July 19, 2021

National Grid Renewables
8400 Normandale Lake Boulevard
Bloomington, Minnesota 55437

Attn: Mr. Jake Wotczak
P: (612) 439-9817
E: jwotczak@nationalgridrenewables.com

Re: Caldwell Phase II Karst Survey and Assessment
Caldwell Solar, LLC
Princeton, Caldwell County, Kentucky
Terracon Project No. 57205061

Dear Mr. Wotczak:

As requested, Terracon Consultants, Inc. (Terracon) is submitting this report summarizing the karst survey and assessment at the proposed Caldwell Solar site in northern Caldwell County, Kentucky.

1.0 PROJECT INFORMATION

The proposed Caldwell-Golden Expansion Solar site (hereinafter referred to as “Caldwell Solar Phase II”) in Caldwell County, Kentucky was assessed for potential karst geohazards underlying the property. An additional 1,900 acres is under consideration for expansion from the original project (Caldwell Karst Survey Report, 2/8/2021) footprint of 1,700 acres, and this region was the focus of the karst assessment. The objective of the karst survey was to identify, locate, and characterize existing karst features with particular emphasis on open throat and/or active sinkhole development which could impact the proposed solar arrays, roadways, and supporting infrastructure. The entire site is underlain by soluble carbonate bedrock forming a regional karst terrain (i.e. a landscape characterized by the presence of sinkholes, caves, sinking and losing streams, and a highly irregular “pinnacled” overburden/bedrock interface).

2.0 SCOPE OF SERVICES

Our karst survey and assessment services were performed in two phases: 1) a desktop data review phase, and 2) a field reconnaissance phase. Terracon assessed the properties indicated on files provided to us (“Caldwell-Golden Expansion Parcel.kmz”, 4/27/2021), hereinafter referred to as the Area of Interest (AOI).

Specifically, Terracon provided the following services:

- Terracon's karst geologists performed a desktop review of readily available resources to identify suspected and/or previously identified and documented karst features (e.g., sinkholes and areas of soil subsidence, cave entrances, closed depressions, and sinking and losing streams) within the AOI, and any features within 0.25 miles of the AOI that were inferred to receive drainage from the AOI.

- Based on the results of the data review, Terracon's karst geologists located and delineated visible surface karst features (e.g., sinkholes and subsidences, cave entrances, closed depressions, and sinking and losing streams) within the proposed AOI, with particular emphasis on features that were inferred to have direct communication with the phreatic zone (e.g.: "open-throat" sinkholes, karst windows, cave entrances, abandoned wells, sinking streams) and areas of high karst activity that could indicate development of pinnacled bedrock. Field observations were made by walking the AOI. Small Scale site maps showing the AOI which was evaluated are included as Appendix A, Exhibits 1 through 3.

- Terracon delineated zones of karst terrain based on the surface karst feature assessment.

- The findings and conclusions of the data review and field study have been summarized in this report. The report includes recommendations on the feasibility of the planned construction in karst areas, indicates higher or lower risk areas within the AOI, and provides recommendations regarding additional studies or investigations for site specific karst features identified during the survey.

2.1 Methods and Procedures

Desktop Data Review

Potential karst features were identified remotely, prior to being located and characterized in the field. This process is intended to significantly reduce the amount of time spent in actual field observation and survey tasks. The review of the existing feature locations within the AOI was accomplished by examining data from the following sources:

1. The Cave Database of the Kentucky Speleological Survey (KSS);
2. Maps of selected karst features available from the United States Geological Survey (USGS) and the Kentucky Geological Survey GIS Sinkhole Database (https://www.uky.edu/KGS/gis/sinkpick.htm);

3. Digital Elevation Models (DEMs) and LIDAR Data (collected 2014);[1]
4. LiDAR derived two-foot contour interval maps for the AOI and surrounding to within 0.25 miles, in order to determine the presence of surface features not included in the above listed databases based on the presence of closed, descending contours or other suspect karst "fingerprint" features;
5. Aerial photographs (both recent and historical); and
6. USGS Topographic 7.5-minute topographic quadrangles.

In addition, Terracon reviewed readily available geological literature for bedrock and structural characteristics. We relied upon the closest resolution geological mapping that exists for the AOI. Each feature was assigned a unique identifier.

Field Survey

Upon completion of the data review, Terracon initiated the field reconnaissance and survey activities. Specifically, the field reconnaissance entailed:

1. Location and verification of potential surface features previously identified in the desktop review;
2. Location of uncatalogued or previously unidentified surface features, specifically sinkholes, cave entrances, dry runs, and sinking streams.

Each survey area was delineated and then examined for features (both catalogued and previously unidentified during the desktop review) in the field. This entailed walking over the survey area in a systematic manner, to observe features that fit the criteria. The locations and outlines of all relevant features were recorded using a sub-meter accuracy GPS device. For this study, the outline (parapet) of a closed depression (sinkhole) was defined as either the last closed descending contour at a 2-foot mapping interval or by the presence of a visible parapet. Cave entrances were identified as single points, unless the entrance was located within a larger sinkhole structure, in which case the cave entrance was indicated as a point within the sinkhole's parapet. Sinking streams were located as points of entry into the subsurface; however, losing streams were identified as linear features. Springs were also identified as points.

