due to the pH sensitivity of aluminum; however, any aluminum mobilize in the unsaturated zone of the deposited tailings would reprecipitate in the saturated zone of the local shallow groundwater where the pH is closer to the minimum solubility for aluminum. Mercury is leached from the black humate sands at a level slightly higher with rainwater than the other leach waters, but black humate sands will not be part of the final tailings, which will be either humate isolates or post-processed sand. Moreover, the amount of mercury leached from the black humate sands by the rainwater is within the dynamic range of mercury leached from all samples tested and is within the expected natural variation within the samples.

In conclusion, we find that the chemistry of the local rainwater is comparable to the local shallow groundwater. The Floridan Aquifer water is slightly more mineralized than both waters. There is no major difference in the SPLP extractions when using rainwater versus either the Floridan Aquifer water or the local shallow groundwater. These results of these requested analysis support the conclusion in the original submittal that mobilization of trace metals will not occur following deposition of the mine tailings. Rainwater infiltration through the upper approximately 5 ft of unsaturated tailings will not leach any significant concentration of metals to the shallow groundwater and the tailings deposited in the saturated zone of the local shallow groundwater will not liberate metals from leaching by the shallow groundwater. Migration of trace metals within the local shallow groundwater of this proposed mine area will be within the limits of natural variation in metal concentrations already measured in the shallow groundwater.

Table 1. Comparison of Rainwater Chemistry versus Local Shallow Groundwater and Floridan Aquifer
July 2021 Addendum to the November 2020 Geochemical Testing and Evaluation Memorandum

Analyte	Units	Floridan Aquifer		Shallow Groundwater		Rain Water	
Alkalinity, Bicarbonate	mg/L	170		12		12	I
Alkalinity, Carbonate	mg/L	5	U	5	U	5	U
Alkalinity, Total	mg/L	170		12		12	I
Aluminum	mg/L	0.02	U	0.08		0.2	U
Ammonia (N)	mg/L	0.2		0.33		0.41	
Antimony	mg/L	0.003	U	0.003	U	0.007	U
Arsenic	mg/L	0.008	U	0.0081	I	0.0005	U
Barium	mg/L	0.04		0.044		0.003	I
Beryllium	mg/L	0.002	U	0.002	U	0.002	U
Boron	mg/L	0.1	U	0.1	U	0.1	U
Bromide	mg/L	0.1	U	0.1	U	0.2	U
Cadmium	mg/L	0.0005	U	0.0005	U	0.001	U
Calcium	mg/L	68		1.7		3.9	
Chloride	mg/L	30		11		2	U
Chromium	mg/L	0.0082	I	0.0083	I	0.005	U
Cobalt	mg/L	0.001	U	0.001	U	0.001	U
Color	PCU	15		40		N/A	
Conductivity	umhos/cm	571		65		151	
Copper	mg/L	0.01	U	0.01	U	0.01	U
Cyanide	mg/L	0.0097	U	0.0097	U	0.004	U
DO Saturation %	%	109.7		103.9		8.92	
Fluoride	mg/L	0.37	I	0.05	U	0.2	U
Iron	mg/L	0.2	U	0.2	U	0.2	U
Lead	mg/L	0.0037	I	0.003	U	0.003	U
Magnesium	mg/L	29		1.2		0.66	
Manganese	mg/L	0.005	U	0.024		0.005	U
Mercury	ng/L	0.5	U	0.68	I	4.2	I
Molybdenum	mg/L	0.004	U	0.004	U	0.004	U
Nickel	mg/L	0.01	U	0.01	U	0.01	U
Nitrate (as N)	mg/L	0.069	I	0.05	U	0.61	I
Nitrite (as N)	mg/L	0.05	U	0.05	U	0.2	U

Analyte	Units	Floridan Aquifer		Shallow Groundwater		Rain Water	
ORP-2580BW	mV	90.7		116.3		N/A	
pH	SU	7.52		7.31		5.63	
Potassium	mg/L	2		0.5	U	0.5	U
Selenium	mg/L	0.04	U	0.04	U	0.0025	U
Silicon	mg/L	18		4.8		0.2	U
Silver	mg/L	0.008	U	0.008	U	0.001	U
Sodium	mg/L	24		8.6		0.96	I
Sulfate	mg/L	130		0.5	U	2	U
Temperature	°C	16.8		14.1		23.2	
Thallium	mg/L	0.01	U	0.01	U	0.01	U
Thorium	ug/L	0.36	U	0.073	U	0.5	U
Tin	mg/L	0.04	U	0.04	U	0.04	U
Titanium	mg/L	0.002	U	0.002	U	0.002	U
Total Dissolved Solids	mg/L	430		73		10	U
Total Hardness (as CaCO3)	mg/L	290		9.3		12	
Total Kjeldahl Nitrogen	mg/L	0.16		0.31		0.572	
Total Organic Carbon	mg/L	3.5	I	8.6		1.4	I
Total Phosphorus (as P)	mg/L	0.055	U	0.061	I	0.15	U
Total Suspended Solids	mg/L	2		6		N/A	
Turbidity	NTU	1.85		6.36		N/A	
Uranium	ug/L	0.35	U	0.07	U	0.4	U
Zinc	mg/L	0.05	U	0.05	U	0.05	U

Table 2. Comparison of SPLP Test Results Using Rainwater, Local Shallow Groundwater, and Floridan Aquifer Water as Leach Solutions for Samples of Post-Processed Sands, Humate Isolates, and Black Humate Sands
July 2021 Addendum to the November 2020 Geochemical Testing and Evaluation Memorandum

Analyte	Unit	Shallow Groundwater (SGW)		Floridan Aquifer (FA)		Rain Water (RW)		Post-Processed Sand (SGW)		Post-Processed Sand (FA)		Post-Processed Sand (RW)		Humate Isolates (SGW)		Humate Isolates (FA)		Humate Isolates (RW)		Black Humate Sand (SGW)		Black Humate Sand (FA)		Black Humate Sand (RW)	
Alkalinity, Bicarbonate	mg/L	12		170		12	I	24		160		17	I	160		180		18	I	10		64		38	
Alkalinity, Carbonate	mg/L	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U
Alkalinity, Total	mg/L	12		170		12	I	24		170		17	I	160		180		18	I	10		64		38	
Aluminum	mg/L	0.08		0.02	U	0.2	U	0.12		0.4		0.66	I	0.26		0.38		0.91		0.18		0.093		1.7	
Ammonia (N)	mg/L	0.33		0.2		0.41		0.29		0.21		0.32		0.14		0.08	I	0.18		0.34		0.2		0.13	
Antimony	mg/L	0.003	U	0.003	U	0.007	U	0.003	U	0.003	U	0.007	U	0.003	U	0.003	U	0.007	U	0.003	U	0.003	U	0.007	U
Arsenic	mg/L	0.0081	I	0.008	U	0.0005	U	0.008	U	0.008	U	0.0005	U	0.008	U	0.008	U	0.0005	U	0.009	I	0.0091	I	0.0009	I
Barium	mg/L	0.044		0.04		0.003	I	0.044		0.034		0.0074		0.0045	I	0.011	I	0.024		0.042		0.027		0.019	
Beryllium	mg/L	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U
Boron	mg/L	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	I	0.1	U	0.1	U	0.1	U	0.23	I
Bromide	mg/L	0.1	U	0.1	U	0.2	U	0.1	U	0.1	U	0.2	U	0.1	U	0.1	U	0.2	U	0.1	U	0.1	U	0.2	U
Cadmium	mg/L	0.0005	U	0.0005	U	0.001	U	0.0005	U	0.0005	U	0.001	U	0.0005	U	0.0005	U	0.001	U	0.0005	U	0.0005	U	0.001	U
Calcium	mg/L	1.7		68		3.9		4.6		64		3.2		78		160		2.1		1.8		38		1.9	
Chloride	mg/L	11		30		2	U	11		29		2	U	11		29		2	U	11		29		2.2	I
Chromium	mg/L	0.0083	I	0.0082	I	0.005	U	0.0095	I	0.0069	I	0.005	U	0.0071	I	0.016	I	0.005	U	0.005	U	0.005	U	0.005	U
Cobalt	mg/L	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U
Color	PCU	40		15		N/A		150		200		N/A		15000		20000		N/A		150		500		N/A	
Conductivity	umhos/cm	65		571		151		68		477		56		385		453		69		72		379		93	
Copper	mg/L	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U
Cyanide	mg/L	0.0097	U	0.0097	U	0.004	U	0.0097	U	0.0097	U	0.004	U	0.0097	U	0.0097	U	0.004	J4U	0.0097	U	0.0097	U	0.004	U
DO Saturation %	%	103.9		109.7		8.92		102.5		101.4		7.78		92.2		98.4		8.25		100.7		104.9		7.52	
Fluoride	mg/L	0.05	U	0.37	I	0.2	U	0.05	U	0.29	I	0.2	U	0.05	U	0.05	U	0.2	U	0.05	U	0.05	U	0.2	U
Iron	mg/L	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.23	I	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U
Lead	mg/L	0.003	U	0.0037	I	0.003	U	0.003	U	0.003	U	0.003	U	0.003	U	0.003	U	0.003	U	0.003	U	0.003	U	0.003	U
Magnesium	mg/L	1.2		29		0.66		2.6		29		1.3		2.3		20		0.53		1.3		23		0.36	I
Manganese	mg/L	0.024		0.005	U	0.005	U	0.025		0.005	U	0.005	U	0.005	U	0.005	U	0.005	U	0.026		0.005	U	0.005	U
Mercury	ng/L	0.68	I	0.5	U	4.2	I	4.9		8.7		11		140		11		24		16		55		70	
Molybdenum	mg/L	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U
Nickel	mg/L	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U
Nitrate (as N)	mg/L	0.05	U	0.069	I	0.61	I	0.052	I	0.057	I	0.59	I	0.12	I	0.17	I	0.62	I	0.059	I	0.052	I	0.64	I
Nitrite (as N)	mg/L	0.05	U	0.05	U	0.2	U	0.05	U	0.05	U	0.2	U	0.05	U	0.05	U	0.2	U	0.05	U	0.05	U	0.2	U

Analyte	Unit	Shallow Groundwater (SGW)		Floridan Aquifer (FA)		Rain Water (RW)		Post-Processed Sand (SGW)		Post-Processed Sand (FA)		Post-Processed Sand (RW)		Humate Isolates (SGW)		Humate Isolates (FA)		Humate Isolates (RW)		Black Humate Sand (SGW)		Black Humate Sand (FA)		Black Humate Sand (RW)	
ORP-2580BW	mV	116.3		90.7		N/A		106.2		119.6		N/A		106.3		120.1		N/A		118.5		109.2		N/A	
pH	SU	7.31		7.52		5.63		27.3		6.92		7.17		7.31		6.9		7.03		6.96		7.33		7.58	
Potassium	mg/L	0.5	U	2		0.5	U	0.5	U	1.9	I	0.5	U	0.75	I	1.9	I	0.5	U	0.5	U	1.9	I	0.5	U
Selenium	mg/L	0.00004	U	0.00004	U	0.0025	U	0.00004	U	0.00004	U	0.0025	U	0.00004	U	0.00004	U	0.0025	U	0.00004	U	0.00004	U	0.0025	U
Silicon	mg/L	4.8		18		0.2	U	5.1		16		0.58	I	3.4		8.5		0.57	I	5		16		0.72	I
Silver	mg/L	0.008	U	0.008	U	0.001	U	0.008	U	0.008	U	0.001	U	0.008	U	0.008	U	0.001	U	0.008	U	0.008	U	0.001	U
Sodium	mg/L	8.6		24		0.96	I	9.4		25		3.6		13		37		8.9		9.3		24		15	
Sulfate	mg/L	0.5	U	130		2	U	0.5	U	130		2.3	I	0.5	U	120		5.6	I	1.9	I	130		5.4	I
Temperature	°C	14.1		16.8		23.2		14.3		15.6		22.6		14.2		15.7		22.9		17.3		16.3		22.7	
Thallium	mg/L	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.012	I	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U
Thorium	µg/L	0.073	U	0.36	U	0.5	U	0.15	U	0.23		0.5	U	4.5		2.5		0.5	U	0.15	U	2.7		0.64	I
Tin	mg/L	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U	0.04	U
Titanium	mg/L	0.002	U	0.002	U	0.002	U	0.0029	I	0.0036	I	0.01		0.017		0.0064	I	0.022		0.0023	I	0.002	U	0.043	
Total Dissolved Solids	mg/L	73		430		10	U	96		450		23		1200		530		54		84		370		77	
Total Hardness (as CaCO3)	mg/L	9.3		290		12		22		280		14		200		470		7.4		9.7		190		8	
Total Kjeldahl Nitrogen	mg/L	0.31		0.16		0.572		1.1		0.46		0.659		7.9		15		0.61		0.51		0.47		0.646	J4
Total Organic Carbon	mg/L	8.6		3.5	I	1.4	I	13		8.9		5.6		320		300		10		10		19		14	
Total Phosphorus (as P)	mg/L	0.061	I	0.055	U	0.15	U	0.055	U	0.081	I	0.15	U	3.7		3.4		0.15	U	0.055	U	0.12		0.2	J4I
Total Suspended Solids	mg/L	6		2		N/A		4		26		N/A		400		5200		N/A		6		12		N/A	
Turbidity	NTU	6.36		1.85		N/A		27.3		10.5		N/A		1000		1000		N/A		27.1		74.6		N/A	
Uranium	µg/L	0.07	U	0.35	U	0.4	U	0.14	U	0.34		0.4	U	9.2		11		0.4	U	0.14	U	0.27	I	0.42	I
Zinc	mg/L	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U

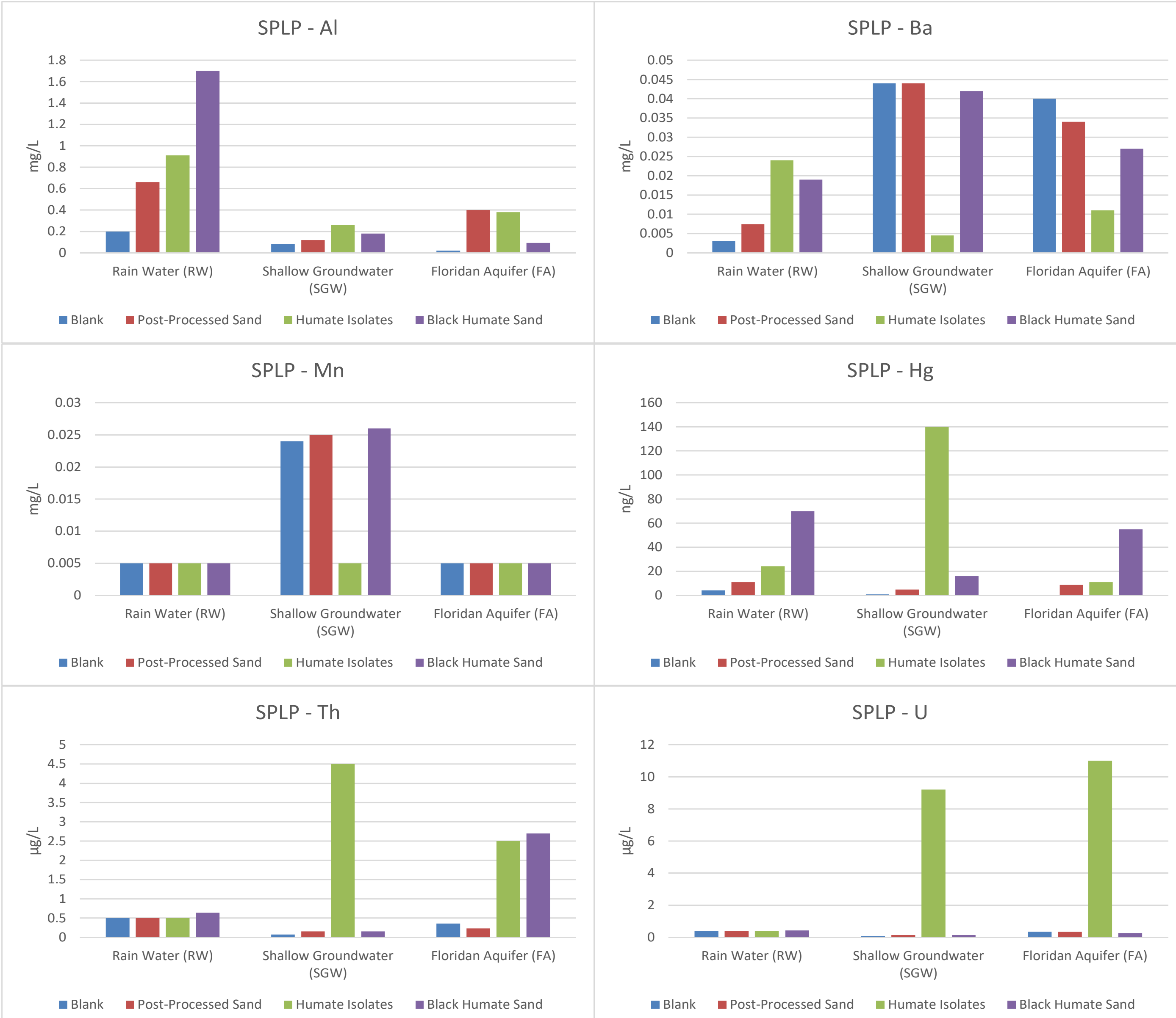

Figure 1. Comparison of SPLP Results Using Rainwater, Local Shallow Groundwater, and Floridan Aquifer Water
July 2021 Addendum to the November 2020 Geochemical Testing and Evaluation Memorandum

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July 15, 2021

Jim Smith
TTL Inc.
4589 Val North Dr.
Valdosta, GA 31602

RE: Workorder: J2106879 Twin Pines Minerals SPLP 2021

Dear Jim Smith:

Enclosed are the analytical results for sample(s) received by the laboratory on Friday, May 21, 2021. Results reported herein conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report. The analytical results for the samples contained in this report were submitted for analysis as outlined by the Chain of Custody and results pertain only to these samples.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Jerry Allen - Project Manager
jallen@aellab.com

Enclosures

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SAMPLE SUMMARY

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID	Sample ID	Matrix	Date Collected	Date Received
J2106879002	SPLP Black Humate	Water	5/21/2021 00:00	5/21/2021 12:00
J2106879004	SPLP Post Process Sand	Water	5/21/2021 00:00	5/21/2021 12:00
J2106879006	SPLP Composite	Water	5/21/2021 00:00	5/21/2021 12:00
J2106879007	Rain Water	Water	5/21/2021 00:00	5/21/2021 12:00

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ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID: **J2106879002** Date Received: 05/21/21 12:00 Matrix: Water
Sample ID: **SPLP Black Humate** Date Collected: 05/21/21 00:00

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
FIELD PARAMETERS								
Analysis Desc: Data entry of field measurements	Analytical Method: Field Measurements							
Conductivity	**93**		**umhos/cm**	**1**			6/8/2021 14:10	J^
Dissolved Oxygen	**7.52**		**mg/L**	**1**			6/8/2021 14:10	J^
Temperature	**22.7**		**°C**	**1**			6/8/2021 14:10	J^
pH	**7.58**		**SU**	**1**			6/8/2021 14:10	J^
METALS								
Analysis Desc: E1631 Analysis,Water	Preparation Method: EPA 1631 E Analytical Method: EPA 1631 E							
Mercury	**70**		**ng/L**	**10**	20	5.0	6/4/2021 15:23	J
Analysis Desc: SW846 6010B Analysis,Water	Preparation Method: SW-846 3010A Analytical Method: SW-846 6010							
Calcium	**2.4**		**mg/L**	**1**	0.80	0.20	6/16/2021 13:01	M
Magnesium	**0.47**		**mg/L**	**1**	0.40	0.10	6/16/2021 13:01	M
Total Hardness (as CaCO3)	**8.0**		**mg/L**	**1**			6/16/2021 13:01	M
Analysis Desc: SW846 6010B Analysis,Dissolved	Preparation Method: SW-846 3005A Analytical Method: SW-846 6010,Dissolved							
Aluminum	**1.7**		**mg/L**	**1**	0.80	0.20	6/16/2021 13:15	M
Boron	**0.23**	**I**	**mg/L**	**1**	0.40	0.10	6/16/2021 13:15	M
Beryllium	**0.0020**	**U**	**mg/L**	**1**	0.0080	0.0020	6/16/2021 13:15	M
Calcium	**1.9**		**mg/L**	**1**	0.80	0.20	6/16/2021 13:15	M
Cadmium	**0.0010**	**U**	**mg/L**	**1**	0.0040	0.0010	6/16/2021 13:15	M
Cobalt	**0.0010**	**U**	**mg/L**	**1**	0.040	0.0010	6/16/2021 13:15	M
Chromium	**0.0050**	**U**	**mg/L**	**1**	0.020	0.0050	6/16/2021 13:15	M
Copper	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:15	M
Iron	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:15	M
Potassium	**0.50**	**U**	**mg/L**	**1**	2.0	0.50	6/16/2021 13:15	M
Magnesium	**0.36**	**I**	**mg/L**	**1**	0.40	0.10	6/16/2021 13:15	M
Manganese	**0.0050**	**U**	**mg/L**	**1**	0.020	0.0050	6/16/2021 13:15	M
Molybdenum	**0.0040**	**U**	**mg/L**	**1**	0.016	0.0040	6/16/2021 13:15	M
Sodium	**15**		**mg/L**	**1**	3.2	0.80	6/16/2021 13:15	M
Nickel	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:15	M
Lead	**0.0030**	**U**	**mg/L**	**1**	0.012	0.0030	6/16/2021 13:15	M
Antimony	**0.0070**	**U**	**mg/L**	**1**	0.28	0.0070	6/16/2021 13:15	M
Silicon	**0.72**	**I**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:15	M^

CERTIFICATE OF ANALYSIS

ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID: **J2106879002**
Sample ID: **SPLP Black Humate**
Date Received: 05/21/21 12:00 Matrix: Water
Date Collected: 05/21/21 00:00

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
Tin	**0.040**	**U**	**mg/L**	**1**	0.16	0.040	6/16/2021 13:15	M
Titanium	**0.043**		**mg/L**	**1**	0.0080	0.0020	6/16/2021 13:15	M
Thallium	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:15	M
Zinc	**0.050**	**U**	**mg/L**	**1**	0.20	0.050	6/16/2021 13:15	M
Analysis Desc: SW846 6020B Analysis,Total	Preparation Method: SW-846 3010A Analytical Method: SW-846 6020							
Arsenic	**0.90**	**I**	**ug/L**	**2**	2.0	0.50	6/16/2021 14:33	J
Selenium	**2.5**	**U**	**ug/L**	**2**	10	2.5	6/16/2021 14:33	J
Silver	**1.0**	**U**	**ug/L**	**2**	4.0	1.0	6/8/2021 20:21	J
Barium	**19**		**ug/L**	**2**	4.0	1.0	6/8/2021 20:21	J
Thorium	**0.64**	**I**	**ug/L**	**2**	2.0	0.50	6/16/2021 14:33	J^
Uranium	**0.42**	**I**	**ug/L**	**2**	1.6	0.40	6/8/2021 20:21	J
WET CHEMISTRY								
Analysis Desc: IC,E300.0,Water	Analytical Method: EPA 300.0							
Bromide	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/1/2021 20:03	J
Chloride	**2.2**	**I**	**mg/L**	**1**	8.0	2.0	6/1/2021 20:03	J
Fluoride	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/3/2021 15:56	J
Nitrate (as N)	**0.64**	**I**	**mg/L**	**1**	0.80	0.20	6/1/2021 20:03	J
Nitrite (as N)	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/1/2021 20:03	J
Sulfate	**5.4**	**I**	**mg/L**	**1**	8.0	2.0	6/1/2021 20:03	J
Analysis Desc: Ammonia,E350.1,Water	Analytical Method: EPA 350.1							
Ammonia (N)	**0.13**		**mg/L**	**1**	0.030	0.015	6/1/2021 15:03	T
Analysis Desc: TKN,E351.2,Water	Preparation Method: Copper Sulfate Digestion Analytical Method: EPA 351.2							
Total Kjeldahl Nitrogen	**0.646**	**J4**	**mg/L**	**1**	0.20	0.087	6/7/2021 08:20	T
Analysis Desc: Total Phosphorus,E365.4,Analysis	Preparation Method: Copper Sulfate Digestion Analytical Method: EPA 365.4							
Total Phosphorus (as P)	**0.20**	**I,J4**	**mg/L**	**1**	0.20	0.15	6/7/2021 08:20	T
Analysis Desc: Alkalinity,SM2320B,Water	Analytical Method: SM 2320B							
Alkalinity, Bicarbonate	**38**		**mg/L**	**1**	20	5.0	5/26/2021 12:38	T
Alkalinity, Carbonate	**5.0**	**U**	**mg/L**	**1**	20	5.0	5/26/2021 12:38	T
Alkalinity, Total	**38**		**mg/L**	**1**	20	5.0	5/26/2021 12:38	T

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ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID: **J2106879002** Date Received: 05/21/21 12:00 Matrix: Water
Sample ID: **SPLP Black Humate** Date Collected: 05/21/21 00:00

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
Analysis Desc: Tot Dissolved Solids,SM2540C	Analytical Method: SM 2540 C							
Total Dissolved Solids	**77**		**mg/L**	**1**	10	10	5/26/2021 15:45	J
Analysis Desc: Cyanide, SM4500-E, Water	Analytical Method: SM 4500-CN-E							
Cyanide	**0.0040**	**U**	**mg/L**	**1**	0.010	0.0040	6/1/2021 16:05	T
Analysis Desc: TOC,SM5310B,Water	Analytical Method: SM 5310B							
Total Organic Carbon	**14**		**mg/L**	**1**	2.0	1.0	5/27/2021 12:59	G

Lab ID: **J2106879004** Date Received: 05/21/21 12:00 Matrix: Water
Sample ID: **SPLP Post Process Sand** Date Collected: 05/21/21 00:00

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
FIELD PARAMETERS								
Analysis Desc: Data entry of field measurements	Analytical Method: Field Measurements							
Conductivity	**56**		**umhos/cm**	**1**			6/8/2021 14:12	J^
Dissolved Oxygen	**7.78**		**mg/L**	**1**			6/8/2021 14:12	J^
Temperature	**22.6**		**°C**	**1**			6/8/2021 14:12	J^
pH	**7.17**		**SU**	**1**			6/8/2021 14:12	J^
METALS								
Analysis Desc: E1631 Analysis,Water	Preparation Method: EPA 1631 E Analytical Method: EPA 1631 E							
Mercury	**11**		**ng/L**	**5**	10	2.5	6/4/2021 15:47	J
Analysis Desc: SW846 6010B Analysis,Water	Preparation Method: SW-846 3010A Analytical Method: SW-846 6010							
Calcium	**3.2**		**mg/L**	**1**	0.80	0.20	6/16/2021 13:04	M
Magnesium	**1.3**		**mg/L**	**1**	0.40	0.10	6/16/2021 13:04	M
Total Hardness (as CaCO3)	**14**		**mg/L**	**1**			6/16/2021 13:04	M

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ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID: **J2106879004** Date Received: 05/21/21 12:00 Matrix: Water
Sample ID: **SPLP Post Process Sand** Date Collected: 05/21/21 00:00

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
Analysis Desc: SW846 6010B Analysis,Dissolved	Preparation Method: SW-846 3005A Analytical Method: SW-846 6010,Dissolved							
Aluminum	**0.66**	**I**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:26	M
Antimony	**0.0070**	**U**	**mg/L**	**1**	0.28	0.0070	6/16/2021 13:26	M
Beryllium	**0.0020**	**U**	**mg/L**	**1**	0.0080	0.0020	6/16/2021 13:26	M
Boron	**0.10**	**U**	**mg/L**	**1**	0.40	0.10	6/16/2021 13:26	M
Cadmium	**0.0010**	**U**	**mg/L**	**1**	0.0040	0.0010	6/16/2021 13:26	M
Calcium	**3.2**		**mg/L**	**1**	0.80	0.20	6/16/2021 13:26	M
Chromium	**0.0050**	**U**	**mg/L**	**1**	0.020	0.0050	6/16/2021 13:26	M
Cobalt	**0.0010**	**U**	**mg/L**	**1**	0.040	0.0010	6/16/2021 13:26	M
Copper	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:26	M
Iron	**0.23**	**I**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:26	M
Lead	**0.0030**	**U**	**mg/L**	**1**	0.012	0.0030	6/16/2021 13:26	M
Magnesium	**1.3**		**mg/L**	**1**	0.40	0.10	6/16/2021 13:26	M
Manganese	**0.0050**	**U**	**mg/L**	**1**	0.020	0.0050	6/16/2021 13:26	M
Molybdenum	**0.0040**	**U**	**mg/L**	**1**	0.016	0.0040	6/16/2021 13:26	M
Nickel	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:26	M
Potassium	**0.50**	**U**	**mg/L**	**1**	2.0	0.50	6/16/2021 13:26	M
Silicon	**0.58**	**I**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:26	M^
Sodium	**3.6**		**mg/L**	**1**	3.2	0.80	6/16/2021 13:26	M
Thallium	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:26	M
Tin	**0.040**	**U**	**mg/L**	**1**	0.16	0.040	6/16/2021 13:26	M
Titanium	**0.010**		**mg/L**	**1**	0.0080	0.0020	6/16/2021 13:26	M
Zinc	**0.050**	**U**	**mg/L**	**1**	0.20	0.050	6/16/2021 13:26	M
Analysis Desc: SW846 6020B Analysis,Total	Preparation Method: SW-846 3010A Analytical Method: SW-846 6020							
Arsenic	**0.50**	**U**	**ug/L**	**2**	2.0	0.50	6/16/2021 14:37	J
Barium	**7.4**		**ug/L**	**2**	4.0	1.0	6/8/2021 20:26	J
Selenium	**2.5**	**U**	**ug/L**	**2**	10	2.5	6/16/2021 14:37	J
Silver	**1.0**	**U**	**ug/L**	**2**	4.0	1.0	6/8/2021 20:26	J
Thorium	**0.50**	**U**	**ug/L**	**2**	2.0	0.50	6/16/2021 14:37	J^
Uranium	**0.40**	**U**	**ug/L**	**2**	1.6	0.40	6/8/2021 20:26	J
WET CHEMISTRY								
Analysis Desc: IC,E300.0,Water	Analytical Method: EPA 300.0							
Bromide	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/1/2021 20:26	J
Chloride	**2.0**	**U**	**mg/L**	**1**	8.0	2.0	6/1/2021 20:26	J
Fluoride	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/3/2021 16:19	J

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ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID: **J2106879004** | Date Received: 05/21/21 12:00 | Matrix: Water
Sample ID: **SPLP Post Process Sand** | Date Collected: 05/21/21 00:00

Sample Description: | Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
Nitrate (as N)	**0.59**	**I**	**mg/L**	**1**	0.80	0.20	6/1/2021 20:26	J
Nitrite (as N)	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/1/2021 20:26	J
Sulfate	**2.3**	**I**	**mg/L**	**1**	8.0	2.0	6/1/2021 20:26	J
Analysis Desc: Ammonia,E350.1,Water	Analytical Method: EPA 350.1							
Ammonia (N)	**0.32**		**mg/L**	**1**	0.030	0.015	6/1/2021 15:04	T
Analysis Desc: TKN,E351.2,Water	Preparation Method: Copper Sulfate Digestion Analytical Method: EPA 351.2							
Total Kjeldahl Nitrogen	**0.659**		**mg/L**	**1**	0.20	0.087	6/7/2021 08:20	T
Analysis Desc: Total Phosphorus,E365.4,Analysis	Preparation Method: Copper Sulfate Digestion Analytical Method: EPA 365.4							
Total Phosphorus (as P)	**0.15**	**U**	**mg/L**	**1**	0.20	0.15	6/7/2021 08:20	T
Analysis Desc: Alkalinity,SM2320B,Water	Analytical Method: SM 2320B							
Alkalinity, Bicarbonate	**17**	**I**	**mg/L**	**1**	20	5.0	5/26/2021 12:43	T
Alkalinity, Carbonate	**5.0**	**U**	**mg/L**	**1**	20	5.0	5/26/2021 12:43	T
Alkalinity, Total	**17**	**I**	**mg/L**	**1**	20	5.0	5/26/2021 12:43	T
Analysis Desc: Tot Dissolved Solids,SM2540C	Analytical Method: SM 2540 C							
Total Dissolved Solids	**23**		**mg/L**	**1**	10	10	5/26/2021 15:45	J
Analysis Desc: Cyanide, SM4500-E, Water	Analytical Method: SM 4500-CN-E							
Cyanide	**0.0040**	**U**	**mg/L**	**1**	0.010	0.0040	6/1/2021 16:07	T
Analysis Desc: TOC,SM5310B,Water	Analytical Method: SM 5310B							
Total Organic Carbon	**5.6**		**mg/L**	**1**	2.0	1.0	5/27/2021 13:11	G

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ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID: **J2106879006** Date Received: 05/21/21 12:00 Matrix: Water
Sample ID: **SPLP Composite** Date Collected: 05/21/21 00:00

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
FIELD PARAMETERS								
Analysis Desc: Data entry of field measurements	Analytical Method: Field Measurements							
Conductivity	**69**		**umhos/cm**	**1**			6/8/2021 14:15	J^
Dissolved Oxygen	**8.25**		**mg/L**	**1**			6/8/2021 14:15	J^
Temperature	**22.9**		**°C**	**1**			6/8/2021 14:15	J^
pH	**7.03**		**SU**	**1**			6/8/2021 14:15	J^
METALS								
Analysis Desc: E1631 Analysis,Water	Preparation Method: EPA 1631 E Analytical Method: EPA 1631 E							
Mercury	**24**		**ng/L**	**5**	10	2.5	6/4/2021 15:55	J
Analysis Desc: SW846 6010B Analysis,Water	Preparation Method: SW-846 3010A Analytical Method: SW-846 6010							
Calcium	**2.1**		**mg/L**	**1**	0.80	0.20	6/16/2021 13:08	M
Magnesium	**0.53**		**mg/L**	**1**	0.40	0.10	6/16/2021 13:08	M
Total Hardness (as CaCO3)	**7.4**		**mg/L**	**1**			6/16/2021 13:08	M
Analysis Desc: SW846 6010B Analysis,Dissolved	Preparation Method: SW-846 3005A Analytical Method: SW-846 6010,Dissolved							
Aluminum	**0.91**		**mg/L**	**1**	0.80	0.20	6/16/2021 13:30	M
Boron	**0.10**	**U**	**mg/L**	**1**	0.40	0.10	6/16/2021 13:30	M
Beryllium	**0.0020**	**U**	**mg/L**	**1**	0.0080	0.0020	6/16/2021 13:30	M
Calcium	**1.7**		**mg/L**	**1**	0.80	0.20	6/16/2021 13:30	M
Cadmium	**0.0010**	**U**	**mg/L**	**1**	0.0040	0.0010	6/16/2021 13:30	M
Cobalt	**0.0010**	**U**	**mg/L**	**1**	0.040	0.0010	6/16/2021 13:30	M
Chromium	**0.0050**	**U**	**mg/L**	**1**	0.020	0.0050	6/16/2021 13:30	M
Copper	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:30	M
Iron	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:30	M
Potassium	**0.50**	**U**	**mg/L**	**1**	2.0	0.50	6/16/2021 13:30	M
Magnesium	**0.43**		**mg/L**	**1**	0.40	0.10	6/16/2021 13:30	M
Manganese	**0.0050**	**U**	**mg/L**	**1**	0.020	0.0050	6/16/2021 13:30	M
Molybdenum	**0.0040**	**U**	**mg/L**	**1**	0.016	0.0040	6/16/2021 13:30	M
Sodium	**8.9**		**mg/L**	**1**	3.2	0.80	6/16/2021 13:30	M
Nickel	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:30	M
Lead	**0.0030**	**U**	**mg/L**	**1**	0.012	0.0030	6/16/2021 13:30	M
Antimony	**0.0070**	**U**	**mg/L**	**1**	0.28	0.0070	6/16/2021 13:30	M
Silicon	**0.57**	**I**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:30	M^

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ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID: **J2106879006**
Sample ID: **SPLP Composite**
Date Received: 05/21/21 12:00 Matrix: Water
Date Collected: 05/21/21 00:00

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
Tin	**0.040**	U	**mg/L**	**1**	0.16	0.040	6/16/2021 13:30	M
Titanium	**0.022**		**mg/L**	**1**	0.0080	0.0020	6/16/2021 13:30	M
Thallium	**0.010**	U	**mg/L**	**1**	0.040	0.010	6/16/2021 13:30	M
Zinc	**0.050**	U	**mg/L**	**1**	0.20	0.050	6/16/2021 13:30	M
Analysis Desc: SW846 6020B Analysis,Total	Preparation Method: SW-846 3010A; Analytical Method: SW-846 6020							
Arsenic	**0.50**	U	**ug/L**	**2**	2.0	0.50	6/16/2021 14:42	J
Selenium	**2.5**	U	**ug/L**	**2**	10	2.5	6/16/2021 14:42	J
Silver	**1.0**	U	**ug/L**	**2**	4.0	1.0	6/8/2021 20:31	J
Barium	**24**		**ug/L**	**2**	4.0	1.0	6/8/2021 20:31	J
Thorium	**0.50**	U	**ug/L**	**2**	2.0	0.50	6/16/2021 14:42	J^
Uranium	**0.40**	U	**ug/L**	**2**	1.6	0.40	6/8/2021 20:31	J
WET CHEMISTRY								
Analysis Desc: IC,E300.0,Water	Analytical Method: EPA 300.0							
Bromide	**0.20**	U	**mg/L**	**1**	0.80	0.20	6/1/2021 20:49	J
Chloride	**2.0**	U	**mg/L**	**1**	8.0	2.0	6/1/2021 20:49	J
Fluoride	**0.20**	U	**mg/L**	**1**	0.80	0.20	6/3/2021 16:42	J
Nitrate (as N)	**0.62**	I	**mg/L**	**1**	0.80	0.20	6/1/2021 20:49	J
Nitrite (as N)	**0.20**	U	**mg/L**	**1**	0.80	0.20	6/1/2021 20:49	J
Sulfate	**5.6**	I	**mg/L**	**1**	8.0	2.0	6/1/2021 20:49	J
Analysis Desc: Ammonia,E350.1,Water	Analytical Method: EPA 350.1							
Ammonia (N)	**0.18**		**mg/L**	**1**	0.030	0.015	6/1/2021 15:12	T
Analysis Desc: TKN,E351.2,Water	Preparation Method: Copper Sulfate Digestion; Analytical Method: EPA 351.2							
Total Kjeldahl Nitrogen	**0.610**		**mg/L**	**1**	0.20	0.087	6/7/2021 08:20	T
Analysis Desc: Total Phosphorus,E365.4,Analysis	Preparation Method: Copper Sulfate Digestion; Analytical Method: EPA 365.4							
Total Phosphorus (as P)	**0.15**	U	**mg/L**	**1**	0.20	0.15	6/7/2021 08:20	T
Analysis Desc: Alkalinity,SM2320B,Water	Analytical Method: SM 2320B							
Alkalinity, Bicarbonate	**18**	I	**mg/L**	**1**	20	5.0	5/26/2021 12:48	T
Alkalinity, Carbonate	**5.0**	U	**mg/L**	**1**	20	5.0	5/26/2021 12:48	T
Alkalinity, Total	**18**	I	**mg/L**	**1**	20	5.0	5/26/2021 12:48	T

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ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID: **J2106879006** Date Received: 05/21/21 12:00 Matrix: Water
Sample ID: **SPLP Composite** Date Collected: 05/21/21 00:00

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
Analysis Desc: Tot Dissolved Solids,SM2540C	Analytical Method: SM 2540 C							
Total Dissolved Solids	**54**		**mg/L**	**1**	10	10	5/26/2021 15:45	J
Analysis Desc: Cyanide, SM4500-E, Water	Analytical Method: SM 4500-CN-E							
Cyanide	**0.0040**	**U,J4**	**mg/L**	**1**	0.010	0.0040	6/1/2021 16:08	T
Analysis Desc: TOC,SM5310B,Water	Analytical Method: SM 5310B							
Total Organic Carbon	**10**		**mg/L**	**1**	2.0	1.0	5/27/2021 13:23	G

Lab ID: **J2106879007** Date Received: 05/21/21 12:00 Matrix: Water
Sample ID: **Rain Water** Date Collected: 05/21/21 00:00

