Revision of
Sinkhole Monitoring and Contingency Plan
RDA, LLC Facility
Williamsburg County, South Carolina

GMA Project #158007

Prepared for

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1.0 Introduction

This document is a revision of the Sinkhole Monitoring and Contingency Plan for the RDA, LLC (RDA) site. The original Sinkhole Monitoring and Contingency Plan was prepared by Groundwater Management Associates, Inc. (GMA) on November 20, 2017. The November 2017 document presented plans for mining to begin on a 45-acre tract known as Segment 5. The first revision of the Sinkhole Monitoring and Contingency Plan (SMCP) was issued on May 16, 2018, and it reflected a change in the mine plan wherein RDA will initially begin mining at Segment 6. The current document is a revision to the plan that reflects feedback comments from the South Carolina Department of Health and Environmental Control (SCDHEC) regarding the May 16, 2018 SMCP.

RDA is applying for a Mine Operating Permit to operate a limestone quarry in Williamsburg County, South Carolina (Figure 1). The mine site entails ten Segments that are proposed to be mined, with a total mine area of approximately 419 acres. Individual Segments range in size from 19.9 to 57.0 acres (Appendix I). The current plan is to begin mining at Segment 6, which is located in the interior of the overall mine property. Segment 6 comprises 53.2 acres, and mining is expected to progress at a rate of 7 acres per year.

The mine will produce crushed limestone aggregate, and the limestone ore will be recovered using open-pit mining. As a condition of mine permitting, RDA must demonstrate that sinkholes will not develop on land outside RDA Quarry's mine permit area as a result of mine dewatering operations. Groundwater Management Associates, Inc. (GMA) was contracted to develop a Sinkhole Monitoring and Contingency Plan that focuses on the initial mining of Segment 6. GMA is a hydrogeological and engineering consulting firm that has experience in mine dewatering, management of groundwater withdrawal effects, and mitigation planning for impacts associated with groundwater withdrawals. We have developed this monitoring and contingency plan to evaluate the hydrologic response of the groundwater system to dewatering withdrawals that are anticipated to support open-pit mining at Segment 6. This plan was prepared in consideration of GMA's prior exploration and aquifer testing in Segment 5 and predictive calculations that were presented in a Hydrogeologic Evaluation report (GMA, 2017). We also reviewed core drilling information and mine plans that were provided by RDA.

The South Carolina Department of Natural Resources (SCDNR) issued a letter dated 10/20/17 (Appendix IV) that expressed concern over the potential for sinkhole development associated with dewatering to support open pit mining at the RDA site (SCDNR, 2017). SCDNR cited a sinkhole event that occurred in Georgetown in 2011, approximately 20 miles east of the RDA site, as an example of the type of sinkhole episode that they are concerned about for the proposed aggregate mine at the RDA site.

The aim of this Sinkhole Monitoring and Contingency Plan is to present specific monitoring tasks that will evaluate the effects of mine dewatering at Segment 6 on a limited area of property within the mine site. Using detailed observations and testing of the areas proximal to Segment 6, RDA can refine mining practices and establish engineering controls to minimize the potential for sinkhole development and to protect surrounding properties from possible adverse impacts.

2.0 Background and Hydrogeologic Setting

GMA's Hydrogeologic Evaluation Report (GMA, April 2017) presented a detailed summary of the geologic setting, ages, lithologies, and formation names that occur beneath the site. The RDA site lies in the Coastal Plain physiographic province of South Carolina.

There are two primary lithologic units occurring beneath the RDA site that will be directly affected by the proposed mining activities. The surficial sediments are silty sands of the Socastee Formation of Middle Pleistocene age. The upper portions of the surficial sediments undoubtedly also include late Pleistocene age to Holocene age sediments that are not mappable on a regional scale. This sequence of shallow unconsolidated sediments comprises the overburden materials. Overburden thickness at the RDA site averages approximately 30 feet.

The Pleistocene Socastee Formation lies unconformably above a hard fossiliferous limestone that grades with depth to a sandy limestone (SGR, 2017). The limestone sequence has been attributed to the Paleocene age Chicora Member of the Williamsburg Formation, and this indurated unit is the ore that is to be mined for aggregate. Of particular interest for the Sinkhole Monitoring and Contingency Plan is the nature and location of indurated carbonate rocks that may chemically weather to produce subsurface voids or caverns.

2.1 Potential Karst Formation

Chemical weathering of carbonate rocks can preferentially dissolve calcium carbonate due to interaction of meteoric water with the rock. Meteoric water has a naturally low pH (typically 5 to 6) due to dissolved CO_2 and the formation of carbonic acid. Interaction of carbonic acid with limestone, made predominantly of Calcite ($CaCO_3$), will gradually dissolve the limestone. This dissolution results in a water-filled void in the rock that previously was filled with solid limestone. Tannins and other organic acids in shallow soil and surface water bodies may further reduce the pH of the water as it moves downward into the limestone, thereby accelerating dissolution rates.

The most common weathering that results from percolation of meteoric water into Tertiary-aged limestones in South Carolina is the dissolution of fossil shells that are made predominantly of the mineral aragonite. Aragonite has the same chemical composition as calcite, but aragonite has a different crystal structure. The aragonite shells are more soluble than the micritic to sparry calcite that fills the spaces between the shell fossils. This preferential weathering results in a moldic texture of the limestone, leaving void spaces where the original shells have been weathered away. Photographs of cores collected from exploratory drilling by SGR (2016) indicate that the upper portion of the limestone contains abundant mollusk shell molds. Moldic limestone porosity tends to develop where aragonitic shell materials are abundant.

If the lithologic composition of the limestone is uniform, weathering of the uppermost portion of the limestone may result in gradual land subsidence over a broad area. This weathering pattern typically

does not result in episodic sinkhole collapse. The contact between the overburden sediments and the limestone is marked by high-porosity low-cohesion sediments where residual siliceous mineral grains (sands and clays) derived from weathering of the underlying limestone will accumulate.

In contrast, if the limestone lithology is heterogeneous, there may be lateral variations across an ore body where some materials may weather more rapidly than other materials. These lateral variations may include differences in mineral composition (facies changes) or structural differences (such as fractures). Local dissolution of limestone to greater depths may occur where heterogeneities are present that foster accelerated weathering. When this occurs, larger voids or caverns may develop. These local cavities will gradually grow over time until they reach a size that cannot support the weight of the overburden materials. Collapse of these cavities results in sinkhole formation. Sinkholes may stabilize as water-filled depressions, or they may expand and coalesce with other similar depressions, ultimately forming headwaters of new drainage systems. Because water is nearly incompressible, a water-filled cavity is partially supported by pore pressure. Depressurization of the cavity may make the cavity unstable and subject to collapse. This may especially be the case when the cavity is partially dewatered. The depth of collapse is limited by the thickness of the limestone. The limestone ore at the RDA site is approximately 20 to 30 feet thick. This relatively thin rock layer, coupled with a shallow burial depth, will not lend itself to forming large, deep sinkhole structures.

The topography of a land surface that is characterized by sinkhole depressions, broad abnormal drainage headwaters, and disappearing streams is called Karst. The topographic features of a Karst terrain provide evidence of the heterogeneities of the subsurface carbonate rocks. Careful examination of topography can be extremely helpful for identifying areas that may be prone to future sinkhole development.

In GMA's Hydrogeologic Evaluation Report, we prepared two LIDAR topographic images of the RDA site and the surrounding area. One of these figures included our interpretations of potential karst areas (see attached Figure 3). This figure was produced based solely upon review of LIDAR data, and no field observations were made at that time to support or modify GMA's preliminary evaluation of potential karst features.

2.2 Site Reconnaissance Evaluation

On October 26, 2017, two GMA geologists, William L. Lyke and James K. Holley, visited the RDA site. The intent of the site visit was to perform a reconnaissance investigation of potential karst features identified in our previous study. Figure 4 presents specific sites of interest that were visited to perform field evaluations of possible karst features. Appendix II includes annotated photographs of features observed during our reconnaissance visit.

Depression areas observed north and east of Segment 5 (see Figure 4) included wide, shallow, wet areas with gently sloping sides. These areas did not exhibit the characteristics of active, or recently active,

local sinkhole formation. Although the depressions north and east of Segment 5 may represent paleokarst, we did not observe evidence in these locations of active sinkhole growth.