Each feature was assigned a unique identifier using the same protocol as the data review. Features verified from the data review retained their original identifiers; however, any feature that could not be verified in the field was removed from the final data set. Any new features were assigned the next number after the last one assigned.

[1] KyFromAbove (https://kyfromabove.ky.gov/)

3.0 GEOLOGY AND TERRAIN

Physiography – The proposed Caldwell Solar Phase II site is situated within the western portion of the Interior Low Plateaus Physiographic Province of Ohio, Kentucky and Tennessee, which extends from the Greater Cincinnati metropolitan region in the Ohio River Valley southward to the Nashville Region of Tennessee. In general, the Interior Low Plateaus range from approximately 380 to 1,200 feet in elevation and comprise primarily rolling plains and eroded/dissected plateaus. This region is almost completely composed of nearly horizontal beds of sandstone, shale, and limestone dating from the Paleozoic Era (541 to 252 million years ago). The Interior Low Plateaus exist at the southeastern area of the Central Lowlands, the boundary occurring where the maximum extent of the Pleistocene glaciers reached.

Specifically, the subsection of the Low Plateaus Physiographic Province in Kentucky is referred to locally as the Mississippian Plateaus or the "Pennyrile" (named for the Pennyroyal plant, *Hedeoma puligiodes*). The Mississippian Plateaus wrap around the Western Kentucky Coalfield Province, in a crescent that opens towards the north. The Mississippian Plateaus in the site area is divided by the Dripping Springs Escarpment into an upland often called the Mammoth Cave Plateau, and an adjacent, lower elevation area called the Pennyroyal Plateau. The Caldwell Site lies within the Pennyroyal Plateau section of Caldwell County, KY.

Topography – The Caldwell Phase II Site is nearly level, with an average elevation (EL) of EL 550. The highest point within the site is at EL 670, in parcel 26-30B-30C-31 at the southernmost end of the site. The majority of the site is characterized by a gently rolling landscape except for the steeper slopes of Farmer Knob which is located in parcel 25-8.

The topography of the site is notably different on either side (north and south) of Skinframe Creek which flows from east to west through the approximate middle of the site (Appendix A, Exhibit 3). Numerous surface tributaries from the southern half of the site feed into Skinframe Creek which eventually disappears into a set of deep sinkholes, northwest and outside of the AOI. In contrast, there are no surface streams present in the northern half of the site and instead a series of sinkholes, dry creek beds, and karst swales generally align in the shape of tributaries towards the direction of Skinframe Creek. The characteristics of the northern half of the site indicate that all surface water sinks into the subsurface and presumably resurges in Skinframe Creek through a series of springs fed by karst conduits and voids.

Geology – The Mississippian Plateau Province is named based on its geology, as it is underlain primarily by karst-prone carbonate units dated to the Mississippian Geologic Period. The following bedrock units are mapped within the survey area and are shown in Exhibit 2, Appendix A and described below:

Tuscaloosa Formation (Kt)
This formation is composed of unconsolidated light-gray gravel with lenses of sand, silt, and clay which overlays the Mississippian carbonate strata in disconnected pockets mainly located in the southern half of the site.

Bethel Sandstone (Mbe)
This formation is only found at the highest elevation areas of the site. It caps the outlier hills and the upland above the crest of the Dripping Springs Escarpment. The Bethel consists of sandstone, siltstone and shale. Post depositional erosion of the underlying Renault Limestone formed channels where the Bethel Sandstone is present, usually from the middle to the top of the Renault Limestone in places.

Renault Limestone (Mre)
Lying above the Levias Limestone is the Renault Limestone, the basal member of the Chester Series of Mississippian age. The formation is 30 to 95 feet in thickness and consists of limestone and shale. The limestone is light gray to medium gray, medium crystalline, with abundant fossil fragments and shaley partings. The Levias shale is calcareous, gray to greenish gray and reddish brown. The Renault is present on slopes of the Dripping Springs Escarpment and its outliers, lying above the Levias Member of the Ste. Genevieve Limestone.

Renault Limestone, Ste Genevieve Limestone, and St. Louis Limestone (Mrss)
This group of formations is a composite of the individual units described in more detail within this section of the report and is simply a derivative of the style of geologic mapping in the region and preference of the author.

Levias Limestone Member of the Ste. Genevieve Limestone (Msgl)
This is the uppermost member of the Ste. Genevieve Limestone, and it occurs around the base of the outlier hills of the Dripping Springs Escarpment described in the topography section above. The Levias Member is 20 to 30 feet thick, present as a light gray, finely crystalline or oolitic limestone. There are scattered thin lenses of greenish-gray sandy shale present at its base, probably rip-ups from the underlying Rosiclare Member.

Rosiclare Sandstone and Fredonia Limestone Members of the Ste. Genevieve Limestone (Msrf)
In general, the Ste. Genevieve Limestone is composed of medium gray to bluish gray limestone with minor clay-shale beds and interbedded oolitic limestone with coarsely crystalline limestone and fine to medium grained calcarenite and calcilutite.

The Rosiclare Sandstone Member of the Ste. Genevieve Limestone was deposited during the Mississippian Period and ranges from approximately 5 to 10 feet thick. This member predominantly consists of very fine grained, calcareous sandstone and limestone.