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
FIELD PARAMETERS								
Analysis Desc: Data entry of field measurements	Analytical Method: Field Measurements							
Conductivity	**151**		**umhos/cm**	**1**			6/8/2021 14:16	J^
Dissolved Oxygen	**8.92**		**mg/L**	**1**			6/8/2021 14:16	J^
Temperature	**23.2**		**°C**	**1**			6/8/2021 14:16	J^
pH	**5.63**		**SU**	**1**			6/8/2021 14:16	J^
METALS								
Analysis Desc: E1631 Analysis,Water	Preparation Method: EPA 1631 E Analytical Method: EPA 1631 E							
Mercury	**4.2**	**I**	**ng/L**	**5**	10	2.5	6/4/2021 16:03	J
Analysis Desc: SW846 6010B Analysis,Water	Preparation Method: SW-846 3010A Analytical Method: SW-846 6010							
Aluminum	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:12	M
Boron	**0.10**	**U**	**mg/L**	**1**	0.40	0.10	6/16/2021 13:12	M
Beryllium	**0.0020**	**U**	**mg/L**	**1**	0.0080	0.0020	6/16/2021 13:12	M
Calcium	**3.9**		**mg/L**	**1**	0.80	0.20	6/16/2021 13:12	M
Cadmium	**0.0010**	**U**	**mg/L**	**1**	0.0040	0.0010	6/16/2021 13:12	M

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ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID: **J2106879007** Date Received: 05/21/21 12:00 Matrix: Water
Sample ID: **Rain Water** Date Collected: 05/21/21 00:00

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
Cobalt	**0.0010**	**U**	**mg/L**	**1**	0.040	0.0010	6/16/2021 13:12	M
Chromium	**0.0050**	**U**	**mg/L**	**1**	0.020	0.0050	6/16/2021 13:12	M
Copper	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:12	M
Iron	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:12	M
Potassium	**0.50**	**U**	**mg/L**	**1**	2.0	0.50	6/16/2021 13:12	M
Magnesium	**0.66**		**mg/L**	**1**	0.40	0.10	6/16/2021 13:12	M
Manganese	**0.0050**	**U**	**mg/L**	**1**	0.020	0.0050	6/16/2021 13:12	M
Molybdenum	**0.0040**	**U**	**mg/L**	**1**	0.016	0.0040	6/16/2021 13:12	M
Sodium	**0.96**	**I**	**mg/L**	**1**	3.2	0.80	6/16/2021 13:12	M
Nickel	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:12	M
Lead	**0.0030**	**U**	**mg/L**	**1**	0.012	0.0030	6/16/2021 13:12	M
Antimony	**0.0070**	**U**	**mg/L**	**1**	0.28	0.0070	6/16/2021 13:12	M
Silicon	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:12	M^
Tin	**0.040**	**U**	**mg/L**	**1**	0.16	0.040	6/16/2021 13:12	M
Titanium	**0.0020**	**U**	**mg/L**	**1**	0.0080	0.0020	6/16/2021 13:12	M
Thallium	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:12	M
Zinc	**0.050**	**U**	**mg/L**	**1**	0.20	0.050	6/16/2021 13:12	M
Total Hardness (as CaCO3)	**12**		**mg/L**	**1**			6/16/2021 13:12	M

Analysis Desc: SW846 6010B Analysis,Dissolved
Preparation Method: SW-846 3005A
Analytical Method: SW-846 6010,Dissolved

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
Aluminum	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:33	M
Boron	**0.10**	**U**	**mg/L**	**1**	0.40	0.10	6/16/2021 13:33	M
Beryllium	**0.0020**	**U**	**mg/L**	**1**	0.0080	0.0020	6/16/2021 13:33	M
Calcium	**3.7**		**mg/L**	**1**	0.80	0.20	6/16/2021 13:33	M
Cadmium	**0.0010**	**U**	**mg/L**	**1**	0.0040	0.0010	6/16/2021 13:33	M
Cobalt	**0.0010**	**U**	**mg/L**	**1**	0.040	0.0010	6/16/2021 13:33	M
Chromium	**0.0050**	**U**	**mg/L**	**1**	0.020	0.0050	6/16/2021 13:33	M
Copper	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:33	M
Iron	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:33	M
Potassium	**0.50**	**U**	**mg/L**	**1**	2.0	0.50	6/16/2021 13:33	M
Magnesium	**0.62**		**mg/L**	**1**	0.40	0.10	6/16/2021 13:33	M
Manganese	**0.0050**	**U**	**mg/L**	**1**	0.020	0.0050	6/16/2021 13:33	M
Molybdenum	**0.0040**	**U**	**mg/L**	**1**	0.016	0.0040	6/16/2021 13:33	M
Sodium	**0.88**	**I**	**mg/L**	**1**	3.2	0.80	6/16/2021 13:33	M
Nickel	**0.010**	**U**	**mg/L**	**1**	0.040	0.010	6/16/2021 13:33	M
Lead	**0.0030**	**U**	**mg/L**	**1**	0.012	0.0030	6/16/2021 13:33	M
Antimony	**0.0070**	**U**	**mg/L**	**1**	0.28	0.0070	6/16/2021 13:33	M
Silicon	**0.20**	**U**	**mg/L**	**1**	0.80	0.20	6/16/2021 13:33	M^
Tin	**0.040**	**U**	**mg/L**	**1**	0.16	0.040	6/16/2021 13:33	M

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ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID:	**J2106879007**	Date Received: 05/21/21 12:00	Matrix: Water
Sample ID:	**Rain Water**	Date Collected: 05/21/21 00:00	

Sample Description: Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
Titanium	**0.0020**	U	mg/L	1	0.0080	0.0020	6/16/2021 13:33	M
Thallium	**0.010**	U	mg/L	1	0.040	0.010	6/16/2021 13:33	M
Zinc	**0.050**	U	mg/L	1	0.20	0.050	6/16/2021 13:33	M
Analysis Desc: SW846 6020B Analysis,Total	Preparation Method: SW-846 3010A Analytical Method: SW-846 6020							
Arsenic	**0.50**	U	ug/L	2	2.0	0.50	6/16/2021 14:47	J
Selenium	**2.5**	U	ug/L	2	10	2.5	6/16/2021 14:47	J
Silver	**1.0**	U	ug/L	2	4.0	1.0	6/8/2021 20:36	J
Barium	**3.0**	I	ug/L	2	4.0	1.0	6/8/2021 20:36	J
Thorium	**0.50**	U	ug/L	2	2.0	0.50	6/16/2021 14:47	J^
Uranium	**0.40**	U	ug/L	2	1.6	0.40	6/8/2021 20:36	J
WET CHEMISTRY								
Analysis Desc: IC,E300.0,Water	Analytical Method: EPA 300.0							
Bromide	**0.20**	U	mg/L	1	0.80	0.20	6/1/2021 21:12	J
Chloride	**2.0**	U	mg/L	1	8.0	2.0	6/1/2021 21:12	J
Fluoride	**0.20**	U	mg/L	1	0.80	0.20	6/3/2021 17:05	J
Nitrate (as N)	**0.61**	I	mg/L	1	0.80	0.20	6/1/2021 21:12	J
Nitrite (as N)	**0.20**	U	mg/L	1	0.80	0.20	6/1/2021 21:12	J
Sulfate	**2.0**	U	mg/L	1	8.0	2.0	6/1/2021 21:12	J
Analysis Desc: Ammonia,E350.1,Water	Analytical Method: EPA 350.1							
Ammonia (N)	**0.41**		mg/L	1	0.030	0.015	6/1/2021 15:12	T
Analysis Desc: TKN,E351.2,Water	Preparation Method: Copper Sulfate Digestion Analytical Method: EPA 351.2							
Total Kjeldahl Nitrogen	**0.572**		mg/L	1	0.20	0.087	6/7/2021 08:20	T
Analysis Desc: Total Phosphorus,E365.4,Analysis	Preparation Method: Copper Sulfate Digestion Analytical Method: EPA 365.4							
Total Phosphorus (as P)	**0.15**	U	mg/L	1	0.20	0.15	6/7/2021 08:20	T
Analysis Desc: Alkalinity,SM2320B,Water	Analytical Method: SM 2320B							
Alkalinity, Bicarbonate	**12**	I	mg/L	1	20	5.0	5/26/2021 12:53	T
Alkalinity, Carbonate	**5.0**	U	mg/L	1	20	5.0	5/26/2021 12:53	T
Alkalinity, Total	**12**	I	mg/L	1	20	5.0	5/26/2021 12:53	T

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ANALYTICAL RESULTS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID: **J2106879007**
Sample ID: **Rain Water**

Date Received: 05/21/21 12:00 Matrix: Water
Date Collected: 05/21/21 00:00

Sample Description:
Location:

Parameters	Results	Qual	Units	DF	Adjusted PQL	Adjusted MDL	Analyzed	Lab
Analysis Desc: Tot Dissolved Solids,SM2540C	Analytical Method: SM 2540 C							
Total Dissolved Solids	**10**	**U**	**mg/L**	**1**	10	10	5/26/2021 15:45	J
Analysis Desc: Cyanide, SM4500-E, Water	Analytical Method: SM 4500-CN-E							
Cyanide	**0.0040**	**U**	**mg/L**	**1**	0.010	0.0040	6/3/2021 11:21	T
Analysis Desc: TOC,SM5310B,Water	Analytical Method: SM 5310B							
Total Organic Carbon	**1.4**	**I**	**mg/L**	**1**	2.0	1.0	5/27/2021 13:34	G

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ANALYTICAL RESULTS QUALIFIERS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

PARAMETER QUALIFIERS

U	The compound was analyzed for but not detected.
I	The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.
J4	Estimated Result

LAB QUALIFIERS

G	DOH Certification #E82001(AEL-G)(FL NELAC Certification)
J	DOH Certification #E82574(AEL-JAX)(FL NELAC Certification)
J^	Not Certified
M	DOH Certification #E82535(AEL-M)(FL NELAC Certification)
M^	Not Certified
T	DOH Certification #E84589(AEL-T)(FL NELAC Certification)

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QUALITY CONTROL DATA

Workorder: J2106879 Twin Pines Minerals SPLP 2021

QC Batch: WCAt/4444 Analysis Method: SM 2320B
QC Batch Method: SM 2320B Prepared:
Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

METHOD BLANK: 3899685

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Alkalinity, Total	mg/L	5.0	5.0	U

QC Batch: WCAj/2468 Analysis Method: SM 2540 C
QC Batch Method: SM 2540 C Prepared:
Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

METHOD BLANK: 3900213

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Total Dissolved Solids	mg/L	10	10	U

QC Batch: WCAg/2675 Analysis Method: SM 5310B
QC Batch Method: SM 5310B Prepared:
Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

METHOD BLANK: 3904467

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Total Organic Carbon	mg/L	1.0	1.0	U

METHOD BLANK: 3904473

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Total Organic Carbon	mg/L	1.0	1.0	U

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QUALITY CONTROL DATA

Workorder: J2106879 Twin Pines Minerals SPLP 2021

QC Batch: WCAt/4536 Analysis Method: EPA 350.1
QC Batch Method: EPA 350.1 Prepared:
Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

METHOD BLANK: 3905409

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Ammonia (N)	mg/L	0.015	0.015	U

QC Batch: WCAj/2513 Analysis Method: EPA 300.0
QC Batch Method: EPA 300.0 Prepared:
Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

METHOD BLANK: 3905598

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Fluoride	mg/L	0.20	0.20	U
Chloride	mg/L	2.0	2.0	U
Nitrite (as N)	mg/L	0.20	0.20	U
Bromide	mg/L	0.20	0.20	U
Nitrate (as N)	mg/L	0.20	0.20	U
Sulfate	mg/L	2.0	2.0	U

QC Batch: WCAt/4574 Analysis Method: SM 4500-CN-E
QC Batch Method: SM 4500-CN-E Prepared:
Associated Lab Samples: J2106879002, J2106879004, J2106879006

METHOD BLANK: 3906749

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Cyanide	mg/L	0.0040	0.0040	U

QC Batch: WCAj/2546 Analysis Method: EPA 300.0
QC Batch Method: EPA 300.0 Prepared:
Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

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QUALITY CONTROL DATA

Workorder: J2106879 Twin Pines Minerals SPLP 2021

METHOD BLANK: 3910432

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Fluoride	mg/L	0.20	0.20	U

QC Batch: WCAt/4640 Analysis Method: SM 4500-CN-E
QC Batch Method: SM 4500-CN-E Prepared:
Associated Lab Samples: J2106879007

METHOD BLANK: 3910498

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Cyanide	mg/L	0.0040	0.0040	U

QC Batch: DGMj/1644 Analysis Method: EPA 1631 E
QC Batch Method: EPA 1631 E Prepared: 06/04/2021 09:15
Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

METHOD BLANK: 3911530

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
METALS				
Mercury	ng/L	0.50	0.50	U

QC Batch: DGMj/1650 Analysis Method: SW-846 6020
QC Batch Method: SW-846 3010A Prepared: 06/08/2021 04:48
Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

METHOD BLANK: 3912764

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
METALS				
Arsenic	ug/L	0.25	0.25	U
Selenium	ug/L	1.2	1.2	U
Silver	ug/L	0.50	0.50	U
Barium	ug/L	0.50	0.50	U
Uranium	ug/L	0.20	0.20	U

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QUALITY CONTROL DATA

Workorder: J2106879 Twin Pines Minerals SPLP 2021

METHOD BLANK: 3912764

QC Batch: WCAt/4748 Analysis Method: EPA 351.2
QC Batch Method: Copper Sulfate Digestion Prepared: 06/06/2021 08:00
Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

METHOD BLANK: 3915046

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Total Kjeldahl Nitrogen	mg/L	0.087	0.087	U

METHOD BLANK: 3915047

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Total Phosphorus (as P)	mg/L	0.15	0.15	U

QC Batch: WCAt/4748 Analysis Method: EPA 365.4
QC Batch Method: Copper Sulfate Digestion Prepared: 06/06/2021 08:00
Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

METHOD BLANK: 3915046

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Total Kjeldahl Nitrogen	mg/L	0.087	0.087	U

METHOD BLANK: 3915047

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
WET CHEMISTRY				
Total Phosphorus (as P)	mg/L	0.15	0.15	U

QC Batch: DGMm/1459 Analysis Method: SW-846 6010
QC Batch Method: SW-846 3010A Prepared: 06/15/2021 03:00

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QUALITY CONTROL DATA

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Associated Lab Samples: J2106879002, J2106879004, J2106879006, J2106879007

METHOD BLANK: 3922493

Parameter	Units	Blank Result	Reporting Limit	Qualifiers
METALS				
Aluminum	mg/L	0.20	0.20	U
Boron	mg/L	0.10	0.10	U
Beryllium	mg/L	0.0020	0.0020	U
Calcium	mg/L	0.20	0.20	U
Cadmium	mg/L	0.0010	0.0010	U
Cobalt	mg/L	0.0010	0.0010	U
Chromium	mg/L	0.0050	0.0050	U
Copper	mg/L	0.010	0.010	U
Iron	mg/L	0.20	0.20	U
Potassium	mg/L	0.50	0.50	U
Magnesium	mg/L	0.10	0.10	U
Manganese	mg/L	0.0050	0.0050	U
Molybdenum	mg/L	0.0040	0.0040	U
Sodium	mg/L	0.80	0.80	U
Nickel	mg/L	0.010	0.010	U
Lead	mg/L	0.0030	0.0030	U
Antimony	mg/L	0.0070	0.0070	U
Silicon	mg/L	0.20	0.20	U
Tin	mg/L	0.040	0.040	U
Titanium	mg/L	0.0020	0.0020	U
Thallium	mg/L	0.010	0.010	U
Zinc	mg/L	0.050	0.050	U

QUALITY CONTROL DATA QUALIFIERS

Workorder: J2106879 Twin Pines Minerals SPLP 2021

QUALITY CONTROL PARAMETER QUALIFIERS

U The compound was analyzed for but not detected.

I The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.

J4 Estimated Result

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QUALITY CONTROL DATA CROSS REFERENCE TABLE

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID	Sample ID	Prep Method	Prep Batch	Analysis Method	Analysis Batch
J2106879002	SPLP Black Humate			SM 2320B	WCAt/4444
J2106879004	SPLP Post Process Sand			SM 2320B	WCAt/4444
J2106879006	SPLP Composite			SM 2320B	WCAt/4444
J2106879007	Rain Water			SM 2320B	WCAt/4444
J2106879002	SPLP Black Humate			SM 2540 C	WCAj/2468
J2106879004	SPLP Post Process Sand			SM 2540 C	WCAj/2468
J2106879006	SPLP Composite			SM 2540 C	WCAj/2468
J2106879007	Rain Water			SM 2540 C	WCAj/2468
J2106879002	SPLP Black Humate			SM 5310B	WCAg/2675
J2106879004	SPLP Post Process Sand			SM 5310B	WCAg/2675
J2106879006	SPLP Composite			SM 5310B	WCAg/2675
J2106879007	Rain Water			SM 5310B	WCAg/2675
J2106879002	SPLP Black Humate			EPA 350.1	WCAt/4536
J2106879004	SPLP Post Process Sand			EPA 350.1	WCAt/4536
J2106879006	SPLP Composite			EPA 350.1	WCAt/4536
J2106879007	Rain Water			EPA 350.1	WCAt/4536
J2106879002	SPLP Black Humate			EPA 300.0	WCAj/2513
J2106879004	SPLP Post Process Sand			EPA 300.0	WCAj/2513
J2106879006	SPLP Composite			EPA 300.0	WCAj/2513
J2106879007	Rain Water			EPA 300.0	WCAj/2513
J2106879002	SPLP Black Humate			SM 4500-CN-E	WCAt/4574
J2106879004	SPLP Post Process Sand			SM 4500-CN-E	WCAt/4574
J2106879006	SPLP Composite			SM 4500-CN-E	WCAt/4574
J2106879002	SPLP Black Humate			EPA 300.0	WCAj/2546
J2106879004	SPLP Post Process Sand			EPA 300.0	WCAj/2546
J2106879006	SPLP Composite			EPA 300.0	WCAj/2546
J2106879007	Rain Water			EPA 300.0	WCAj/2546

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QUALITY CONTROL DATA CROSS REFERENCE TABLE

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID	Sample ID	Prep Method	Prep Batch	Analysis Method	Analysis Batch
J2106879007	Rain Water			SM 4500-CN-E	WCAt/4640
J2106879002	SPLP Black Humate	EPA 1631 E	DGMj/1644	EPA 1631 E	CVAj/1144
J2106879004	SPLP Post Process Sand	EPA 1631 E	DGMj/1644	EPA 1631 E	CVAj/1144
J2106879006	SPLP Composite	EPA 1631 E	DGMj/1644	EPA 1631 E	CVAj/1144
J2106879007	Rain Water	EPA 1631 E	DGMj/1644	EPA 1631 E	CVAj/1144
J2106879002	SPLP Black Humate	SW-846 3010A	DGMj/1650	SW-846 6020	ICMj/1250
J2106879004	SPLP Post Process Sand	SW-846 3010A	DGMj/1650	SW-846 6020	ICMj/1250
J2106879006	SPLP Composite	SW-846 3010A	DGMj/1650	SW-846 6020	ICMj/1250
J2106879007	Rain Water	SW-846 3010A	DGMj/1650	SW-846 6020	ICMj/1250
J2106879002	SPLP Black Humate	Copper Sulfate Digestion	WCAt/4748	EPA 351.2	WCAt/4777
J2106879004	SPLP Post Process Sand	Copper Sulfate Digestion	WCAt/4748	EPA 351.2	WCAt/4777
J2106879006	SPLP Composite	Copper Sulfate Digestion	WCAt/4748	EPA 351.2	WCAt/4777
J2106879007	Rain Water	Copper Sulfate Digestion	WCAt/4748	EPA 351.2	WCAt/4777
J2106879002	SPLP Black Humate	Copper Sulfate Digestion	WCAt/4748	EPA 365.4	WCAt/4778
J2106879004	SPLP Post Process Sand	Copper Sulfate Digestion	WCAt/4748	EPA 365.4	WCAt/4778
J2106879006	SPLP Composite	Copper Sulfate Digestion	WCAt/4748	EPA 365.4	WCAt/4778
J2106879007	Rain Water	Copper Sulfate Digestion	WCAt/4748	EPA 365.4	WCAt/4778
J2106879002	SPLP Black Humate	SW-846 3005A	DGMm/1459	SW-846 6010,Dissolved	ICPm/1453
J2106879002	SPLP Black Humate	SW-846 3010A	DGMm/1459	SW-846 6010	ICPm/1453
J2106879004	SPLP Post Process Sand	SW-846 3005A	DGMm/1459	SW-846 6010,Dissolved	ICPm/1453
J2106879004	SPLP Post Process Sand	SW-846 3010A	DGMm/1459	SW-846 6010	ICPm/1453
J2106879006	SPLP Composite	SW-846 3005A	DGMm/1459	SW-846 6010,Dissolved	ICPm/1453
J2106879006	SPLP Composite	SW-846 3010A	DGMm/1459	SW-846 6010	ICPm/1453
J2106879007	Rain Water	SW-846 3005A	DGMm/1459	SW-846 6010,Dissolved	ICPm/1453
J2106879007	Rain Water	SW-846 3010A	DGMm/1459	SW-846 6010	ICPm/1453
J2106879002	SPLP Black Humate	Field Measurements	FLDj/	Field Measurements	FLDj/
J2106879004	SPLP Post Process Sand	Field Measurements	FLDj/	Field Measurements	FLDj/

CERTIFICATE OF ANALYSIS

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QUALITY CONTROL DATA CROSS REFERENCE TABLE

Workorder: J2106879 Twin Pines Minerals SPLP 2021

Lab ID	Sample ID	Prep Method	Prep Batch	Analysis Method	Analysis Batch
J2106879006	SPLP Composite	Field Measurements	FLDj/	Field Measurements	FLDj/
J2106879007	Rain Water	Field Measurements	FLDj/	Field Measurements	FLDj/

J2106879

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☐ Gainesville: 4965 SW 41st Blvd. • Gainesville, FL 32608
☐ Jacksonville: 6681 Southpoint Pkwy. • Jacksonville, FL
☐ Miramar: 10200 USA Today Way, Miramar, FL 33025 • 954.889.2288
☐ Tallahassee: 1288 Cedar Center Drive, Tallahassee, FL 32301 • 850.219.6274 • Fax 850.219.6275
☐ Tampa: 9610 Princess Palm Ave. • Tampa, FL 33619 • 813.630.9616 • Fax 813.630.4327

Client Name: Jacobs Eng / Twin Pines Minerals
Address: 10 10th Street NW
Suite 1400
Phone: 678-530-4415
FAX:
Contact: BT Thomas
Sampled By: TPM / TTL
Turn Around Time: ☐ STANDARD ☐ RUSH
Page ____ of ____

Project Name: Twin Pines Mine SPLP 2021
P.O. Number/Project Number:
Project Location:
FDEP Facility No:
Project Name and Address:
Profile 67169
Special Instructions:
☐ ADaPT ☐ EQuIS ☐ Other

BOTTLE SIZE & TYPE
ANALYSIS REQUIRED: Analysis per Twin Pines Mine SPLP 2021 Proposal from Todd Romero
Preservation
Field-Filtered?

SAMPLE ID	SAMPLE DESCRIPTION	Grab Comp	SAMPLING DATE	SAMPLING TIME	MATRIX	NO. COUNT	LABORATORY I.D. NUMBER
SA-HES-19-100	10-20'				SO	1	001
SA-HES-19-470	15-20'				SO	1	002
SA-HES-19-338	15-20'				SO	1	003
SA-HES-19-486	15-20'				SO	1	004
SA-HES-19-343	25-30'				SO	1	005
SA-HES-19-336	15-20'				SO	1	006
PT 414 POLYMER FOR SOLIDS SETTLING							

Matrix Code: WW = wastewater SW = surface water GW = ground water DW = drinking water O = oil A = air SO = soil SL = sludge

Preservation Code: I = ice H=(HCl) S = (H2SO4) N = (HNO3) T = (Sodium Thiosulfate)

Received on Ice ☐ Yes ☐ No ☐ Temp taken from sample ☐ Temp from blank ☐ Where required, pH checked Temperature when received ______ (in degrees celcius)

DCN: AD-051 Form last revised 10/15/2015

Device used for measuring Temp by unique identifier (circle IR temp gun used) J: 9A G: LT-1 LT-2 T: 10A A: 3A M: 3A S: 1V

	Relinquished by:	Date	Time	Received by:	Date	Time
1	[signature]	5/14/21	9:42	[signature]	5/14/21	942
2						
3						
4						

FOR DRINKING WATER USE:
(When PWS Information not otherwise supplied) PWS ID: ______
Contact Person: ______ Phone: ______
Supplier of Water: ______
Site-Address: ______

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- ☐ **Gainesville:** 4965 SW 41st Blvd. • Gainesville, FL 32608 • 352.37
- ☐ **Jacksonville:** 6681 Southpoint Pkwy. • Jacksonville, FL 32216 •
- ☐ **Miramar:** 10200 USA Today Way, Miramar, FL 33025 • 954.889.2
- ☐ **Tallahassee:** 1288 Cedar Center Drive, Tallahassee, FL 32301 • 850.2...
- ☐ **Tampa:** 9610 Princess Palm Ave. • Tampa, FL 33619 • 813.630.9616 • Fax 813.630.4327

* J 2 1 0 6 8 7 9 *

Client Name: Jacobs Eng. / Twin Pines Minerals

Address: 10 10th Street NW Suite 1400

Phone: 678-530-4415

FAX:

Contact: BT Thomas

Sampled By: TPM / TTL

Turn Around Time: ☐ STANDARD ☐ RUSH

Page____ of ____

Project Name: Twin Pines Mine SPLP 2021

P.O. Number/Project Number:

Project Location:

FDEP Facility No:

Project Name and Address:

Special Instructions:

☐ ADaPT ☐ EQuIS ☐ Other

BOTTLE SIZE & TYPE

ANALYSIS REQUIRED: Analysis per Twin Pines Mine 2021 SPLP proposal from Todd Romero

LABORATORY I.D. NUMBER

Preservation

Field-Filtered?

SAMPLE ID	SAMPLE DESCRIPTION	Grab Comp	SAMPLING DATE	SAMPLING TIME	MATRIX	NO. COUNT
5/11/2021	RAINFALL				RW	1
5/6/2021	RAINFALL				RW	1
5/10/2021	OW1BS GROUNDWATER				GW	2
	Post Processed Sand				SO	2
	Black Humate Sand				SO	2

Matrix Code: WW = wastewater SW = surface water GW = ground water DW = drinking water O = oil A = air SO = soil SL = sludge

Preservation Code: I = ice H=(HCl) S = (H2SO4) N = (HNO3) T = (Sodium Thiosulfate)

Received on Ice ☒ Yes ☒ No ☒ Temp taken from sample ☐ Temp from blank

☐ Where required, pH checked Temperature when received 4.0 (in degrees celcius)

DCN: AD-051 Form last revised 10/15/2015

Device used for measuring Temp by unique identifier (circle IR temp gun used) (J: 9A) G: LT-1 LT-2 T: 10A A: 3A M: 3A S: 1V

	Relinquished by:	Date	Time	Received by:	Date	Time
1	[signature]	5/14/21	9:43	[signature]	5/14/21	9:43
2						
3						
4						

FOR DRINKING WATER USE:

(When PWS Information not otherwise supplied) PWS ID:________

Contact Person:________ Phone:________

Supplier of Water:________

Site-Address:________

Work Order:	J2106879
Client:	Twin Pines Minerals, LLC
Project ID:	Twin Pines Minerals SPLP 2021

I. Receipt

No Exceptions were encountered.

II. Holding Times

Preparation: All holding times were met.

Analysis: All holding times were met.

III. Method

Analysis: SM 4500-CN-E

Preparation:

IV. Preparation

Sample preparation proceeded normally.

V. Analysis

Calibration: All acceptance criteria were met.

Blanks: All acceptance criteria were met.

Surrogates: All acceptance criteria were met.

Spikes The matrix spike recovery of Cyanide for J2106879006 was outside control criteria. Recoveries in the Laboratory Control Sample (LCS) is acceptable, which indicates the analytical batch was in control. No further corrective action was required.

Internal Standard: All acceptance criteria were met.

Samples: All acceptance criteria were met.

Other: All acceptance criteria were met.

Serial Dilution: All acceptance criteria were met.

Duplicates: All acceptance criteria were met.

Work Order:	J2106879
Client:	Twin Pines Minerals, LLC
Project ID:	Twin Pines Minerals SPLP 2021

I. Receipt

No Exceptions were encountered.

II. Holding Times

Preparation:	All holding times were met.
Analysis:	All holding times were met.

III. Method

Analysis:	EPA 351.2
Preparation:	Copper Sulfate Digestion

IV. Preparation

Sample preparation proceeded normally.

V. Analysis

Calibration:	All acceptance criteria were met.
Blanks:	All acceptance criteria were met.
Surrogates:	All acceptance criteria were met.
Spikes	The matrix spike recovery of TKN for J2106511001 and J2106879001 was outside control criteria. Recoveries in the Laboratory Control Sample (LCS) and %RPD were acceptable, which indicates the analytical batch was in control. The matrix spike outlier suggests a potential low bias in these matrixes. No further corrective action was required.
Internal Standard:	All acceptance criteria were met.
Samples:	All acceptance criteria were met.
Other:	All acceptance criteria were met.
Serial Dilution:	All acceptance criteria were met.
Duplicates:	All acceptance criteria were met.

Work Order:	J2106879
Client:	Twin Pines Minerals, LLC
Project ID:	Twin Pines Minerals SPLP 2021

I. Receipt

No Exceptions were encountered.

II. Holding Times

Preparation: All holding times were met.

Analysis: All holding times were met.

III. Method

Analysis: EPA 365.4

Preparation: Copper Sulfate Digestion

IV. Preparation

Sample preparation proceeded normally.

V. Analysis

Calibration: All acceptance criteria were met.

Blanks: All acceptance criteria were met.

Surrogates: All acceptance criteria were met.

Spikes: The matrix spike recovery of TP for J2106511001 and J2106879001 was outside control criteria. Recoveries in the Laboratory Control Sample (LCS) and %RPD were acceptable, which indicates the analytical batch was in control. The matrix spike outlier suggests a potential low bias in these matrixes. No further corrective action was required.

Internal Standard: All acceptance criteria were met.

Samples: All acceptance criteria were met.

Other: All acceptance criteria were met.

Serial Dilution: All acceptance criteria were met.

Duplicates: All acceptance criteria were met.

ATTACHMENT B

Supporting Document for Response to Comment #2

Modeling the Groundwater Flow System at the Proposed Twin Pines Mine on Trail Ridge Prepared by GSI Environmental, Inc. – Revision Date - September 14, 2021

GSI ENVIRONMENTAL

MODELING THE GROUNDWATER FLOW SYSTEM AT THE PROPOSED TWIN PINES MINE ON TRAIL RIDGE

Prepared for:

Twin Pines Minerals, LLC
Proposed Heavy Minerals Mine
St. George, Charlton County, Georgia

Prepared by:

Sorab Panday, Ph.D.
Robert Wyckoff
Gao Martell
GSI Environmental Inc.
19200 Von Karman Avenue, Suite 800
Irvine, California 92612
949.679.1070

GSI Job No. 5844
Issued: 14 September 2021

MODELING THE GROUNDWATER FLOW SYSTEM AT THE PROPOSED TWIN PINES MINE ON TRAIL RIDGE
Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

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MODELING THE GROUNDWATER FLOW SYSTEM AT THE PROPOSED TWIN PINES MINE ON TRAIL RIDGE
Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

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MODELING THE GROUNDWATER FLOW SYSTEM AT THE PROPOSED TWIN PINES MINE ON TRAIL RIDGE
Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

1.0 EXECUTIVE SUMMARY

Twin Pines Minerals, LLC (TPM) has submitted a permit application to the Georgia Environment Protection Division (GA EPD) for a surface mining permit 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 as shown on Figures 1 and 2.

The objective of this report is to document the revised groundwater modeling efforts conducted to evaluate the impact of the proposed TPM mine on the Trail Ridge hydrologic system. The revised model addresses issues raised by GA EPD, which include (1) the addition of a continuous consolidated black sand unit within the model, and (2) the placement of a bentonite soil amendment layer in order to reconstitute the consolidated black sand unit post-mining.

This modeling report also assesses the impact of varying bentonite mixtures in a soil amendment layer within the reclaimed sands on the system hydrogeology. This was done by conducting a sensitivity analysis of the system to the hydraulic conductivity of the bentonite mixture. The model does not simulate the physical process of placing the bentonite-enhanced soil layer. The modeling suggests a 10.9% bentonite mixture in the amended sand layer provides the least amount of hydrogeologic impact at the mine site.

The results of modeling efforts presented in this report indicate that post-mining conditions will have no significant impact on water levels in and near the Okefenokee National Wildlife Refuge. Additionally, the existing Trail Ridge hydrologic divide separating the Okefenokee Swamp to west from the Saint Mary's River to the east will be maintained.

2.0 BACKGROUND

The location of the proposed TPM mine is shown on Figure 1. The proposed mining area is approximately 582 acres and is located about 2.9 miles southeast of the Okefenokee National Wildlife Refuge (ONWR). The overall project study area consisted of approximately 12,000 acres that include five tracts identified as Loncala, Dallas Police & Fire, Keystone, TIAA, and Adirondack as shown on Figure 2. TPM no longer has access to the TIAA tract.

Heavy mineral sands will be excavated to a maximum depth of 50 feet in the surficial aquifer within the proposed mining area, with about 98% of the post-processed sand (sand tailings) returned to the mine pit. The depth of mining will not exceed the water surface elevation of the swamp. The dragline will move through the mining area excavating approximately 100-feet wide by 50-feet-deep cuts, in an east to west or west to east direction. Mining rates are anticipated to vary from approximately 100-200 feet of pit length excavation per day. As the pit advances into unmined areas, the inactive portion of the pit will be filled with sand tailings.

Within one to two weeks of the commencement of mining, sand tailings will be returned to the pit as mining continues to advance. Mine reclamation will include placement of a low-permeability layer (bentonite-sand mixture) approximately 3 feet thick, placed approximately 8-25 feet below the reclaimed land surface. The topography of the reclaimed mine spoils will be returned as close as possible to pre-mining elevations. The extraction of heavy minerals is estimated to be completed in about 4 years as shown on Figure 3.

TPM has conducted several studies related to this permit application including:

1. Field activities were conducted to characterize the local hydraulic properties of the surficial aquifer within the proposed study area documented by Holt et al., (2019a). Aquifer pumping tests and slug tests were conducted on wells within the study area to determine the areal and vertical distribution of hydraulic conductivity of the surficial aquifer materials.
2. The geology of the surficial aquifer within the proposed study area was characterized and documented by Holt et al., (2019b). The boring logs of wells within the proposed study area were evaluated to characterize the subsurface geology.
3. Water quality analyses of groundwater and surface water within the proposed study area documented by Holt et al., (2019c). Water samples were analyzed for pH, dissolved oxygen, specific conductance, Oxidation Reduction Potential and major constituents with groundwater protection standards. The analyses serve to provide background conditions for a pre-mining state of water quality at the site.
4. Local and regional climate data were evaluated and documented by Holt et al., (2019d). Precipitation and evapotranspiration were evaluated to estimate groundwater recharge to the surficial aquifer within the study area.
5. A hydrogeologic conceptual model was developed and documented by Holt et al., (2019e). Water level data from piezometers and observation wells, water level differences between shallow and deep piezometer pairs, and potentiometric surface maps were developed to understand subsurface hydrogeologic conditions.
6. Laboratory testing was conducted to evaluate hydrogeologic properties of the soil types as documented by Holt et al., (2019f). Measurements for the various subsurface units helped to quantify the hydraulic conductivity, and to understand contrast between the hydrogeological units and variability within each unit.
7. A geologic conceptual model was developed and documented by Holt et al., (2019g). The major subsurface lithologies of the surficial aquifer includes (with increasing depth) an unconsolidated and semi-consolidated sand unit; a consolidated black sand unit; a silty-clayey sand unit; and a sandy clay unit overlying the Hawthorn Group.
8. A groundwater flow model was developed and documented by Holt et al., (2020a). The groundwater flow model was the culmination of all the data collection and model conceptualization efforts, meant to evaluate the pre- and post-mining hydrogeologic conditions in the study area.
9. A United States Army Corps of Engineers individual permit application submitted by TPM summarizes the data assimilation, conceptual model development, and groundwater modeling efforts along with other required studies as documented by TTL (2020a).
10. Additional modeling conducted to evaluate the impact of adding soil amendments to the reclamation process as documented by Holt et al., (2020b). The groundwater modeling conducted by Holt et al., (2020a) did not include a layer of bentonite treated sand to maintain higher water levels beneath Trail Ridge and minimize impacts to the groundwater divide. Therefore, further analyses were conducted to note the impact on water levels and flows as suggested by the State Geologist Dr. James Kennedy, during an August 2020 meeting.

These documents have gone through several rounds of review and comments by Georgia Environmental Protection Division (GA EPD). The reviews and responses include:

1. A letter dated March 23, 2020, from GA EPD (Dr. James Kennedy) to Mr. Stephen C. Wiedl submitting comments to TTL's report "Impact of the Proposed Twin Pines Mine on the Trail Ridge Hydrologic System" (Kennedy 2020a).
2. A response by TTL on November 13, 2020, to GA EPD's comments of March 23, 2020. (TTL, 2020b).
3. Comments provided by GA EPD on November 25, 2020, to the TTL submittal of November 13, 2020 (Kennedy 2020b).
4. Response by TTL on January 25, 2021, to review comments from GA EPD of November 25, 2020 (TTL, 2021).
5. Comments provided to TTL on April 14, 2021, by GA EPD (Kennedy, 2021) as part of a Twin Pines Permit Coordination Document.

The back and forth of comments and responses led to resolution of several concerns; however, other issues remain as noted in the last set of comments provided by GA EPD on April 14, 2021 (Kennedy, 2021). The primary remaining concerns regarding the groundwater flow model were: (1) to justify and address recharge values used in the model that deviated from both local studies and a regional USGS evaluation of recharge in the area; (2) to provide a better structural representation of the consolidated black sand unit within the groundwater model; and (3) to constrain modeled parameter values to those observed from field studies and laboratory tests that have been conducted. To address these groundwater flow model related issues and concerns, a new numerical model was developed that is consistent with the consolidated black sand unit structural representation in the geologic conceptual site model, includes hydrogeologic properties consistent with field and laboratory measurements, implements wetland and surface drainage features indicated by the National Hydrograph Dataset (NHD, USGS, 2021), and simulates hydrogeologic conditions represented by the conceptual model. The study evaluates a range of potential recharge conditions at the site and further addresses impact of uncertainties in the data via a sensitivity analysis.

3.0 CONCEPTUAL SITE MODEL

The studies conducted by TPM related to site geology and hydrogeology were evaluated to develop a conceptual site model for the study area of interest. The modeling study area is indicated on Figure 2. Only the Surficial Aquifer is of concern for the current evaluations; therefore, the clays of the upper Hawthorn Group at the base of the Surficial Aquifer form the lower boundary of the study domain.

3.1 Hydrostratigraphic Units

The subsurface soil sediments that comprise the Surficial Aquifer include unconsolidated and semi-consolidated sand units that extend from land surface down to the Hawthorn Formation. A layer of consolidated black sands lies generally from 8 to 25 feet beneath the land surface. The unconsolidated sands are further interlayered unconformably with zones of semi-consolidated to consolidated sands, silty-clayey sands, and sandy clays. Aquifer tests conducted on deeper wells indicate that the hydraulic conductivity of the unconsolidated sands is lower, at elevations below 120 ft above mean sea level. The Hawthorn Group forms the base of the Surficial Aquifer.