We did observe a grouping of sinkhole ponds east and south of Segment 5. These depressions were mapped previously, and they appear to follow a generally north to south linear structure that may indicate a subsurface limestone condition (possibly fracture or lithologic difference) that is prone to sinkhole formation. We photographed five of these ponds, and they are labeled Sinkhole Pond 1 through Sinkhole Pond 5 on Figure 4. These ponds were relatively steep-sided enclosed depressions that appeared to have been active sinkholes in the recent past. However, none of these features appeared to be unstable or actively growing. Most had relatively mature Tupelo and other swamp trees growing within the ponds. These trees indicate that the ponds likely have been stable for decades.

The site reconnaissance confirmed that karst features occur within 1000 feet of Segment 5. The majority of these features occur west and southwest of Segment 5, and most are within the RDA property boundaries. The observed Sinkhole Ponds provide easily accessible features to monitor during the initiation of mining.

Because RDA has updated the mining plan to begin mining at Segment 6, many of the identified karst features that were proximal to Segment 5 are now more than 1000 feet away from the proposed initial mine block at Segment 6. Furthermore, there is a desire to evaluate areas up to 2000 feet from the mine face for the potential for sinkhole development. Therefore, the monitoring plan must be modified to address the new initial mine area and the projected hydraulic effects of the initial mining operation.

3.0 Monitoring Plan

GMA has developed a multi-faceted monitoring plan to evaluate the potential formation of active sinkhole features associated with the proposed mine dewatering at the RDA site. The mining plan involves initial open-pit mining on a 53.2-acre tract in the interior of the site (Segment 6). Mining of Segment 6 will proceed at a rate of approximately 7 acres per year, meaning that completion of Segment 6 will take approximately 7.5 years to complete. The monitoring plan presented below focuses only on monitoring areas proximal to Segment 6 during the initial ~7.5 years of mining. Results of active monitoring during the mining of Segment 6 will guide monitoring procedures as mining progresses into other mine segments. The monitoring plan will be regularly updated as new observations are made of site conditions. Any update shall be reviewed and approved by DHEC before implementation. Depending upon the results of the monitoring program, mining procedures may be modified to help reduce the potential for sinkhole development.

3.1 Baseline Evaluation

It is essential to perform a detailed baseline evaluation of conditions in the vicinity of the RDA site prior to initiating mining. The baseline evaluation for areas near Segment 6 involves: 1) topographic

evaluation through interpretation of LIDAR data, 2) reconnaissance and documentation of the site features, 3) aerial surveillance of Segment 6 and the surrounding area within 1,000 feet of the proposed mine face, and 4) correlation of data and ground truthing. The 1,000-feet monitoring area surrounding Segment 6 is based upon site observations and considering hydraulic estimates of drawdown outside the mine. GMA's prior hydrogeologic evaluation predicted that approximately 20 feet of drawdown would occur within 1,000 feet of the mine. GMA recently completed groundwater modeling of dewatering at Segment 6 (GMA, 2019). The modeling results indicated that drawdown within 1000 feet of the mine would actually be less than 20 feet.

Item 1 of the baseline evaluation has been partially completed though prior and recent interpretations of LIDAR data. Figure 4 includes an updated karst feature interpretation on a LIDAR map for the area covering all of Segment 6 and the adjacent property within 1000 feet of the proposed mine face for Segment 6.

Item 2 (reconnaissance) was mostly completed on October 26, 2017. Since the reconnaissance investigation, GMA has identified 3 areas adjacent to Segment 6 where potential karst features may exist (Figure 6), but these features were not visited on October 26th. Prior to initiating mining in Segment 6, additional reconnaissance and documentation will be performed of the 3 areas identified on Figure 6.

For completing baseline **item 3**, an aerial drone survey will be performed over Segment 6 and the 1,000 feet area surrounding Segment 6. The aerial survey will include a gridded flyover and video documentation as well as local targeted aerial inspection of specific potential karst features identified.

Item 4 - LIDAR topographic data and field reconnaissance will be matched with the aerial imagery to develop a correlation between the three data sets. Ground-truthing will be conducted to test the validity of the correlations between the data sets. All of the located suspected karst features will be visited to verify if features are karst in nature. If verified as karst features, coordinates will be established, sites will be photographed, and dimensions will be measured and recorded. The baseline survey shall be submitted to DHEC prior to the start of dewatering activities.

3.2 Establish Monitoring Stations

Representative monitoring stations shall be established where physical monitoring of potential karst features will be performed on a regular schedule (see Fig. 7). These stations will be readily accessible to mine personnel to visually inspect, monitor, and measure on a periodic basis (per Fig. 7).

GMA has selected two existing representative sinkhole ponds (Labeled Sinkhole Pond 1 and Sinkhole Pond 5) that will be regularly monitored during the mining of Segment 6. Each of the sinkhole ponds will be equipped with a staff gauge for visual observation of pond water levels. In addition, each of the ponds will be surveyed by a registered land surveyor to establish the length, width, and depth of the ponds. Permanent reference survey stakes or pins will be established marking the edges of the ponds

and establishing the elevation (relative to mean sea level) of the survey stakes. These reference stakes will be tied to the pond level staff gauges so that the water elevations can be monitored over time. The stations will be resurveyed on a periodic basis (per Fig. 7) to evaluate changes in the sizes of the ponds and to determine if land subsidence occurs after mining commences.

GMA has proposed two sinkhole pond monitoring stations based upon available information. Three other features of interest have been identified that need to be further evaluated. Other stations could be added in the future, if warranted by field observations surrounding the mine.

3.3 Monitoring Tasks and Proposed Schedule

Regular monitoring of site conditions will be conducted per Fig. 7 to provide a mechanism for evaluating the potential for sinkhole development in response to mine dewatering. The monitoring program entails four elements of evaluations. Each of these elements is described in the following sections.

3.3.1 Groundwater Level Monitoring

Nine perimeter compliance wells have been selected around the perimeter of the RDA site, and these are designated as Perimeter Monitoring Well Stations (PMW well series). Figure 5 illustrates the locations of these Perimeter compliance wells. These stations are PMW-1, PMW-2, PMW-3, PMW-4, PMW-5, PMW-6, PMW-7, PMW-8, and PMW-9. These well locations are also shown on the RDA Mine Map. The Perimeter compliance wells will be constructed prior to mining, and the wells will be screened within the limestone ore. Each compliance well casing will be surveyed for elevation relative to mean sea level. This will allow for water-level measurements at the wells to be converted to groundwater elevation. A baseline equipotential map will be made for the limestone aquifer using pre-mining groundwater elevations collected from the compliance wells.

Most of the perimeter compliance wells are quite distant from the initial block to be mined at Segment 6. A minimum of three, possibly four, additional Sinkhole Monitoring Well Stations (SMWS well series) will be constructed less than 1000 feet from the mine area at Segment 6 (see Figure 5). These stations are SMWS-100, SMWS-101, SMWS-102 & SMWS-103 and are located on the RDA Mine Map. Each Sinkhole Monitoring Well Station will include one well screened in the limestone and a second well screened in the overburden layer. The casing elevations of these additional monitoring wells will also be surveyed so that water-level data collected from the wells can be incorporated into equipotential maps.

3.3.2 Pond Water Level Monitoring

Water-level monitoring will also be conducted at Sinkhole Ponds 1 and 5 using the surveyed staff gauges. Periodic water-level measurements will be made by RDA staff by simply taking a visual reading of the staff gauge per Fig. 7. An alternate means of water-level recording could be implemented via use of a pressure transducer/data logger.

3.3.3 Reconnaissance of Key Areas of Interest

Areas of interest identified during GMA's site reconnaissance on October 26, 2017 will be periodically revisited after mining commences per Fig. 7. A physical walkover and photographic inspection will be conducted to look for evidence of water-level changes and land surface subsidence. Figure 6 identifies the planned periodic reconnaissance area to be observed. Additional reconnaissance of the area between 1000 feet and 2000 feet from the mine face may be performed if aerial evaluation indicates changes that warrant closer inspection.

3.3.4 Aerial Evaluation

Periodic aerial drone survey investigation of the area within 1,000 feet of Segment 6 (Figure 6) will be conducted per Fig. 7. The aerial drone survey will include a repeat survey of the baseline aerial survey. The aerial survey approach should be adjusted, as necessary, to provide more intensive video surveillance of site features that appear to differ significantly from the baseline aerial investigation. Ground-truthing will occur of areas within the survey where significant differences are observed as compared to the baseline evaluation.