The Fredonia Limestone Member of the Ste. Genevieve Limestone was deposited during the Mississippian Period and ranges in thickness from approximately 200 to 250 feet thick. The limestone comprising of this member is broken into three major types, described in detail below.

1. Light-gray and oolitic, found in zones 10 to 30 feet thick;
2. Light-to medium-gray, finely crystalline, commonly dolomitic with rare chert modules (typically found in the lower 60 feet); and
3. Light-to medium-gray, medium-to coarsely crystalline, fossil fragments evident.

The base of this unit is typically cherty limestone as it transitions to the underlying unit, and weathers to a dark reddish-brown soil with dense or oolitic chert fragments.

<u>St. Louis Limestone (Mslu and Msll)</u>
This formation has a maximum thickness of 220 feet and is an olive-gray to brownish-gray limestone with fine grained, thick to very thick bedding. The formation is often separated into an upper and lower unit, but they are lithologically quite similar. The St. Louis Limestone contains rounded nodules of glassy chert and a few angular blocks of dark-gray fossiliferous chert, locally abundant.

Faults and Structure – Several faults are present in the project area which run approximately southwest to northeast, creating abnormal and discontinuous dips and outcrops. These faults juxtapose bedding patterns, orientations, and different bedrock types resulting in discontinuities which are favorable conditions for karst development. The most notable fault is located within parcel 25-8 which shows signs of right-lateral offset alongside Farmer Knob and may account for the comparatively isolated higher topography and swale located along the mapped extent of the structure. The normal faults located in the southern half of the site do not appear to have a significant impact to the topography.

Karst Geology – The site is within the classic Pennyroyal Plateau region, an area characterized by tens of thousands of sinkholes, sinking streams, dry valleys, springs, and caverns. It is of note that the limestones of the Pennyroyal Lowland below the Dripping Springs Escarpment are not capped by the soft sandstone that is found on the Mammoth Cave Plateau to the east. For this reason, there is a much higher concentration of karst features located in this area, most of which have open throats that lead directly into the subsurface, and are not clogged with sandstone residual sediment as are often found within the Mammoth Cave upland area.

Based on a 1-mile buffer data review of the site from the Kentucky Speleological Society (KSS) two small documented caves were identified. Crider Mill Cave is located along the sinking creek just north the project site and Crider Road (Appendix A, Exhibit 3), and Francis Cave is located to the east of parcel 25-8 along the base of Bright Hill. A detailed cave map from 1977 was available for Crider Mill Cave (Figure 1) and very little data was present for Francis Cave.

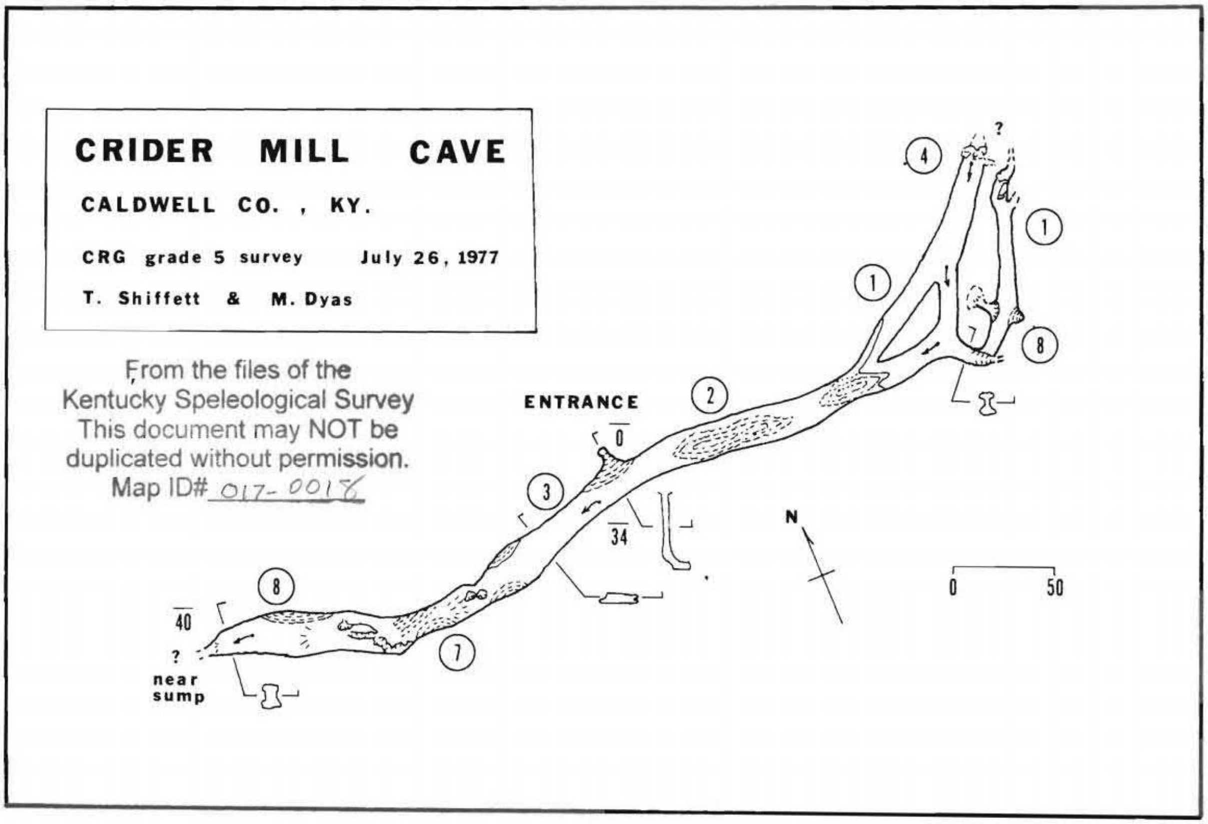


Figure 1. Detailed map of Crider Mill Cave.