The geologic conceptual model previously developed in Holt (2020a) did not include a continuous black sand layer and instead attempted to produce statistically similar geologic conditions for the Surficial Aquifer. This was noted by GA EPD who indicated that the environment of deposition for the aeolian sands would allow for horizontal continuity (Kennedy 2020a). The TTL (2020b) response was that the black sands are diagenetic and originate due to circulation of groundwaters through the sediments. The response further noted that indicator kriging suggested small horizontal correlation lengths for the consolidated black sand units. In response, GA EPD indicated that the paleo-groundwater condition would cause the black sands to be continuously distributed across the site (Kennedy, 2020b). In addition, GA EPD evaluated that the cross-sections developed in Holt et al, (2019g) showing on average, that the consolidated black sands cover approximately 69% of the study area. Table 1 reproduces the work of the State Geologist Dr. Kennedy, and a check of these estimates confirms the calculations. However, there was disagreement as to the continuity of the consolidated black sand unit expressed by TTL (2021). Finally, in response, GA EPD provided the following reasons as to why a layer of consolidated black sands should be considered (Kennedy, 2021) in the numerical model:

1. Because units in adjacent boreholes should be connected as per standard geological practice.
2. Because there is no evidence that consolidated black sand is not present between borings that do show its presence and therefore it should be included to be conservative.
3. Because the effective hydraulic conductivity in the model did not correspond to site conditions unless a consolidated black sand unit was included in the numerical model.
4. Because even if it is discontinuous, a layer of consolidated black sand should be incorporated to cover 69% of the study area as noted from Table 1 and the TTL cross-sections.
5. Because even with a discontinuous layer for the consolidated black sand, it should be continuous enough to affect the presence of the shallow water table along Trail Ridge.

The model has been revised accordingly. The stratigraphic units identified from soil borings, piezometers and wells were assimilated into a database for the current modeling effort. Figure 4 shows the locations where consolidated black sands were present in the log. There are distinct zones (demarcated visually on the figure) where consolidated black sands do exist in the logs and where they do not exist. There is also an area just to the west of Trail Ridge, which may be a transition zone. This is also a location of highest density of data. The consolidated black sands are present in 65 % of the borings and they cover approximately 77 % of the study area (Figure 4).

As shown by these findings and noted by GA EPD, a modified hydrogeologic conceptual model is considered with a continuous layer of consolidated black sands as shown on Figure 5. The hydrogeologic units (also called hydrostratigraphic units) within the study area are as follows:

- The uppermost hydrogeologic unit beneath the land surface consists of unconsolidated and semi-consolidated sands and is labeled hydrostratigraphic (HSU) unit 1. Figure 6 shows the land surface elevation, and Figure 7 shows the thickness of this hydrostratigraphic unit. This unit has a fairly high hydraulic conductivity value and is generally between 10 and 20 feet thick except along the lateral extents of the study area where it is thinner because the Hawthorn Group is closer to land surface with increasing distance from the crest of Trail Ridge.
- The consolidated black sands layer is considered as hydrostratigraphic unit 2 with a top elevation and thickness shown on Figure 8 and Figure 9, respectively. The layer elevation and thickness were evaluated from the shallowest occurrence of consolidated black sands noted in the boring logs, that are greater than 1 foot in thickness, which were then interpolated across the site. The consolidated black sands have a low value of hydraulic conductivity and act as an aquitard or barrier to flow between the surficial sands and the sand units below.

- The sands that lie beneath the consolidated black sands forms hydrostratigraphic unit 3 with a top elevation and thickness shown on Figure 10 and Figure 11, respectively. Hydrostratigraphic unit 3 is also denoted as the silty clayey sand unit.
- The lower permeability sands and sandy clay materials that overlie the Hawthorn Group form hydrostratigraphic unit 4 with a top elevation, thickness, and bottom elevation shown on Figure 12, Figure 13, and Figure 14, respectively. It is noted that hydrostratigraphic unit 4 is not a well-defined conforming unit but has been defined from the aquifer tests at deeper wells that indicate a lower hydraulic conductivity.

Layer elevations and thicknesses were evaluated and interpolated from the available boring log information. These elevations and thicknesses were used for layer discretization in the numerical model.

3.2 Hydrogeologic Properties

Hydraulic properties of the various hydrogeologic units were assimilated from field and laboratory information collected by Holt et al., (2019a, 2019b, 2019f, 2019g). Figures 15, 16, 17, and 18 show the hydraulic conductivity values in hydrostratigraphic units 1, 2, 3 and 4, respectively, as obtained from available tests. The horizontal hydraulic conductivity is of greater significance in units considered as aquifers since it governs the flow of water within the aquifer. The vertical hydraulic conductivity is of greater importance in aquitard units since it controls the flow across the aquitard unit.

The horizontal hydraulic conductivity value of hydrostratigraphic unit 1 (the unconsolidated / semi-consolidated sand unit) ranges from generally 30 to 50 feet/day with some lower horizontal hydraulic conductivity values of about 1 to 10 ft/day to the south of the study area. This unit acts as an aquifer considering its high hydraulic conductivity values.

Hydrostratigraphic unit 2 (the consolidated black sands) has a vertical hydraulic conductivity value ranging from 4.6×10^{-6} to 7.4×10^{-3} feet/day. Higher values previously reported from aquifer and/or slug tests may not be representative of the consolidated black sands alone, considering that the consolidated black sands are very tight geological materials. Therefore, only data with ranges of K shown in Figure 16 are considered as part of this study. Hydrostratigraphic unit 2 acts as an aquitard between units 1 and 3, considering its low hydraulic conductivity values. Laboratory values of hydraulic conductivity for the consolidated black sands were generally in the range of 0.003 feet/day to 4×10^{-5} feet/day (10^{-6} to 10^{-8} cm/second).

The horizontal hydraulic conductivity value for hydrostratigraphic unit 3 (the silty clayey sand unit) ranges from 20 to 54 feet/day along the ridge, with lower hydraulic conductivity values of about 1 to 10 ft/day off the ridge. This unit acts as an aquifer considering its high hydraulic conductivity values.

The horizontal hydraulic conductivity value for hydrostratigraphic unit 4 (the sandy clay unit) ranges from 1 to 10 feet/day. This unit acts as an aquifer even with its lower hydraulic conductivity values. The Hawthorn Group at the bottom of Surficial Aquifer has even lower hydraulic conductivity values and it acts as an aquitard separating the Surficial Aquifer from the underlying Floridan Aquifer units.

3.3 Groundwater Flow

Groundwater flow occurs within the study area due to recharge from precipitation. Water flows mainly from the centerline of Trail Ridge towards the west and the east, discharging into local streams and wetlands. Groundwater may also flow out of the west and east boundaries of the study area as there is no flow barrier at the study area boundary. Measured water levels were as high as 174 feet above mean sea level along the crest of Trail Ridge and drop to about 120 feet along the western boundary of the study area and about 80 feet along the eastern boundary of the study area, following the topography of Trail Ridge.

The hydrogeology of the flow system in the Shallow Aquifer at the site is typically understood as a “Toth Flow” problem (Toth, 1963), where topographically driven flow dominates. Essentially, as shown on Figure 5, groundwater flows along short flow-paths from recharge areas along Trail Ridge, to discharge areas in adjacent wetlands or surface drainage features with the shallow water table closely following ground surface. The consolidated black sands provide resistance to flow between hydrogeologic unit 1 and hydrogeologic unit 3 due to their low vertical hydraulic conductivity and affect the presence of the shallow water table along Trail Ridge.

Figure 19 shows the water level elevations in wells and piezometers within the study area averaged for 2019 conditions. The data were assimilated through the first 10 months of 2019 by Holt et al., (2019e). Depth to groundwater generally ranged from just below ground surface to five feet below ground surface; however, during periods of increased precipitation, water levels in some piezometers were above the top of well casing. Hydrographs plotted by Holt et al., (2019e) indicate that water level elevations generally declined from January through June 2019, followed by a sharp increase in July with subsequent decline from August through October. These water level changes follow rainfall periods.

Figure 20 shows the potentiometric surface map for July 26, 2019 (from Holt et al., 2019e). Groundwater elevations at the site generally mimic land surface topography with groundwater flowing to the west and east of Trail Ridge which forms a hydrologic divide within the underlying Surficial Aquifer. Thus, groundwater flow along the west side of Trail Ridge is to the west, and along the east side of Trail Ridge is to the east.

Figure 21 shows the average water level differences in shallow and deep piezometer pairs as evaluated by Holt et al., (2019e). Gradients are noted to be downward through most of the study area (negative values) indicating recharge from hydrogeologic unit 1 into hydrogeologic units 3 and 4 below. Upward gradients are noted in western and northern portions of the study area below the ridge, where the deeper sands of the Surficial Aquifer discharge to streams and wetlands. The water level differences are largest along Trail Ridge and are smaller to the west than to the east.

3.4 Recharge

Groundwater recharge occurs due to precipitation water that infiltrates into the soil after consideration of evaporation or runoff from the land surface. Groundwater recharge was evaluated by Holt et al., (2019d) to be about 3.5 inches/year by subtracting evapotranspiration estimates (39.5 inches/year) from local precipitation values (43 inches/year). The numerical groundwater flow model of Holt et al., (2020a) used an initial estimate of 4.5 inches/year, which was reduced to 2.8 inches/year during the calibration process. During review of the model, GA EPD performed their own investigation of recharge at the location of the proposed mine site. Using information from USGS (2008), and the source of that information from USGS (2003), Dr. James Kennedy estimated through personal communication with the author of the published dataset that recharge in the area of the proposed mine site was about 4.1 inches/year. Since this rate is more aligned with the initial estimates from Holt et al., (2019d), GA EPD (Kennedy, 2021) requested further information on the model that assigned a reduced rate of 2.8 inches/year.

Average groundwater recharge is a difficult parameter to estimate accurately and more so at a local scale the size of the study area. There can be spatial variability due to local hydrogeologic and topographic conditions as well as temporal variability considering long-term climatic conditions. Therefore, we further evaluated the data to estimate a reasonable recharge rate or range of possible recharge rates at the site.

A regional recharge estimate of about 4.13 inches/year was derived by Dr. Kennedy from the USGS (2003) data and approach. The approach is based on the consideration that long-term average recharge in a watershed is equal to the baseflow to streams within that watershed, absent any other sinks such as diversions or pumping. The estimated value of recharge was based on streamflow that occurred during the period 1951 – 1980 at the St. Mary's gage near Gross, Florida. The approach accounts for groundwater recharge after consideration of runoff, evaporation, or pumping. Since this value lies between the earlier site estimates, it seems to be a reasonable value of recharge to use in the model. A sensitivity analysis was conducted on the range of recharge values with the numerical model, to note the impact.

3.5 Discharge

Groundwater within the study area discharges to wetlands and stream channels. The stream channels are dry or may contain very little flow except during wet periods. Figure 22 shows the NHD delineation of wetlands and stream channels in the study area. Groundwater may also discharge laterally across the study area lateral boundaries as there are no hydraulic barriers located along the study area boundary.

4.0 NUMERICAL MODEL CONSTRUCTION

The conceptual model discussed above forms the basis for development of the numerical groundwater flow model. The model was used to assess the pre- and post-mining conditions within the study area.

The three-dimensional modular groundwater-flow model software MODFLOW-NWT (Niswonger et al., 2011), developed by the U.S. Geological Survey, was used for the simulations. The Groundwater Vistas, Version 8 (Rumbaugh and Rumbaugh, 2020), graphical user interface was used to interface with MODFLOW-NWT for pre-processing the data and constructing the model, for post-processing and evaluating results, and to create figures and maps. Construction of the numerical model required evaluating the objectives and the conceptual site model, establishing the time period of the simulation, and designing the spatial resolution necessary to perform the simulation. The site location is shown on Figure 1.

MODFLOW-NWT (Niswonger et al., 2011) was selected for this study because it has the capabilities required for the evaluation, is readily available as an open-source, public domain software, and has robust simulation routines to handle numerical difficulties associated with drying and rewetting of model areas, varying topography, or contrasting hydrogeologic properties.

MODFLOW-NWT solves for three-dimensional flow of water in the subsurface using the finite-difference approach. The finite-difference numerical method "discretizes" the modeled domain into model cells that are rectangular in map view but whose top and bottom elevations may vary vertically to conform to stratigraphic geometries. Each model cell represents a part of the domain that is encompassed by that model cell and model inputs and outputs are generated for this discretized system for each cell within the model domain. Groundwater flow simulations can be performed on this discretized domain using a steady-state or transient approach. In a steady-state approach, the groundwater flow equations are solved for long-term average conditions, while a transient approach solves for the groundwater flow at different times, as flow conditions and water levels change through time due to changing recharge or discharge conditions. Modeling objectives, and the behavior of the hydrogeologic system determine how a numerical groundwater model is discretized in space and whether steady-state or transient simulations are necessary.

4.1 Model Discretization

The model domain was discretized for the current study as shown on Figure 23. The study area was divided into 64 columns and 62 rows of cells. The grid block size is a uniform 500 feet in the x- and y- coordinate directions and the proposed mine area contains 100 model cells in the aerial direction (Figure 23). The grid block thickness is variable, to enable the grid to conform to hydrogeologic units and to post-mining backfill conditions.

The stratigraphic layer elevations and thicknesses of the numerical model honor the hydrogeologic conceptual model depicted on Figures 6 through 14, though additional numerical layers have been added so as to allow post-mining conditions to be accurately represented – mining is anticipated to occur up to different depths from stratigraphic contacts between the hydrogeologic units and therefore additional numerical layers were included in the model to accommodate those post-mining conditions. Figure 24 shows the model layering in relation to the hydrostratigraphic layers. If a hydrostratigraphic layer is divided into more than one numerical layer, the sub-discretization is performed with equal thickness allocated to the numerical layers that represent a hydrostratigraphic layer, except where it is specifically allocated to represent the bottom of post-mining back-fill materials. Figure 25 shows N-S and E-W cross-sections of the numerical model grid (cross-section locations are also depicted on Figure 23).

The numerical model was run using a steady-state approach. Though fluctuations were noted in the water level hydrographs, they were seasonal and did not exhibit long-term trends. GA EPD has further examined the State Water Plan model which showed little change in hydraulic heads between high and low recharge periods and noted that steady-state simulation conditions could be used to evaluate conditions at the mine (Kennedy, 2020b).

4.2 Model Parametrization

The numerical model cells are all assigned with initial horizontal and vertical hydraulic conductivity values for the associated hydrogeologic units. Figures 15 through 18 show initial estimates of hydraulic conductivity at wellbore locations from various aquifer and laboratory tests, which were then interpolated across the site to provide values for the entire domain. The anisotropy (horizontal to vertical hydraulic conductivity ratio) of the units was taken as 1:1 for the consolidated black sands and 10:1 for the other hydrogeologic units. Layers containing the consolidated black sand were zoned into regions where the consolidated black sands did and did not exist, and a transition zone as depicted on Figure 4. Initial hydraulic conductivity values in the transition zone were in between those of the unconsolidated sand and the consolidated black sand. The initial hydraulic conductivity distributions were then changed during the model calibration process.

4.3 Model Boundary Conditions

Model boundary conditions applied on the top surface of the model included recharge of precipitation and discharge to stream channels and wetlands within the model domain. Model boundary conditions also include prescribed water levels along the east and west lateral boundaries in all layers of the model to allow water to migrate out of the domain laterally. Since the groundwater flow system is mainly in the east-west direction with Trail Ridge acting as a hydrogeologic divide, there is no flow occurring across the north and south boundaries of the model domain or through the Hawthorn Group at the bottom. The boundary conditions on the top model layer are noted on Figure 23.

Recharge was applied uniformly to the land surface at a rate of 4.13 inches/year, which is based upon estimates for the proposed mine area calculated by the USGS (2003). The conceptual model evaluations above, noted that estimates can range from 3.5 to 4.5 inches/year (Holt, 2019d and Holt 2020a). A sensitivity analysis was conducted to note the impact of recharge uncertainty on model results.

The bottom boundary was considered a no-flow boundary because the Hawthorn Formation at the base of the Surficial Aquifer has very low permeability and flow through it is negligible in comparison to flow conditions in the Surficial Aquifer.

Wetlands are discharge areas for groundwater. Stream channels in the area may recharge groundwater during periods of rainfall events but are otherwise locations of groundwater discharge. The drain boundary in MODFLOW-NWT was used to represent wetlands and streams. The drain boundary allows water to flow out of the groundwater system when water levels are at or above a prescribed “drain” elevation – no flow occurs when groundwater levels are below the “drain” elevation. Thus, for MODFLOW models, drains can receive water from the modeled aquifer but cannot simulate losses from surface water features to the aquifer. A river boundary condition in MODFLOW can receive water from the modeled aquifer as well as discharge water to the modeled aquifer. Drains were used to simulate the surface water features shown in Figures 22 and 23 and no rivers were represented since there are no rivers within the model domain. The streambed elevation or the elevation of the wetland were assigned as the “drain” elevations. The drain boundary includes a conductance term to represent sediments at the bottom of the streams, wetlands, or lining of the streambed. A high conductance value (10^7 ft^2/d) was used for the drains to allow water to freely drain without resistance from near surface depositions or alterations

Prescribed water level conditions (prescribed head conditions of MODFLOW-NWT) were provided along the east and west lateral model boundaries in all model layers. The prescribed water level elevation was set to land surface at the location of wetlands, and to 1 foot below land surface where there were no wetlands along the boundary. The prescribed water level conditions were not provided in layer 1 at locations also coincident with drain boundary conditions. The northern and southern lateral boundaries were no-flow conditions because they are parallel to the direction of groundwater flow with minimal flow across them.

5.0 MODEL CALIBRATION

The numerical model was constructed using Groundwater Vistas Version 8 (Rumbaugh and Rumbaugh, 2020). Model files were then generated for MODFLOW-NWT, which runs the model and creates output files that were then imported into Groundwater Vistas for further analysis. A model developed with preliminary estimates of the hydrogeologic properties usually does not match site conditions very well and requires “calibration”, which is done by adjusting the model parameters to obtain a best fit between the model calculations and the field data. Model calibration was performed using expert hydrogeological judgement aided with automatic calibration tools provided by the computer software PEST (Doherty, 2010). Consistency with the conceptual model was also evaluated and adjustments were made to modeled hydraulic conductivity values within reasonable ranges for each of the hydrogeologic units, until the model was considered calibrated.

All available field data were used for model calibration and include average water level measurements of Figure 19 and water level differences between piezometer pairs noted on Figure 21. The water level contour maps of Figure 20 were also evaluated visually during calibration. Finally, in areas outside of wetland or stream channels, the calibration was constrained to try and keep water levels below land surface.

Model calibration was evaluated quantitively as well as qualitatively. Quantitative calibration metrics include evaluating that the basic statistics of the goodness of fit between modeled water levels and measured water levels of Figure 19 are within acceptable professional standards. The errors were also displayed on a map to note if there was any spatial bias in the calibration (i.e., if there were regions that consistently overpredict or underpredict water levels). Water level differences of Figure 21 were considered during calibration but were not evaluated further. Qualitative metrics include visual comparison of simulated water level contours against estimates of Figure 20. Modeled depth to water and standing water above land surface in locations where stream channels or wetlands do not exist were also evaluated to note consistency of the model with conditions at the site; this was done by plotting the difference between the top elevation of model layer 1 and the water level in model layer 1, where negative values represent ponded water depth and positive values represent depth to water.

The hydraulic conductivity values of the hydrostratigraphic units were varied to calibrate the model. Estimates derived from aquifer tests and laboratory studies shown on Figures 15 through 18 were assigned as initial values within each respective hydrostratigraphic unit and hydraulic conductivity values were then adjusted by the automatic calibration software PEST on a set of interpolation points termed “pilot points”. The hydraulic conductivity field was constrained to stay within reasonable limits of measured conditions. The results of a PEST automated parameter estimation simulation were evaluated for the quantitative and qualitative calibration metrics discussed in the previous paragraph. Each parameter estimation simulation was also evaluated to note that hydraulic conductivity values for the various hydrogeologic units were reasonable and that the conceptual model was represented appropriately by the numerical model. Calibration proceeded in this manner until satisfactory results were obtained for the calibration metrics, hydrogeologic property values, and conceptual flow conditions.

6.0 MODEL CALIBRATION RESULTS FOR PRE-MINING CONDITIONS

The Trail Ridge hydrologic system model was developed for steady-state conditions and calibrated as discussed above. The model represents pre-mining conditions of groundwater flow and its interaction with surface-water features in the study area.

Figures 26, 27, 28 and 29 show the calibrated horizontal hydraulic conductivity distribution of the four hydrogeologic units in the model. The values are within the range of observed conditions for the various hydrogeologic layers. Specifically, it is noted that the consolidated black sands layer hydraulic conductivities range from 0.0028 feet/day 4 x 10^{-5} feet/day (10^{-6} to 10^{-8} cm/second) as was obtained in laboratory and field tests. The other hydrogeologic units also had calibrated hydraulic conductivity values within similar ranges to their field or laboratory estimated values.

Figure 30 shows the fit between modeled water levels and measured water levels and Table 2 shows the model calibration statistics. The match between simulated and observed water levels is noted to be good for the range of water levels at the site. The mean of the residual error was small 3.23 ft compared to the range of observed heads (over 60 ft), and the normalized root mean squared error was 5.1 %.

Figure 31 shows the simulated water level contours. The simulated water levels reflect the topography of Trail Ridge and show the influence of stream channels. The simulated water levels also resemble the potentiometric surface map for July 2019, depicted in Figure 20.

Figure 32 shows the modeled depth to water, which is 1-5 feet below land surface within most of the study area. There are a few small areas off from the ridge where the model simulated water levels above ground surface (simulated ponding). It is likely that since these ponded areas are adjacent to either streams or wetlands (Figure 22 and 32), they may also be seepage locations not identified on the NHD dataset.

Considering all the above metrics, the pre-mine model is determined to be well calibrated to long-term steady-state conditions at the site.

The water budget for the pre-mining simulation is shown on Table 3. 52% of groundwater recharge is noted to flow into streams and wetlands on the west of Trail Ridge while 42% flows into wetlands and streams on the east side of the ridge. Figure 33 provides a map of the areas east and west of Trail Ridge for water budget evaluations.

7.0 POST-MINING ANALYSIS

For post-mining conditions, the mined volume will be backfilled with homogenized reclaimed sand. The geometry of the mine pit and mine advancement conditions are shown on Figure 3. The sands will be mined to a maximum depth of 50 feet below ground surface. Mine reclamation will include a layer of bentonite treated sand approximately 3 feet thick, where the top of the bentonite treated sand will be placed as close as possible to top of the consolidated black sands of pre-mining conditions. The model does not simulate the physical process of placing the bentonite-enhanced soil layer. The topography of the reclaimed mine spoils will be returned as close to pre-mining elevations as possible. The additional numerical layers included in the model were intended to account for the natural occurring transitions between hydrostratigraphic units, the demarcation between unmined and mined volumes, and to explicitly account for the placement of 3 feet of bentonite treated sand. Figure 34 shows a cross-section of the model through the mine pit indicating the various mined and unmined layers.

The hydraulic conductivity of reclaimed sands was evaluated to be approximately 2.8 feet/day (1 x 10^{-3} cm/s) from experiments conducted on homogenized sands from the area (Holt et al., 2019f). Experiments were also conducted on evaluating the hydraulic conductivity of a sand mixture with different percentages of bentonite. Holt et al., (2020b) further fit a regression equation to the hydraulic conductivity as a function of the percent of bentonite in the mixture, reproduced here as:

$$\text{Log}(K_{sb}) = (-0.3567\ pB - 3.108)$$

Where K_{sb} is the hydraulic conductivity of the sand-bentonite mixture in units of cm/sec, and pB is the percent of bentonite added to the sand. This equation indicates a hydraulic conductivity value for sand of 7.8 x 10^{-4} cm/sec (2.2 feet/day), with no bentonite present. This is in line with the 1 x 10^{-3} cm/s (2.8 feet/day) value estimated by Holt et al., (2019f) for homogenized sands. Hydraulic conductivity of the sand-bentonite mixture is 1 x 10^{-4} cm/s (0.28 feet/day) with 2.5% bentonite; 1 x 10^{-5} cm/s (0.028 feet/day) with 5.3% bentonite; 1 x 10^{-6} cm/s (2.8 x 10^{-3} feet/day) with 8.1% bentonite; and 1 x 10^{-7} cm/s (2.8 x 10^{-4} feet/day) with 10.9 % bentonite (Holt et al., 2020b).

The groundwater model for post-mining conditions was developed using the calibrated model for pre-mining conditions. The mined volume was replaced by homogenized reclaimed sand spoils with a hydraulic conductivity value of 1 x 10^{-3} cm/s (2.8 feet/day) and included a layer of bentonite treated sand approximately 3 feet thick and 8 to 25 feet below the reclaimed land surface. The reclaimed homogenized sand spoils and bentonite treated sands were only simulated within the proposed mining area as shown on Figure 3 (and select subsequent report figures).

Four different values of hydraulic conductivity for bentonite treated sand layer were evaluated to assess the impact of varying amounts of bentonite in the amended soil layer mix. These include:

- 1 x 10^{-3} cm/sec (2.8 feet/day) representing no bentonite;
- 1 x 10^{-5} cm/s (0.028 feet/day) representing a 5.3% bentonite mix;
- 1 x 10^{-7} cm/s (2.8 x 10^{-4} feet/day) assuming a 10.9% bentonite mix; and
- 2.7 x 10^{-8} cm/s (7.7x 10^{-5} feet/day) representing 12.5% bentonite in the mix.

These analyses help to assess the changes in hydrogeologic conditions due to different bentonite mixtures in the amended sand/bentonite layer and are useful to provide input to the bentonite mixture percentages that would be most beneficial in reducing post-mining hydrogeologic impacts.

Figures 35, 36, 37, and 38 show the simulated water level contours for post-mining conditions with 0%, 5.3%, 10.9% and 12.5% bentonite mixture respectively in the 3-feet thick treated sand layer. The water levels are generally similar to pre-mining conditions for all cases of bentonite mix, except in the immediate vicinity of the mine. The groundwater divide is similarly maintained to the pre-mining simulation (Figure 31) across all scenarios and simulations though water levels are generally noted to be higher within the mined area, with increasing bentonite content of the amended sands.

Figures 39, 40, 41, and 42 show the difference in simulated water level contours between pre-mining and post-mining conditions with 0%, 5.3%, 10.9% and 12.5% bentonite mixture, respectively, in the 3-feet thick treated sand layer. Both the 0% and 5.3% bentonite amended soil scenarios exhibit similar results where water levels are generally maintained through much of the proposed mine footprint but decrease by as much as 6 feet relative to pre-mining conditions on the northeast side of the proposed mine area.

The 10.9% bentonite mixture results in a 2-5 feet rise in groundwater elevation within the mine footprint. Along and adjacent to the mine boundary, declines in water level elevations following mining are generally less than 1 foot with one model cell showing a decline of approximately 2 feet.

The high bentonite mixture scenario (12.5%) causes as much as 9 feet of water level rise within the mine footprint, which results in simulated groundwater elevations greater than 5 feet above ground surface. This scenario also shows declines adjacent to the mine boundary that are consistent in magnitude with the 10.9% bentonite soil amendment scenario but spread over a slightly increased area.

For all scenarios, water level changes were negligible in and near the Okefenokee National Wildlife Refuge.

The water level rise for post-mining conditions increases with increase in percent of bentonite in the amended sands because it increasingly acts as a barrier to downward flow thus affecting the shallow water table along the ridge. Water levels are noted to decline just outside of the mine footprint, with those declines being largest under the no bentonite scenario. The modeled water levels did not change near the eastern or western model boundaries. The water level changes for post-mining conditions are influenced by the groundwater flow system adjusting to homogeneous sand spoils and the amended sand layer replacing the original hydrogeology within the mined area.

Table 4 shows the water budget components for pre- and post-mining conditions. It is noted that discharge to the wetlands changes minimally across all scenarios.

In conclusion, it is noted that for post-mining conditions, bentonite amended soils perform best to approximate pre-mining conditions at around 10.9% for both water levels and groundwater discharge to streams and wetlands.

8.0 SENSITIVITY ANALYSIS

A sensitivity analysis was conducted on the calibrated model to determine the impact of parameter changes to the calibration results as well as to the post-mining predictions. For these sensitivities, the parameter values were raised and lowered by prescribed factors and the change in model calibration errors was evaluated for each case. These parameters were then categorized into high, medium, and low sensitivity groups based on the change in calibration statistics resulting from the change in the parameter value. For each parameter, the resulting post-mining predictions are also evaluated and categorized into high, medium, and low sensitivity groups. The parameters are then categorized into “sensitivity types” as defined by ASTM International (formerly the American Society for Testing and Materials) (ASTM, 1994, 2000) for uncertainty evaluations of the post-mining predictions. The sensitivity types categorize how parameters change the model calibration versus the model predictions and are as follows:

- Type I sensitivity is defined for parameters that cause insignificant changes to the calibration residuals as well as to model conclusions/predictions of interest. Type I sensitivity is of no concern because regardless of the value of the input, the prediction is also insensitive.
- Type II sensitivity is defined for parameters that cause significant changes to the calibration residuals but insignificant changes to model conclusions/predictions of interest. Type II sensitivity is of no concern because the prediction is not sensitive to the calibration.
- Type III sensitivity is defined for parameters that cause significant changes to the calibration residuals as well as to the model conclusions/predictions. Type III sensitivity is of no concern because even though the model’s predictions change as a result of variation of the input variable value, the calibration residuals are also sensitive, and the model becomes uncalibrated as a result. Thus, model calibration ensures that the predictions considered are appropriate for the modeled system.
- Type IV sensitivity is defined for parameters that cause insignificant changes to model calibration residuals but significant changes to the model predictions. Type IV sensitivity is of concern because, over the range of that parameter in which the model can be considered calibrated, the conclusions or predictions of the model can change.

The parameters that were evaluated for the sensitivity study include the recharge rate, the hydraulic conductivity of the consolidated black sand hydrogeologic unit, and the hydraulic conductivity value for the unconsolidated and semi-consolidated sand layers.

8.1 Sensitivity to Recharge Rate

The first set of sensitivity simulations was conducted on the recharge rate applied to the steady-state models. For this sensitivity analysis, the recharge rate was varied within the estimated range of recharge values noted from various studies in the area. Two model runs were performed, one with the recharge rate raised to 4.5 inches/year, and the other with the recharge rate lowered to 3.5 inches/year (the calibrated model had a recharge rate of 4.13 inches/year). The mean residual and root-mean-square (RMS) error for this sensitivity are noted on Figure 43. It is noted that the calibration (pre-mining) water level errors are generally not sensitive to the recharge rates and therefore, the water levels would be similar if a different value were assigned to the model. Increasing the recharge raises average water levels slightly while decreasing recharge creates a greater relative decline in simulated water levels although, overall, this decline remains small. Therefore, given the minimal difference in changes in simulated head values across the simulations, sensitivity of the model calibration to recharge is low.

Table 5 shows the water budget components for the sensitivity analysis. It is noted that even though recharge rates vary between the simulations, the percent of discharge to the different boundaries was not significantly affected. Thus, sensitivity of the model predictions (discharge percentages and pre- versus post-mining water level changes) to recharge is low.

Considering a low sensitivity to calibration and low sensitivity to the predictions, recharge may be categorized as a Type I sensitivity. This sensitivity is not of concern because a change in the parameter value does not cause a significant change in the calibrated model or the results.

8.2 Sensitivity to Hydraulic Conductivity of Consolidated Black Sand Layers

The next set of sensitivity simulations was conducted on the hydraulic conductivity of the consolidated black sand numerical layers. For this sensitivity analysis, the hydraulic conductivity of the consolidated black sand hydrogeologic unit was varied up and down by a factor of 5. The mean residual and RMS error for this sensitivity are noted on Figure 44. It is noted that the calibration (pre-mining) water level errors are minimally sensitive to the hydraulic conductivity of the consolidated black sand and therefore, simulated water levels would be similar over this range of tested K values. Decreasing the hydraulic conductivity of the consolidated black sand results in a slightly higher simulated water level on average, which leads to a slight increase in the RMS error. Increasing the hydraulic conductivity of the consolidated black sands has a lesser relative effect on the RMS error and the change in residual mean is still quite small. Thus, sensitivity of the model calibration to hydraulic conductivity of the consolidated black sands layer is low within a factor of 5.

Table 6 shows the water budget components for the sensitivity analysis. It is noted that the percent of discharge to the different boundaries was not significantly affected. Thus, sensitivity of the model predictions (discharge percentages and pre- versus post-mining water level changes) to hydraulic conductivity value of the consolidated black sands hydrogeologic layer is low.

Considering a low sensitivity to calibration and low sensitivity to the predictions, hydraulic conductivity values of the consolidated black sands may be categorized as a Type I sensitivity. This sensitivity is not of concern because a change in the parameter value, within the range evaluated, does not cause a change in the calibrated model or the results.

8.3 Sensitivity to Hydraulic Conductivity of Unconsolidated and Semi-Consolidated Sand and the Silty Clayey Sand

The next set of sensitivity simulations was conducted on the hydraulic conductivity of the unconsolidated sand layers (hydrogeologic units 1 and 3). For this sensitivity analysis, the hydraulic conductivity of hydrogeologic units 1 and 3 was varied up and down by a factor of 5. The mean residual and RMS error for this sensitivity are noted on Figure 45. It is noted that the calibration (pre-mining) water level errors are sensitive to the hydraulic conductivity of the sandy units and therefore, the water levels would change if values were used outside of the range used in the calibrated model and/or observed data. Decreasing the hydraulic conductivity of the unconsolidated sand results in high simulated groundwater elevations while increasing hydraulic conductivity causes a substantial decline in the water level elevations as noted by the residuals. Thus, sensitivity of the model calibration to the hydraulic conductivity of the unconsolidated and semi-consolidated sand and the silty clayey sand layer is high.

Table 7 shows the water budget components for the sensitivity analysis. It is noted that the percent of discharge to the different boundaries was affected by lowering or raising the hydraulic conductivity of the sands. Thus, sensitivity of the model predictions (discharge percentages and pre- versus post-mining water level changes) to hydraulic conductivity value of the unconsolidated sands hydrogeologic layers is relatively high. However, it is noted that the discharge percentages for post-mining conditions are similar to those of the respective pre-mining condition indicating that there may be some uncertainty in the discharge depending on uncertainty in the parameter value. However, it is also noted that pre- and post-mining conditions are similar for each sensitivity indicating that mining does not change those percentages.

Considering a high sensitivity to calibration and high sensitivity to the predictions, the hydraulic conductivity value of the unconsolidated sands may be categorized as a Type III sensitivity. This sensitivity is not of concern because although the model's predictions would change as a result of variation of the input variable value, the calibration residuals are also sensitive, and the model becomes more uncalibrated as a result and model calibration ensures that the predictions considered are appropriate for the modeled system. Furthermore, as indicated in Table 7, pre- and post-mining discharges are similar no matter the sensitivity being evaluated.

8.4 Summary of Sensitivity Simulations

Table 8 shows the sensitivity simulations categorized as per the ASTM (1994, 2000) approach. It is noted that recharge and hydraulic conductivity of the consolidated black sands have a Type I sensitivity, while hydraulic conductivity of the unconsolidated and semi consolidated sand units (hydrogeologic units 1 and 3) have a Type III sensitivity. These types of sensitivities indicate that the variations or uncertainties in the parameter values are not of concern to the results of the model within the ranges tested.

9.0 SUMMARY AND CONCLUSIONS

This report documents the numerical groundwater flow modeling effort conducted to evaluate the impact of the proposed mine on the hydrogeologic system of Trail Ridge and surrounding areas including the Okefenokee National Wildlife Refuge. Available hydrologic, hydrogeologic and climate data were assimilated and evaluated to develop a conceptual model of the flow system. A numerical model was then developed based on the conceptual model and calibrated to available data for steady-state, pre-mining conditions. The model was then used to evaluate post-mining conditions and how the hydrogeologic system may have changed as a result of mining. The model also assessed the impact of different bentonite mixtures in a soil amendment layer within the reclaimed sands, on the system hydrogeology. This was done by conducting a sensitivity analyses of the system to the hydraulic conductivity of the bentonite mixture. A 10.9% bentonite mixture in the amended sand layer provides the least amount of hydrogeologic impact around the mine site.

Sensitivity analyses were also conducted on key inputs to the model including recharge rate, hydraulic conductivity of the consolidated black sand, and hydraulic conductivity of the unconsolidated and semi-consolidated sands. The recharge rate was changed from 4.13 inches/year to 3.5 inches/year and to 4.5 inches per year, which is the general range of estimated average recharge conditions in the vicinity of the proposed mine. The hydraulic conductivity values were varied by a factor of 5 to estimate a bound for its range of uncertainty. These sensitivity analyses indicate that the results are reliable. The water budgets for pre- and post-mining conditions are similar for the different sensitivity analyses indicating that mining does not impact these water budget values for the various sensitivity cases.

In conclusion, the current model has been completed to address the concerns of the GA EPD and results indicate that mining activities will have no significant impact on water levels in and near the Okefenokee National Wildlife Refuge. Additionally, the existing Trail Ridge hydrologic divide separating the Okefenokee Swamp to west from the Saint Mary's River to the east will always be maintained.

10.0 REFERENCES

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Tables

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Table 1. Computation of Consolidated Black Sand Areal Coverage in Study Area

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia

Cross-Section	Total Length (feet)	Total Length Consolidated Black Sand (feet)	Percentage of Cross-Section Without Consolidated Black Sand
A-A'	20,700	15,500	25.1%
B-B'	19,400	15,200	21.6%
C-C'	25,900	22,000	15.1%
D-D'	20,100	14,900	25.9%
E-E'	23,300	11,500	50.6%
F-F'	23,500	11,400	51.5%
G-G'	25,500	23,000	9.8%
H-H'	7,700	5,900	23.4%
I-I'	17,900	14,600	18.4%
J-J'	11,500	11,500	0.0%
K-K'	26,000	7,800	70.0%
L-L'	25,500	17,000	33.3%
M-M'	22,000	14,300	35.0%
N-N'	15,700	12,700	19.1%
O-O'	13,500	5,800	57.0%
P-P'	21,800	12,400	43.1%
Q-Q'	25,000	16,000	36.0%
R-R'	19,200	11,500	40.1%
S-S'	14,800	11,000	25.7%
T-T'	6,000	3,000	50.0%
U-U'	5,600	5,600	0.0%
V-V'	6,700	6,700	0.0%
W-W'	26,800	22,500	16.0%
X-X'	13,800	10,200	26.1%
Total	437,900	302,000	31.0%

Table 2. Calibration Statistics for Steady-State Simulation

Twin Pines Minerals, LLC, St. George

Charlton County, Georgia

Statistic	Model Values
Number of targets	87
Number of observations	87
Range in observed values	63.79
Minimum residual	-6.09
Maximum residual	9.02
Sum of squared residuals	9.05E+02
Root mean square (RMS) error	3.23
Residual mean	0.76
Absolute residual mean	2.39
Standard deviation	3.14
Scaled residual mean	0.012
Scaled absolute residual mean	0.037
Scaled standard deviation	0.049
Scaled RMS error	0.051

Table 3. 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)	Lateral Outflows	1.1%	5.4%	6.5%
	Outflow to Modflow Drain Package[3]	52.0%	41.5%	93.5%
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.

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Table 4. 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)	Lateral Outflows	1.1%	5.4%	6.5%	1.1%	5.4%	6.5%
	Outflow to Modflow Drain Package[3]	52.0%	41.5%	93.5%	52.0%	41.6%	93.5%
Percent Mass Balance Error		0.0%			0.0%		

Water Budget Component		5.3% Bentonite Soil Amendment			10.9 % Bentonite Soil Amendment			12.5% Bentonite Soil Amendment		
		West	East	Total	West	East	Total	West	East	Total
Inflows (gallons per minute)	Recharge	2,669	2,113	4,782	2,669	2,113	4,782	2,669	2,113	4,782
Outflows (as % of Total Recharge)	Lateral Outflows	1.1%	5.4%	6.5%	1.1%	5.4%	6.5%	1.1%	5.4%	6.5%
	Outflow to Modflow Drain Package[3]	52.0%	41.6%	93.5%	52.1%	41.5%	93.6%	52.0%	41.6%	93.5%
Percent Mass Balance Error		0.0%			0.0%			0.1%		

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.