3.3.5 Monitoring Schedule

The planned monitoring schedule (Fig. 7) includes more frequent monitoring of features that will be less labor intensive. Monitoring tasks will include monthly, quarterly, and annual events. Figure 7 provides the planned monitoring schedule for evaluation of the Segment 6 mining over the proposed ~7.5 years of mining. The monitoring schedule may be adjusted, as appropriate, based upon observations in the first couple of years of mine operation. Results of monitoring tasks will be reported to SCDHEC.

4.0 Contingency Plan

If mine dewatering for Segment 6 results in development of new sinkholes or growth of existing sinkhole features, RDA will need to have an appropriate plan in place to respond to the occurrences. Potential sinkholes that could occur can be categorized as one of three scenarios: 1) Sinkholes within the active Segment 6 mine area, 2) Sinkholes outside Segment 6 but on the permitted property, and 3) Sinkholes outside of the permitted area. Each of these scenarios may warrant a different response depending on the nature of the sinkholes that may develop.

4.1 Sinkholes within the Active Segment 6 Mine Area

When overburden is stripped within an active limestone mine area, it is common for small local sinkholes to be encountered. Most of these features are not an obstacle to mine progression, and they do not require any response. If larger sinkhole features are encountered within the Segment 6 active mine block, the mine Superintendent will determine the significance of the features and devise appropriate response plans to maintain a safe working environment in the mine while continuing to mine through the sinkhole area. If significant cavities (>10 feet diameter or >5 feet vertical thickness) are encountered in the opening of the Segment 6 mine pit, these features will be measured and documented to gain additional understanding of the nature of cavernous voids that may occur at the site. The vertical and horizontal dimensions should be measured, and the features will be photographed. In addition, the location (latitude and longitude) of each significant feature will be documented using a GPS. The mine Superintendent will develop a cataloguing system to record the location and attributes of each significant void so that future statistical analyses can be made on the prevalence of cavernous voids that occur in the limestone. These records shall be made available to DHEC upon request.

4.2 Sinkholes Outside Segment 6 but Within the Permit Boundary

If sinkholes develop, or grow, in areas outside Segment 6 but on the permitted property, the mine Superintendent will catalogue the location and size of the sinkholes and determine if the existence or growth of the feature(s) poses an imminent risk to mining roads and other on-site infrastructure. This catalogue shall be made available to DHEC upon request. If mine infrastructure is at risk, then steps will need to be taken to either relocate the road or equipment or to attempt to stabilize the sinkhole. If the formation or reactivation of sinkholes is observed within the 50 foot undisturbed perimeter buffer of the mine permit area, the operator shall report the sinkhole to DHEC within 24 hours, noting the size, depth and location. The operator shall submit a written report to DHEC within 5 business days, recommending actions to prevent any potential off-site impacts. DHEC may require additional measures to prevent any potential off-site impacts, if needed. Evidence for reactivation of a sinkhole depression would include: 1) Any obvious change in the depression where there is an increase in area covered by the depression, 2) an increase in depth or the appearance of a scarp on the edge of a depression, and 3) If the depression was originally water filled, any significant lowering of water level greater than seasonal fluctuation in groundwater levels. Seasonal groundwater level fluctuations will be determined from observations of the perimeter monitoring well network.

Based upon the nature and occurrence of any new or growing sinkholes outside Segment 6, but on permitted property, modified mining methods may be undertaken to reduce the development or growth of sinkholes on the property. The modified mining methods would be undertaken if it is determined by the operator or DHEC that there is a risk of sinkholes occurring outside the permit boundary. Modified mining methods could include, but are not limited to: 1) reduced dewatering accompanied by more frequent water-level monitoring responses outside Segment 6, and/or 2) construction of re-infiltration trenches outside the active mine block to rehydrate the limestone and

minimize drawdown effects outside the active mine. A reduction in dewatering will require partial wet-mining techniques to be implemented.

The SMWS wells will provide important water-level data in areas on the RDA property where sinkhole potential is considered higher, and these data will be used to gauge the groundwater responses to reduced dewatering and re-infiltration. The water-level observations will be used, along with aerial reconnaissance and LIDAR data, to evaluate the relationship between dewatering levels in the active mine pit and the potential effects on sinkhole developments. If a clear relationship can be developed, then this relationship will guide future mining scenarios, including establishing a threshold pumping water level in the active mine.

4.3 Sinkholes on Land Outside the Permit Boundary

In the unlikely event that sinkholes develop, or sinkhole development becomes likely, on property outside the permit boundary, it will be vital to ensure that public safety is protected. The operator shall report a sinkhole occurrence on property outside the permit boundary to DHEC within 24 hours and file a written report to DHEC within 5 business days. If the sinkhole is located on land adjacent to the permitted land, the operator shall immediately implement the contingency plan below. If the sinkhole is located beyond adjacent parcels, DHEC shall make a determination if modifications to the mining methods are required. Rapid modifications to mining methods will be needed to mitigate the occurrence, or threat of occurrence, of sinkholes outside the mine permit area. The requirement to modify mining methods will not apply to lands outside the permit boundary where land owner(s) have granted the mine operator a waiver to damages, approved by DHEC, for the occurrence or threatened occurrence of sinkholes on their property. Contingencies for operational modifications will progressively include the following, as needed:

1) Reduction by 25% in the amount of dewatering used for mining,
2) Construction of re-infiltration trenches to minimize drawdown outside the mine, and
3) Converting to wet-mining.

DHEC may require additional measures to prevent any potential off-site impacts, if needed.

The first modification to mine operations in response to off-site sinkhole threat will entail an immediate 25% reduction in mine withdrawal volumes. This reduction in pumping is expected to result in a 25% rebound of water level in the active mine pit. A rebound in water level will require partial wet-mining methods to allow continued extraction of the ore to the desired mine depth. The reduction in groundwater withdrawals will also trigger an increased frequency of water-level monitoring (weekly) in the SMWS and PMW wells to determine the water-level recovery that results from the reduced mine withdrawal. Water-level monitoring frequency may be reduced over time at DHEC's discretion as water-levels re-equilibrate with the reduced withdrawal rate.

If the 25% reduction in withdrawal does not mitigate sinkhole threat or growth on properties outside the permit boundary, then construction of a re-infiltration trench may be implemented between the active mine area and the direction of off-site sinkhole threat. The re-infiltration trench will be excavated

to the top of the limestone ore, and water withdrawn from the mine will be directed into the trench to provide a local groundwater mound between the active mine and the area of off-site sinkhole threat. The re-infiltration trench water level should initially be kept a minimum of 10 feet above the limestone. The re-infiltration trench water level may be increased, as needed, to a maximum level of 5 feet below original land surface. Diligent (weekly) water-level monitoring in the trench and in SMWS and PMW wells will continue as water-levels in the trench are raised, until DHEC approves a reduction in monitoring.

If re-infiltration does not provide the desired reduction in sinkhole threat, then the mine will switch to a complete wet-mining operation that does not require continuous groundwater withdrawals. Wet mining involves extracting ore without the need for pit dewatering.

The mine Superintendent will maintain detailed records of new occurrences, or threats, of sinkhole development on properties outside the permitted area, and on the results of modified mining methods. These records shall be made available to DHEC upon request. The records of mine modifications implemented for Segment 6 will guide future mining strategies for expanded mining into other segments of the site.

5.0 Conclusions

The RDA facility will involve mining of limestone for aggregate production. The most efficient means of mining is to dry mine using dewatering of the active pit. In dry mining, the water level in the pit is lowered close to the bottom of the ore being extracted. Tertiary Period limestones in South Carolina tend to have high secondary porosity due to partial dissolution of minerals in the rock. Local chemical weathering may result in naturally occurring open voids or cavities in the rock. When these open voids are filled with groundwater, the water helps to support the cavity and make it less prone to collapse and sinkhole development. When dewatering of the limestone is necessary to support dry mining, the area surrounding the open pit will be depressurized. If existing voids in the rock become unstable due to depressurization, the roof of the void may collapse, allowing the overlying unconsolidated sediments to collapse into the void, thereby forming a sinkhole. This is a common attribute of limestone aggregate mines in the Atlantic Coastal Plain of North America.