Crider Mill Cave has an approximate 34-foot-deep (vertical) pit entrance. The horizontal main passage consists of a few hundred feet of stream passage with ceiling heights ranging from 1-8 feet. The stream flows from northeast to southwest, mirroring the sinking stream alignment at the surface. The cave stream sumps[2] at either end of the passages. This small cave indicates that there may be other similar stream cave passages beneath the sinking stream segments identified within the AOI. These passages more than likely flood during precipitation events and the water flows along the surface stream channel for a short time, until it sinks back into the subsurface passages.

4.0 SURVEY RESULTS AND DISCUSSION

4.1 Data Review

Based on the methods and procedures for the data review as detailed previously in Section 2.1, suspect karst features were identified throughout the site. In total, two hundred and thirty-two (232) point karst features and thirty-three (33) area karst features were identified within the AOI for a total number of two hundred and sixty-five (265) suspected karst features (Figure 2;

[2] A cave passage that is submerged under water.

Appendix D, Table 1). The largest area features ranged in size from 100 to 1,000 feet in length and width, but only a few feet in depth; therefore, it would be very difficult to identify these subtle features in the field. It is important to note that greater than 50% of the suspect karst features were located within two parcels (25-8 and 16-34A-17-5). The number of the suspect karst features per parcel are shown in the table below.

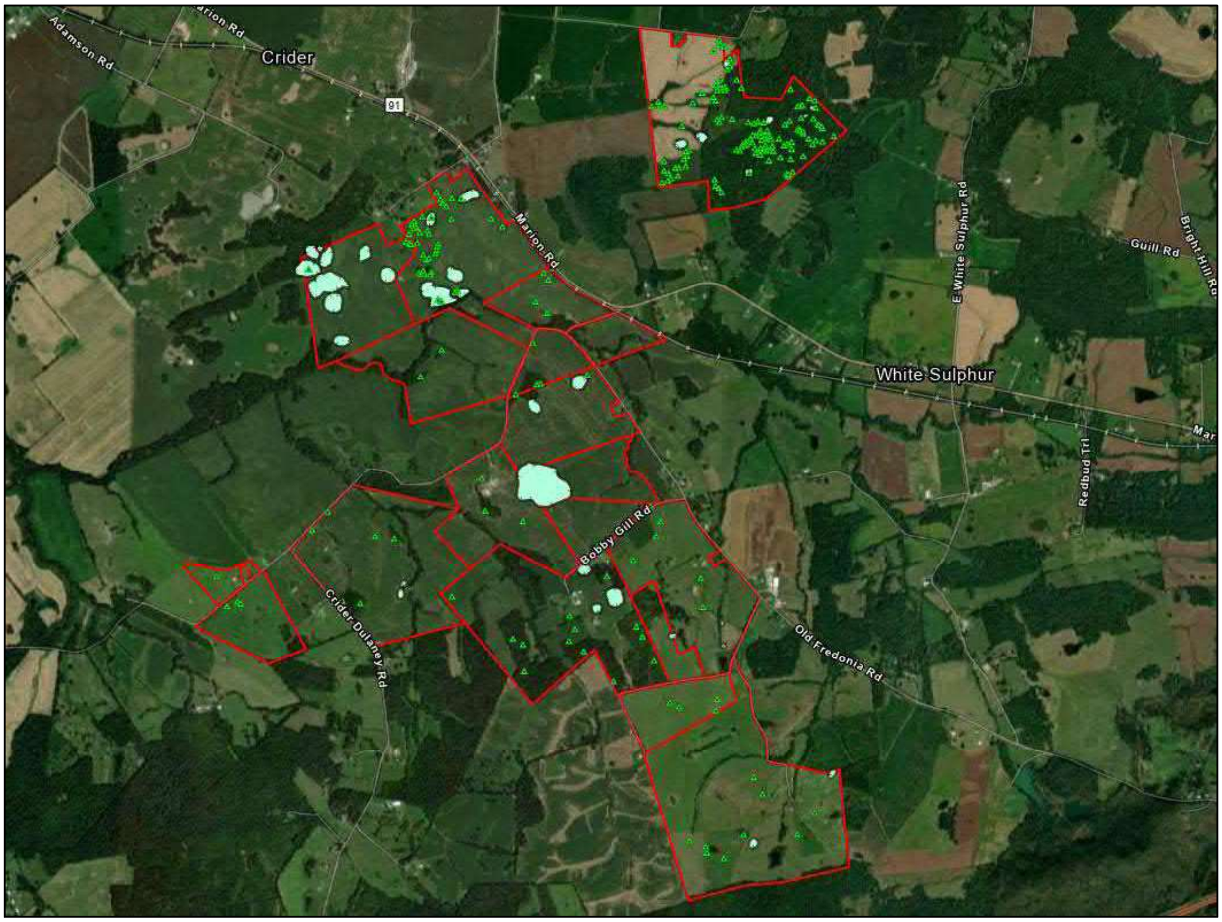


Figure 2. Map of the site showing the SKF zones identified during the data review prior to field exploration. Proposed workspace (outlined in red), SKF (green points and blue areas).