Table 5. Pre- and Post-Mining Water Budget Comparisons For Recharge Rates

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia

Water Budget Component		Pre-Mining Recharge of 4.13 in/yr			Pre-Mining Recharge of 3.5 in/yr			Pre-Mining Recharge of 4.5 in/yr		
		West[1]	East[2]	Total	West	East	Total	West	East	Total
Inflows (gallons per minute)	Recharge	2,669	2,113	4,782	2,262	1,791	4,052	2,908	2,303	5,210
Outflows (as % of Total Recharge)	Lateral Outflows	1.1%	5.4%	6.5%	1.1%	5.8%	7.0%	1.0%	5.2%	6.2%
	Outflow to Modflow Drain Package[3]	52.0%	41.5%	93.5%	51.6%	41.4%	93.0%	52.3%	41.5%	93.8%
Percent Mass Balance Error		0.0%			0.0%			0.0%		

Water Budget Component		10.9% Bentonite w/ Recharge of 4.13 in/yr			10.9% Bentonite w/ Recharge of 3.5 in/yr			10.9% bentonite w/ Recharge of 4.5 in/yr		
		West	East	Total	West	East	Total	West	East	Total
Inflows (gallons per minute)	Recharge	2,669	2,113	4,782	2,262	1,791	4,052	2,908	2,303	5,210
Outflows (as % of Total Recharge)	Lateral Outflows	1.1%	5.4%	6.5%	1.1%	5.8%	7.0%	1.0%	5.2%	6.2%
	Outflow to Modflow Drain Package	52.1%	41.5%	93.6%	51.7%	41.4%	93.1%	52.2%	41.5%	93.8%
Percent Mass Balance Error		0.0%			0.0%			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.

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Table 6. Pre- and Post-Mining Water Budget Comparisons For Consolidated Black Sands Hydraulic Conductivity

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia

Water Budget Component		Pre-Mining w/ Calibrated Hydraulic Conductivity			Pre-Mining Calibration Value x 5			Pre-Mining Calibration Value ÷ 5		
		West[1]	East[2]	Total	West	East	Total	West	East	Total
Inflows (gallons per minute)	Recharge	2,669	2,113	4,782	2,669	2,113	4,782	2,669	2,113	4,782
Outflows (as % of Total Recharge)	Lateral Outflows	1.1%	5.4%	6.5%	1.0%	4.9%	5.9%	1.1%	5.7%	6.8%
	Outflow to Modflow Drain Package[3]	52.0%	41.5%	93.5%	52.0%	42.1%	94.1%	52.8%	40.5%	93.2%
Percent Mass Balance Error		0.0%			0.0%			0.0%		

Water Budget Component		10.9% Bentonite w/ Calibrated Hydraulic Conductivity			10.9% Bentonite w/ Calibration Value x 5			10.9% bentonite w/ Calibration Value ÷ 5		
		West	East	Total	West	East	Total	West	East	Total
Inflows (gallons per minute)	Recharge	2,669	2,113	4,782	2,669	2,113	4,782	2,669	2,113	4,782
Outflows (as % of Total Recharge)	Lateral Outflows	1.1%	5.4%	6.5%	1.0%	4.9%	5.9%	1.1%	5.7%	6.8%
	Outflow to Modflow Drain Package	52.1%	41.5%	93.6%	52.1%	42.0%	94.0%	52.6%	40.6%	93.2%
Percent Mass Balance Error		0.0%			0.0%			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.

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Table 7. Pre- and Post-Mining Water Budget Comparisons For Unconsolidated & Semi-Consolidated Sands Hydraulic Conductivity

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia

Water Budget Component		Pre-Mining w/ Calibrated Hydraulic Conductivity			Pre-Mining Calibration Value x 5			Pre-Mining Calibration Value ÷ 5		
		West[1]	East[2]	Total	West	East	Total	West	East	Total
Inflows (gallons per minute)	Recharge	2,669	2,113	4,782	2,669	2,113	4,782	2,669	2,113	4,782
Outflows (as % of Total Recharge)	Lateral Outflows	1.1%	5.4%	6.5%	1.8%	7.9%	9.7%	0.7%	4.1%	4.8%
	Outflow to Modflow Drain Package[3]	52.0%	41.5%	93.5%	48.4%	41.9%	90.3%	53.5%	41.7%	95.2%
Percent Mass Balance Error		0.0%			0.0%			0.0%		

Water Budget Component		10.9% Bentonite w/ Calibrated Hydraulic Conductivity			10.9% Bentonite w/ Calibration Value x 5			10.9% bentonite w/ Calibration Value ÷ 5		
		West	East	Total	West	East	Total	West	East	Total
Inflows (gallons per minute)	Recharge	2,669	2,113	4,782	2,669	2,113	4,782	2,669	2,113	4,782
Outflows (as % of Total Recharge)	Lateral Outflows	1.1%	5.4%	6.5%	1.8%	7.9%	9.7%	0.7%	4.1%	4.8%
	Outflow to Modflow Drain Package	52.1%	41.5%	93.6%	48.4%	41.9%	90.3%	53.4%	41.8%	95.2%
Percent Mass Balance Error		0.0%			0.0%			0.0%		

Notes:

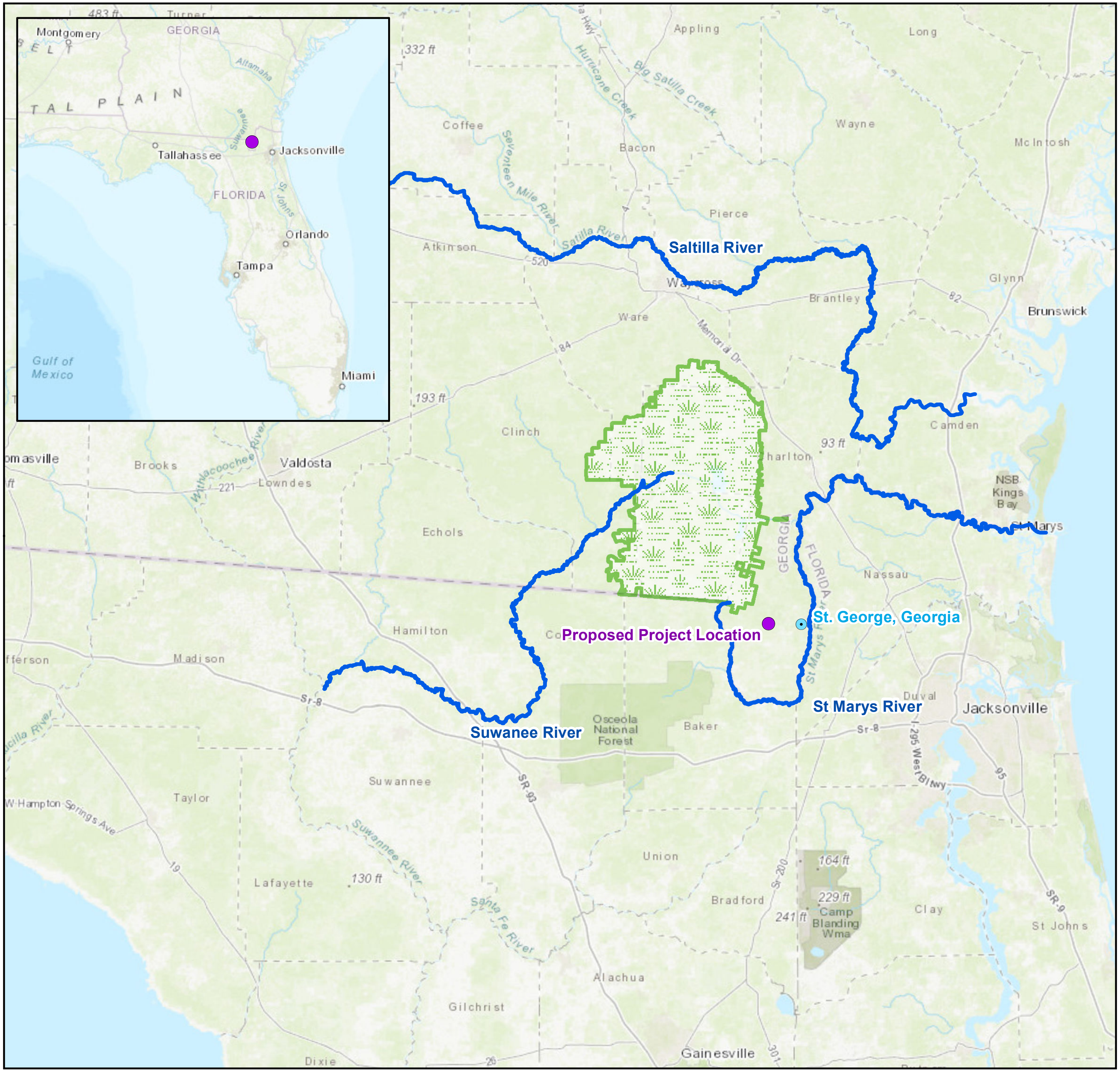
1. West refers to the west of the Trail Ridge crest as shown on Figure 33.
2. East refers to the east of the Trail Ridge crest as shown on Figure 33.
3. Modflow drain packages represents National Hydrography Dataset wetlands and streams as shown on Figures 22 and 23.

Table 8. Model Sensitivity Categorization
Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

Sensitivity Simulation	Calibration Sensitivity	Predictive Sensitivity	ASTM Sensitivity Type
Recharge Rate	Low	Low	Type I
Consolidated Black Sands Hydraulic Conductivity	Low	Low	Type I
Unconsolidated and Semi-Consolidated Sand Hydraulic Conductivity	High	High	Type III

Figures

Figures (cont.)



N

LEGEND

- St. George, Georgia
- Proposed Project Location
- Major Regional River Networks
- Okefenokee National Wildlife Refuge

Notes:

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

Scale in Miles

0 10 20

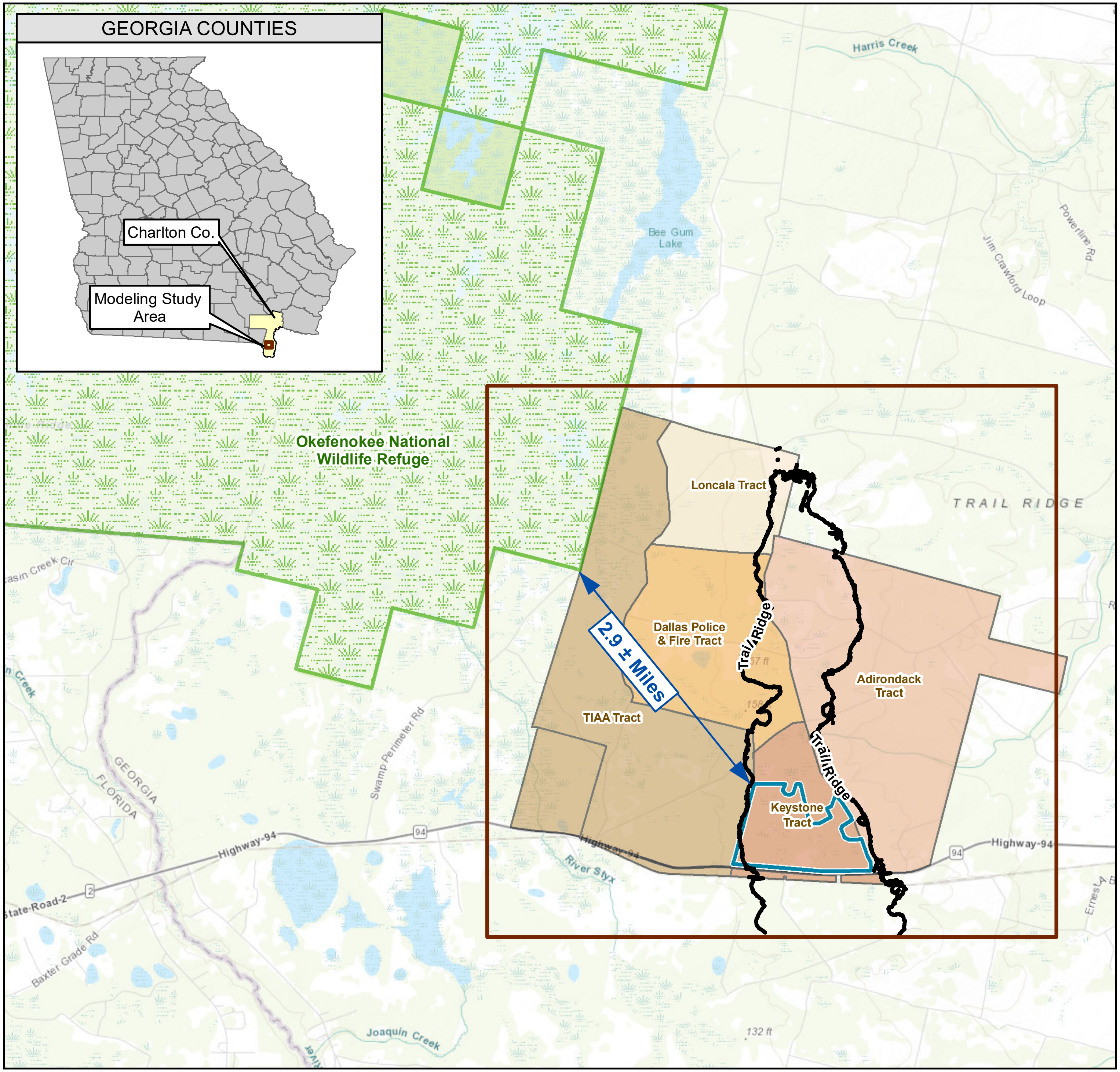
GSI ENVIRONMENTAL

Figure 1
Location of Proposed
Twin Pines Minerals Mine

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

GSI Job No. 5844	Drawn By: RLW
Issued: 15-Jul-2021	Chk'd By: SP
Map ID: Figure01	Appv'd By: SP

FIGURE 1



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Adirondack Tract
- Dallas Police & Fire Tract
- Keystone Tract
- Loncala Tract
- TIAA Tract
- Okefenokee National Wildlife Refuge
- Modeling Study Area

Notes:

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

Scale in Miles

0 0.75 1.5

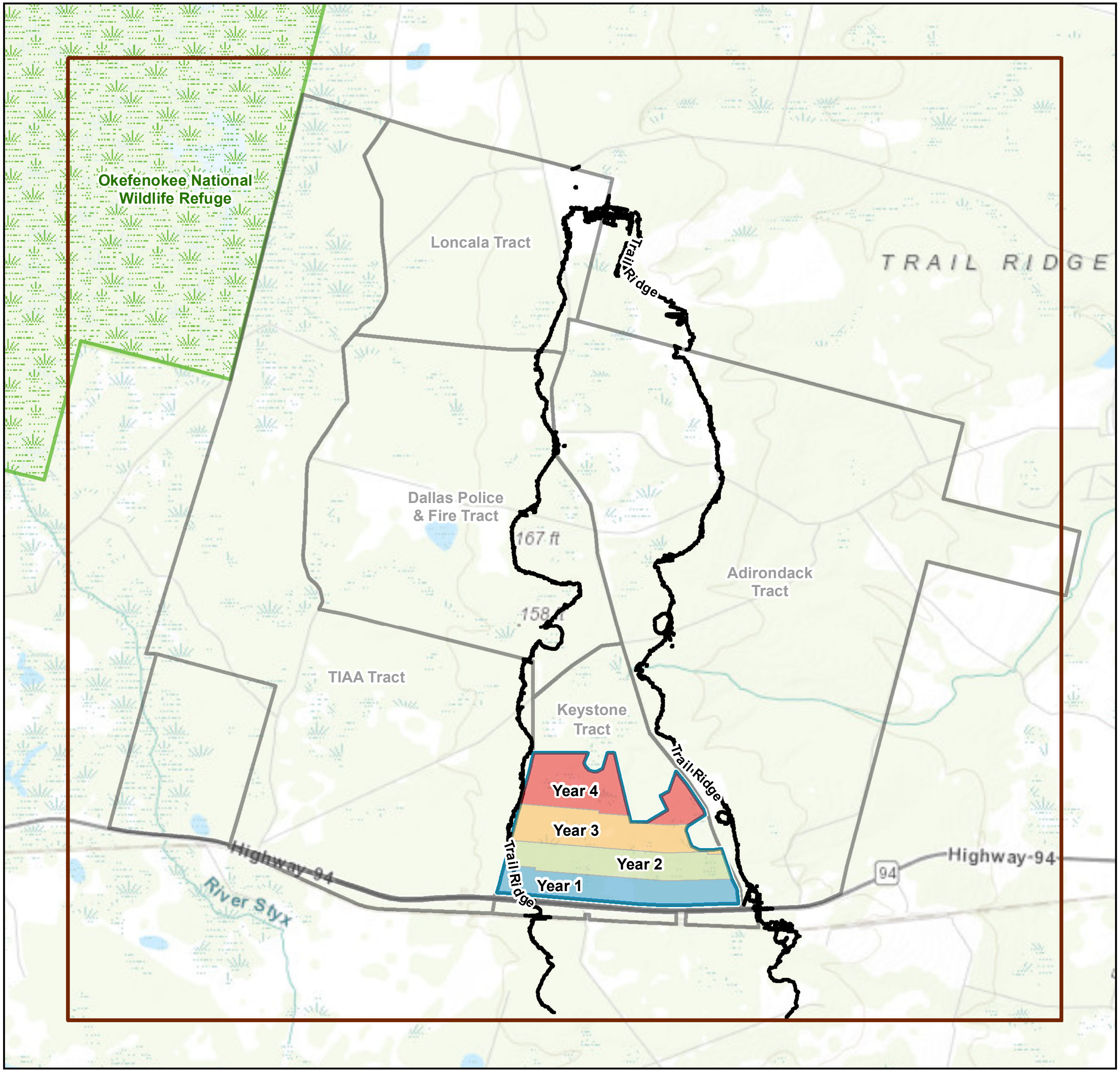
GSI ENVIRONMENTAL

Figure 2
Project Study & Proposed Mining Area

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

Mine Schedule

- Year 1
- Year 2
- Year 3
- Year 4
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- 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

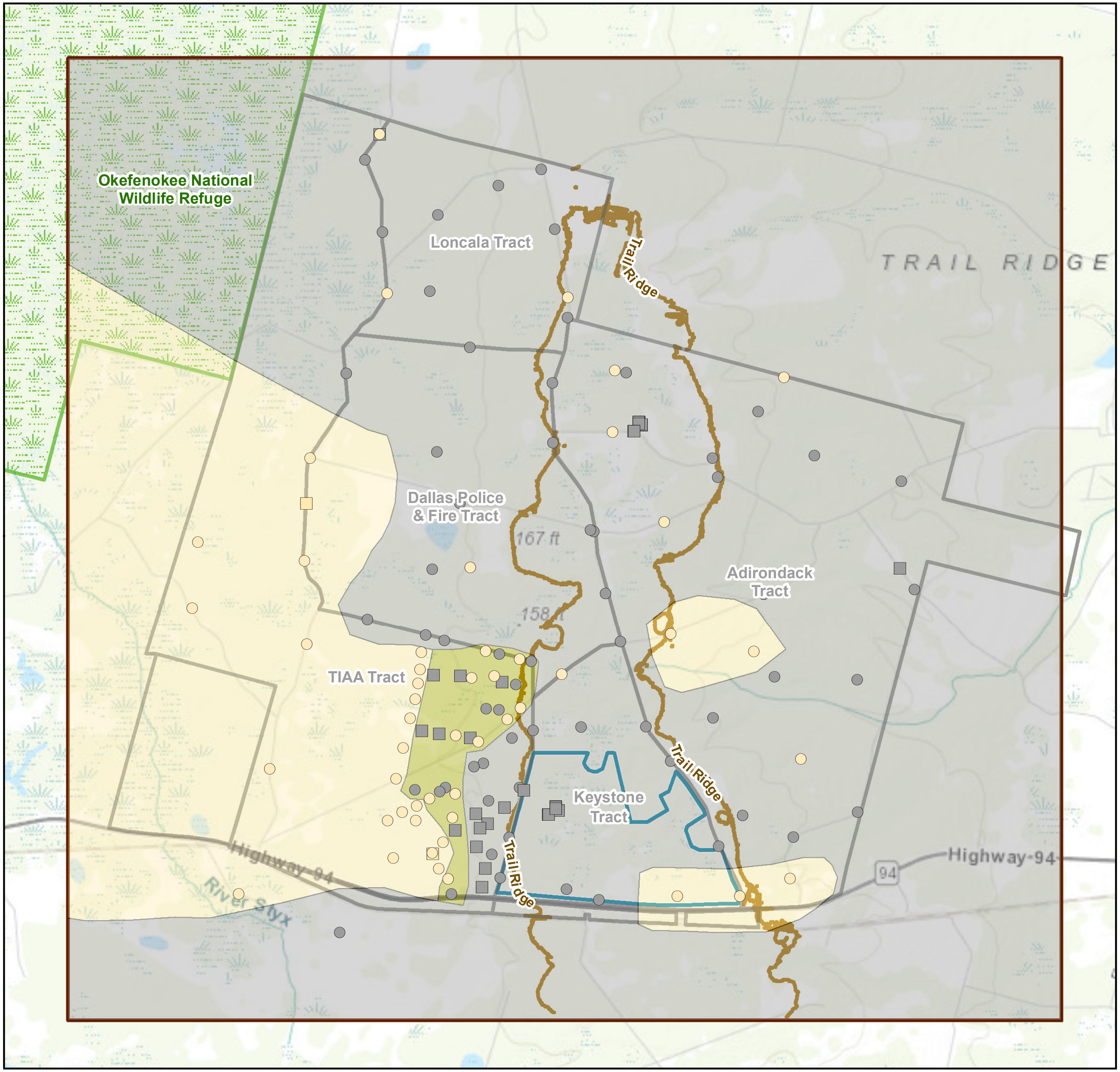
GSI ENVIRONMENTAL

Figure 3
Mining Schedule

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

- 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

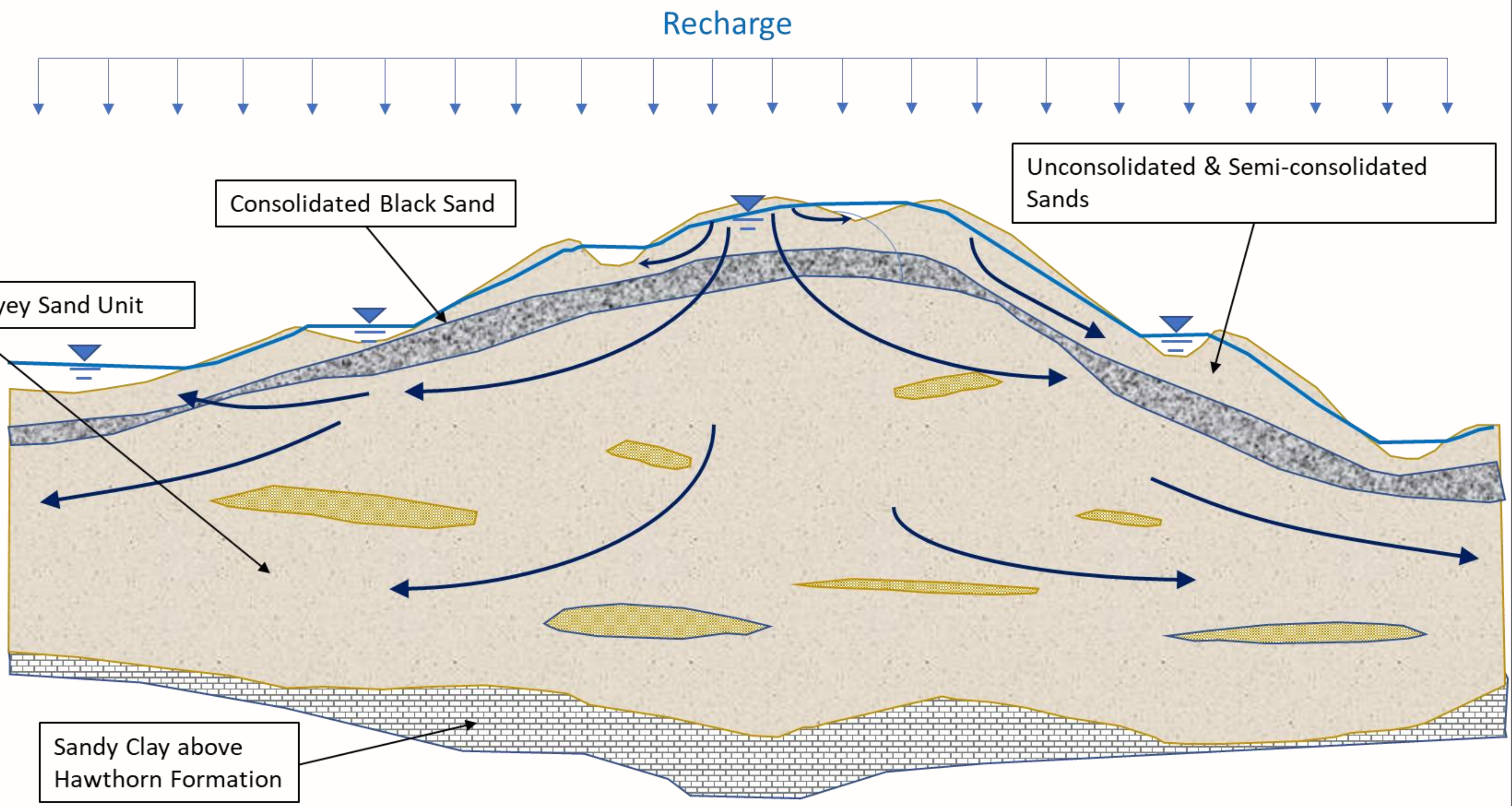
GSI ENVIRONMENTAL

Figure 4
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: Figure04	Appv'd By: SP

FIGURE 4



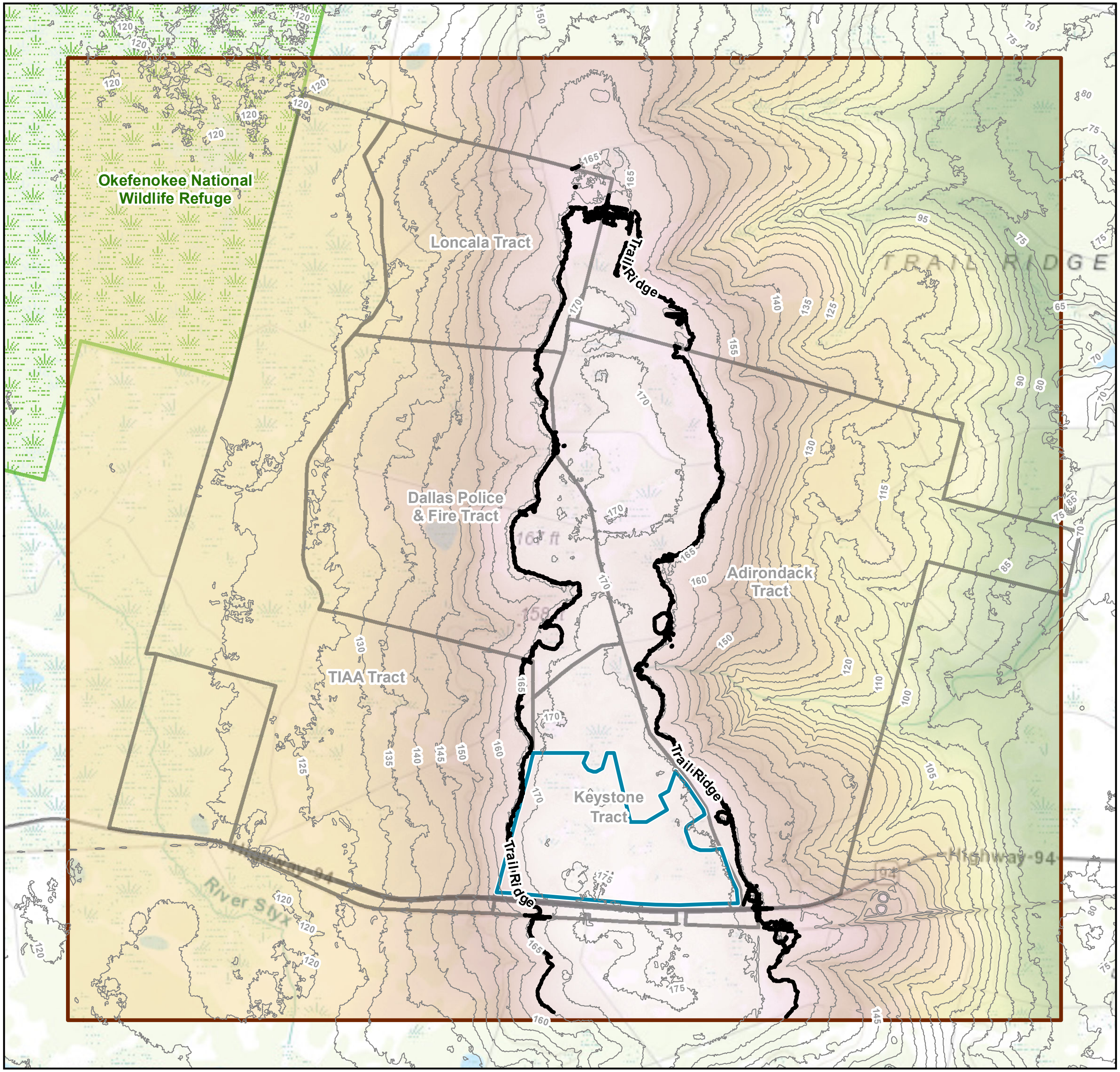
GSI Job No. 5844	Drawn By: GM		
Issued: 15 July 2021	Chk'd By: SP		
Revised:	Aprv'd By: SP		
Scale:	**Figure 5**		

GSI ENVIRONMENTAL

Conceptual Hydrogeologic Model of the Surficial Aquifer

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- USGS 10 Feet Elevation Contours
- Modeling Study Area
- Okefenokee National Wildlife Refuge

USGS 10m Digital Elevation Model (Feet)

High : 180.044

Low : 62.99

Notes:

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

Scale in Miles

0 0.5 1

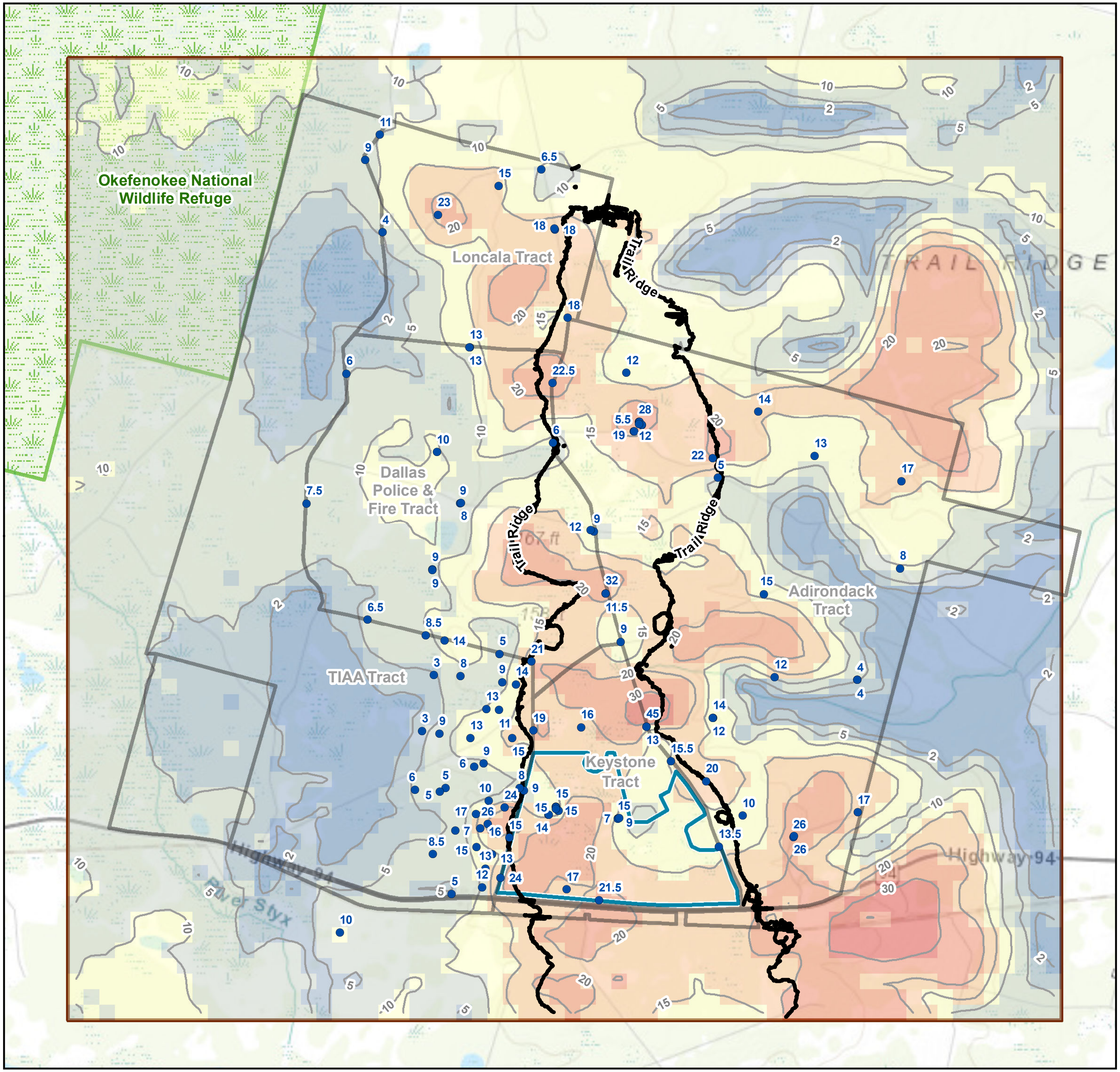
GSI ENVIRONMENTAL

Figure 6
Project Study Area
Ground Surface Elevation

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: Figure06	Appv'd By: SP

FIGURE 6



N

LEGEND

- Well Log Unconsolidated & Semiconsolidated Sand Thickness (Feet)
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Hydrostratigraphic Unit 1 Thickness Contours (Feet)

Hydrostratigraphic Unit 1 Thickness (Feet)

- 0.50 - 2.00
- 2.01 - 5.00
- 5.01 - 10.00
- 10.01 - 15.00
- 15.01 - 20.00
- 20.01 - 30.00
- 30.01 - 41.17
- 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

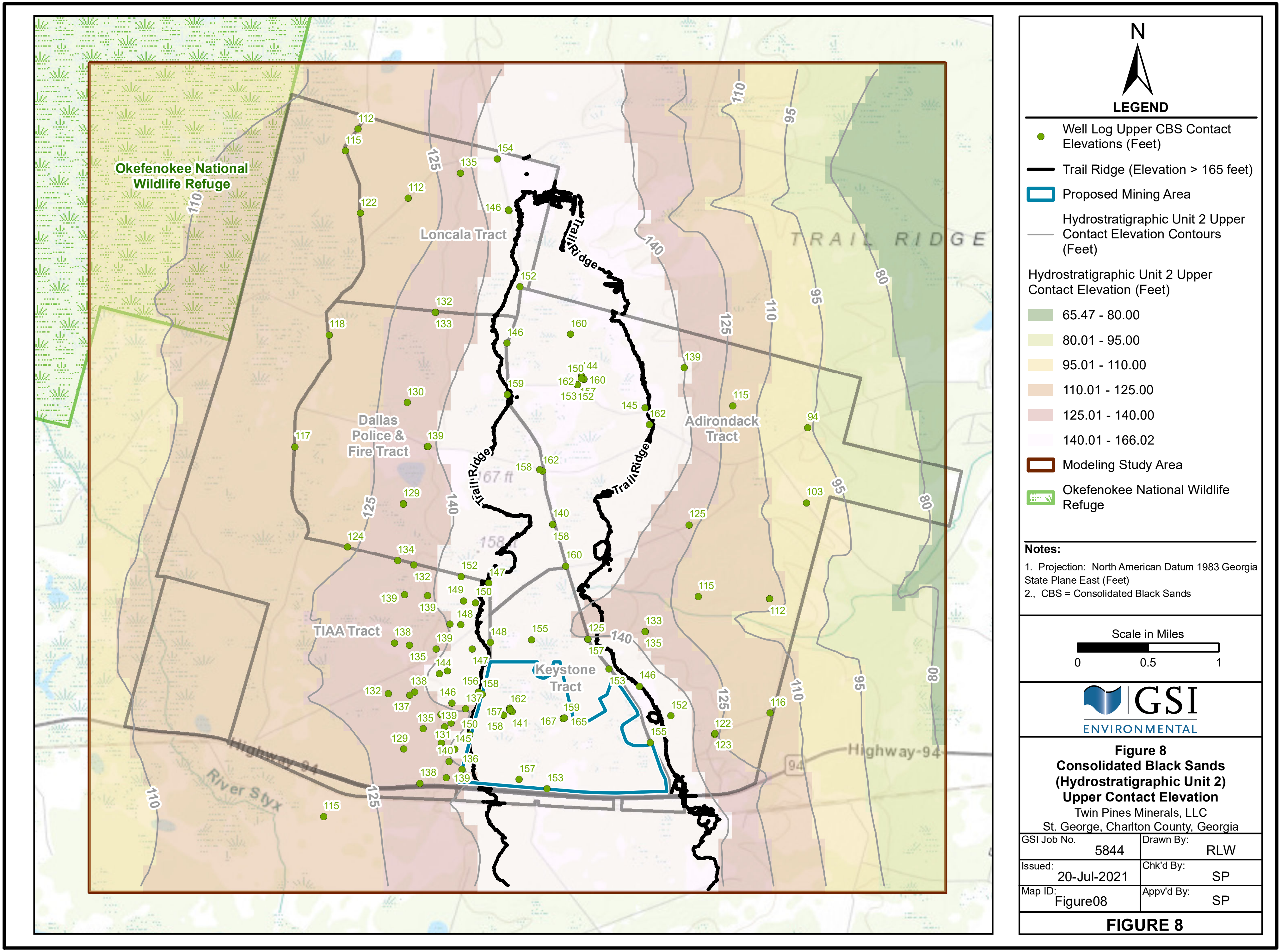
GSI ENVIRONMENTAL

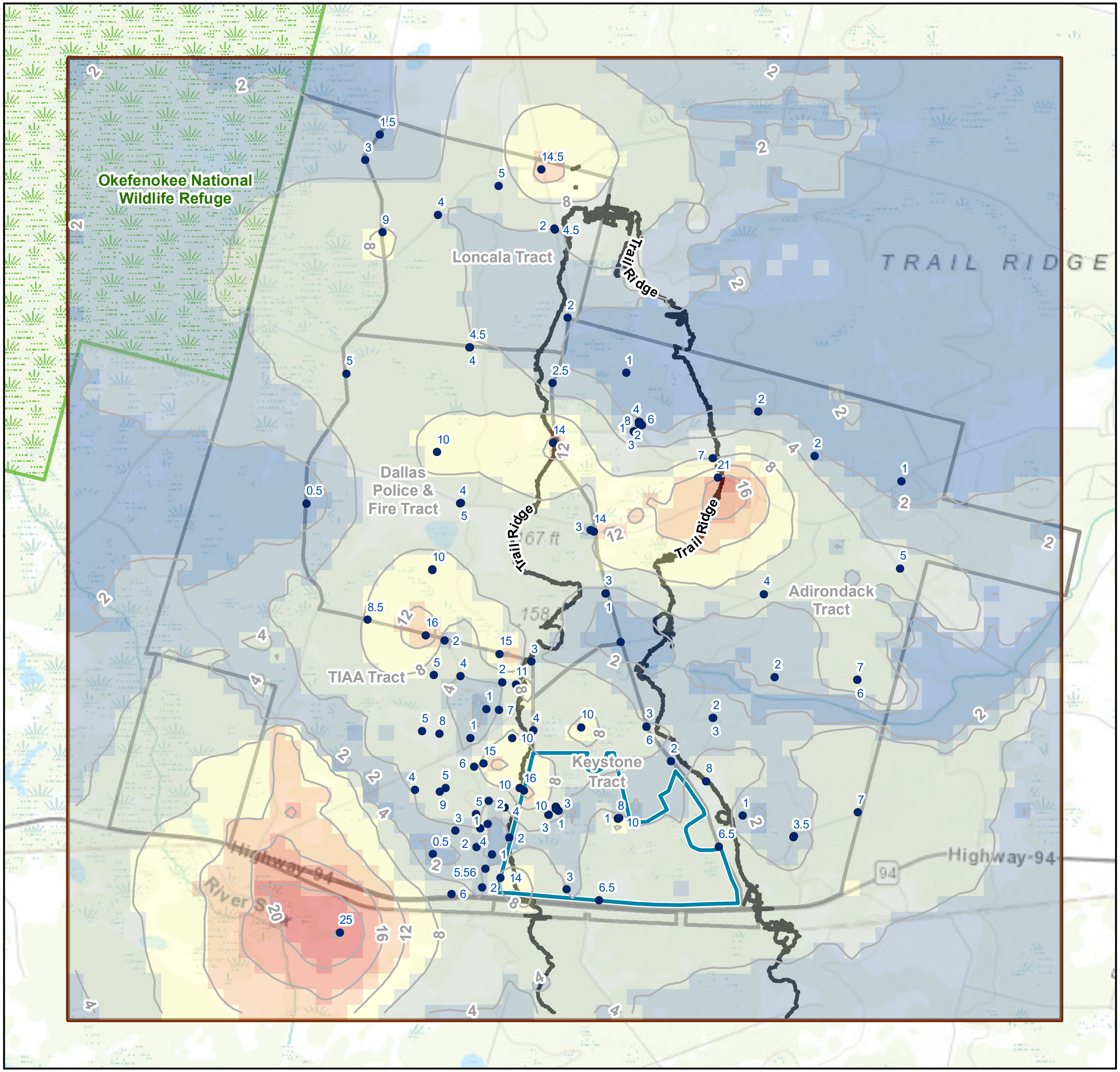
Figure 7
Unconsolidated & Semiconsolidated Sand (Hydrostratigraphic Unit 1) Thickness