The Sinkhole Monitoring and Contingency Plan presented herein is based upon extensive experience with numerous similar facilities in the region. The monitoring plan focuses on diligent baseline evaluations followed by regular follow-up monitoring to detect changes that may occur in proximity to the active mine. The RDA mine plan will focus initial mining on an interior segment of the property that is more than 1000 feet away from any occupied structures. Diligent regular monitoring of groundwater levels will be made to ascertain if the groundwater system surrounding the initial mine pit responds in a manner that is consistent with predictive calculations developed in the Hydrogeologic Evaluation of the site. Existing sinkhole features will be carefully measured and regularly monitored to determine if and how these features respond to mine groundwater withdrawals. The monitoring plan also includes

broader investigative methods, include periodic reconnaissance as well as aerial surveillance and ground truthing, to investigate potential sinkhole development in areas surrounding the mine pit that do not already exhibit characteristic karst topography. Observations from the initial ~7.5 years of mining at Segment 6 will lead to a better understanding of the tendency, or lack thereof, for sinkholes to develop in response to mining at the site. The experience gained from mining at Segment 6 will be used to develop refined monitoring plans for expansion of mining into other segments of the site. The monitoring plan will be updated, as needed, based upon site observations and approval from DHEC.

A response plan has also been developed that presents appropriate steps to be taken for three scenarios of potential sinkhole formation. The most important part of the response plan is to act immediately to protect public safety and private property outside the mine. The response plan elements presented herein have been used successfully by other mining entities in the region to address issues with off-site sinkhole threats. The primary goal of the monitoring plan for the RDA site is to understand how and if sinkholes will develop in response to mining at the site. Equipped with this understanding, RDA can implement mining methods and establish optimum buffers to prevent off-site sinkhole development.

6.0 Report Certification

This Revised Sinkhole Monitoring and Contingency Plan was prepared by Groundwater Management Associates, Inc., a professional consulting company that employs geologists and engineers that are licensed in South Carolina. The document is a revision to the May 16, 2018 SMCP, and the text incorporates responses to comments from SCDHEC on the May 16, 2018 SHCP. This report was prepared by James K. Holley and William L. Lyke.

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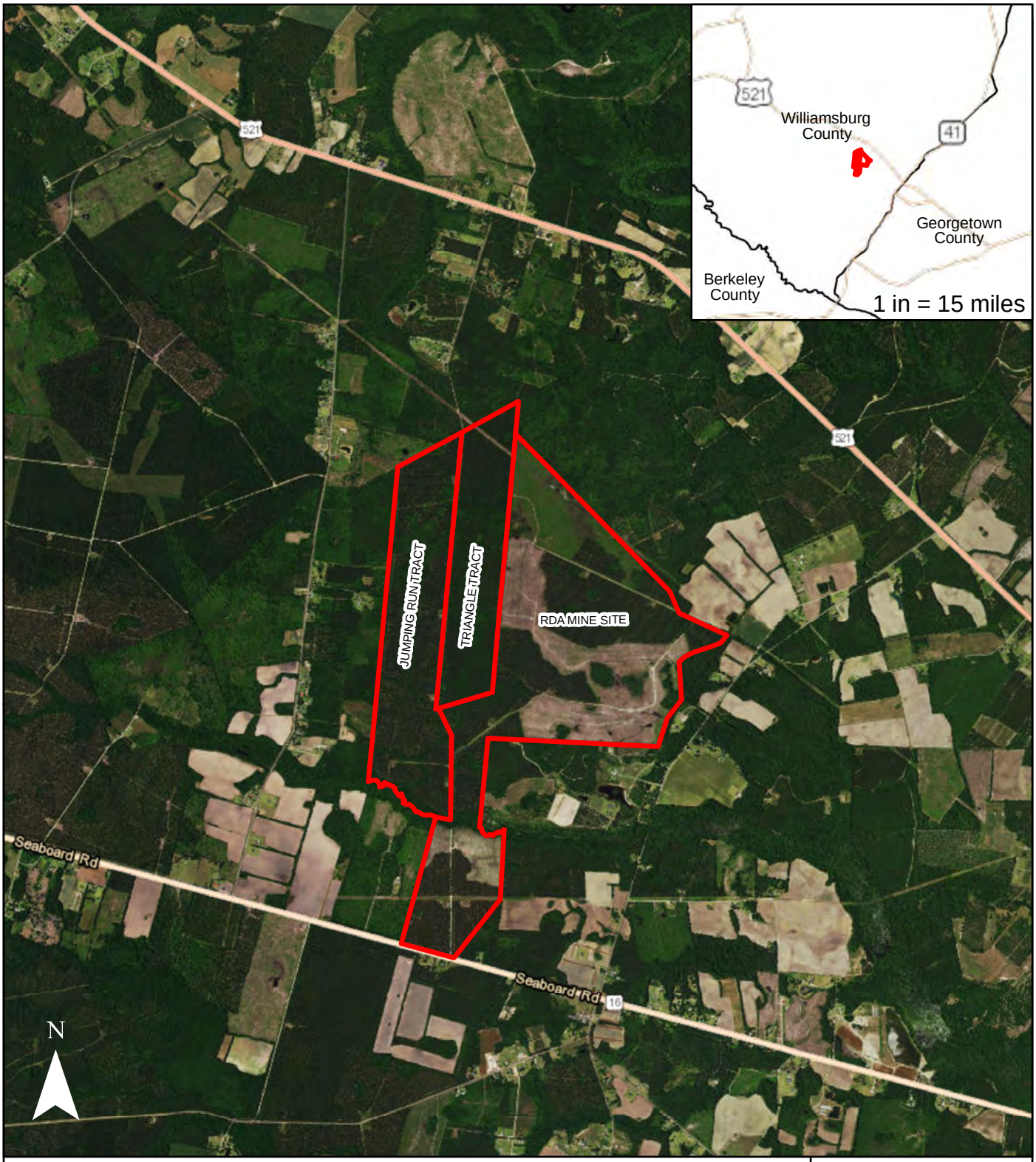


LEGEND

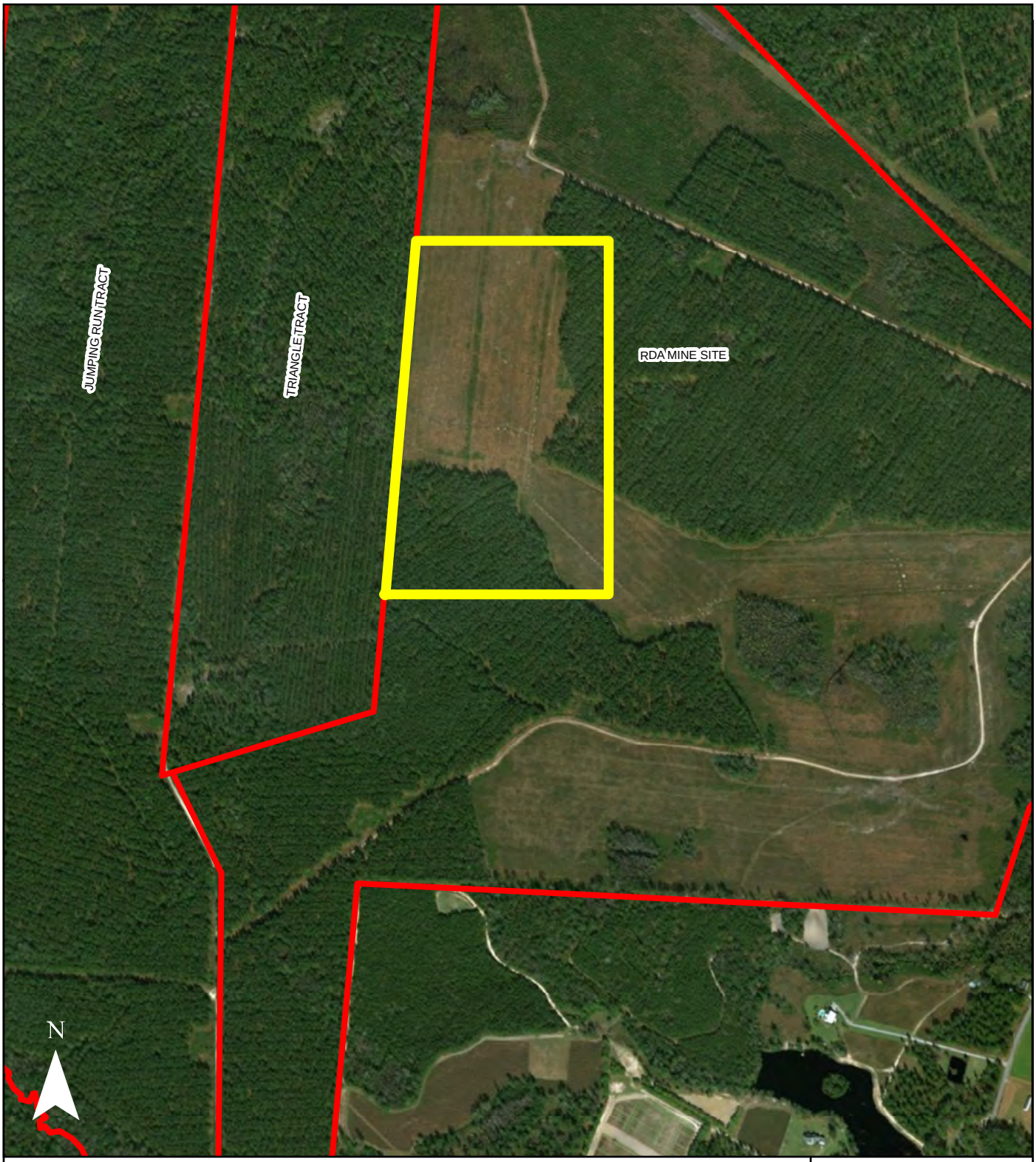
RDA PROPERTY BOUNDARY

0 3000'