Parcel ID	Suspect Point Karst Features	Suspect Area Karst Features
25-8	130	7
16-34A-17-5	37	5
16-34B-47A-49	4	9
16-34A-17-5	2	0
25-11A	8	0
26-1A	4	2
26-3	0	1
26-17A	5	2

Parcel ID	Suspect Point Karst Features	Suspect Area Karst Features
26-16	4	0
26-15-15A	13	3
26-14	3	0
17-14	6	2
17-7A	4	0
26-16	3	0
26-30B-30C-31	9	2

The shaded relief map derived from LiDAR data show concentrations of suspect karst features as shown in Figure 3A, where the topography and location of focused water flow increases sinkhole occurrence and severity. In some cases, broad and shallow closed depressions may have a smaller subsequent collapse along the base or walls of the structure, indicating a reactivation of the sinkhole (Figure 3B). The imagery of the site provides evidence to suggest the presence of sinkholes, even when the LiDAR and 2-foot contour data does not suggest a closed depression. For example, the presence of small groups or single trees in an otherwise developed agriculture field, implies that the landowner has avoided the area for a reason (Figure 3C). In karst prone areas such as this site, these avoidance areas are more often than not either karst features or shallow bedrock, which are both important to investigate during the field survey.

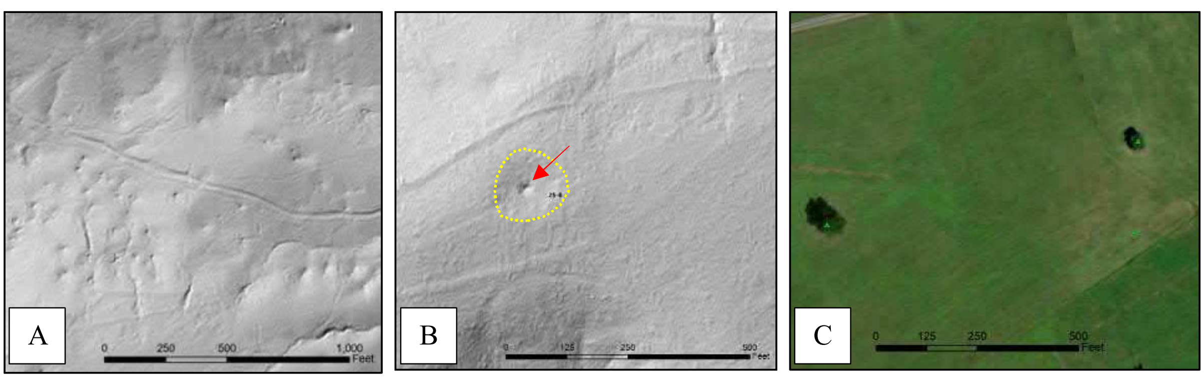


Figure 3. (A) Very dense region of steep walled suspect karst features within parcel 25-8. (B) A suspect karst feature where the broad sinkhole (yellow dashed line) has a smaller subsequent collapse in the center (red arrow). (C) Example of lone trees in an agriculture field which are avoided by the property owner. In areas mapped as underlain by karst, this pattern indicates that there may be karst features near these trees.

Although the entire expansion region is underlain by carbonate bedrock the distribution of suspect karst features is concentrated within specific areas. This is most likely controlled by lithologic variability within different formations and the deformation and fracturing of bedrock related to faults as shown in Appendix A, Exhibit 2. Many factors control the occurrence of karst features, but the number of clastic units between the carbonate beds, hydrologic conditions, purity of the carbonate layers, topographic relief, and thickness of soil overlying the bedrock may vary between faulted regions within the proposed expansion area and influence the distribution of karst features. For example, the densest concentration of karst features is in parcel 25-8 where both fracturing related to the strike slip faulting and significant vertical relief likely increase the frequency and severity of the karst features. Although the strike slip fault that passes through Farmer Knob is shown to terminate against Marion Road, it is highly likely that it extends in the southwestern direction past the roadway (shown as black dashed line in Figure 4) and that deformation related to this fault may account for karst feature presence being abundant in parcels 16-34A-17-5 and 16-34B-47A-49, and Crider Mill cave also being located along this alignment. As seen in Figure 4, there is a concentration of suspect karst features near the strike slip fault and the number of features decreases away from the fault zone south of Skinframe Creek.