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: Figure07	Appv'd By: SP

FIGURE 7


Okefenokee National Wildlife Refuge
Loncala Tract
Dallas Police & Fire Tract
TIAA Tract
Keystone Tract
Adirondack Tract
TRAIL RIDGE
Trail Ridge
Highway-94
River Styx
N
LEGEND
Well Log Upper CBS Contact Elevations (Feet)
Trail Ridge (Elevation > 165 feet)
Proposed Mining Area
Hydrostratigraphic Unit 2 Upper Contact Elevation Contours (Feet)
Hydrostratigraphic Unit 2 Upper Contact Elevation (Feet)
65.47 - 80.00
80.01 - 95.00
95.01 - 110.00
110.01 - 125.00
125.01 - 140.00
140.01 - 166.02
Modeling Study Area
Okefenokee National Wildlife Refuge
Notes:
1. Projection: North American Datum 1983 Georgia State Plane East (Feet)
2., CBS = Consolidated Black Sands
Scale in Miles
0 0.5 1
GSI ENVIRONMENTAL
Figure 8
Consolidated Black Sands (Hydrostratigraphic Unit 2) Upper Contact Elevation
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: Figure08
Appv'd By: SP
FIGURE 8



N

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

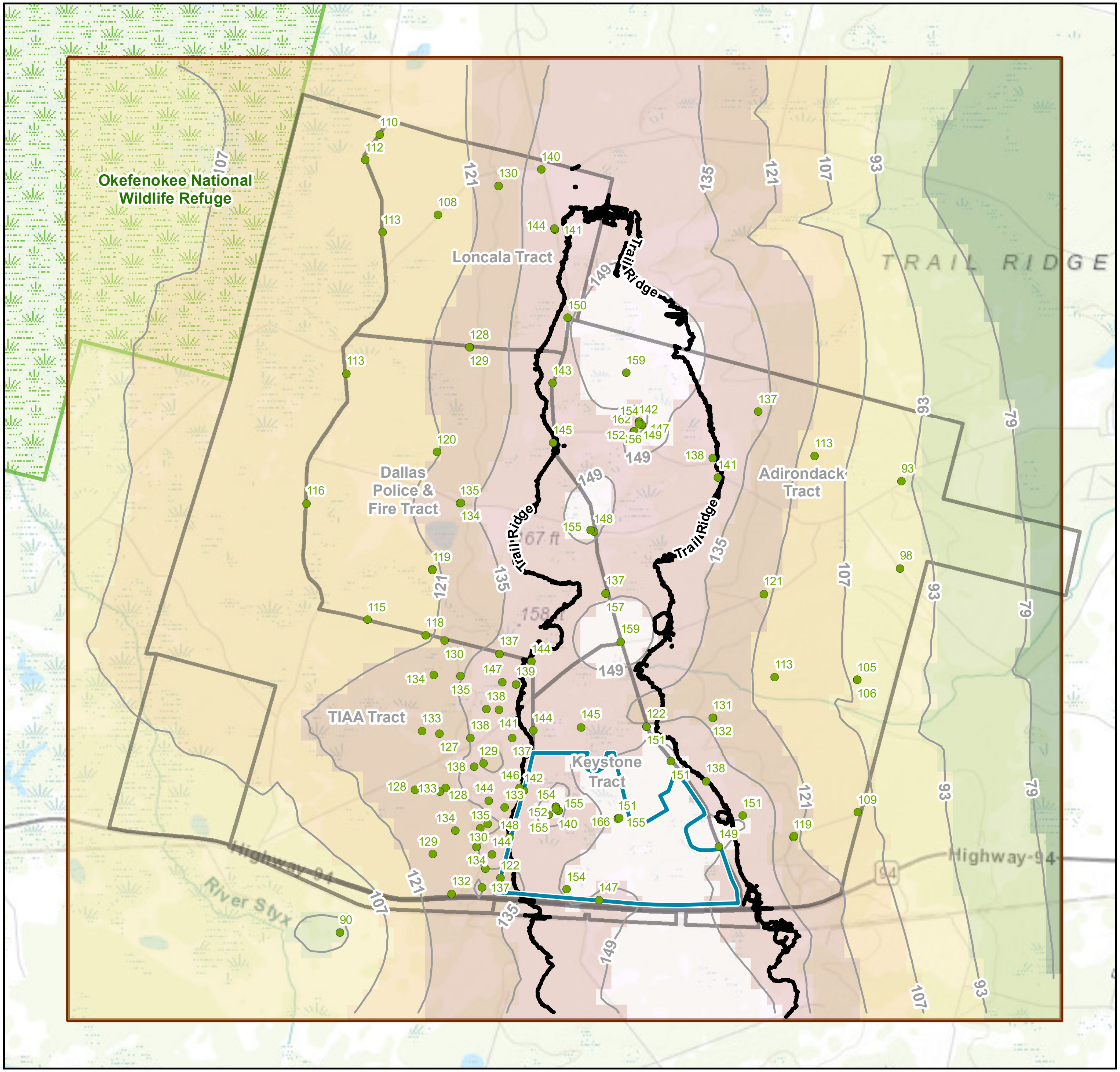
GSI ENVIRONMENTAL

Figure 9
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: Figure09	Appv'd By: SP

FIGURE 9



N

LEGEND

- Well Log Upper Silty Clayey Sand Contact Elevations (Feet)
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Hydrostratigraphic Unit 3 Upper Contact Elevation Contours (Feet)

Hydrostratigraphic Unit 3 Upper Contact Elevation (Feet)

- 64.97 - 79.00
- 79.01 - 93.00
- 93.01 - 107.00
- 107.01 - 121.00
- 121.01 - 135.00
- 135.01 - 149.00
- 149.01 - 162.26
- Modeling Study Area
- Okefenokee National Wildlife Refuge

Notes:

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

Scale in Miles

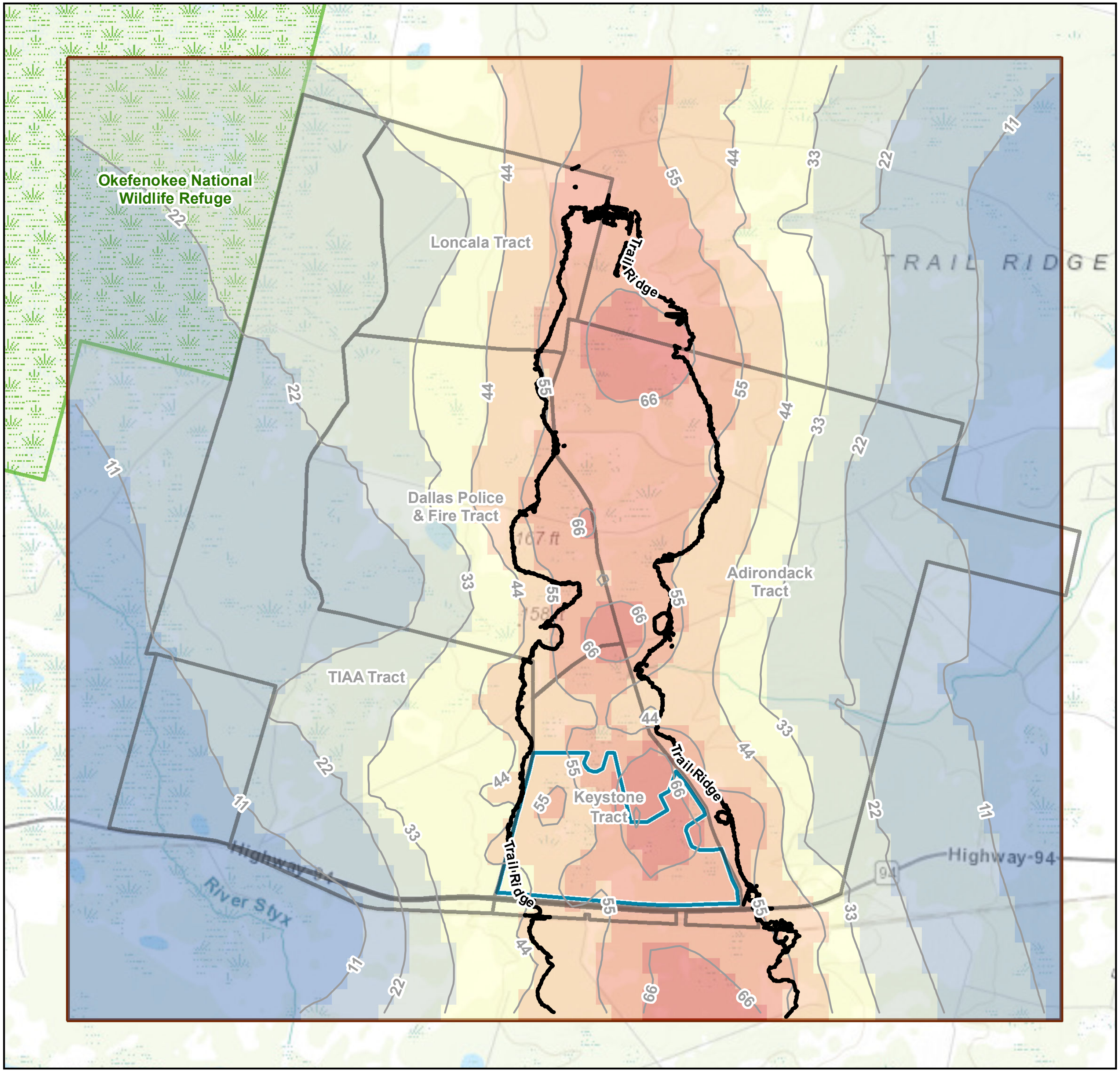
0 0.5 1

GSI ENVIRONMENTAL

Figure 10
Silty Clayey Sand Unit (Hydrostratigraphic Unit 3) Upper Contact Elevation
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: Figure10	Appv'd By: SP

FIGURE 10



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Hydrostratigraphic Unit 3 Thickness Contours (Feet)

Hydrostratigraphic Unit 3 Thickness (Feet)

- 1.61 - 11.00
- 11.01 - 22.00
- 22.01 - 33.00
- 33.01 - 44.00
- 44.01 - 55.00
- 55.01 - 66.00
- 66.01 - 75.93
- Modeling Study Area
- Okefenokee National Wildlife Refuge

Notes:

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

Scale in Miles

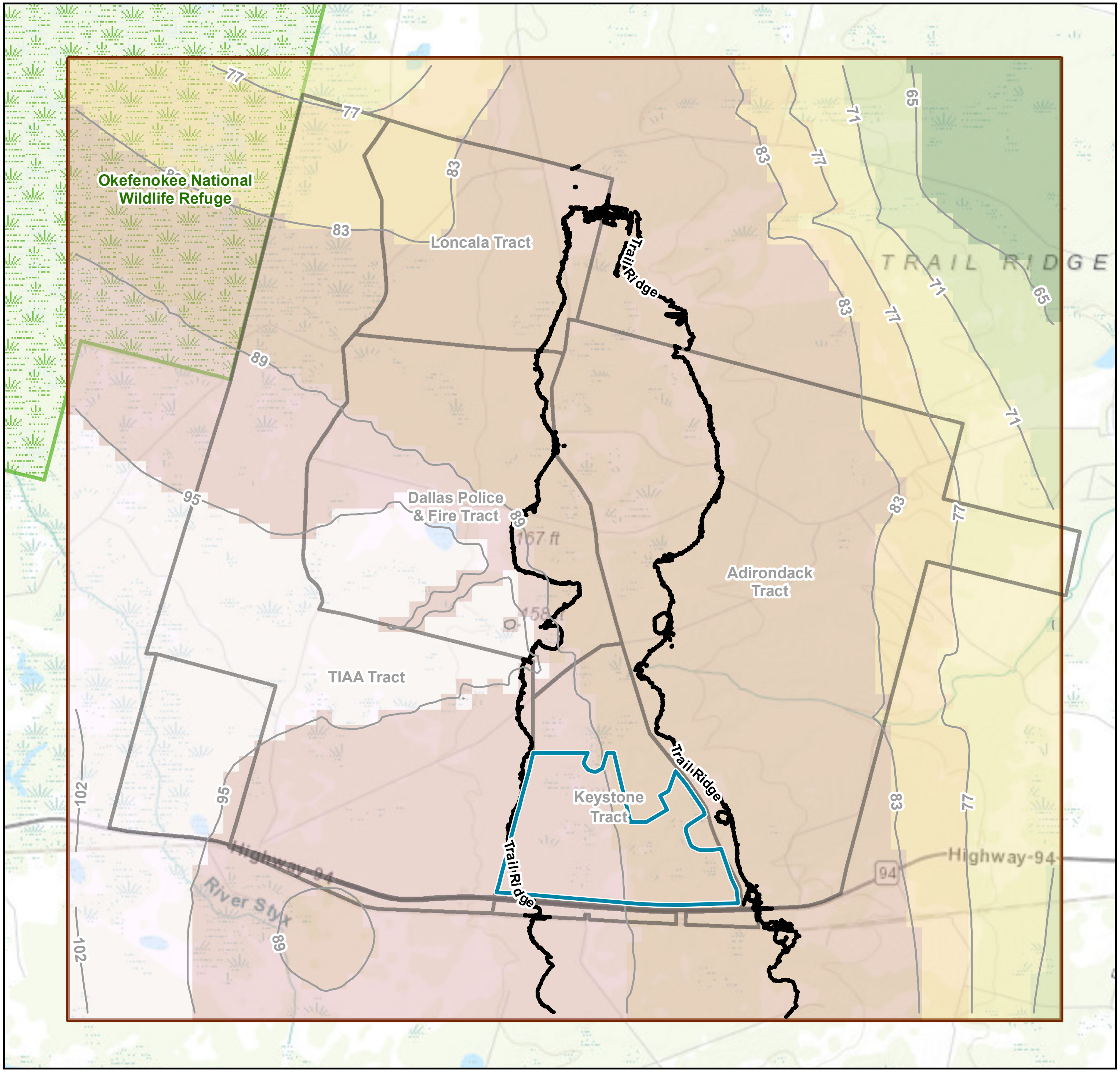
0 0.5 1

GSI
ENVIRONMENTAL

Figure 11
Silty Clayey Sand Unit (Hydrostratigraphic Unit 3) 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: Figure11	Appv'd By: SP

FIGURE 11



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Hydrostratigraphic Unit 4 Upper Contact Elevation Contours (Feet)

Hydrostratigraphic Unit 4 Upper Contact Elevation (Feet)

- 59.01 - 65.00
- 65.01 - 71.00
- 71.01 - 77.00
- 77.01 - 83.00
- 83.01 - 89.00
- 89.01 - 95.00
- 95.01 - 102.81
- Modeling Study Area
- Okefenokee National Wildlife Refuge

Notes:

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

Scale in Miles

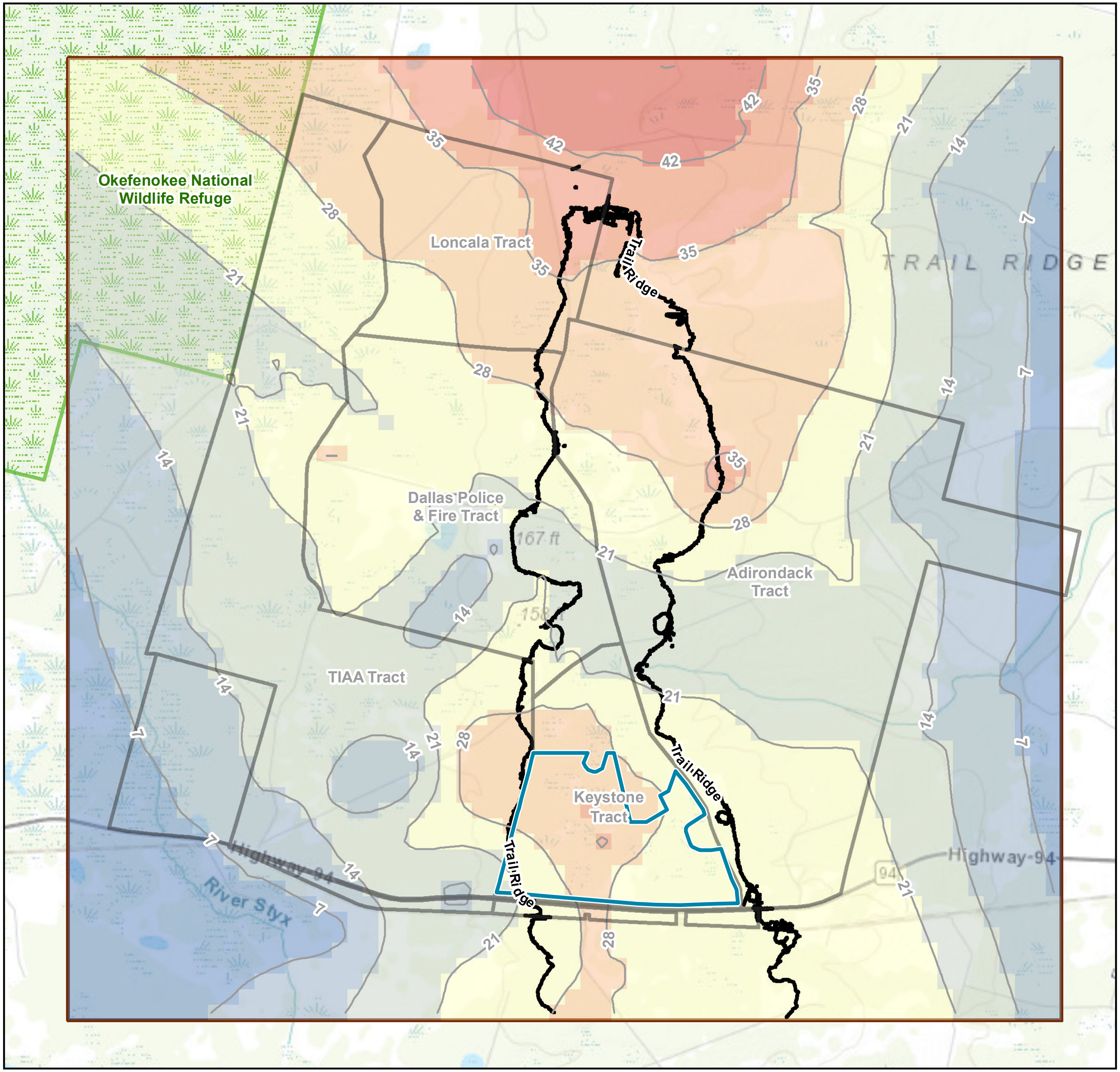
0 0.5 1

GSI ENVIRONMENTAL

Figure 12
Sandy Clay Unit
(Hydrostratigraphic Unit 4)
Upper Contact Elevation
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: Figure12	Appv'd By: SP

FIGURE 12



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Hydrostratigraphic Unit 4 Upper Contact Elevation Contours (Feet)

Hydrostratigraphic Unit 4 Thickness (Feet)

- 1.80 - 7.00
- 7.01 - 14.00
- 14.01 - 21.00
- 21.01 - 28.00
- 28.01 - 35.00
- 35.01 - 42.00
- 42.01 - 49.14
- 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

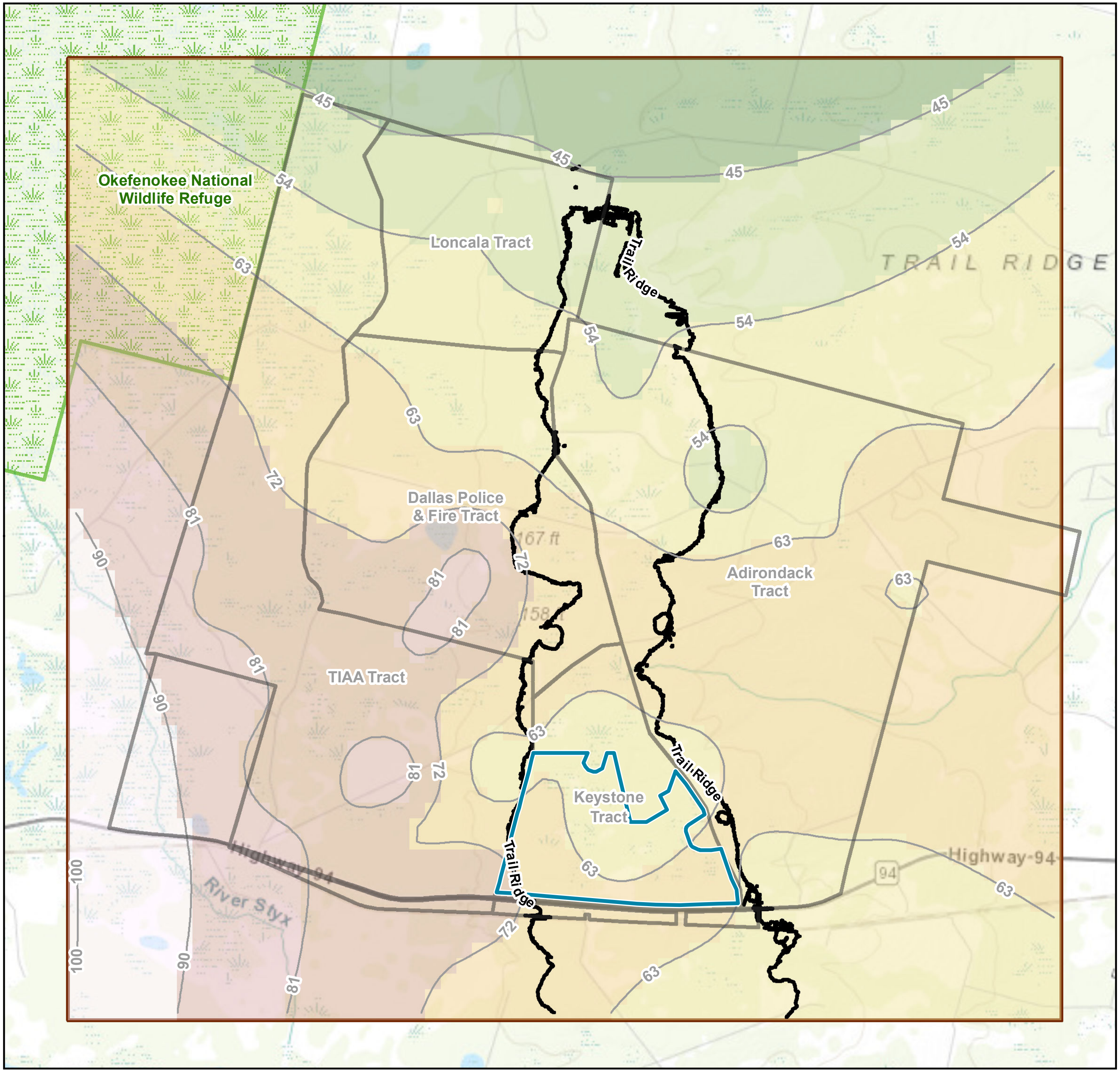
GSI ENVIRONMENTAL

Figure 13
Sandy Clay Unit (Hydrostratigraphic Unit 4) 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: Figure13	Appv'd By: SP

FIGURE 13



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Hawthorn Confining Unit Bottom Contact Elevation Contours (Feet)

Hawthorn Confining Unit Bottom Contact Elevation (Feet)

- 36.20 - 45.00
- 45.01 - 54.00
- 54.01 - 63.00
- 63.01 - 72.00
- 72.01 - 81.00
- 81.01 - 90.00
- 90.01 - 100.20
- 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

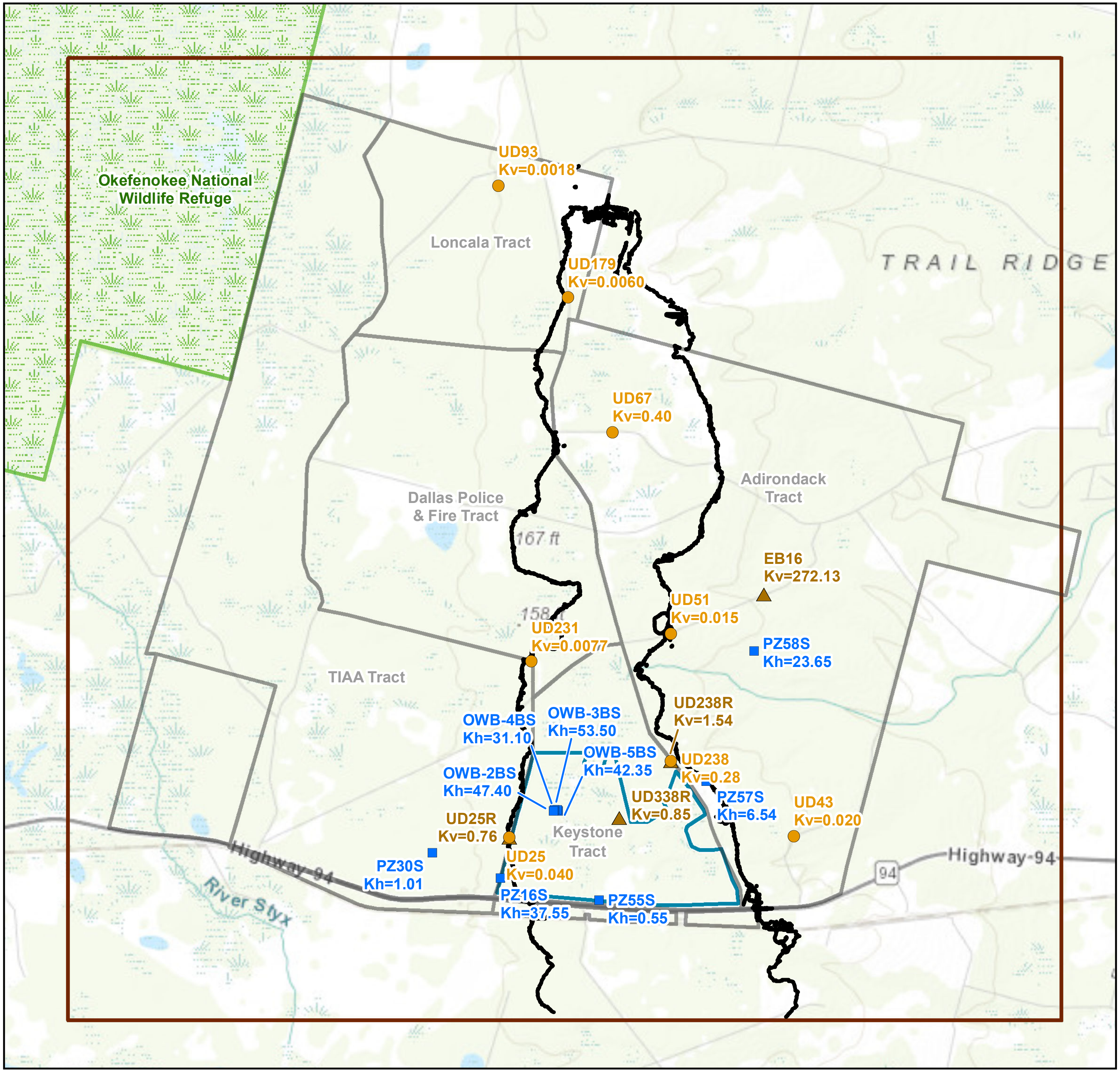
GSI ENVIRONMENTAL

Figure 14
Hawthorn Confining Unit Contact Elevation

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: Figure14	Appv'd By: SP

FIGURE 14



N

LEGEND

- Vertical Hydraulic Conductivity (Kv) Values (Feet/Day) - Soil Sample Potentially Affected by Drilling Muds
- Vertical Hydraulic Conductivity (Kv) Values (Feet/Day) - Soil Sample

Aquifer and Slug Test Horizontal Hydraulic Conductivity (Kh)

- Reported Test Value (Feet/Day)
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Modeling Study Area
- Okefenokee National Wildlife Refuge

Notes:

1. Projection: North American Datum 1983 Georgia State Plane East (Feet)
2. Where lab or field tests result in multiple K estimates at a given location for the layer, the arithmetic average is shown for Kh; harmonic mean shown for Kv.

Scale in Miles

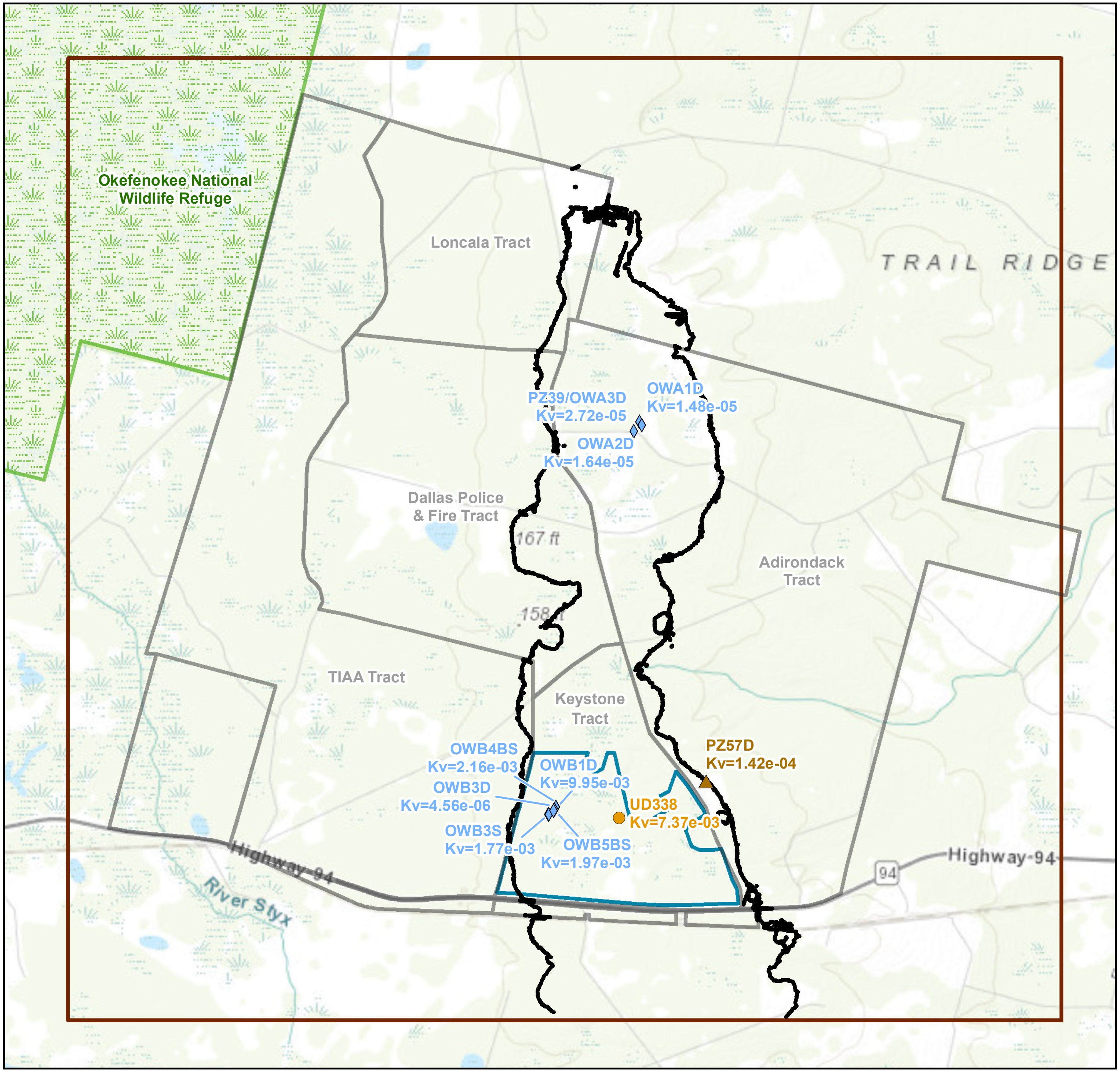
0 0.5 1

GSI ENVIRONMENTAL

Figure 15
Unconsolidated & Semiconsolidated Sand (Hydrostratigraphic Unit 1) Hydraulic Conductivity
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: Figure15	Appv'd By: SP

FIGURE 15



N

LEGEND

- Vertical Hydraulic Conductivity (Kv) Values (Feet/Day) - Soil Sample Potentially Affected by Drilling Muds
- Vertical Hydraulic Conductivity (Kv) Values (Feet/Day) - Soil Sample
- Vertical Hydraulic Conductivity (Kv) Values (Feet/Day) - Aquifer Test Derived
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Modeling Study Area
- Okefenokee National Wildlife Refuge

Notes:
1. Projection: North American Datum 1983 Georgia State Plane East (Feet)
2. Where lab or field tests result in multiple K estimates at a given location for the layer, the arithmetic average is shown for Kh; harmonic mean shown for Kv.
3. Only available lab and field data with K values of less than 0.014 feet/day (5e-6 cm/sec) are shown and considered representative of consolidated black sands.

Scale in Miles

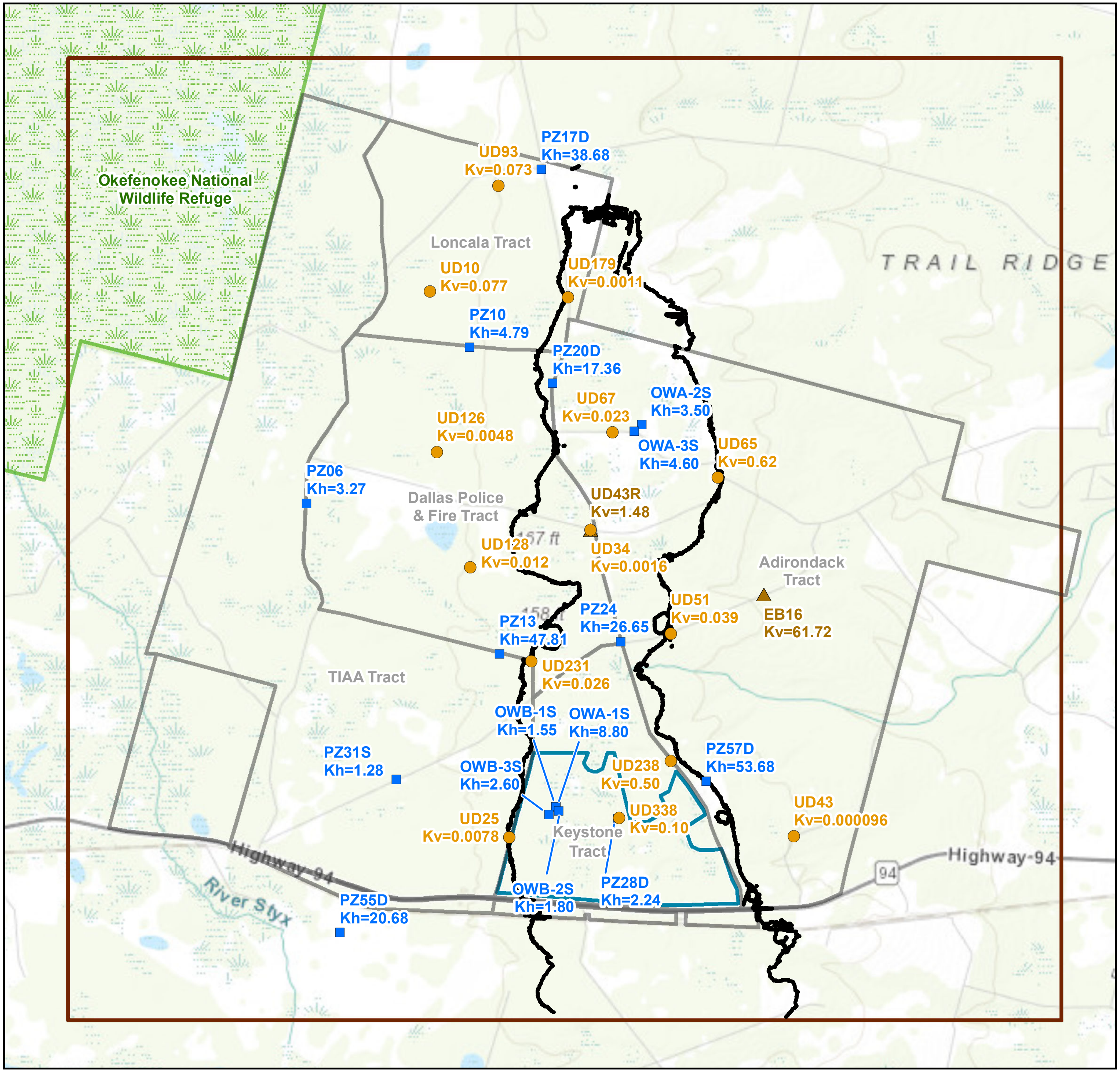
0 0.5 1

GSI ENVIRONMENTAL

Figure 16
Consolidated Black Sands (Hydrostratigraphic Unit 2) Hydraulic Conductivity
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: Figure16	Appv'd By: SP

FIGURE 16



N

LEGEND

- Vertical Hydraulic Conductivity (Kv) Values (Feet/Day) - Soil Sample Potentially Affected by Drilling Muds
- Vertical Hydraulic Conductivity (Kv) Values (Feet/Day) - Soil Sample

Aquifer and Slug Test Horizontal Hydraulic Conductivity (Kh)

- Reported Test Value (Feet/Day)
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Modeling Study Area
- Okefenokee National Wildlife Refuge

Notes:

1. Projection: North American Datum 1983 Georgia State Plane East (Feet)
2. Where lab or field tests result in multiple K estimates at a given location for the layer, the arithmetic average is shown for Kh; harmonic mean shown for Kv.