SCALE IN FEET

GMA

DRAWINGS/158007/ FIG1_KAS_Site_Location_20171108.mxd	SITE LOCATION MAP	DATE: 11/15/2017
PROJECT NO.: 158007	RDA, LLC - ANDREWS, WILLIAMSBURG CO., SC	FIGURE 1



LEGEND

SEGMENT 6

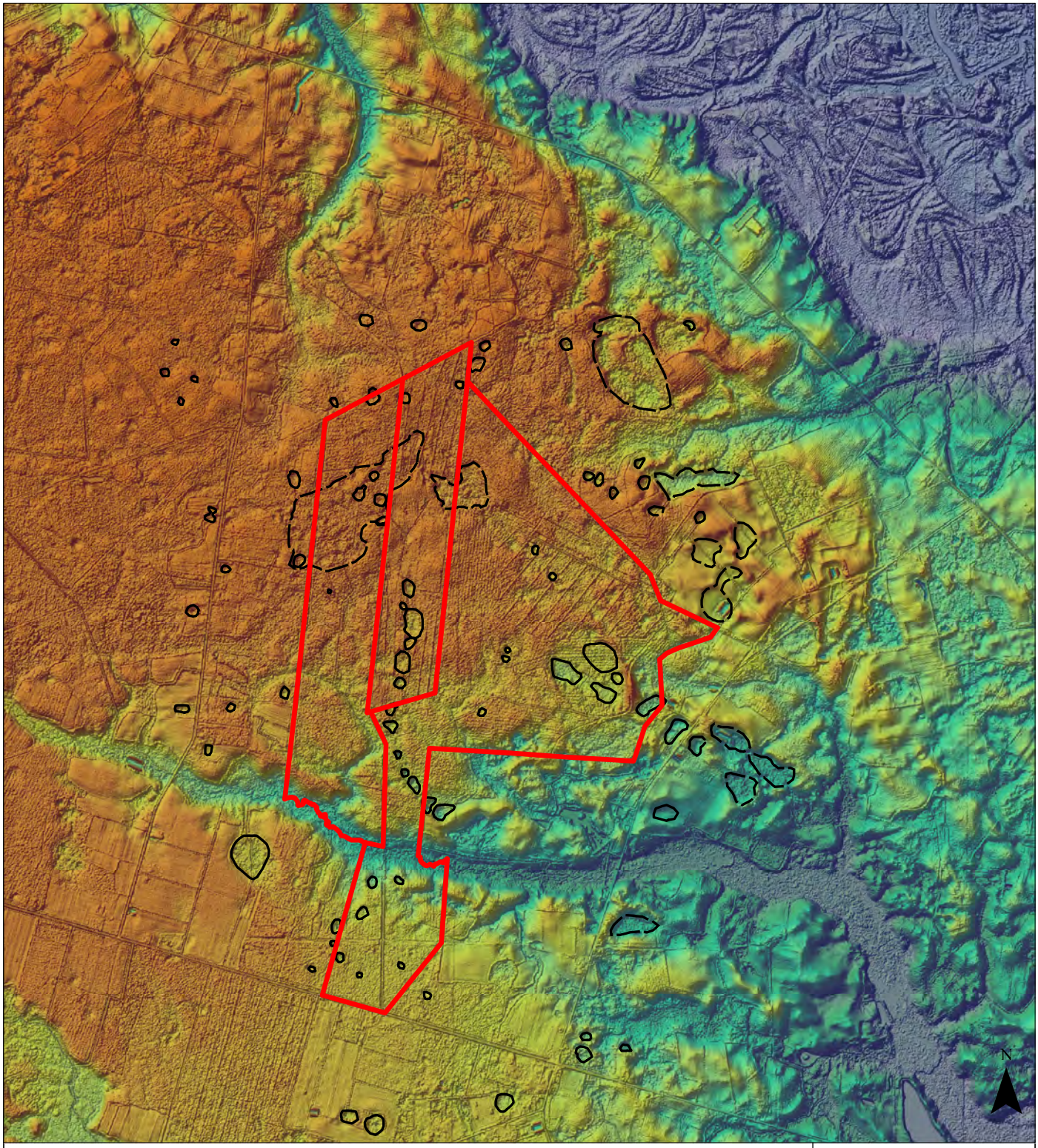
RDA PROPERTY BOUNDARY

0 800'

SCALE IN FEET

GMA

DRAWINGS/158007/ FIG2REV_KAS_Aerial_Segment_6_20180515.mxd	AERIAL PHOTOGRAPHY OF THE RDA PROPERTY AND PROPOSED SEGMENT 6 INITIAL MINE SITE	DATE: 05/15/2018
PROJECT NO.: 158007	RDA, LLC - ANDREWS, WILLIAMSBURG CO., SC	FIGURE 2



LEGEND

High : 50 FT ABS

Low : 10 FT ABS

INTERPRETED KARST FEATURE

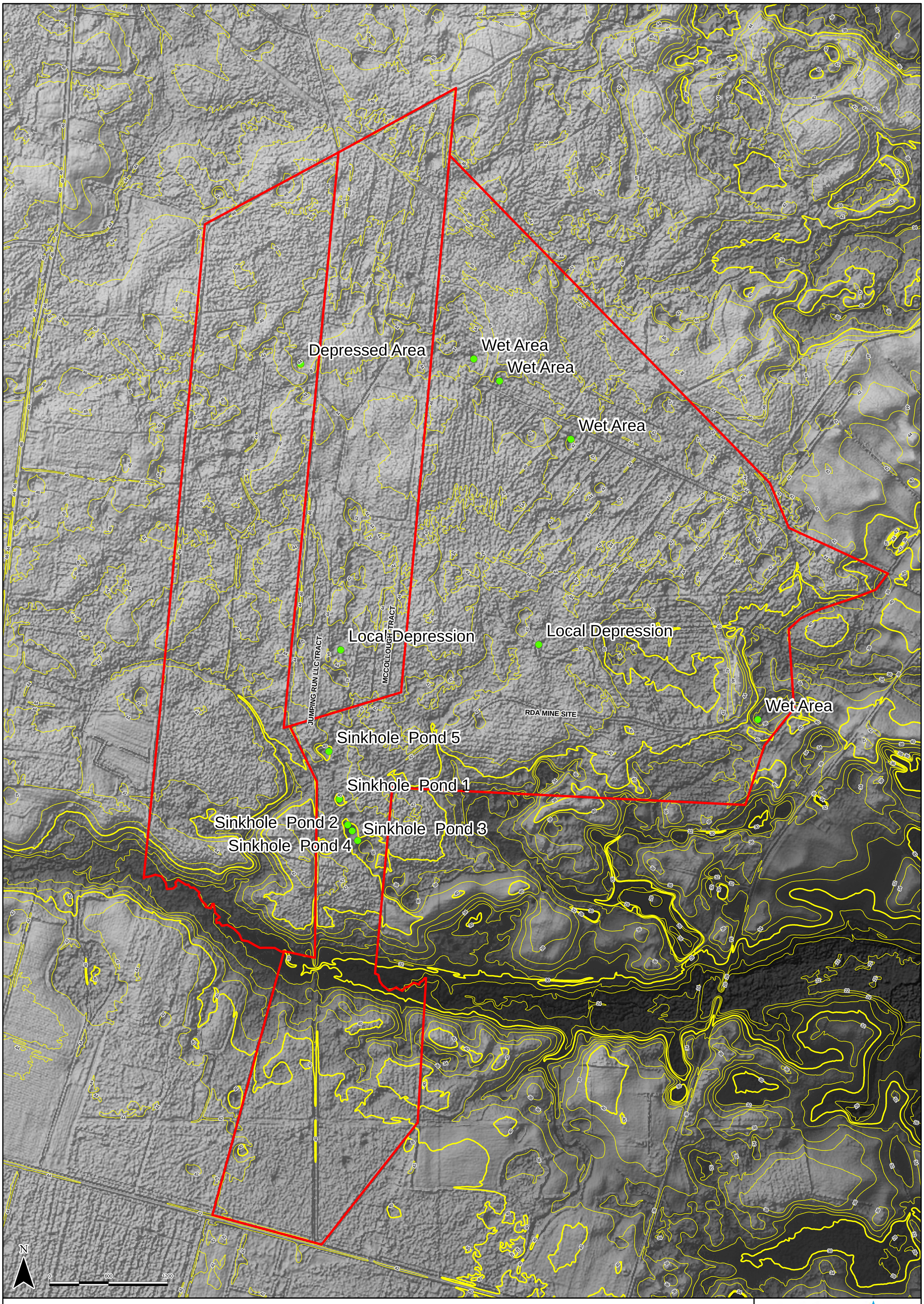
LOW AREA (PALEO KARST?)