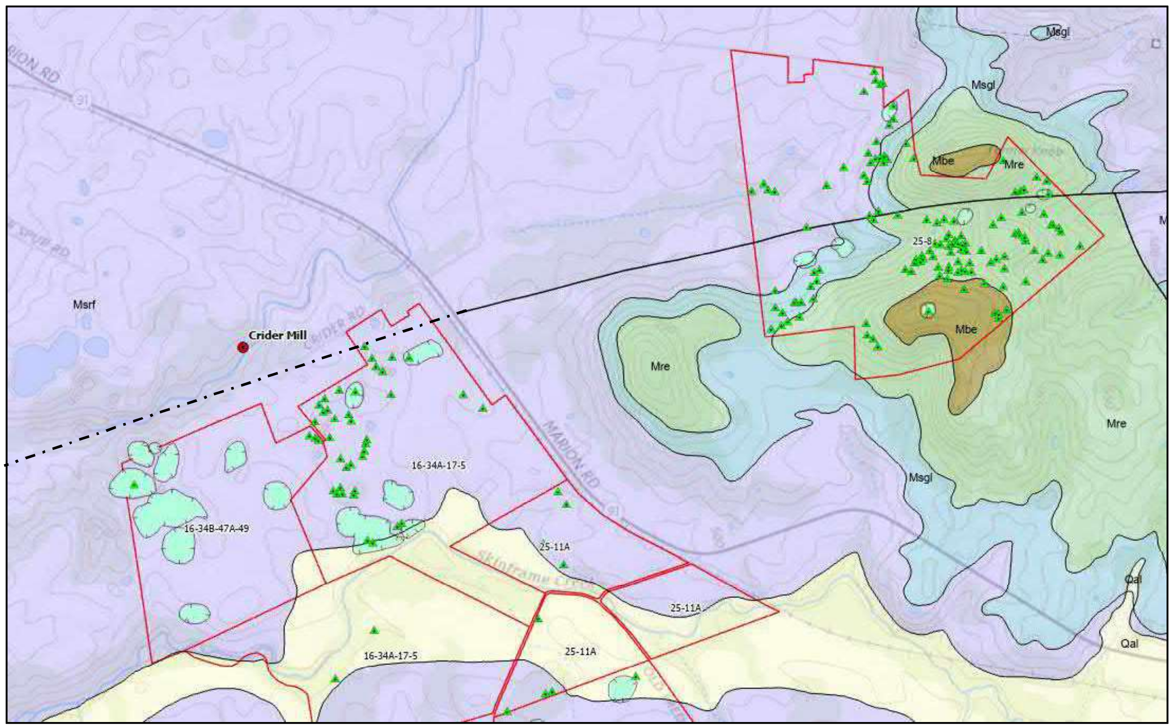


Figure 4. Geologic map of the northernmost parcels in the study where the highest concentration of suspect karst features was identified. There is a correlation between suspect karst feature occurrence and proximity to the strike slip fault (shown by solid black line) and the extrapolation of the fault (shown by dashed black line). Suspect karst feature points are shown by green triangle symbols, area features are shown as blue polygons, and the parcels are shown by the red polygons.

4.2 Field Survey

The field survey was performed during three separate site visits from May 17 – 19, 2021, June 23 – 24, and June 29, 2021, by Munal Pandey (Terracon Staff Engineer) and Jacob Helsley (Terracon Staff Geologist). The AOI was assessed for karst development in the parcels where the geological mapping suggested there was the possibility of the development of karst terrain and/or where the data review indicated the possible presence of existing surface karst features (e.g. closed depressions, sinkholes, caves, or karst springs). A total of two hundred and forty-two (242) karst features were verified in the field. A summary of the karst feature inventory documented during the field survey is included in map format in Appendix B, photolog format in Appendix C, and table format in Appendix D.

5.0 KARST RISK RANKINGS

5.1 Examples of Features Used to Develop Risk Ranking

A total of eight different types of karst features with varying characteristics impacting the risk ranking are shown below. The following exemplary karst feature "types" are representative of the various characteristics used to develop the risk ranking. In some cases, the following feature types may have more than one of the characters used in the risk ranking development, nevertheless they are included here as examples.

Type 1 – This type of karst feature is characterized by the presence of an open throat at the base and active erosion along the walls and parapet of the feature. These features are considered the highest risk since they are actively growing and may continue to collapse and widen during construction activities and post development. An example of such a feature is shown below in Figure 5.

Figure 5. A sinkhole (25-8-044) undergoing erosion and expansion of the parapet limits as demonstrated by the rough, raveling, and incised surfaces. In addition, the open throats present in the base of the sinkholes readily receive surface runoff with little to no filtration.

Type 2 – This type of karst feature is characterized by the presence of an incised drainage channel leading to the karst feature indicating that focused drainage enters the structure, which commonly results in active erosion and growth of the sinkhole (Figure 6). In addition, they nearly always contain an open throat. Additionally, these features can be problematic as potential construction activities within the drainage may result in the uncontrolled flow of water transporting sediment and contaminants into the subsurface via the open throat. Awareness of the drainage catchment extent and implementation of proper erosion and sediment controls (ESC) are crucial for these types of karst features.

Figure 6. Two examples of drainage channels leading towards sinkholes with open throats. The photo on the left shows soil raveling at the point of water entry into the subsurface (25-8-022) and the photo on the right shows a drainage channel leading to bedrock bound open throats (25-8-075).