Scale in Miles

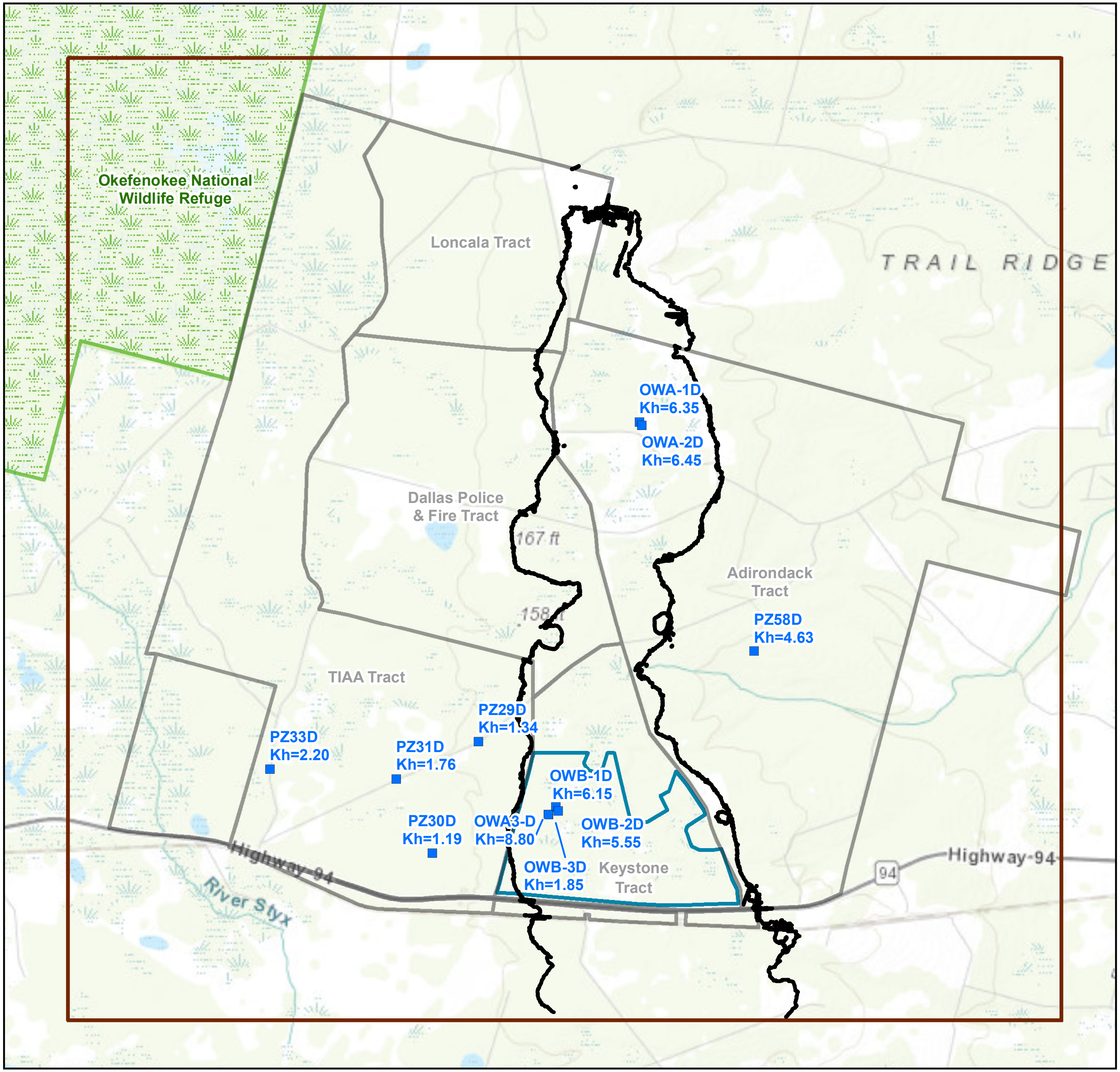
0 0.5 1

GSI ENVIRONMENTAL

Figure 17
Silty Clayey Sand Unit (Hydrostratigraphic Unit 3) Hydraulic Conductivity
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: Figure17	Appv'd By: SP

FIGURE 17



N

LEGEND

Aquifer and Slug Test Horizontal Hydraulic Conductivity (Kh)

- Reported Test Value (Feet/Day)
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Modeling Study Area
- Okefenokee National Wildlife Refuge

Notes:
1. Projection: North American Datum 1983 Georgia State Plane East (Feet)
2. Where lab or field tests result in multiple K estimates at a given location for the layer, the arithmetic average is shown for Kh.

Scale in Miles

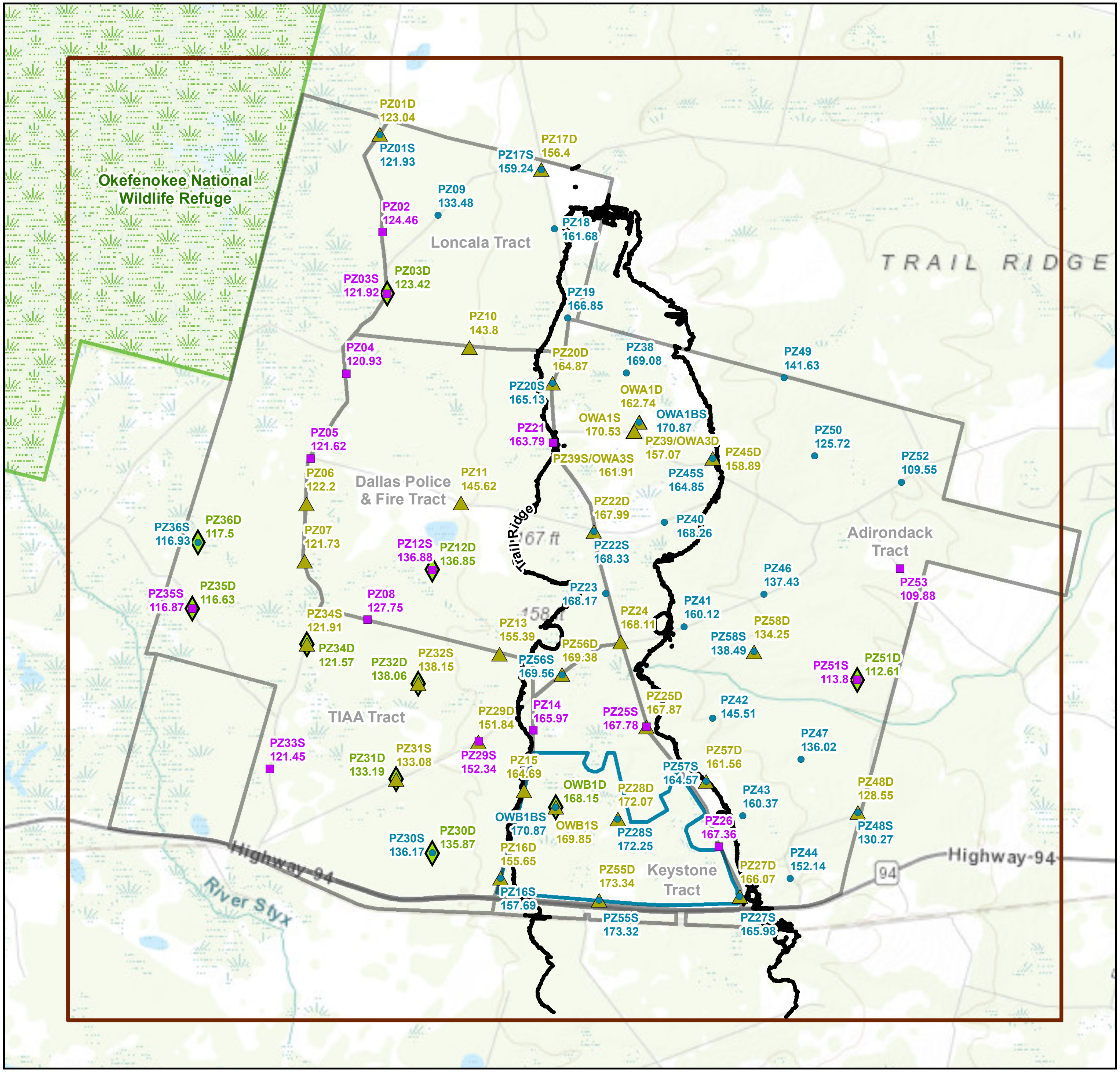
0 0.5 1

GSI ENVIRONMENTAL

Figure 18
Sandy Clay Unit
(Hydrostratigraphic Unit 4)
Hydraulic Conductivity
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: Figure18	Appv'd By: SP

FIGURE 18



N

LEGEND

- HSU 1 (Unconsolidated & Semiconsolidated) Average Groundwater Elevations (Feet)
- HSU 2 (Consolidated Black Sands) Average Groundwater Elevations (Feet)
- HSU 3 (Silty Clayey Sand) Average Groundwater Elevations (Feet)
- HSU 4 (Sandy Clay Unit) Average Groundwater Elevations (Feet)
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Modeling Study Area
- Okefenokee National Wildlife Refuge

Notes:
1. Projection: North American Datum 1983 Georgia State Plane East (Feet)
2. HSU = Hydrostratigraphic Unit

Scale in Miles

0 0.5 1

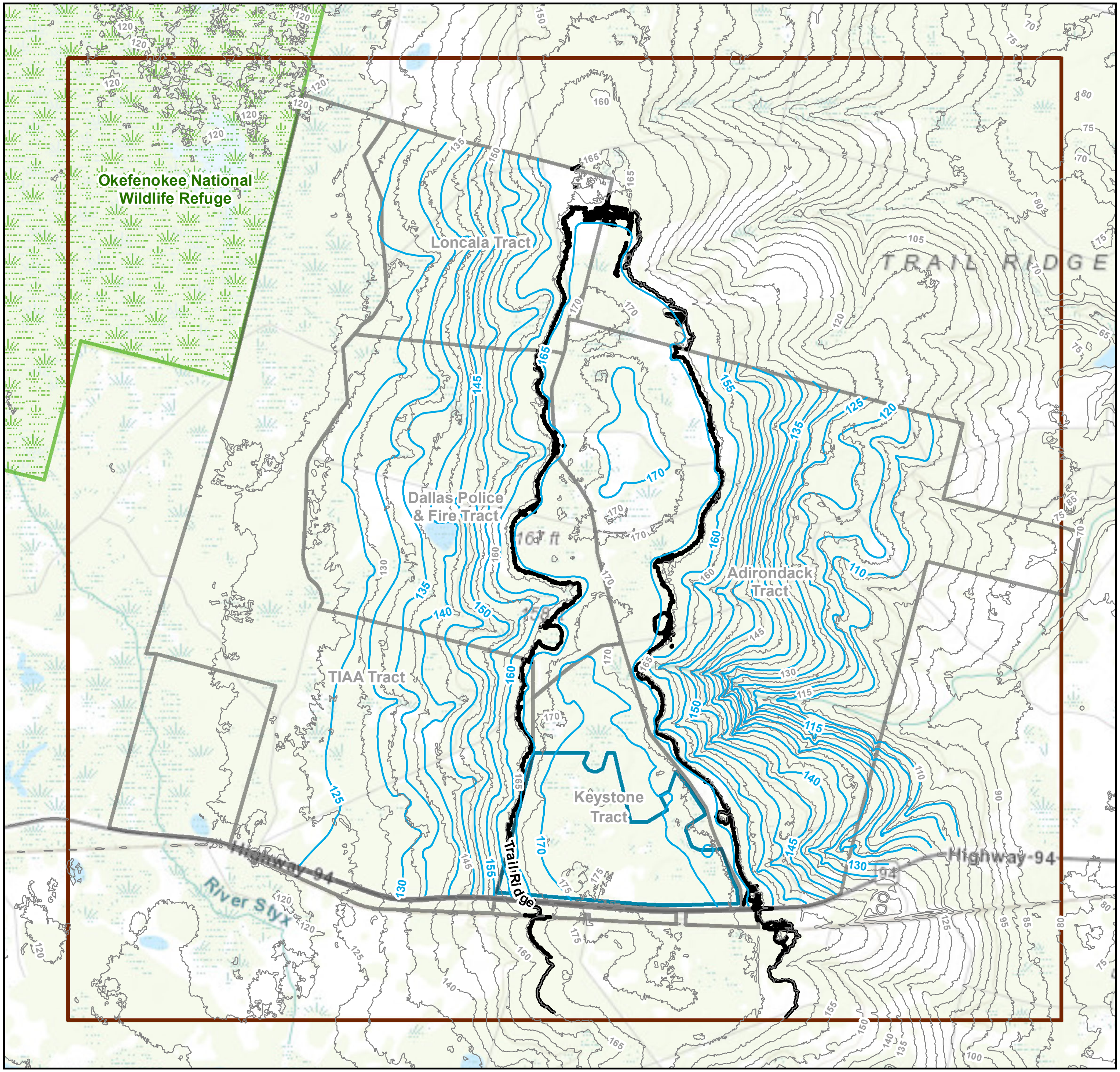
GSI ENVIRONMENTAL

Figure 19
Average Well and Piezometer Groundwater Elevations January 2019 - October 2019

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: Figure19	Appv'd By: SP

FIGURE 19



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- USGS 10 Feet Elevation Contours
- Surficial Aquifer Potentiomentric Surface Contours (Feet)
- Proposed Mining Area
- 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

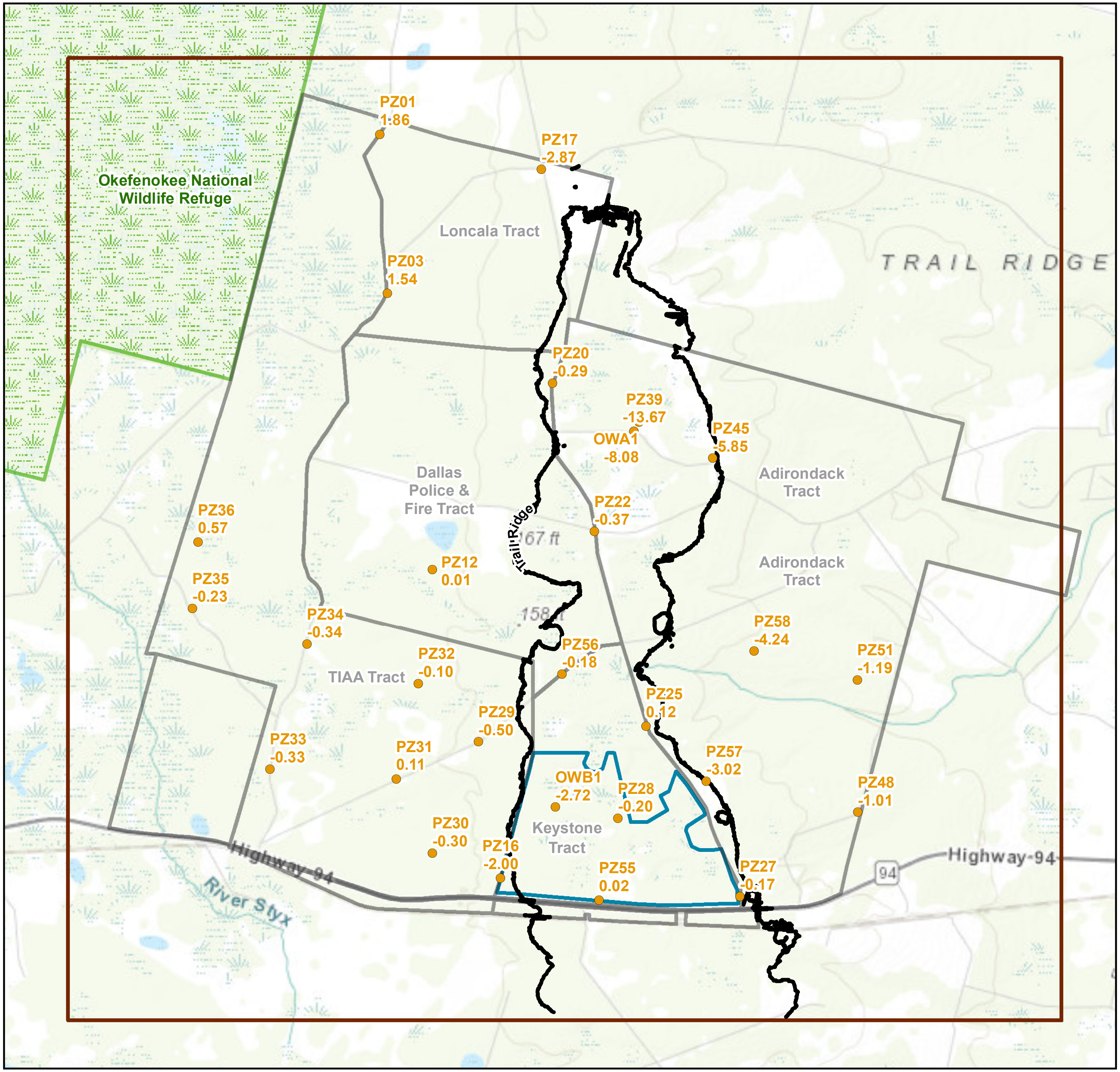
GSI ENVIRONMENTAL

Figure 20
Surficial Aquifer Potentiometric Surface Map January 26, 2019

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: Figure20	Appv'd By: SP

FIGURE 20



N

LEGEND

- Shallow/Deep Piezometer Pairs - Average Groundwater Differences (Feet)
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Modeling Study Area
- Okefenokee National Wildlife Refuge

Notes:

1. Projection: North American Datum 1983 Georgia State Plane East (Feet)
2. Negative (Positive) values indicated downward (upward) flow.

Scale in Miles

0 0.5 1

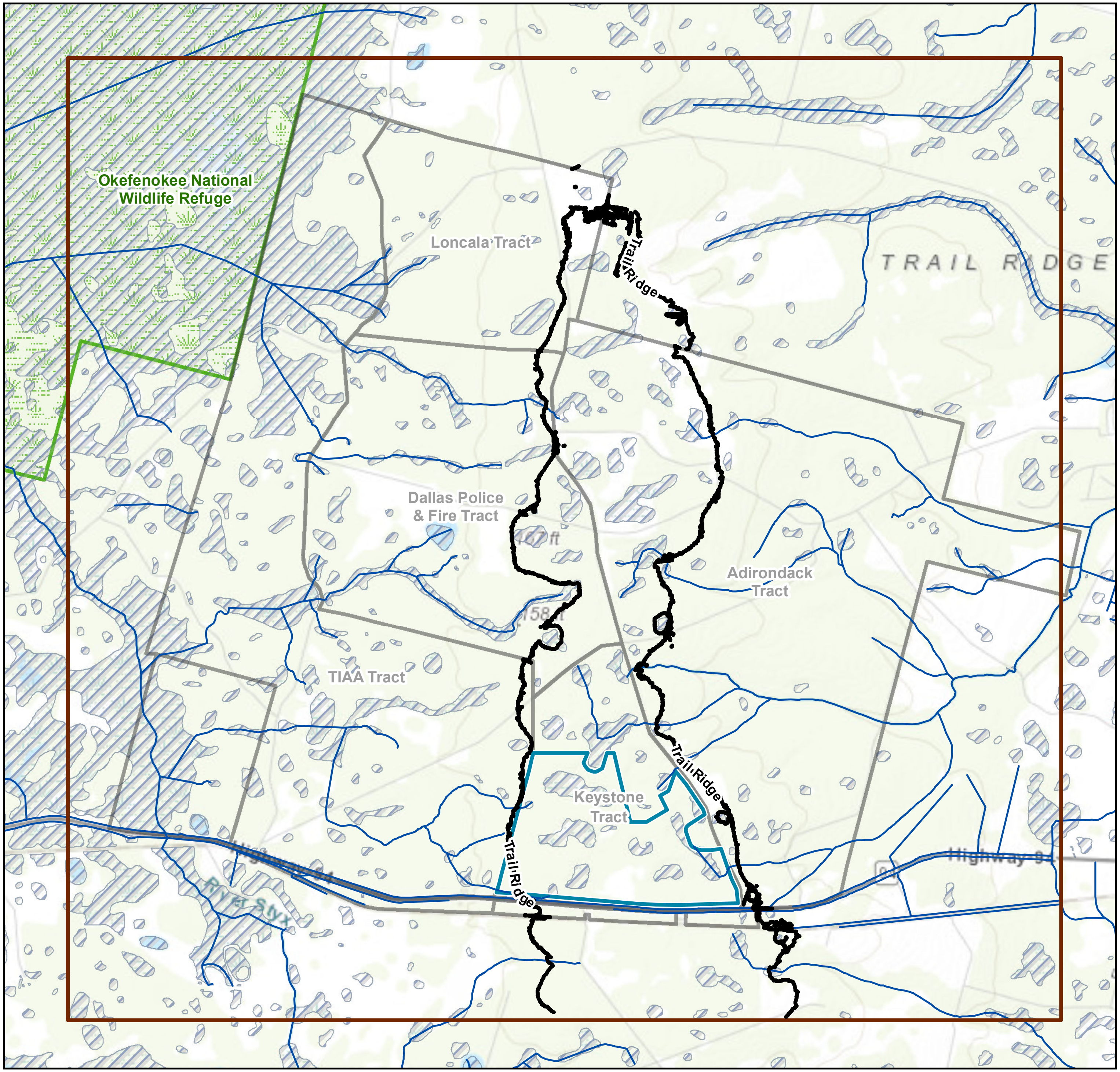
GSI ENVIRONMENTAL

Figure 21
Average Water Level Differences - Shallow and Deep Piezometer Pairs

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: Figure21	Appv'd By: SP

FIGURE 21



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- National Hydrography Dataset (NHD) Stream Channels
- National Hydrography Dataset (NHD) Wetlands
- Modeling Study Area
- Proposed Mining Area
- Okefenokee National Wildlife Refuge

Notes:

1. Wetlands and stream channels are from the National Hydrography Dataset by the USGS.
2. Projection: North American Datum 1983 Georgia State Plane East (Feet)

Scale in Miles

0 0.5 1

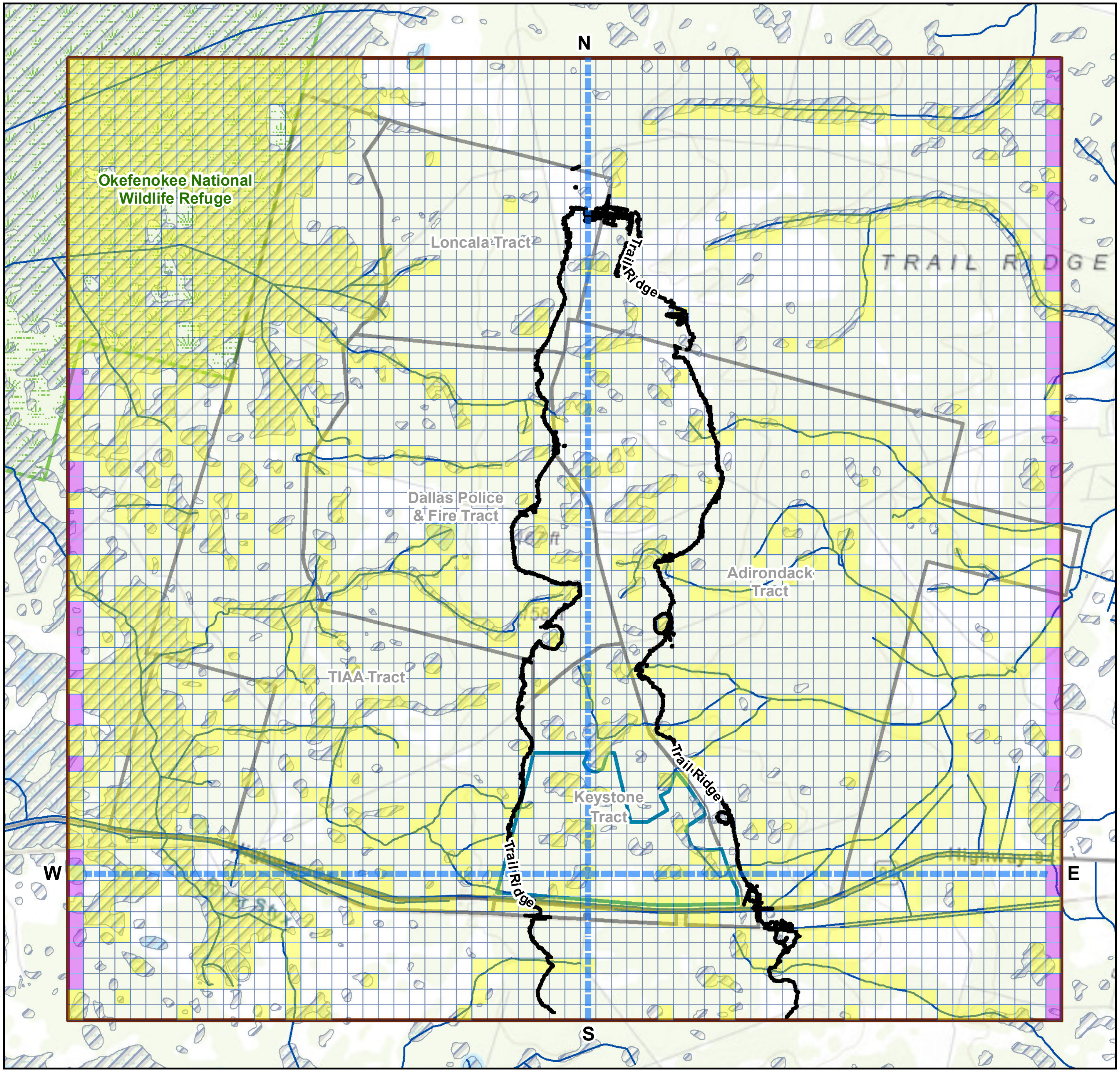
GSI ENVIRONMENTAL

Figure 22
National Hydrography Dataset Delineated Wetlands and Stream Channels in Study Area

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: Figure22	Appv'd By: SP

FIGURE 22



N

LEGEND

- Cross Section Locations
- Trail Ridge (Elevation > 165 feet)
- Constant Heads Boundary Condition - Layer 1
- Drain Package Boundary Condition - Layer 1
- Numerical Groundwater Flow Model Grid - Cells with No Boundary Conditions
- Modeling Study Area
- National Hydrography Dataset (NHD) Stream Channels
- National Hydrography Dataset (NHD) Wetlands
- Proposed Mining Area
- Okefenokee National Wildlife Refuge

Notes:

1. Model grid cells are 500 by 500 feet wide, forming 62 rows and 64 columns in each of the 4 layers.
2. Projection: North American Datum 1983 Georgia State Plane East (Feet)

Scale in Miles

0 0.5 1

GSI ENVIRONMENTAL

Figure 23
Model Grid & Layer 1
Boundary Conditions

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: Figure23	Appv'd By: SP

FIGURE 23

Hydrostratigraphic Unit	Model Layer
Hydrostratigraphic Unit 1 (Unconsolidated and Semiconsolidated Sand)	Model Layer 1
Hydrostratigraphic Unit 2 (Consolidated Black Sand)	Model Layer 2
	Model Layer 3
Hydrostratigraphic Unit 3 (Silty Clayey Sand Unit)	Model Layer 4
	Model Layer 5
	Model Layer 6
Hydrostratigraphic Unit 4 (Sandy Clay Unit)	Model Layer 7

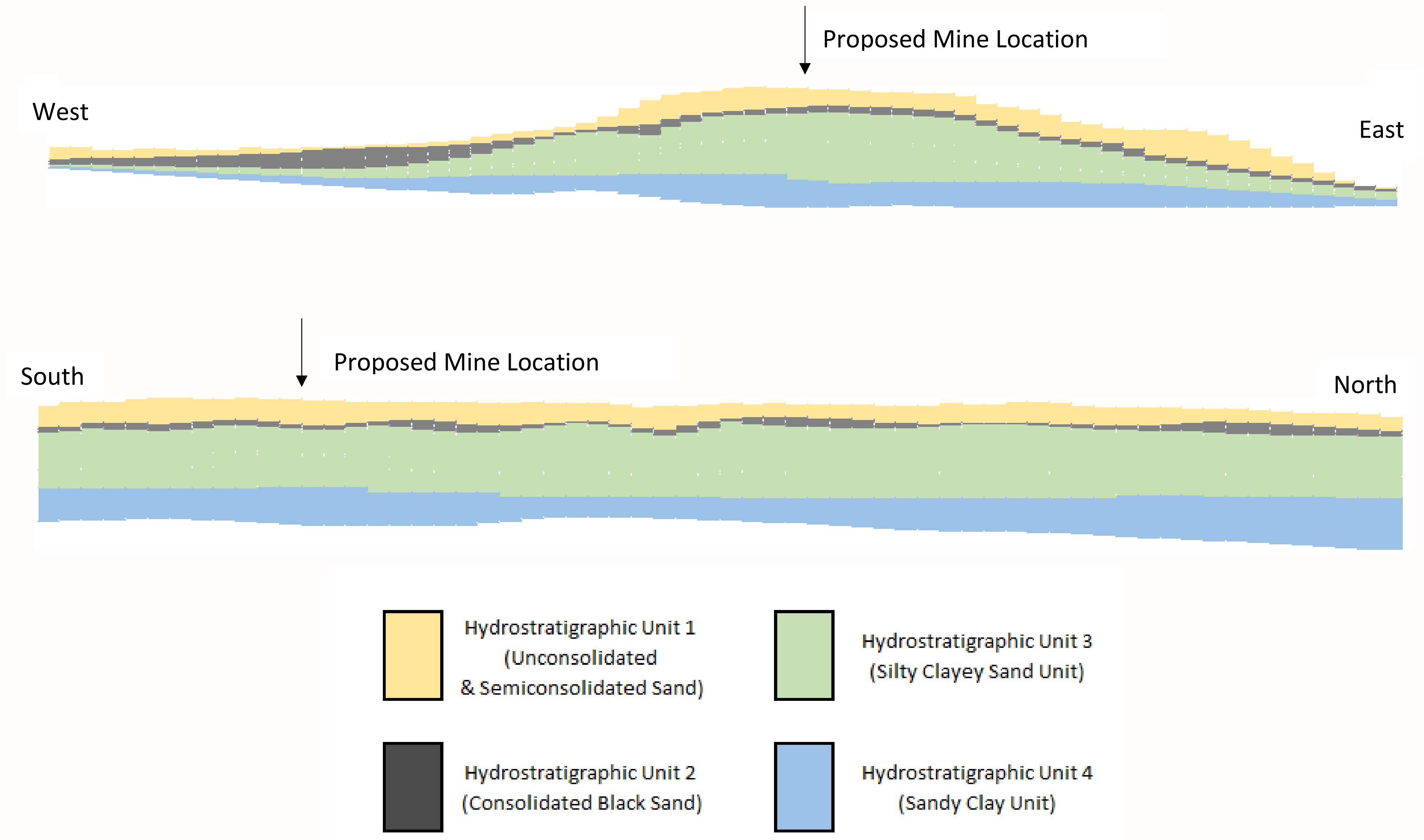
GSI ENVIRONMENTAL

GSI Job No.	5844	Drawn By:	RLW
Issued:	15 July 2021	Chk'd By:	SP
Revised:		Aprv'd By:	SP
Scale:		**Figure 24**	

Correlation Between Hydrostratigraphy and Numerical Model Layers

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia



Note: Cross section locations provided on Figure 23.

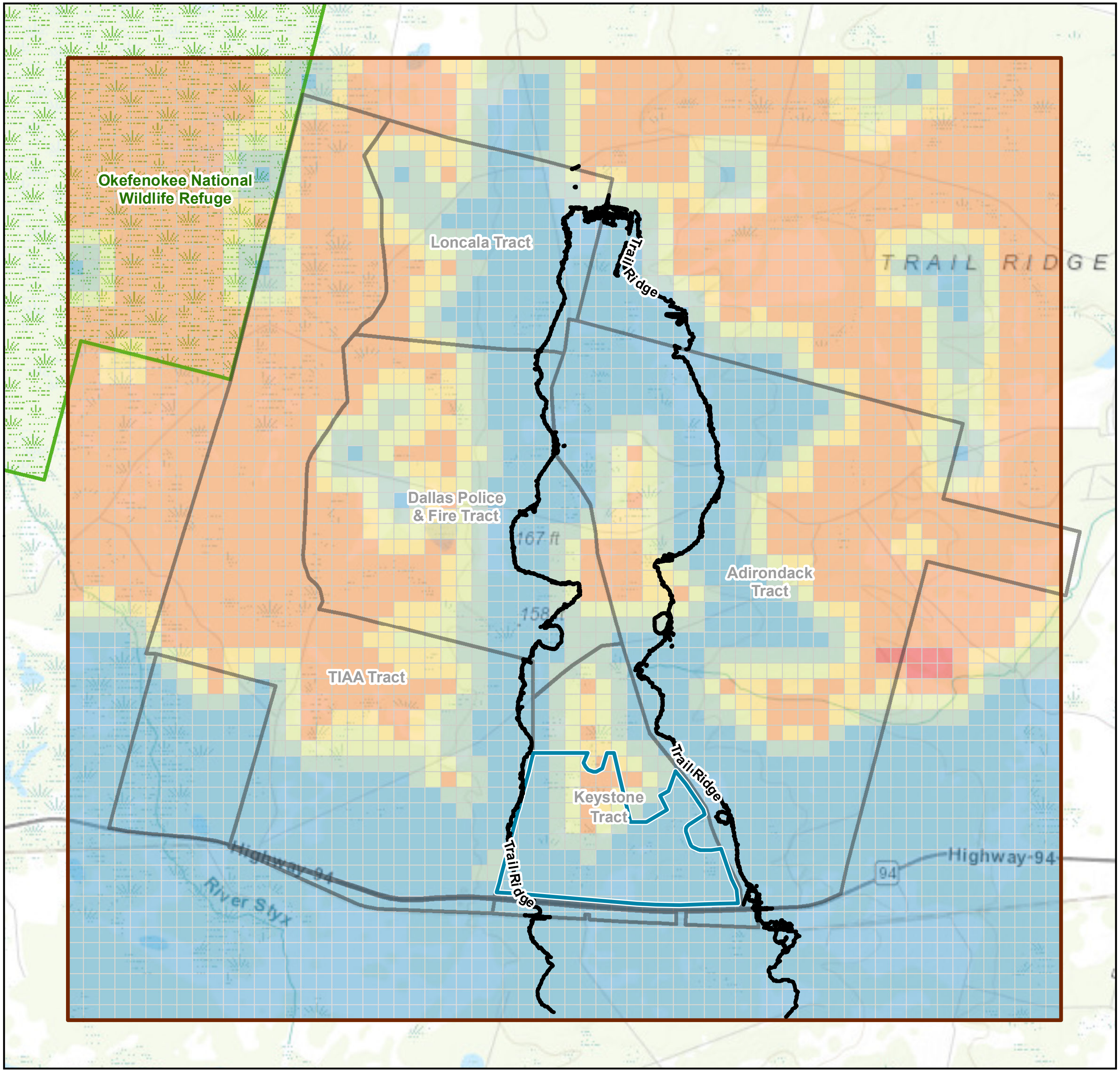
GSI ENVIRONMENTAL

GSI Job No.	5844	Drawn By:	RLW
Issued:	15 July 2021	Chk'd By:	SP
Revised:		Aprv'd By:	SP
Scale:		**Figure 25**	

Numerical Model North-South and East-West Cross Sections

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia



N

LEGEND

- Trail Ridge (Elevation > 165 feet)

Horizontal Hydraulic Conductivity (Feet/Day)

- 0.1 to 15
- 15 to 30
- 30 to 45
- 45 to 60
- 60 to 75
- 75 to 77.5
- 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

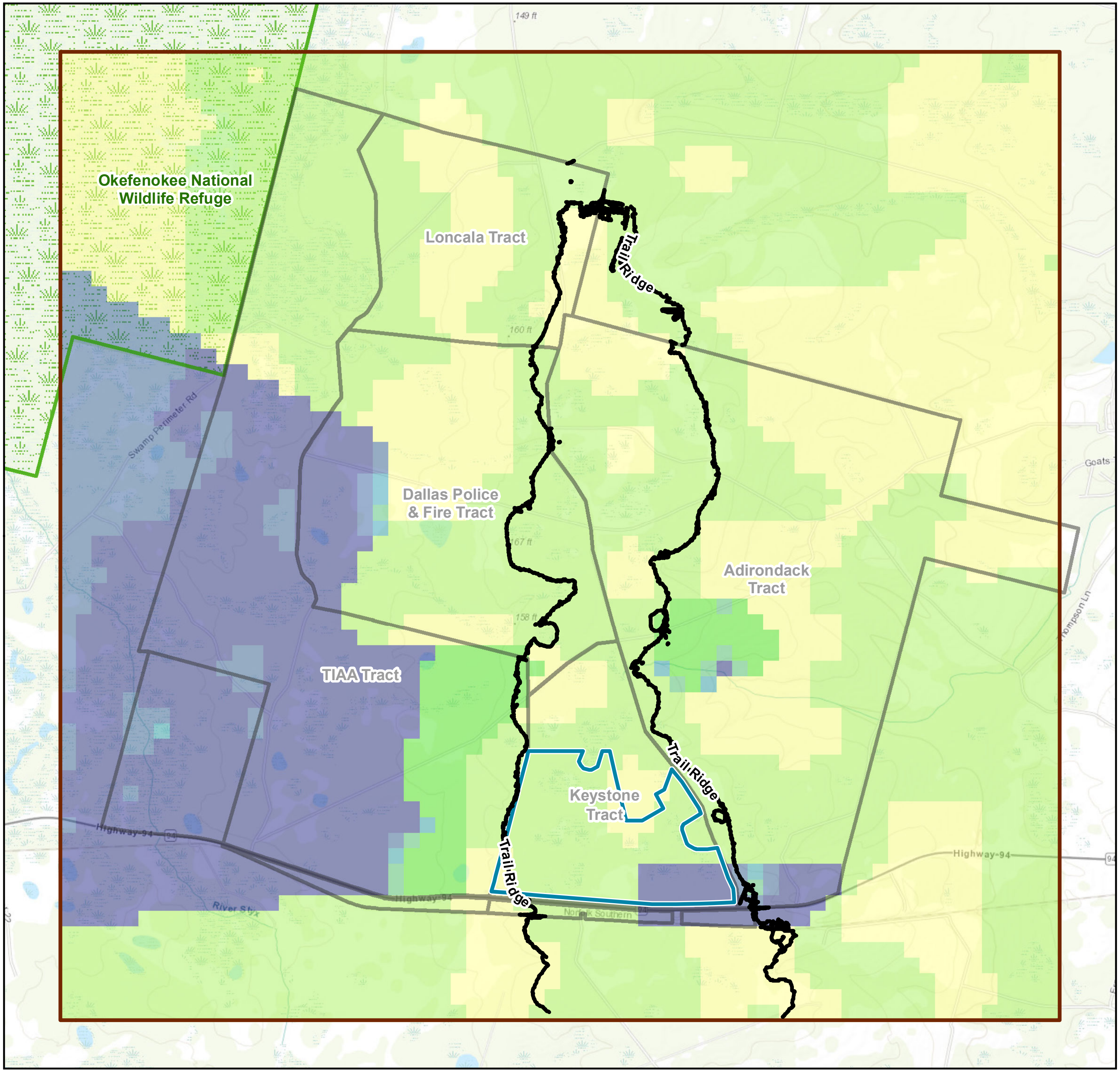
0 0.5 1

GSI ENVIRONMENTAL

Figure 26
Calibrated Horizontal Hydraulic Conductivity in Unconsolidated and Semiconsolidated Sand (HSU 1)
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: Figure26	Appv'd By: SP

FIGURE 26



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

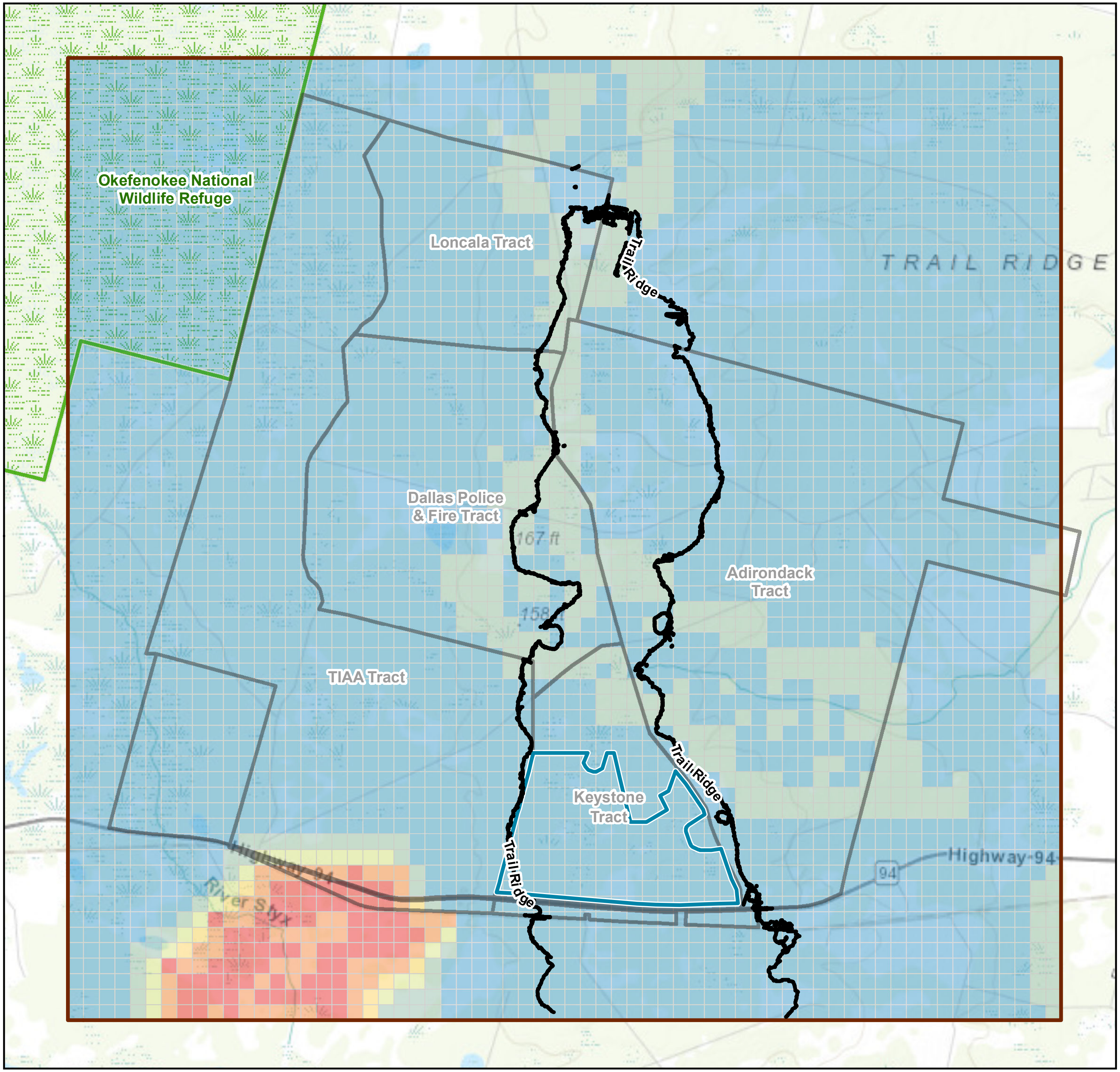
0 0.5 1

GSI ENVIRONMENTAL

Figure 27
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: Figure27	Appv'd By: SP