MINE PROPERTY BOUNDARY

0 1,500 3,000 Feet

GMA

DRAWINGS/158007/ FIG3_KAS_Karst_Features_20171108.mxd	POTENTIAL KARST FEATURES IDENTIFIED FROM LiDAR DATA	DATE: 11/8/2017
PROJECT NO. 158007	RED MOUNTAIN TIMBER TRACT, WILLIAMSBURG CO., SC	FIGURE 3



LEGEND

MINE PROPERTY BOUNDARY

TOPOGRAPHIC CONTOUR

ELEVATION (FT)

HIGH : 67 FT ABS

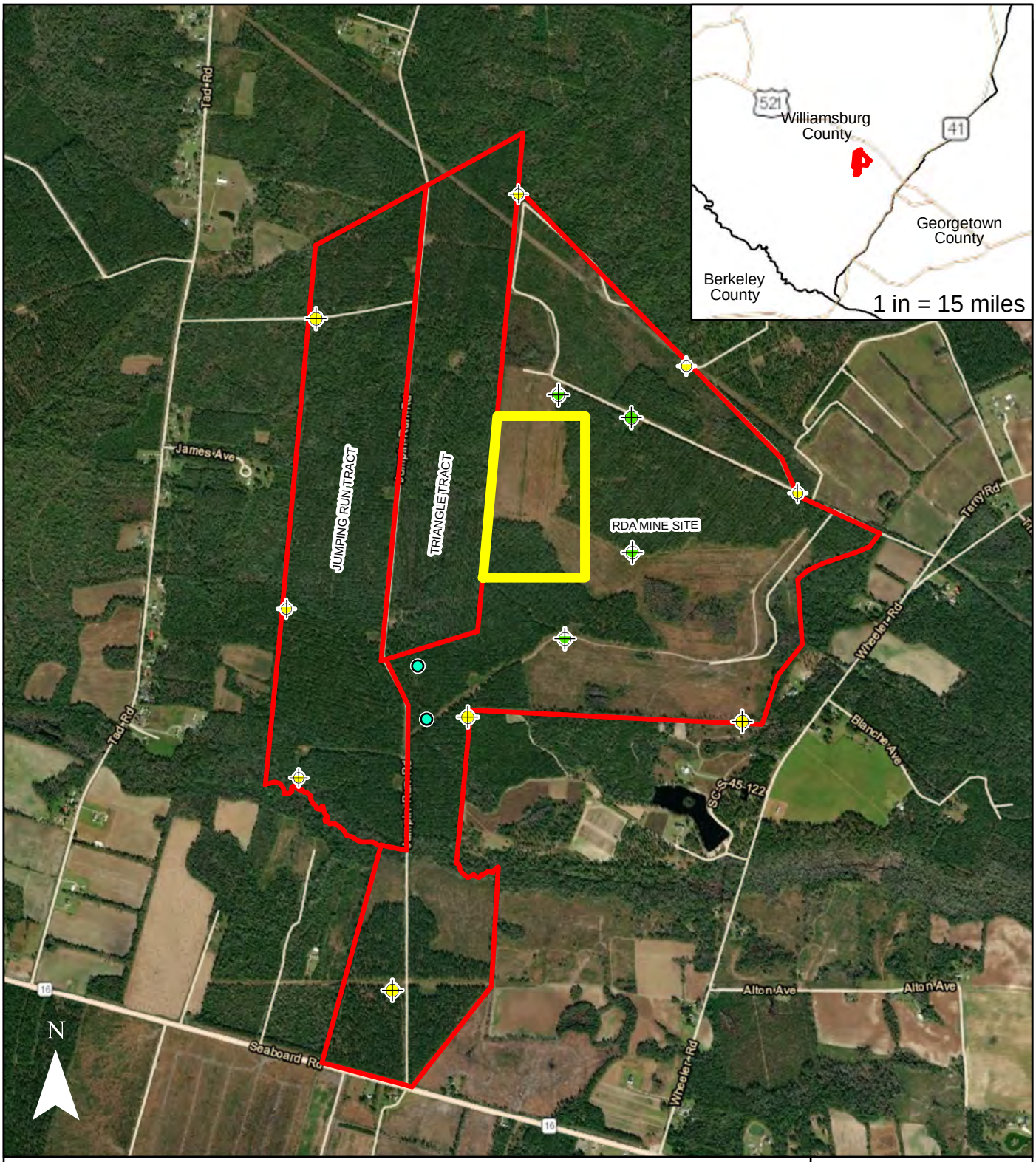
LOW : 6 FT ABS

RECONNAISSANCE LOCATION

GMA

GROUNDWATER MANAGEMENT ASSOCIATES, INC.

FILE: DRAWINGS/158007/ KAS_Recon_Location_map_20171109.mxd	LiDAR MAP OF AREA NEAR SEGMENT 5 WITH LOCAL KARST FEATURES VISITED ON 10/26/2017	DATE: 11/15/2017
PROJECT NO. 158007	RDA, LLC - ANDREWS, WILLIAMSBURG CO., SC	FIGURE 4



LEGEND

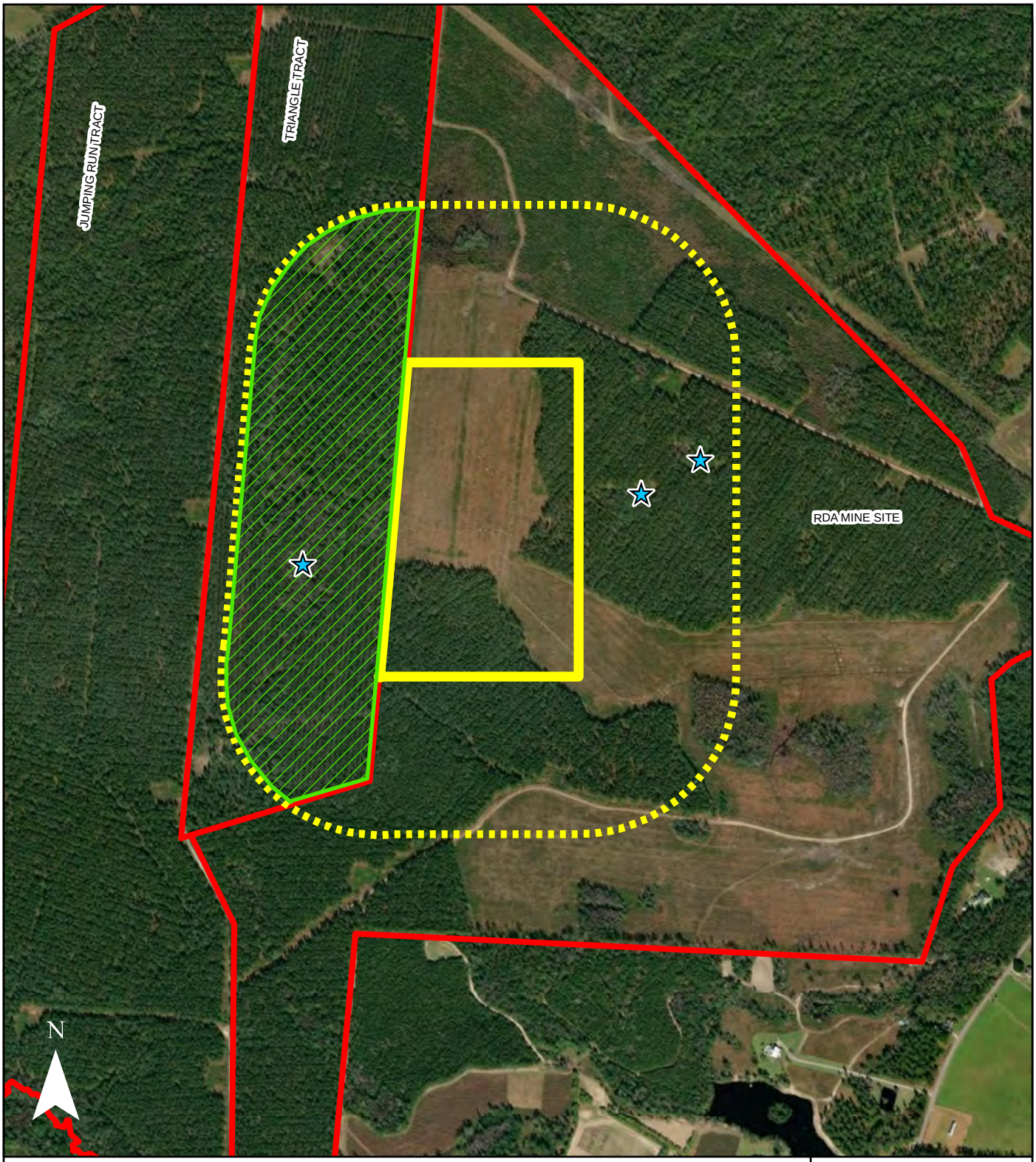
- SINKHOLE MW STATIONS FOR SINKHOLE EVALUATION
- STAFF GAUGE AT SINKHOLE PONDS 1 & 5
- PERIMETER MW STATIONS
- SEGMENT 6
- RDA PROPERTY BOUNDARY