Type 3 – This type of karst feature has an open throat and rough, irregular parapet edges, indicating active erosion, collapse, and growth. The features are typically small (<5 feet) yet indicate that the area around the soil piping is undergoing sinkhole development which may widen, deepen, and affect the surrounding area (Figure 7). It is commonplace to observe multiple soil piping features which may all be feeding into a single open throat in the subsurface. These features pose a significant risk because the karst features are actively developing; therefore, remediation or avoidance is necessary.

Figure 7. Examples of soil piping structures and open throats which are newly developed and indicate that growth and widening of these features is likely. Left = 25-8-012 and Right = 25-8-093.

Type 4 – This type of karst feature is a sinkhole with a cave entrance located at the base or within the sidewall of the structure (Figure 8). Caves pose a significant risk since they are relatively large openings that can receive surface runoff, may contain significantly sized chambers and passages below the surface, and may host cave fauna and sensitive biological habitats. Aside from having certified spelunkers enter the caves and map out the passages, geophysical techniques are often utilized to determine the presence, extent, depth, and size of cave passages in relationship to planned construction. During this survey a total of 6 new possible cave entrances were found in features 25-8-105, 25-8-110, 25-8-126, 25-8-128, 25-8-143, 16-34A-17-5-206.


Figure 8. Two cave entrances observed during the field survey, where the right entrance is located within a low wall of bedrock (25-8-105) the left image shows a cave entrance at the base of a sinkhole (25-8-128).

Type 5 – This type of karst feature has an open throat within the structure, yet the remainder of the sinkhole is overgrown with vegetation and the parapet appears to be stable[3] (Figure 9). Although there is an opening present leading into the subsurface, the protection and stabilization of the feature by maintaining a vegetated buffer dramatically reduces the risk of impacting the subsurface habitat during construction activities.


Figure 9. Examples of overgrown open throats located at the base of sinkholes. The presence of the plant life indicates that little to no recent erosion has occurred. Left = 25-8-045 and Right = 25-8-031.

[3] Circular or oval sinkhole parapets are assumed to have reached equilibrium.

Type 6 – This type of karst feature is characterized by bedrock bound open throats and rock outcrops either located at the base of sinkholes or within generally flat laying bedrock benches (Figure 10). Although the open throats clearly connect to the subsurface, the bedrock does not present much risk of collapse or change in architecture unless the bedrock layer is very thin above an open chamber. The bright green moss growing near the open throat of feature 25-8-063 (Figure 10), indicates the presence of water vapor which implies that the opening is connected to a possible larger cave system below.


Figure 10. Bedrock bound open throats located within a bedrock outcrop flush with ground shown on the left (25-8-063) or at the base of a depression shown on the right (25-8-107).

Type 7 – This type of sinkhole has been used by farmers and landowners as a convenient place to deposit field rock, trees, trash, and an assortment of various other items and materials. These karst features were present within the AOI and most typically observed to be infilled with trash and occasional trees (Figure 11). Since these may have been partially or completely filled, it is impossible to fully characterize these features for the presence or absence of an open throat. Therefore, we assume that there is an open throat at the base in order to be conservative for protection measures during construction activities.


Figure 11. Examples of trash and tree filled sinkholes observed during the field survey. The feature on the left (26-30B-30C-31-203) is filled with cut tree trunks and limbs and the feature on the right (16-34A-17-5-220) is filled with old vehicles.

Type 8 – This type of feature is present as small depressions ranging in size from a few feet in length, width and depth, and are typically flush with the ground and exhibit minor soil raveling (Figure 12). There are no open throats within the structures and typically little to no considerable growth of the feature occurs over time unless the topography and hydrology change.


Figure 12. Examples of small depressions where a leaf litter covered feature is shown on the left (25-8-069) and a feature with minor soil raveling along the wall is shown on the right (25-8-109).

Type 9 – This type of sinkhole is present as a broad and shallow depression, ranging in size from tens to hundreds of feet in diameter and commonly referred to as a “mature” or paleokarst sinkhole (Figure 13). Mature sinkholes often have a roughly circular parapet outline, are bowl shaped, lacking any opening to the subsurface (i.e. “throat”) or showing evidence of active soil raveling or tension cracks around the parapet. Thus, whatever conduit or opening into the underlying karst aquifer that may have functioned to create the structure is probably now clogged with soil, which would act as a filter for water infiltrating from the surface.


Figure 13. Examples of mature sinkholes. The feature on the left (16-34B-47A-49-236) is a large closed depression with evidence of ponding at the center due to the presence of facultative wetland plants[4]. The image on the right (26-30B-30C-31-202) shows a closed depression which has presumably been repurposed into a pond.

[4] Plants that typically grow in wetland environments.

5.2 Risk Character Analysis and Results

Karst risk was assessed per karst feature through the compilation of a data matrix comprising five karst feature variables or "characters". These variables were assessed per karst feature by analyzing the field notes, observing the photographs, and considering the overall context and resources from the desktop data review.

It is of note that this type of data analysis and reduction (i.e. character analysis) is designed to assist in minimizing subjectivity in assessment of karst features for overall risk. The tabulation of the data analysis is present in Appendix D, Table 2.