FIGURE 27



N

LEGEND

Trail Ridge (Elevation > 165 feet)

Horizontal Hydraulic Conductivity (Feet/Day)

- 0.1 to 15
- 15 to 30
- 30 to 45
- 45 to 60
- 60 to 75
- 75 to 87.5

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

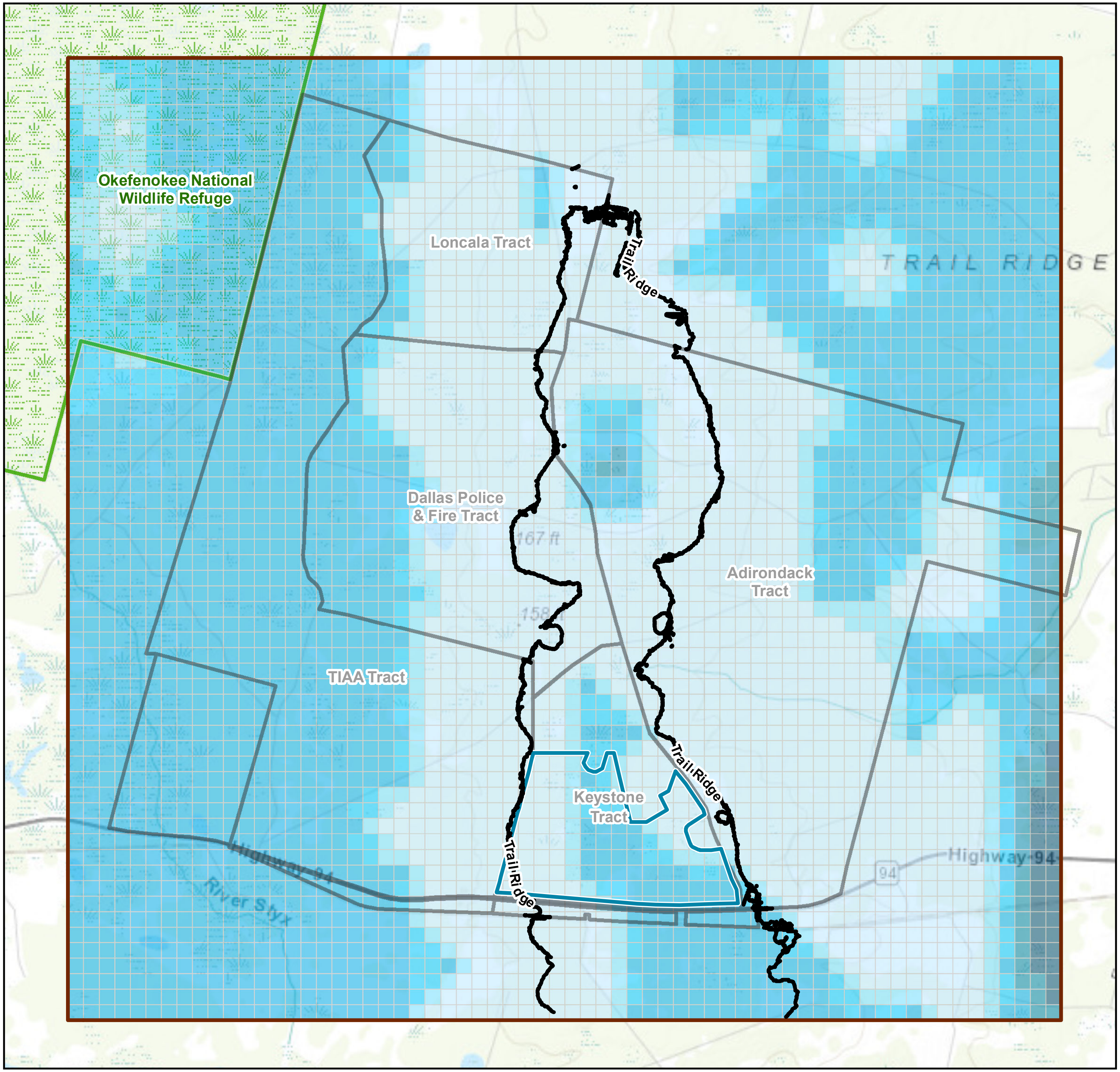
0 0.5 1

GSI ENVIRONMENTAL

Figure 28
Calibrated Horizontal Hydraulic Conductivity in Silty Clayey Sand Unit (HSU 3)
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: Figure28	Appv'd By: SP

FIGURE 28



Notes:

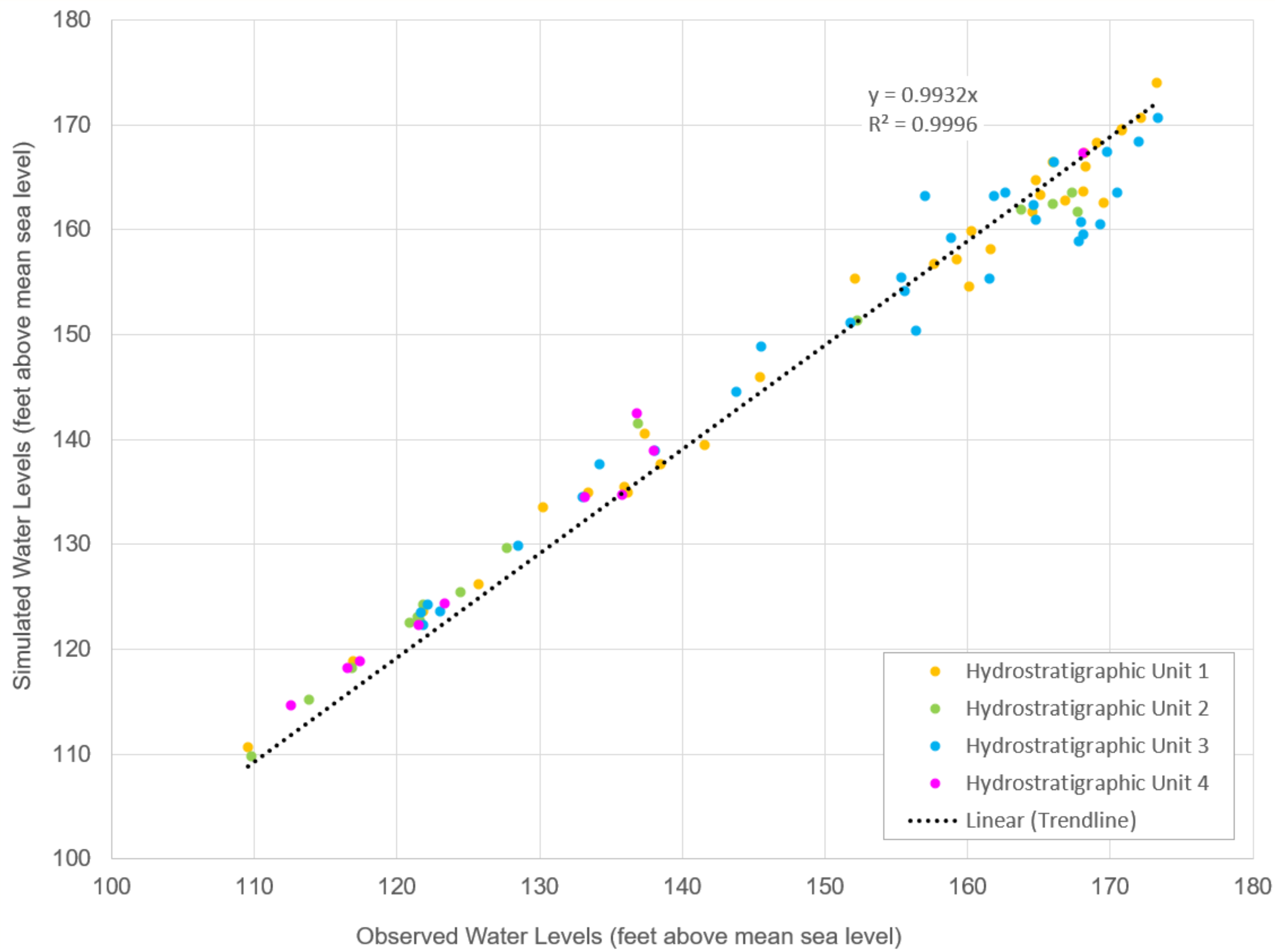
1. HSU = hydrostratigraphic unit
2. Projection: North American Datum 1983 Georgia State Plane East (Feet)

GSI ENVIRONMENTAL

Figure 29
Calibrated Horizontal Hydraulic Conductivity in Sandy Clay Unit (HSU 4)
Twin Pines Minerals, LLC
St. George, Charlton County, Georgia

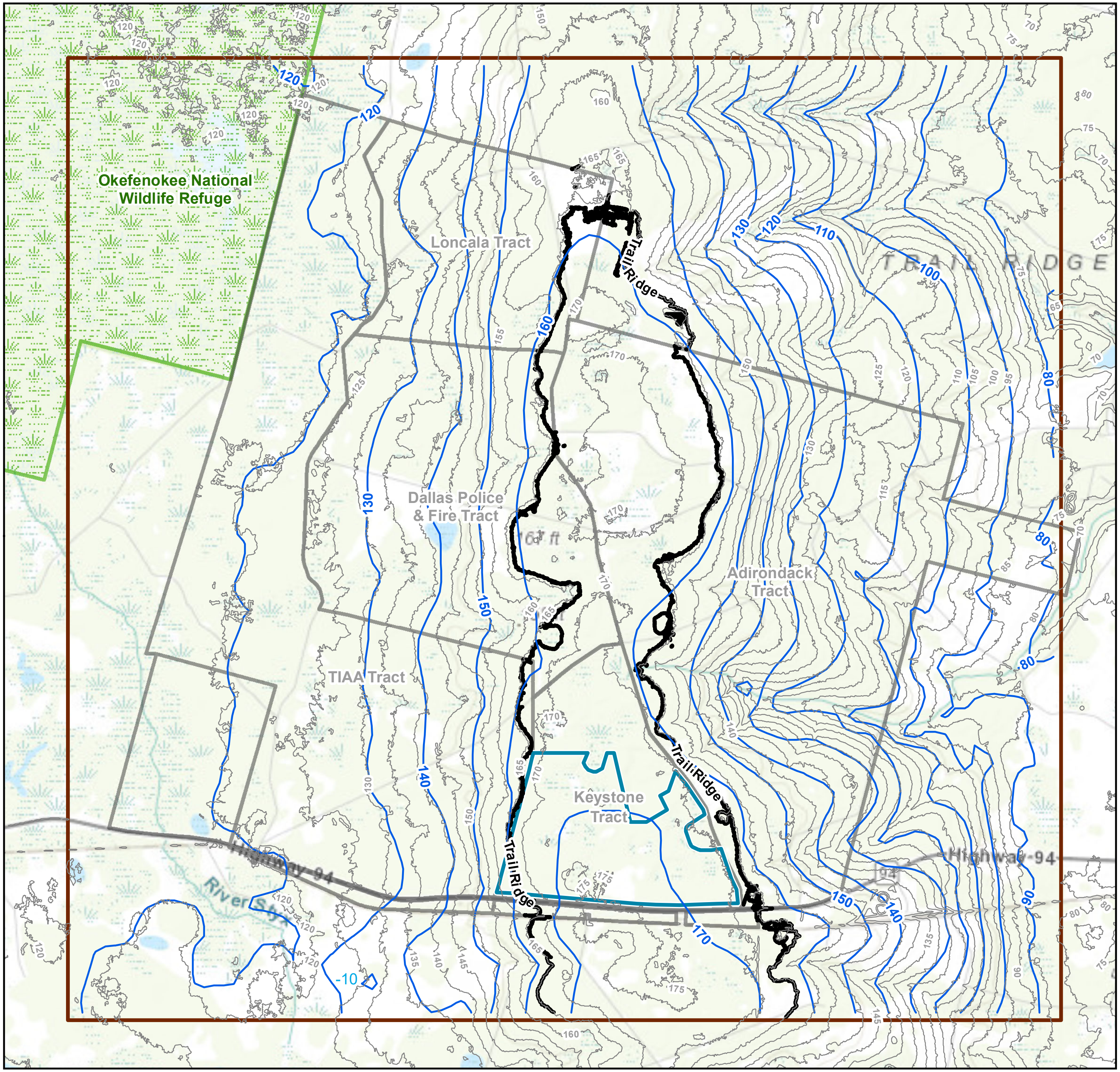
GSI Job No.: 5844	Drawn By: GM
Issued: 20-Jul-2021	Chk'd By: SP
Map ID: Figure29	Appv'd By: SP

FIGURE 29



GSI Job No. 5844	Drawn By: GM	**Observed vs. Simulated Water Levels for Calibrated Simulation**
Issued: 15 July 2021	Chk'd By: SP	Twin Pines Minerals, LLC
Revised:	Aprv'd By: SP	St. George, Charlton County, Georgia
Scale:	**Figure 30**	

GSI ENVIRONMENTAL



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- USGS 10 Feet Elevation Contours
- Simulated Water Level Contours (feet above mean sea level)
- Proposed Mining Area
- 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

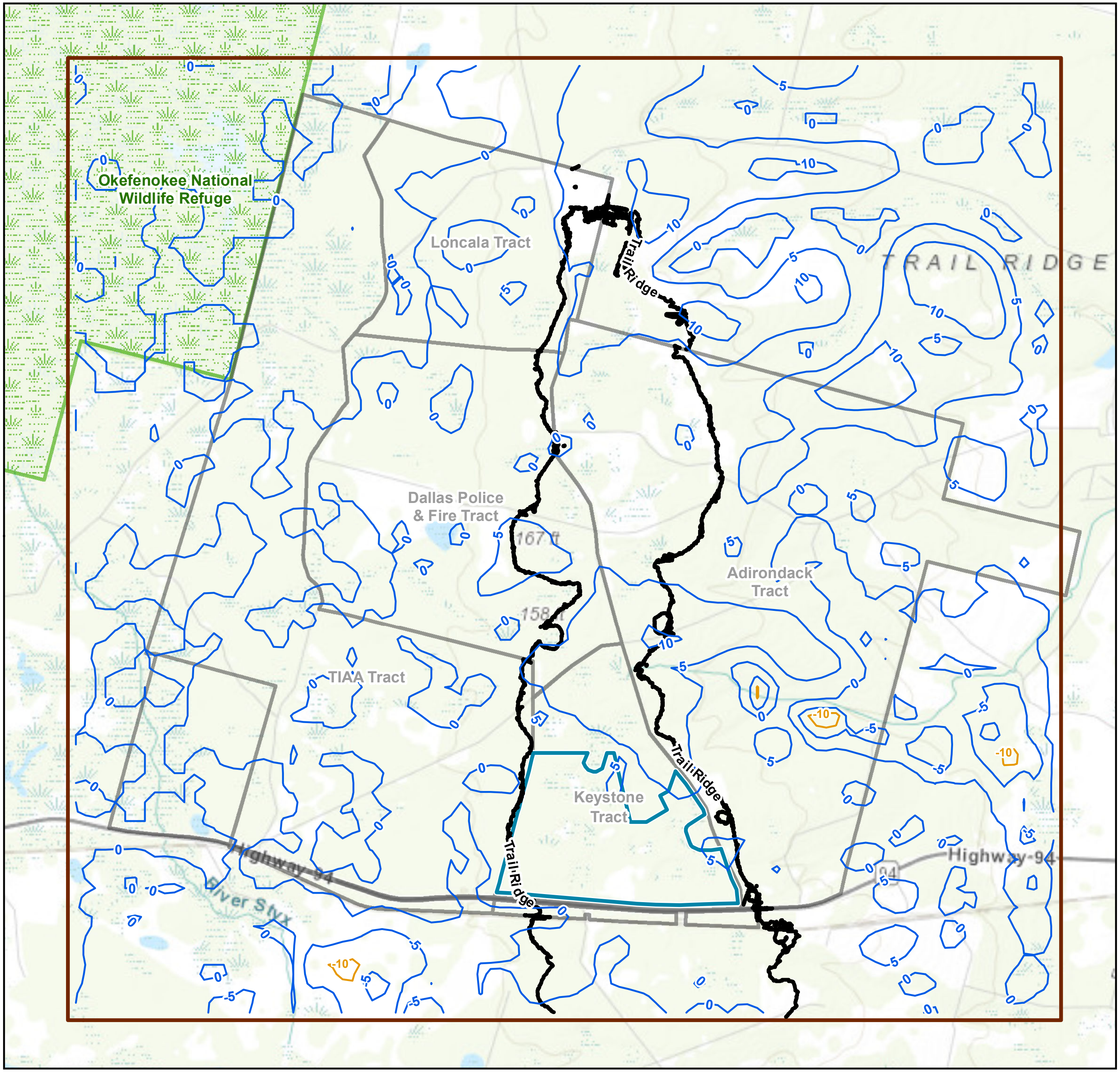
GSI ENVIRONMENTAL

Figure 31
Simulated Water Level Contours

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: Figure31	Appv'd By: SP

FIGURE 31



Notes:

1. Projection: North American Datum 1983 Georgia State Plane East (Feet)
2. Negative values indicate water levels above ground surface.

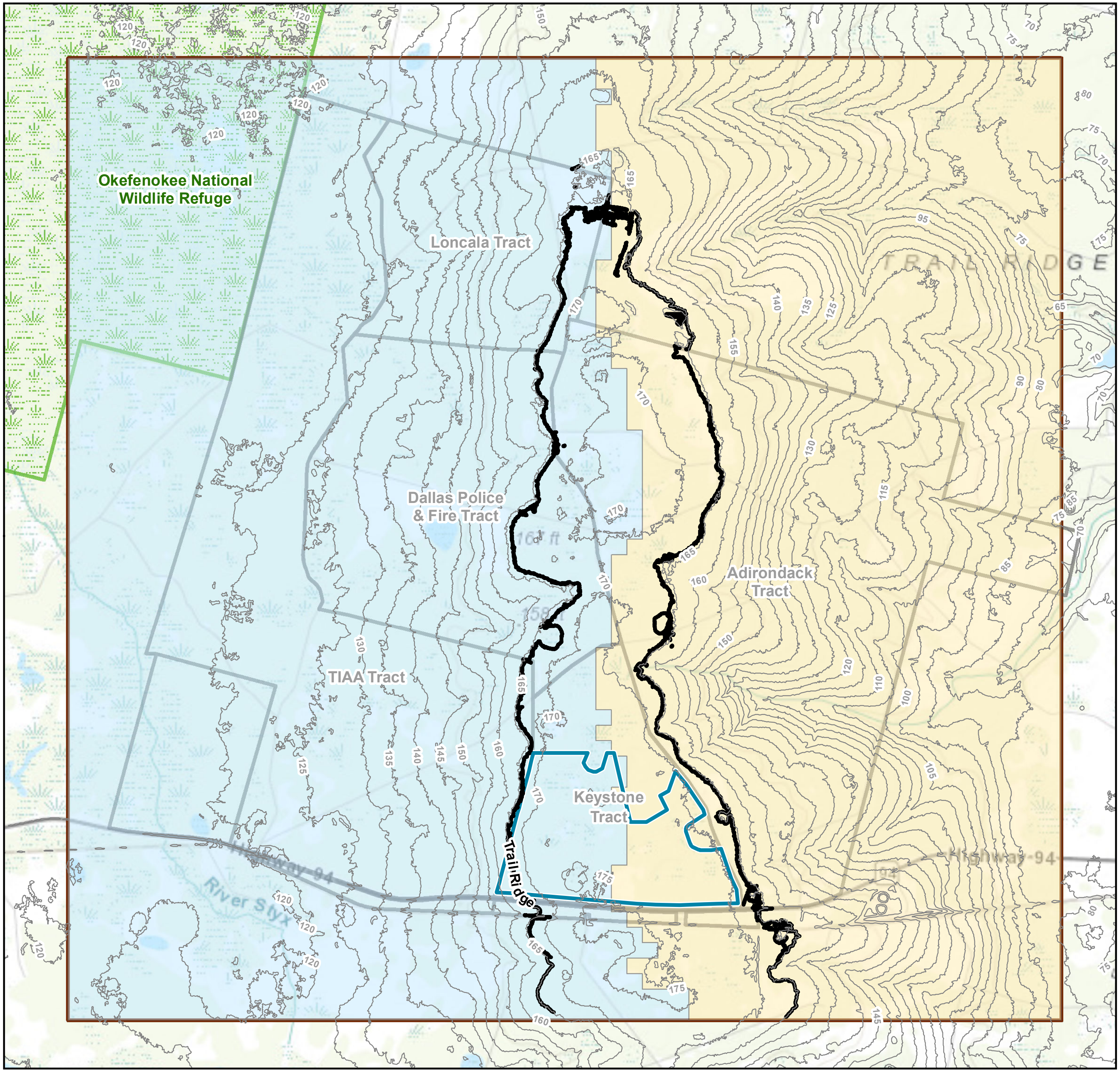
GSI ENVIRONMENTAL

Figure 32
Simulated Depth to Water Table

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: Figure32	Appv'd By: SP

FIGURE 32



N

LEGEND

- USGS 10 Feet Elevation Contours
- Trail Ridge (Elevation > 165 feet)
- Proposed Mining Area
- Mass Balance Calculation Area - East of Trail Ridge
- Mass Balance Calculation Area - West of Trail Ridge
- 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

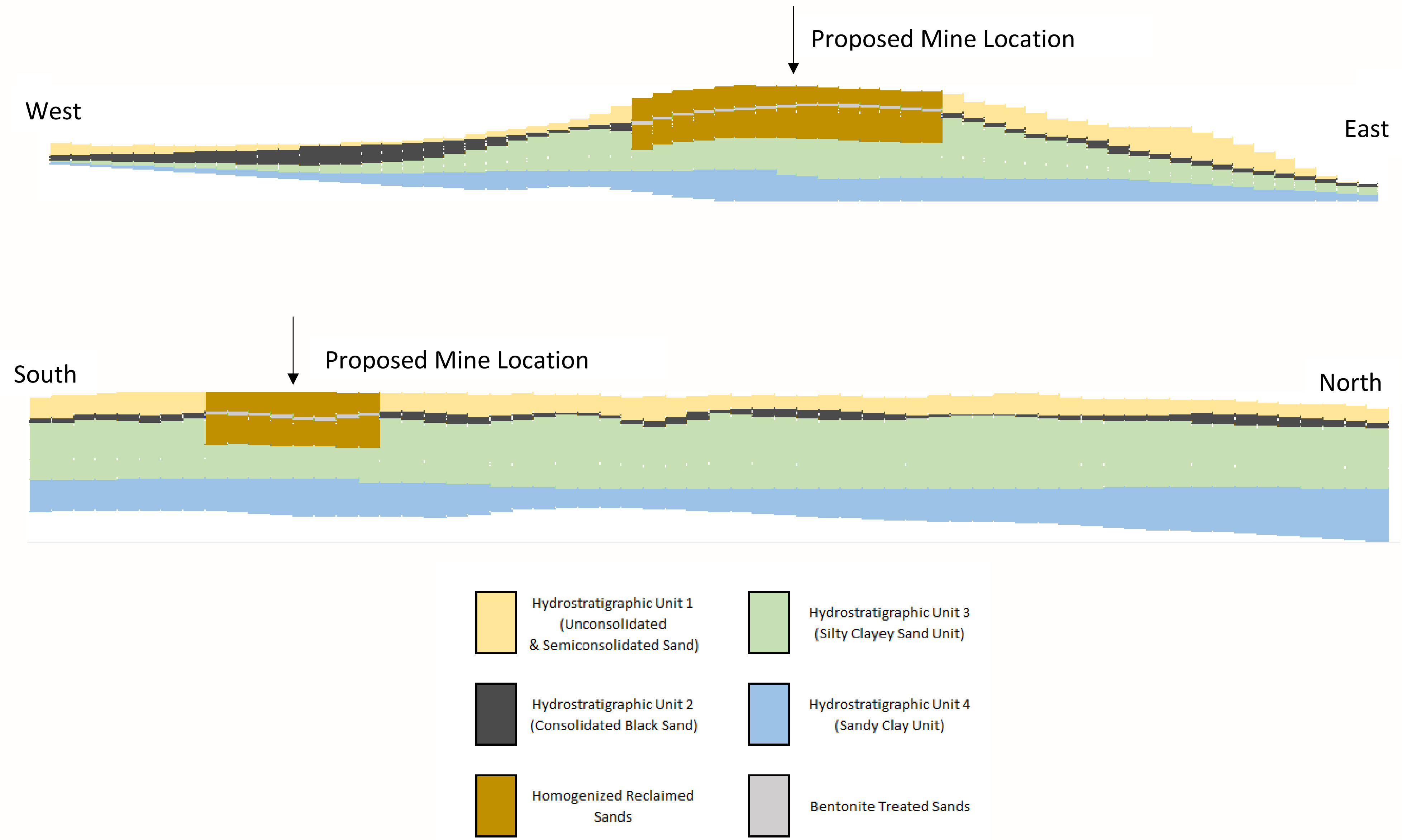
GSI ENVIRONMENTAL

Figure 33
Pre-Mining Simulation Water Budget Calculation Areas

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: Figure33	Appv'd By: SP

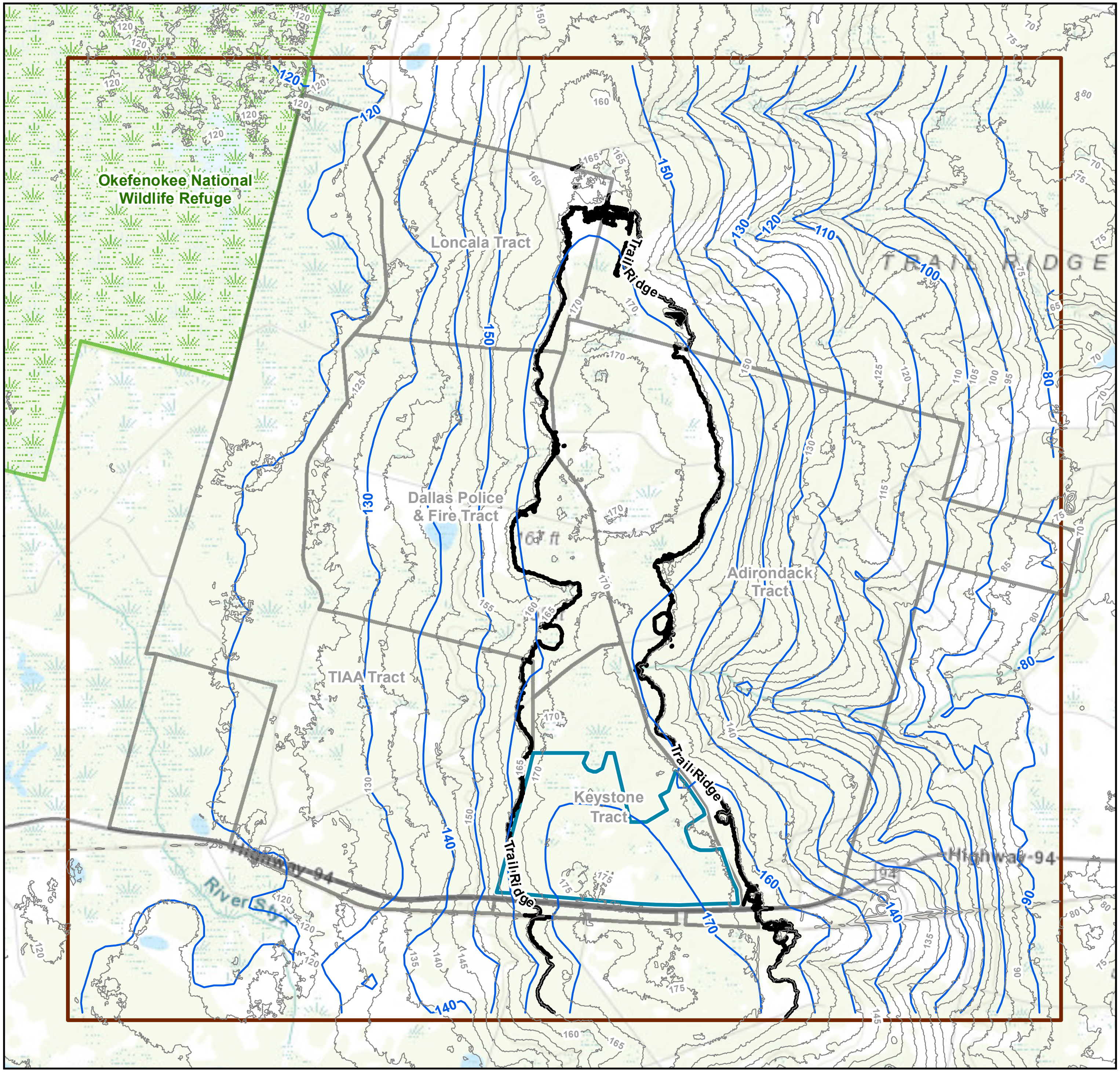
Figure 33



Note: Cross section locations provided on Figure 23.

GSI ENVIRONMENTAL

GSI Job No. 5844	Drawn By: RLW	**Post-Mining Conditions Cross Section**
Issued: 15 July 2021	Chk'd By: SP	Twin Pines Minerals, LLC
Revised:	Aprv'd By: SP	St. George, Charlton County, Georgia
Scale:	**Figure 34**	



N

LEGEND

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

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

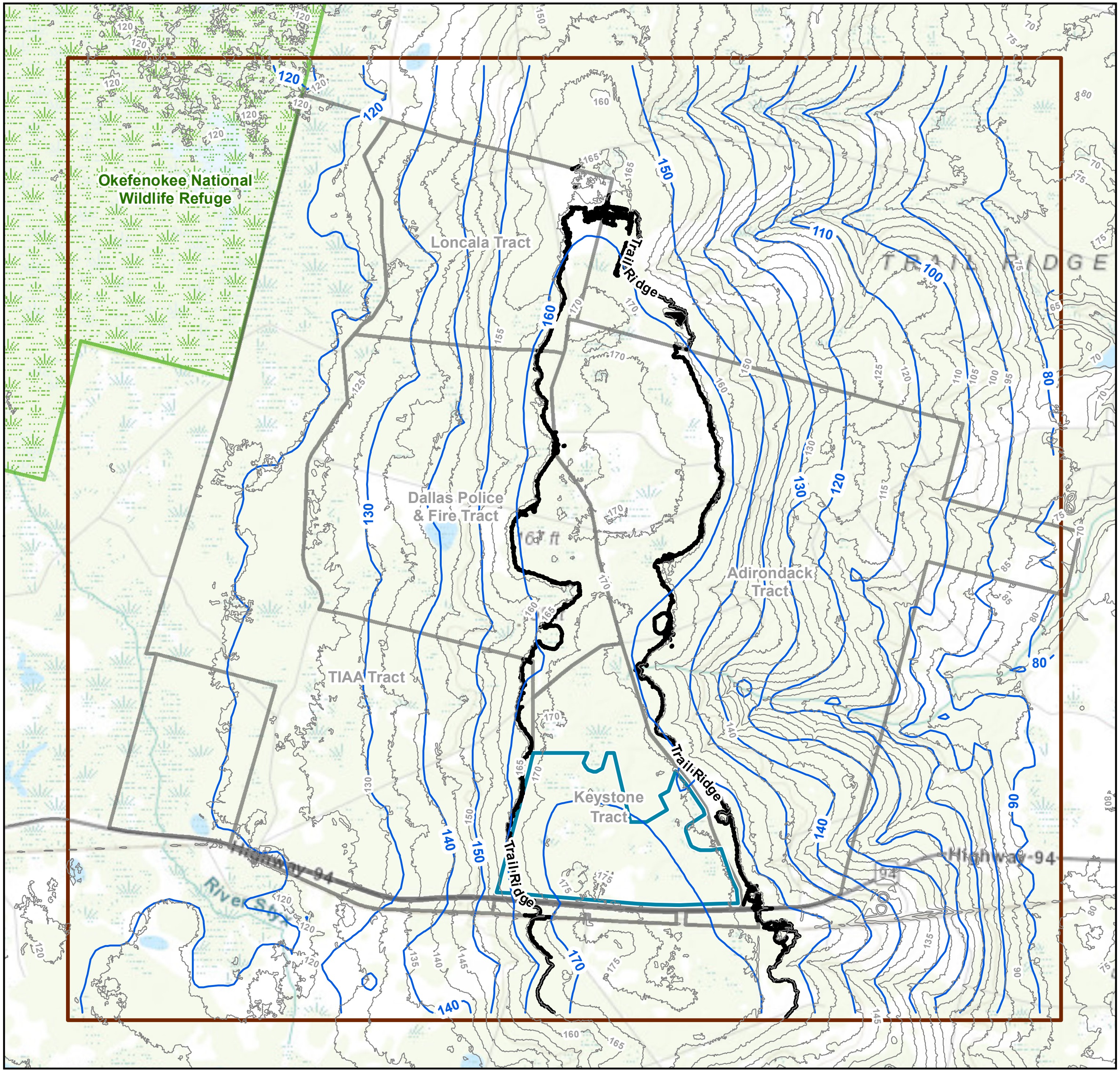
Scale in Miles
0 0.5 1

GSI ENVIRONMENTAL

Figure 35
Simulated Water Level Contours for Post-Mining Conditions with No Bentonite
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: Figure35	Appv'd By: SP

FIGURE 35



N

LEGEND

- Trail Ridge (Elevation > 165 feet)
- USGS 10 Feet Elevation Contours
- Simulated Water Level Contours (feet above mean sea level)
- Proposed Mining Area
- 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

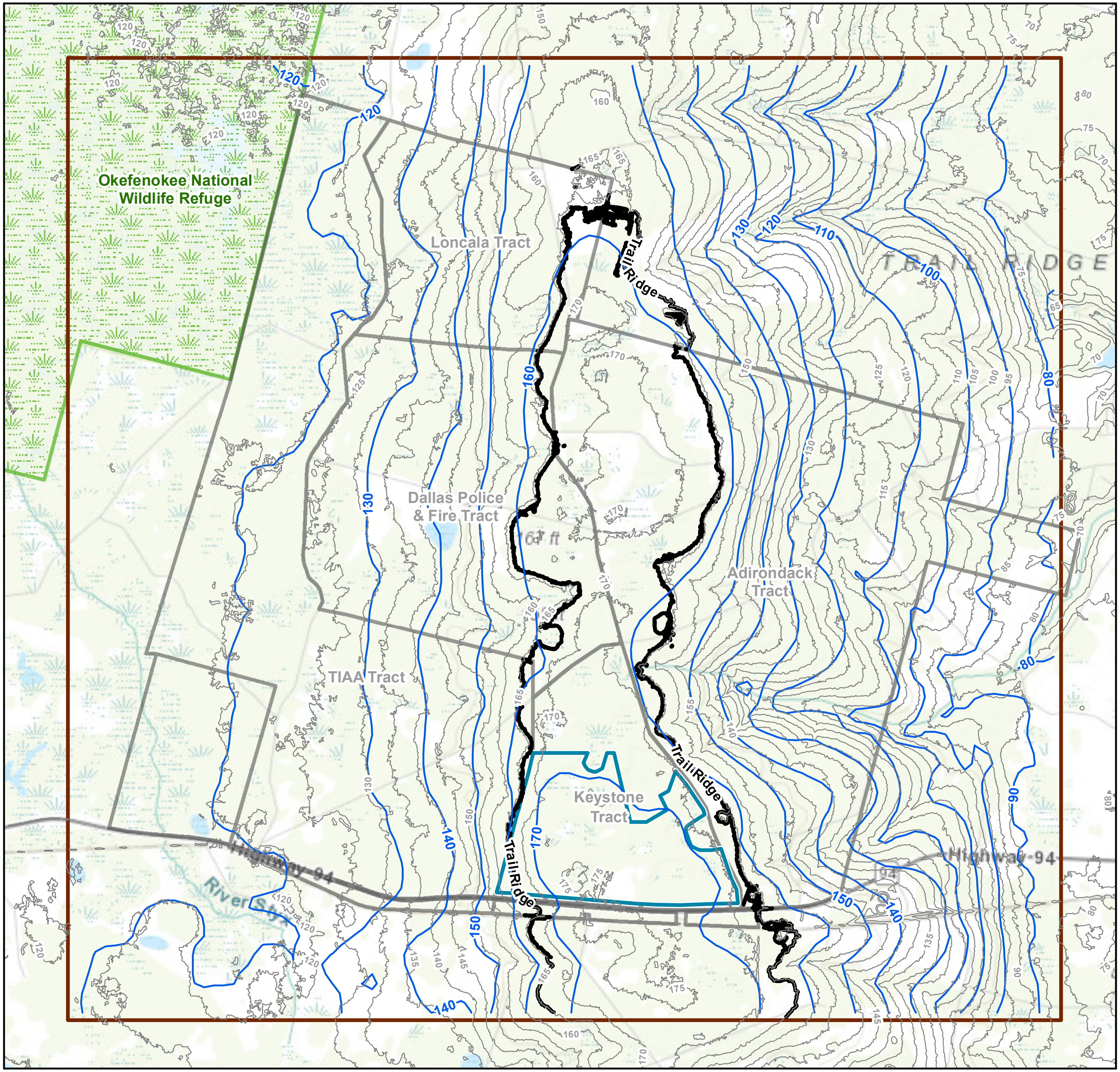
GSI ENVIRONMENTAL

Figure 36
Simulated Water Level Contours for Post-Mining Conditions with 5.3% Bentonite

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: Figure36	Appv'd By: SP

FIGURE 36



N

LEGEND

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

Notes:

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

Scale in Miles

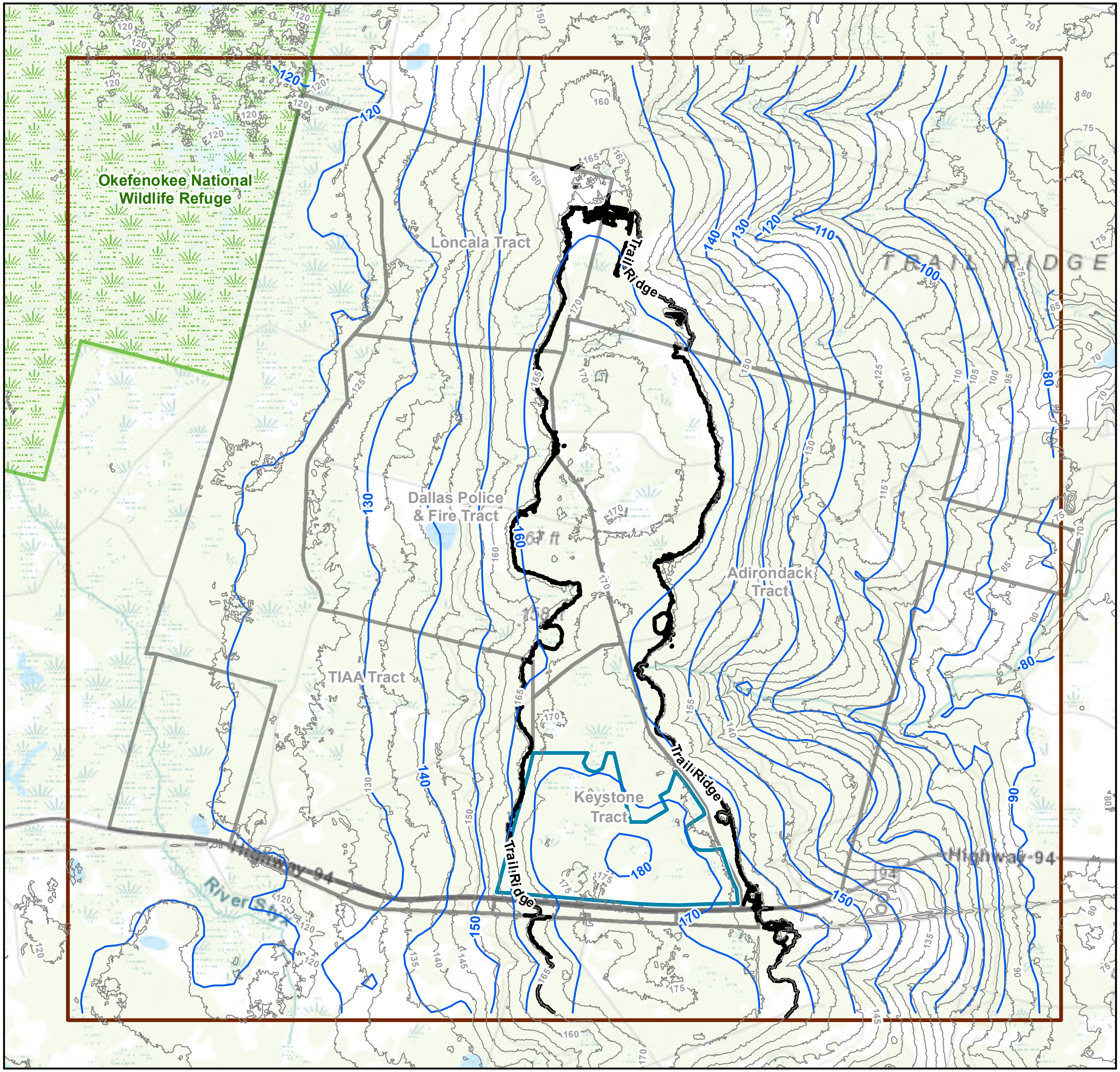
0 0.5 1

GSI ENVIRONMENTAL

Figure 37
Simulated Water Level Contours for Post-Mining Conditions with 10.9% Bentonite
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: Figure37	Appv'd By: SP

FIGURE 37



N

LEGEND

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

Notes:

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

Scale in Miles

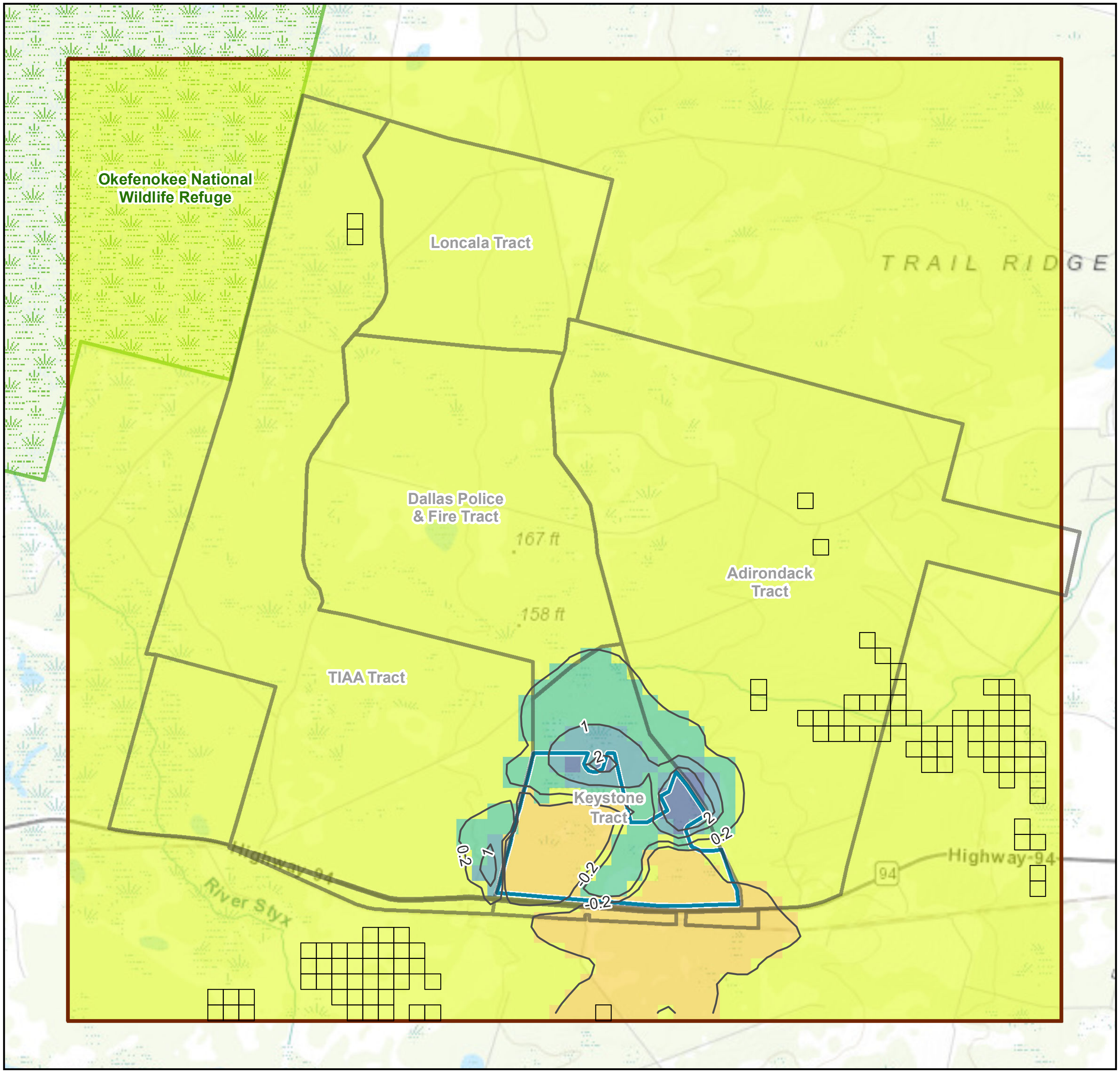
0 0.5 1

GSI ENVIRONMENTAL

Figure 38
Simulated Water Level Contours for Post-Mining Conditions with 12.5% Bentonite
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: Figure38	Appv'd By: SP

FIGURE 38



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)

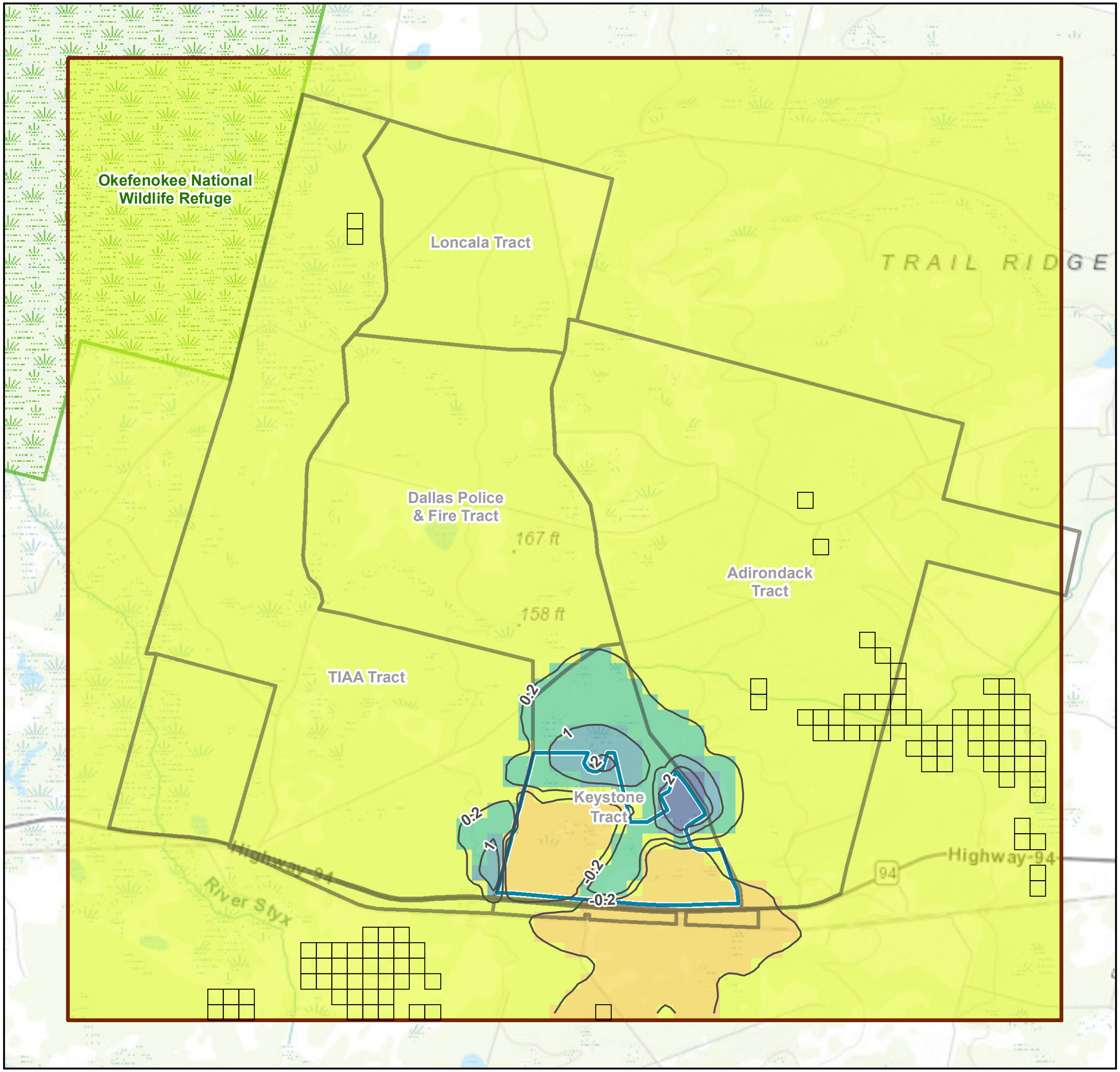
Scale in Miles
0 0.5 1

GSI ENVIRONMENTAL

Figure 39
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: Figure39	Appv'd By: SP

FIGURE 39



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)

- -1.84 - -0.20
- -0.19 - 0.20
- 0.21 - 1.00
- 1.01 - 2.00
- 2.01 - 6.48

Okefenokee National Wildlife Refuge

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

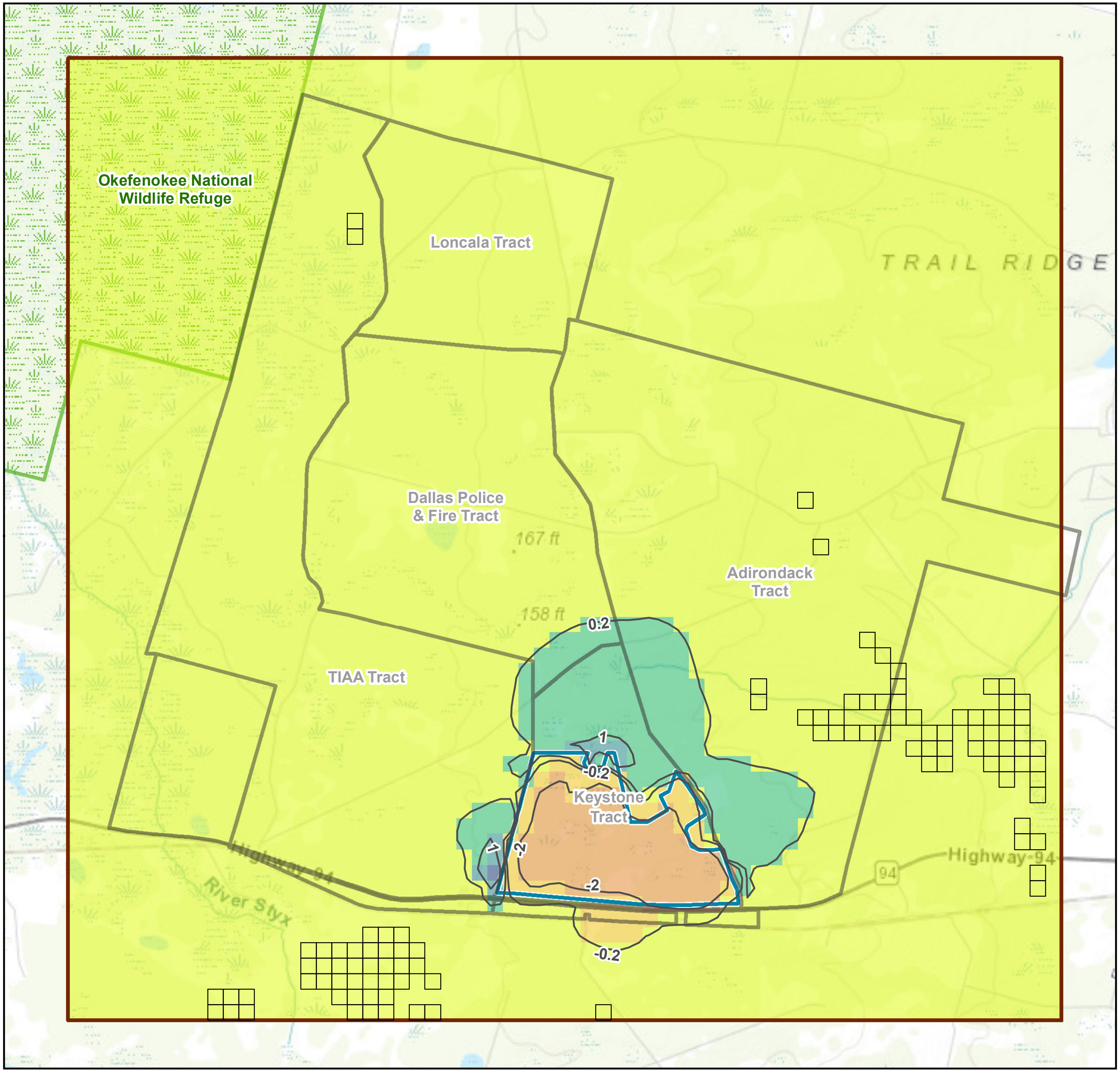
Scale in Miles
0 0.5 1

GSI ENVIRONMENTAL

Figure 40
Water Table Difference
5.3% 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: Figure40	Appv'd By: SP

FIGURE 40



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)

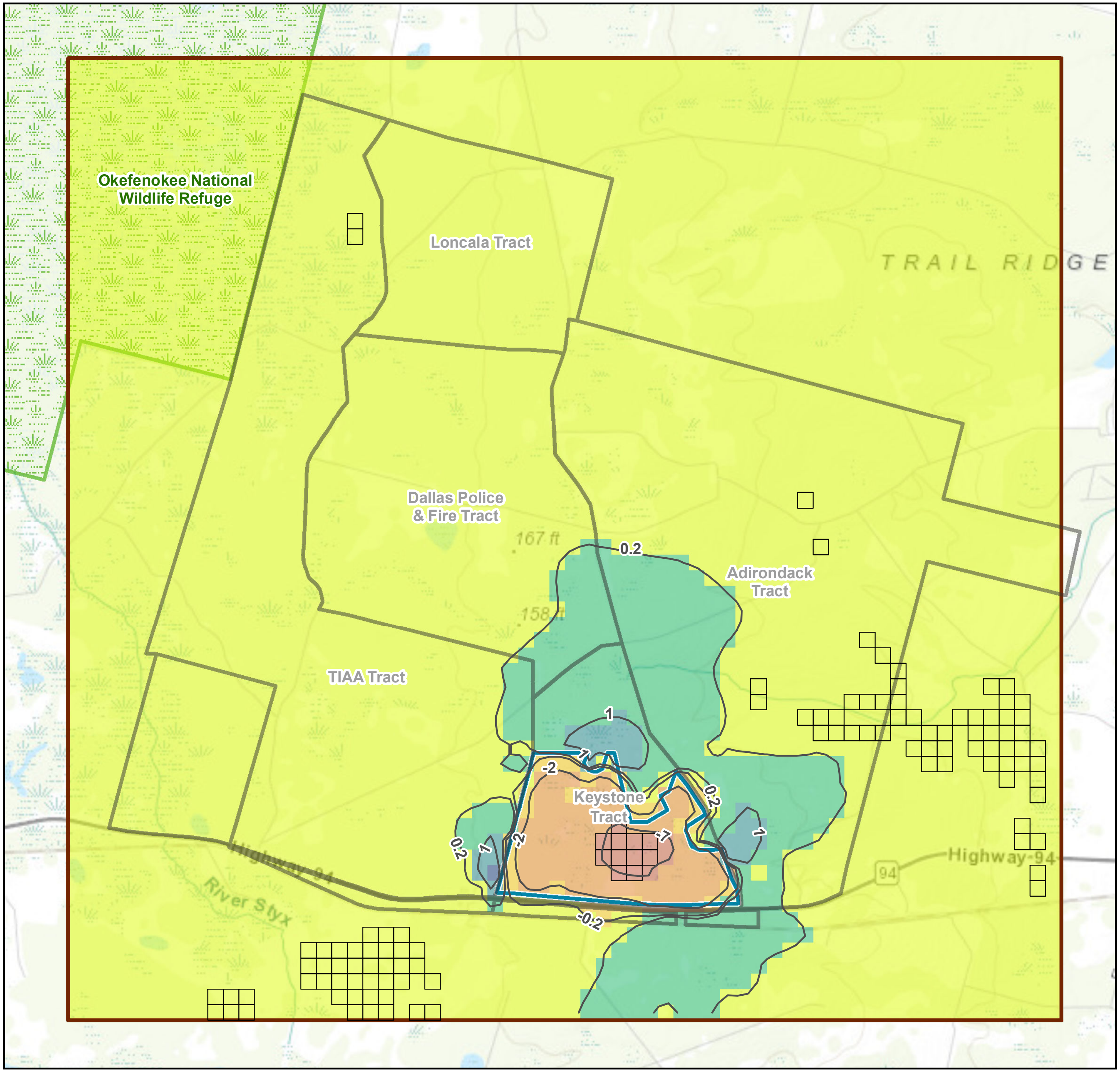
Scale in Miles
0 0.5 1

GSI ENVIRONMENTAL

Figure 41
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: Figure41	Appv'd By: SP

FIGURE 41



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)

- -9.58 - -7.00
- -6.99 - -2.00
- -1.99 - -0.20
- -0.19 - 0.20
- 0.21 - 1.00
- 1.01 - 2.00
- 2.01 - 2.02

Okefenokee National Wildlife Refuge

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

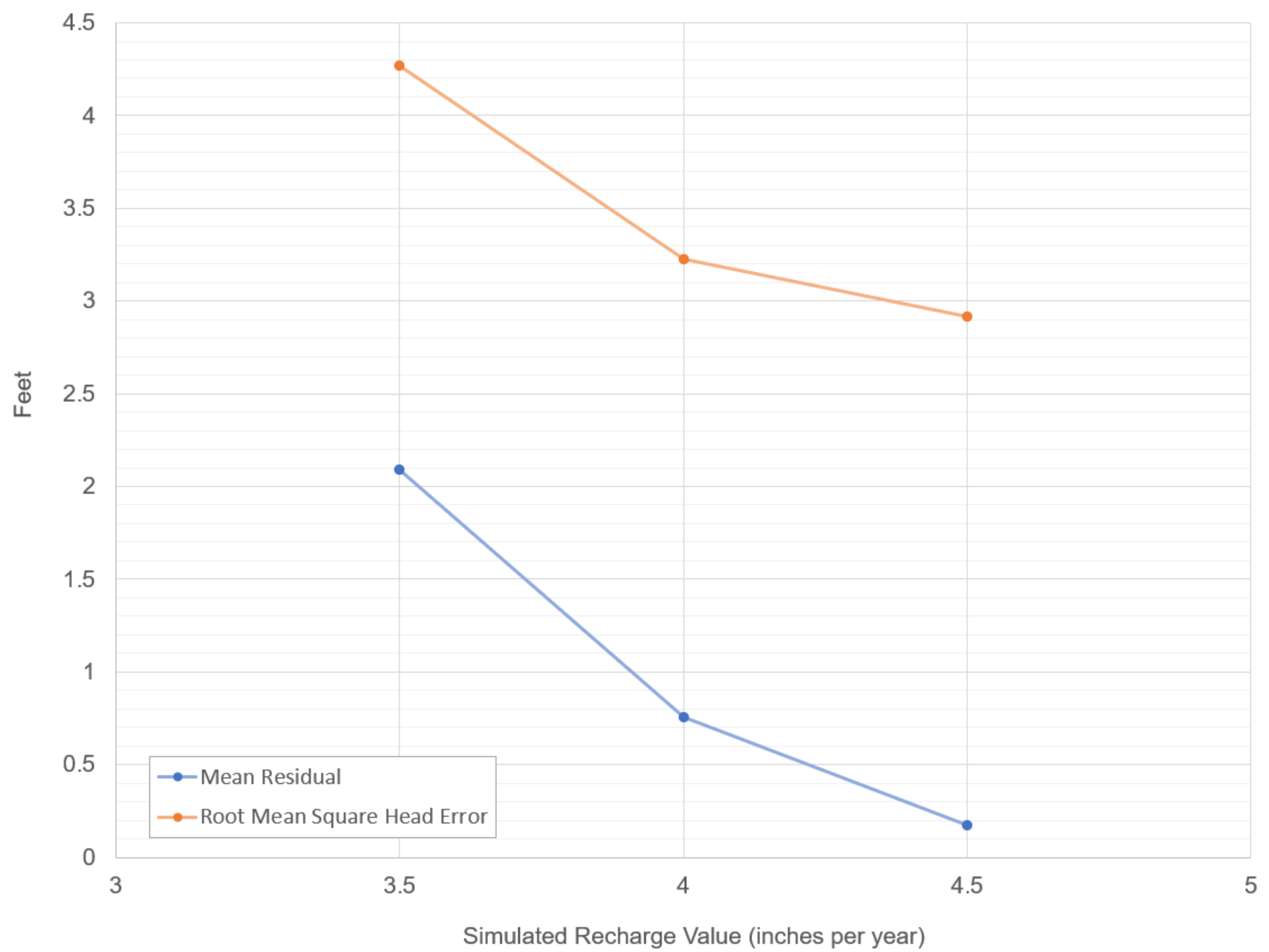
Scale in Miles
0 0.5 1

GSI ENVIRONMENTAL

Figure 42
Water Table Difference
12.5% 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: Figure42	Appv'd By: SP

FIGURE 42

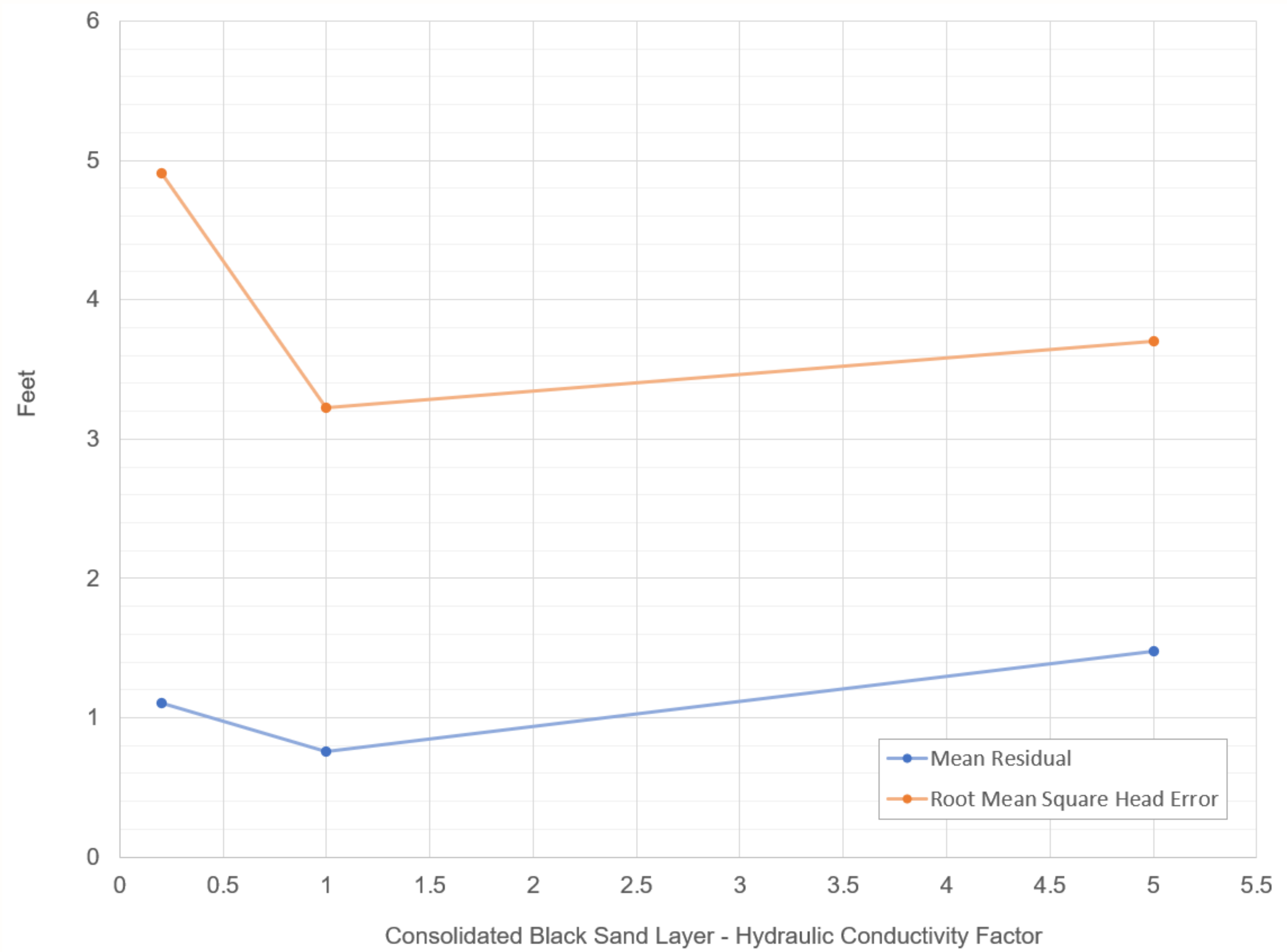


Note:
The calibrated model recharge value was 4 inches per year.

GSI ENVIRONMENTAL

GSI Job No.	5844	Drawn By:	GM
Issued:	15 July 2021	Chk'd By:	SP
Revised:		Aprv'd By:	SP
Scale:		**Figure 43**	

Pre-Mining Model Statistics
For Recharge Sensitivities
Twin Pines Minerals, LLC
St. George, Charlton County, Georgia



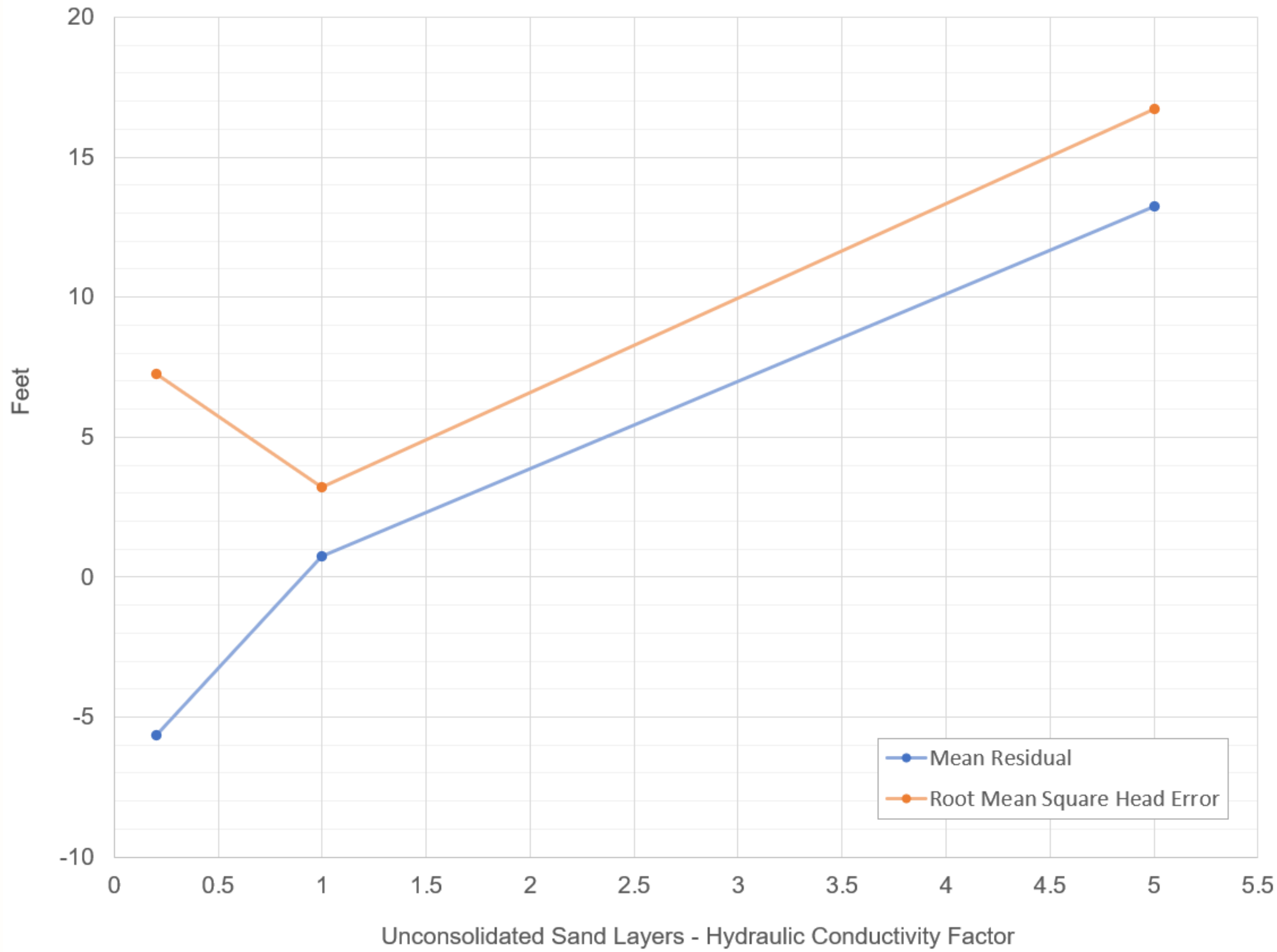
GSI ENVIRONMENTAL

GSI Job No.	5844	Drawn By:	GM
Issued:	15 July 2021	Chk'd By:	SP
Revised:		Aprv'd By:	SP
Scale:		**Figure 44**	

Pre-Mining Model Statistics for Consolidated Black Sand Hydraulic Conductivity Sensitivities

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia



GSI Job No. 5844	Drawn By: GM
Issued: 15 July 2021	Chk'd By: SP
Revised:	Aprv'd By: SP
Scale:	**Figure 45**

Pre-Mining Model Statistics for Unconsolidated Sand Layers Hydraulic Conductivity Sensitivities

Twin Pines Minerals, LLC

St. George, Charlton County, Georgia

APPENDICES

Appendix A

Response to Comments Provided to TTL on 4/14/21

APPENDIX A
RESPONSE TO COMMENTS PROVIDED TO TTL ON APRIL 14, 2021 BY DR. JAMES KENNEDY (KENNEDY, 2021) AS PART OF A TWIN PINES PERMIT COORDINATION DOCUMENT

Permit application documents have been submitted by Twin Pines Minerals (TPM) to develop a heavy mineral sand mine along Trail Ridge in Charlton County, Georgia. These include site studies and modeling studies which were summarized in the permit application document (TTL, 2020). The documents have gone through several rounds of review and comments from the Georgia Environmental Protection Division (GA EPD) by the State Geologist, Dr. Kennedy. This document is a response to comments by GA EPD on the impact of mining, on the hydrogeology of the region, as part of the Twin Pines Permit Coordination Document for Charlton County (Kennedy (2021)). In general, a new numerical model was developed that addresses the major concerns of the previous modeling efforts. The model development and results are reported in GSI (2021).

The entire comment from Dr. Kennedy will not be repeated here since he has done detailed examinations and reported them as part of his comments. Instead, the comment number will be noted, and the comment will be summarized for the response.

Comment 5a: Attach documents to the MLUP.

Response: Not model related.

Comment 5b: Initial groundwater recharge rate at the site was estimated as 4.54 inches/year, however, the model applied 2.8 inches/year. Calculations using USGS Open File Report (OFR) 2003-311 data show an average of 4.13 inches/year. The comment essentially requests justification for the use of 2.8 inches/year.

Response: A recharge value of 4.13 inches/year was used for the steady-state groundwater flow model. This is the value estimated for the study area from the USGS data cited above.

An evaluation of recharge over the study area was conducted and it was noted that recharge could vary between 4.5 inches/year and 3.5 inches/year as noted in GSI (2021). The USGS data was examined further and was noted to be a reasonable approach to estimating long-term recharge for the model. Also, a sensitivity analysis was conducted on the range of recharge values to note the impact on calibration to pre-mining conditions and on post-mining conditions.

Comment 5c: The comment requests clarification on requirement of soil amendments.

Response: Soil amendments were modeled in different amounts to note the most effective bentonite mix for the soil amendment layer. A mix using 10.9 % bentonite over the entire mined area was simulated to be the best amendment for minimizing hydrogeologic impacts at and around the mine site.

Comment 5d: The comment indicates that the groundwater flow modeling of soil amendments should be done and that will help to determine how hydrology changes from pre-mining conditions.

Response: We have conducted groundwater flow modeling with various mixtures of bentonite in the amendments and noted how and where the amendments impact the pre-mining hydrogeology. Larger amounts of bentonite in the amendment cause water levels to rise higher to where they may be intercepted by wetlands and stream channels. It was determined that minimal impacts occurred with a 10.9% mixture of bentonite.

Comment 5e: The comment requests clarification on continuity of black sands.

Response: We have conducted similar computations to those conducted by Dr. Kennedy regarding continuity of black sands and have come to a similar conclusion that about 69% of the area contains consolidated black sands.

Comment 5f: The comment requests further analyses of consolidated black sands if it is not conceptualized to be continuous enough to affect the presence of the shallow water table along Trail Ridge.

Response: We have conducted similar computations to Dr. Kennedy regarding continuity of black sands and have come to a similar conclusion that about 69% of the area contains consolidated black sands.

Comment 5g: The comment requests that a hydrogeologic layer of consolidated black sands be included in the model for several reasons listed.

Response: We agree with the reasons and have a layer of consolidated black sands included in the model.

Comment 5h: The comment requests clarification on how rainwater interacting with the reclaimed mine may affect the chemistry of the groundwater discharge to surface waters.

Response: Not model related.

Comment 6a: Attach documents to the MLUP.

Response: Not model related.

Comment 6b: This comment requests use of data to determine presence or absence of consolidated black sands.

Response: We have mapped the logs with presence and absence of consolidated black sands and used that information to delineate locations where consolidated black sands are present and where they may be absent. This is detailed in GSI (2021). This data indicated that the study area was mostly covered with continuous black sands with small areas where they did not exist, and a small zone showing a transition between where the continuous black sands exist and where they do not.

Comment 6c: This comment requests use of hydraulic conductivity values for consolidated black sands that are in line with data from the site. Also, the comment indicates that slug test data that show higher values may not be appropriate for consolidated black sands.

Response: We have mapped the hydraulic conductivity estimates from laboratory and field experiments in GSI (2021). They are low in the range of 10^{-6} to 10^{-8} cm/sec as noted by GA EPD and that higher values in the range of 5 x 10^{-5} to 10^{-2} cm/sec may indicate composite conductivities with overlying and underlying materials. The model developed in GSI (2021) also uses values in the range of 10^{-6} to 10^{-8} cm/sec for the consolidated black sands.

REFERENCES

GSI (2021). Modeling the Groundwater Flow System at the Proposed Twin Pines Mine on Trail Ridge, July 16, 2021.

Kennedy (2021), Twin Pines Permit Coordination Document Charlton County: Saunders Demonstration Mine, Comments from April 14, 2021.

TTL (2020), Individual Permit Application for Twin Pines Minerals, LLC, Saunders Demonstration Mine Saint George, Charlton County, Georgia (SAS-2018-00554), March 4, 2020.

GSI ENVIRONMENTAL

Appendix B

Response to Comments Provided to Twin Pines Minerals, LLC on 9/10/21

APPENDIX B
RESPONSE TO COMMENTS PROVIDED TO TWIN PINES MINERALS, LLC ON SEPTEMBER 10, 2021, BY GEORGIA DEPARTMENT OF NATURAL RESOURCES ENVIRONMENTAL PROTECTION DIVISION AND DR. JAMES KENNEDY (EPD, 2021)

Permit application documents have been submitted by Twin Pines Minerals (TPM) to develop a heavy mineral sand mine along Trail Ridge in Charlton County, Georgia. This document is a response to comments by the Georgia Department of Natural Resources Environmental Protection Division (EPD) regarding the development of a groundwater model to assess the impact of mining, on the hydrogeology of the region, as part of an Application for a Surface Mining Permit and Mining Land Use Plan (MLUP) Twin Pines Permit Coordination Document for Charlton County (TTL, 2021).

The entire comment from EPD will not be repeated here but does include the EPD comments specific to development of the groundwater model.

2. Exhibit I Modeling the GW Flow System Comments James L. Kennedy Ph.D., P.G.

Page 1: The description of the method to be used to place the bentonite-enhanced layer of soil will not work given that the mine pit will not be dewatered. It was noted that placement of the bentonite-enhanced soil layer is not a modeling issue, which is correct, but the description of the process on Page 1 must say placement of the bentonite-enhanced soil layer cannot be simulated by the model.

Response: The modeling report text has been updated as requested in Section 1.0 that provides the Executive Summary (page 1) as well as in Section 7.0 on Post-Mining Analysis section (page 11).

Page 8: Explicitly explain what use of the drains versus rivers means in the model. In MODFLOW drains can receive water from the modeled aquifer but cannot recharge the modeled aquifer. A river can both receive water from the modeled aquifer and discharge water to the modeled aquifer. Explain that the drains were modeled based on the surface water courses shown on Figures 22 and 23. Explain that no rivers were modeled because there are no rivers within the model domain.

Response: The modeling report text (Section 4.3 Model Boundary Conditions – page 9) has been updated as requested.

Page 8: Say how many grids there are in the mining area (there are enough grids).

Response: The modeling report text has been updated as requested, in Section 4.1 on Model Discretization (page 8).

Page 12: Please say explicitly if the addition of bentonite was simulated in the mining area shown on Figure 3 (and later figures) or if it was simulated for the entire are (it was simulated in the mining area shown on Figure 3 but that needs to be clarified in the report).

Response: The modeling report text has been updated as requested in Section 7.0 on Post-Mining Analysis section (page 12).

Does the software used for the model include an LGR (Local Grid Refinement) capability? If it does LGR should be used to model the mine area. LGR could be used to model the mine area at a grid size of 250 ft. x 250 ft. LGR is not needed to make the model acceptable, but it would be helpful to see a more detailed numerical analysis of the mining area.

Response: Local grid refinement (LGR) capability can be directly implemented for models built using MODFLOW-2005 but not with the MODFLOW-NWT code that was used for simulation of the proposed Twin Pines Minerals project.

Revising the code to MODFLOW-USG would allow grid refinement specific to the proposed mine area; however, this would also introduce unnecessary complexity to the modeling effort and, therefore, no changes to the modeling code have been implemented.

REFERENCES

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

Georgia Department of Natural Resources Environmental Protection Division (EPD) (2021), Twin Pines Permit Coordination Document Charlton County: Saunders Demonstration Mine, Comments from September 10, 2021.

TTL (2021). Part 2 Response to EPD Permit Coordination Comments, July 16, 2021.