0 1750'

SCALE IN FEET

GMA

DRAWINGS/158007/ FIG5REV2_KAS_MWs_Guage_20190318.mxd	MAP SHOWING PROPOSED MONITORING WELLS AND SINKHOLE POND MONITORING STATIONS	DATE: 03/18/2019
PROJECT NO.: 158007	RDA, LLC - ANDREWS, WILLIAMSBURG CO., SC	FIGURE 5



LEGEND

- SUPPLEMENTAL BASELINE RECONNAISSANCE FEATURES
- SEGMENT 6
- RDA PROPERTY BOUNDARY
- SEGMENT 6 1000 ft BUFFER & BASELINE EVALUATION AREA
- PROPOSED QUARTERLY RECONNAISSANCE AREA

0 900'

SCALE IN FEET

GMA

DRAWINGS/158007/ FIG2REV3_KAS_Prop_Recon_20190318.mxd	PROPOSED AREAS FOR RECONNAISSANCE AND AERIAL EVALUATIONS NEAR SEGMENT 6	DATE: 03/18/2019
PROJECT NO.: 158007	RDA, LLC - ANDREWS, WILLIAMSBURG CO., SC	FIGURE 6

Figure 7. Schedule for Monitoring

Monitoring Task	Prior to Mining	Continuous	Monthly	Quarterly	Annually	Comments
Reconnaissance and Baseline Evaluation	■					Locate & characterize karst features in baseline evaluation area. Submit to DHEC prior to start of mining.
Groundwater Level Monitoring		■				Monitor continuously. Summarize & submit data quarterly to DHEC.
Pond Level Monitoring			■			Monitor monthly and report quarterly during active mining of Segment 6.
Reconnaissance of Key Areas				■		Monitor quarterly for the duration of active mining in Segment 6 and report annually.
Aerial Evaluation					■	Perform drone flyover on an annual basis. Submit analysis to DHEC in annual report. Initial survey results submitted to DHEC prior to dewatering.
Survey Selected Features						Select representative existing features (ponds). Survey baseline dimensions (length, width, & elevation) using permanent markers and report in annual report.
Segment 6 Sinkhole and Void Space Inventory		■				After overburden is removed and limestone exposed on each cut, but prior to drilling & blasting. Summarize data in annual report.

Continuous water level monitoring will employ automatic data recorders.

Appendix I

RDA Mine Map Prepared by Kennedy Consulting Services, LLC

NORTH

TO THE INTERSECTION OF SEABOARD ROAD AND ±3713' TO THE TOWN OF ANDREWS

SEABOARD ROAD 66' R/W

JUMPIN RUN ROAD (DIRT RD.)

JUMPIN RUN ROAD

WHEELER RD. 66' R/W

TERRY ROAD (DIRT ROAD)

MURRAY UPSTREAM GUAGE

MURRAY DOWNSTREAM GUAGE

PMW-1

PMW-2

PMW-3

PMW-4

PMW-5

PMW-6

PMW-7

PMW-8

PMW-9

SMWS-100

SMWS-101

SMWS-102

SMWS-103

POND GUAGE

GATE GUAGE

BUFFER ALONG MURRAY SWAMP EXTENDS TO EITHER THE +35' MSL CONTOUR OR 75' WIDE, WHICHEVER IS GREATER

MURRAY SWAMP WETLAND BUFFER IS 75'

BUFFER

SEDIMENT RETENTION & WATER STORAGE

PRIMARY CRUSHER

SHOP AND EQUIPMENT STORAGE

APPROXIMATE LOCATION OF CONVEYOR

PROCESS PLANT WETLANDS BUFFER

OFFICE AND SCALES

ENTRANCE LOCATION

ACCESS ROAD

BUFFER

SANTEE COOPER TRANSMISSION LINE 100' RIGHT OF WAY

BUFFER ALONG MURRAY SWAMP EXTENDS TO EITHER THE +35' MSL CONTOUR OR 75' WIDE, WHICHEVER IS GREATER

APPROXIMATE LOCATION OF PIPE CARRYING GROUND WATER FROM PUMP STATION TO SEDIMENT RETENTION & WATER STORAGE

EXISTING ROAD

JR VEGETATIVE FILTER

50' WETLANDS BUFFER (TYPICAL)

HAUL ROUTE

50' JR PROPERTY LINE BUFFER

MINE PERMIT BOUNDARY

50' WETLANDS BUFFER (TYPICAL)

JR BERM 7

JR BERM 6

JR BERM 5

JR BERM 8

BERM 9

BERM 3

BERM 1

BERM 4

BERM 2

TOP OF CUT

TOP OF ROCK (LIMIT OF BLASTING)

SEG 8 45.5 AC.

SEG 9 38.5 AC.

SEG 10 31.4 AC.

SEG 5 45.0 AC.

SEG 6 53.2 AC.

SEG 7 57.0 AC.

SEG 3 37.9 AC.

SEG 4 45.2 AC.

SEG 2 45.2 AC.

SEG 1 19.9 AC.

SINKHOLE POND 1 MONOTORING

SINKHOLE POND 5 MONOTORING

FUTURE MINE DISTURBANCE AREA

WMW 200 N=606627.7070 E=2409478.3209

WMW 201 N=606679.5734 E=2409131.8437

WMW 202 N=607045.4727 E=2409264.1728

WMW 203 N=603884.6371 E=2410818.1245

WMW 204 N=603527.8335 E=2411071.7702

WMW 205 N=603807.0344 E=2411148.1503

WMW 206 N=603571.3826 E=2411442.0063

WMW 207 N=603330.3802 (E=2411801.0437

WMW 208 N=603660.4287 E=2411798.0328

50' PROPERTY LINE BUFFER

50' WETLANDS (TYPICAL)

VEGETATIVE FILTER (TYPICAL)

50' WETLANDS BUFFER (TYPICAL

50' PROPERTY LINE BUFFER

50' EASEMENT

50' POWER LINE BUFFER

30' ACCESS EASEMENT

OVERBURDEN (TYPICAL)

SANTEE COOPER TRANSMISSION LINE 100' RIGHT OF WAY

ARCHAEOLOGICAL SITE 38WG185

MINIMUM 50' BUFFER FOR ARCHAEOLOGICAL SITE

LEGEND

AFFECTED AREAS (LAND DISTURBED BY MINE ACTIVITY)

- PIT, PROCESS PLANT, HAUL ROADS & SHOP
- BERMS
- VEGETATIVE FILTERS
- WETLANDS TO BE MINED
- WETLAND ID NUMBER 2

BUFFERS (PROTECTED LAND)

- PROPERTY BUFFERS
- ARCHAEOLOGICAL SITE
- PROTECTED WETLAND BUFFERS
- PROTECTED WETLANDS 6
- SEDIMENT RETENTION & WATER STORAGE
- PLANNED PERIMETER MONITORING WELL STATION PMW
- EXISTING PERIMETER MONITORING WELL STATION SMWS
- PLANNED SINKHOLE MONITORING WELL STATION PMW
- EXISTING SINKHOLE MONITORING WELL STATION SMWS
- EXISTING STAFF GUAGE GATE GUAGE
- PLANNED WETLAND MONITORING WELL STATION WMW

GRAPHIC SCALE

400 0 200 400 800 1600

(IN FEET)
1 inch = 400 ft.

REVISIONS

	Description	Date	By
1	ADD BUFFER TO WETLAND 28; MINING WILL AVOID	7/30/17	BC
2	LOCATE, AVOID AND BUFFER JUMPIN RUN ROAD	9/08/17	BC
3	ADD PRIMARY CRUSHER AND CONVEYOR ACROSS MURRAY SWAMP	9/08/17	BC
4	INCREASE BUFFER ALONG MURRAY SWAMP; ADD MONITORING WELLS	12/05/17	BC
5	RELOCATE SMWS FOR SEGMENT 6 START UP	5/25/18	BC
6	ADD MONITORING WELLS DRILLED OCTOBER 2018	11/16/18	BC

Kennedy Consulting Services, LLC
Craig Kennedy, P.G.
KCS
Office: 403 Seaside court Lexington, SC 29072 Tel. 803.399.1133 • Cell 803.960.2562
Mail: P.O. Box 364 Irmo, SC 29063 craigkennedy.KCS@gmail.com

RDA, LLC
RDA Mine
Prepared for
RDA, LLC
Anderson Township, Williasburg County , South Carolina

Project No.: KCS 16-88
Date: 01-24-17
Approved by: RCK
Drawn by: B.C.
Scale: 1"=400'

Sheet No. 1 of 2

Appendix II

Site Photographs from GMA Site Visit Dated 10/26/17

Sinkhole Pond 1 located in a drainage system southwest of the initial quarry pit area. The pond is located immediately north of the access road.

Sinkhole Pond 1 located in a drainage system southwest of the initial quarry pit area. The pond is located immediately north of the access road.

Sinkhole Pond 2 located in a drainage system southwest of the initial quarry pit area. The pond is located immediately south of the access road.

Sinkhole Pond 2 located in a drainage system southwest of the initial quarry pit area. The pond is located immediately south of the access road.

Sinkhole Pond 3 located in a drainage system southwest of the initial quarry pit area. The pond is located southwest of Sinkhole Pond 2.

Sinkhole Pond 3 located in a drainage system southwest of the initial quarry pit area. The pond in located southwest of Sinkhole Pond 2.

Sinkhole Pond 3 located in a drainage system southwest of the initial quarry pit area. The pond is located southwest of Sinkhole Pond 2.

Sinkhole Pond 4 located in a drainage system southwest of the initial quarry pit area. The pond is located southwest of Sinkhole Pond 3.

Sinkhole Pond 5 located in a drainage system southwest of the initial quarry pit area. The pond in located northwest of Sinkhole Pond 1.

Local depression located west of the initial quarry pit area.

Wet area east of the initial quarry pit area.

Wet area north of the initial quarry pit area.

Appendix III

SCDNR Letter Dated 10/20/17

South Carolina Department of
Natural Resources

1000 Assembly Street Suite 336
PO Box 167
Columbia, SC 29202

Alvin A. Taylor
Director
Lorianne Riggin
Director, Office of
Environmental Programs

October 20, 2017

Mr. Joe Koon
SCDHEC
BLWM/DMSWM
2600 Bull Street
Columbia, SC 29201-1708

REFERENCE: Mining Application # I-002171, RDA LLC
RDA Mine, Williamsburg County

Dear Mr. Koon:

Personnel with the South Carolina Department of Natural Resources (SCDNR) have reviewed the proposed project, including a site visit with the applicant's agents on October 9, 2017, and evaluated its impact on natural resources. As such, SCDNR offers the following preliminary items of concern.

Project Description
The proposed mine is located approximately 5 miles northwest of Andrews near the intersection of US 521 and Jumping Run Road in Williamsburg County. The applicant proposes to mine limestone from a 622.7 acre affected area. The proposed site also includes 158.1 acres of future impacts/reserves and 187.6 acres of undisturbed buffers for a total permitted area of 968.4 acres. The average depth of mining will be approximately 55 feet from the ground surface with a maximum depth of 65 feet and a maximum pit floor elevation of 21 feet below mean sea level. The proposed mine will involve the pumping of groundwater and require a NPDES permit for point source discharge. The application states that jurisdictional wetlands will be affected, but mine plans are to first avoid wetlands. The information provided indicates that there are 92.8 acres of jurisdictional wetlands and 25.47 acres of isolated wetlands on the tract. The applicant has submitted a request for a jurisdictional determination to the U.S. Army Corps of Engineers. The wetlands outside the proposed disturbance areas are planned for protection with a 50-foot (typical) upland buffer. A proposed reclamation plan has been submitted, indicating the site will be restored to lakes and grasslands after mining.

Agency Concerns
Isolated wetlands, as those found on the site, provide important habitat for herpetofauna for breeding and foraging, as well as provide source water for other wildlife. Wetlands function to provide nutrient cycling, filtering water and improving its quality, as well as serves a sink to promote groundwater recharge. Excavating around the wetland areas on the mining site will likely lead to degradation of these important functions as a result of the lowering of groundwater elevations.

Due to the nature of limestone interacting with groundwater, SCDNR has concerns regarding the projected groundwater withdrawals, inducing sinkholes. If a sinkhole should open, it could harm the wetland avoidance and buffer areas, as well as surrounding properties. Our review of the Hydrogeologic Evaluation document (Appendix D) reveals that the pump tests indicate a leaky aquifer condition and Figure 6 shows potential existing karst features within, and near, to the proposed mine area. If the overlying Pleistocene sediments are in hydraulic connection with the limestone, as proposed

in the preliminary hydrologic testing, and the groundwater levels are lowered for mining, there is risk of sinkhole reactivation or formation. This could occur by the removal of water from known and unidentified dissolution cavities within the limestone.

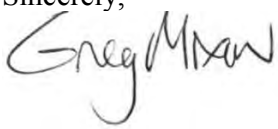
The total removal of water or lowering of its head pressure within the limestone could weaken it and foster collapse. Thence, the overlying unconsolidated sediments could then flow into the cavities and cause surface collapse. This is the model used to describe the induced sinkholes that occurred in Georgetown, SC in 2011. In Georgetown, a dewatering project lowered the head pressure in the same geological unit this mine proposes to excavate. Prior to pumping, the hydrostatic head was above the elevation of the limestone. Therefore, the water was pushing up on the overlying materials; head pressure in the limestone was partially supporting the overlying unconsolidated sediments. When the head pressure was lowered, the limestone collapsed under the weight of the overlying material and the sediments flowed downward into the cavities. If the material on the proposed mine site is under similar hydrostatic head conditions (a positive head elevation higher than the upper elevation of the limestone), then a similar condition with its associated risks could occur.

Additionally, SCDNR has concerns regarding the potential for significant water quality impacts to Murray Swamp associated with the use of the existing road crossing and the proposed location of the process plant, shop and equipment storage areas. Murray Swamp is a tributary to the Black River, a State Scenic River, located approximately 6 miles downstream from the site. Volatile organic compounds, dust and other pollutants from these areas could adversely impact downstream water quality and aquatic life if these areas are not adequately buffered and managed. Water quality data from the SCDNR State Stream Assessment indicates the pH of the water in Murray Swamp is already close to the upper (more alkaline) tolerance thresholds for water tupelo and bald-cypress. Substantial limestone dust or mine runoff inputs to Murray Swamp would likely result in increased mortality of these dominant tree species and should, therefore, be minimized. The construction of a new road crossing, if required, will result in direct fill of wetlands in Murray Swamp as well as significant habitat loss due to the segmentation of the swamp and impacts to hydrologic flow and connectivity.

SCDNR recommends that the above concerns be researched and addressed prior to the issuance of any federal or state permits and certifications. SCDNR reserves the right to provide additional comments and will provide a final permit recommendation as more information becomes available regarding project impacts, details of operation or response to agency concerns.

Should you have any questions or need more information, please do not hesitate to contact me by email at mixong@dnr.sc.gov or by phone at 803.734.3282.

Sincerely,



Greg Mixon
Inland Environmental Coordinator