The variables (characters) embodied in creating the risk data matrix and resulting risk assessment summary are:

1. Presence of an open throat
2. Parapet characteristics
3. Degree of soil raveling
4. Drainage leading to the karst feature
5. Presence and quality of vegetation

Explanation of the Characters

Character 1 – The presence of an open throat (e.g. an opening into the subsurface, usually at the base of a sinkhole, an opening within a rock outcrop, or a cave entrance) in a karst feature is important since it may allow the unimpeded flow of surface runoff into the subsurface and eventually the groundwater table. This is a serious environmental concern to the groundwater and proper erosion and sediment control and buffering must be utilized during construction around these types of karst features.0
Coding: Absent = 0; Small/Unknown = 1; Large/Open = 2

Character 2 - The shape and conformation of the parapet of each karst feature is important because the smoothness of the edge indicates the degree of erosion, growth, and overall activity of the karst feature. Typically, the rougher the parapet edge the more active the karst feature, and hence higher risk for the surface to continue to change.
Coding: Parapet Stable/Circular = 0; Irregular/Unstable = 1

Character 3 - Coeval with parapet shape changes and erosion, soil raveling of the sinkhole walls, throat, and subsidiary channels is a good indicator for sinkhole activity and risk. We further distinguish soil raveling into "minor raveling" and "raveling" to differentiate between levels of erosion and growth inside the karst feature.
Coding: No raveling = 0; Minor raveling = 1; Major/severe raveling = 2

Character 4 - An important factor that we note when assessing karst features, is evidence for surface drainage focused into the karst feature. This is typically manifested as matted down grass/vegetation in the direction of the sinkhole in the case of surface runoff (sheet flow) or distinct erosion and channel development where water commonly drains into the karst features. If the channel leading to the karst feature exhibits signs of erosion and downcutting, then this further supports the notion that the karst feature base level is decreasing and typically growing.
Coding: No evidence of drainage = 0; Sheet flow = 1; Drainage channel = 2

Character 5 - The presence, type, and state of vegetative cover surrounding and within the karst feature is an indicator for sinkhole development and the existence of a natural buffer. If little to no vegetative cover is present within the sinkhole then this indicates that it is changing fast enough to inhibit plant growth and that it is vulnerable to surface runoff. If the sinkhole is overgrown, then this signifies that the sinkhole is more stable and that a natural vegetated buffer is present, which functions to filter out suspended soil/contamination in surface runoff.
Coding: Fully vegetated = 0; Partially vegetated = 1; Soil/rock = 2

Based on the character analysis, we have assigned a low, moderate or high-risk category of each of the confirmed karst features present, specifically to this site. If the defined character sum was 0 it is our interpretation that the feature is very low risk to site development. If the sum was 1-2, we believe the feature is a low risk to site development. If the sum was 3-4, we believe the feature is a moderate risk to site development. If the sum was 5-6, we believe the feature is a high risk to site development. For features where their characters summed to 7-9, we believe present very high risk for continued karstification and site development and throughout the operation of the proposed facility.

The degree of risk we identify for these karst features indicates our professional opinion regarding the likelihood of the karst feature becoming unstable or accelerate its growth. The risk rankings should be used as a planning tool to aid in assessing the overall risk of developing the site. However, it should be clearly understood that even karst features designated as low risk can become unstable and negatively impact the proposed development. It is impossible to eliminate the risk of karst features, but measures can be taken to reduce the risk of karst issues.

6.0 KARST RISK RECOMMENDATIONS

The karst risk recommendations entail a suite of approaches for each karst risk level. These various solutions for karst features will depend upon the type and scope of the project, the amount of cut and fill planned for the AOI, the presence of karst dependent rare threatened and endangered species, and the hydrologic significance of the karst aquifer (e.g. municipal drinking water supply). For the specific development of remediation, alternative foundations, or detailed additional studies, it is recommended that a Terracon karst geologist monitor construction activities to ensure that proper protocol is applied and to be available for consultation in the event that new karst features develop during grading activities onsite. The karst avoidance and/or mitigation measures for each karst feature risk level are presented below. Please note that the recommendations from a higher risk category can always be applied to lower features.

Very High Risk

- Avoidance and buffering
- Additional investigations may lower risk ranking

Moderate to High Risk

- Avoidance and buffering
- Additional Investigations
- Remediation (If necessary)

Low Risk

- Span karst features

Very Low Risk

- Grade and monitor

The preferred option is to avoid all karst features if possible, since every feature does bring a variable amount of risk to both the project infrastructure and the karst aquifer. In addition, avoidance preserves the vegetated buffer, especially for features which have reached equilibrium naturally. For this avoidance scenario we recommend a minimum buffer of 25 feet which should remain in an undisturbed natural state[5] through all periods of construction and subsequent facility operations. In addition, a 150-foot buffer should be established around each karst feature during construction where vehicles may not be refueled, and stockpiles of equipment or fuel should not be stored. The 150-foot buffer may need to be extended or modified if a significant drainage area has been delineated outside of an open throat feature. This does not mean construction is prohibited within this buffer, only that certain construction related activities, primarily storage of fuel and equipment, should not occur within this area.

In the case where avoidance is not possible then the next steps may include remediation of the karst features (e.g. reverse graded filter, pillow remediation, cap grouting, etc.) and conducting additional studies (Section 7.0) to shed light on the extent, characteristics, and impact that the karst feature may have on the surface. Remediation will vary for each karst feature based on characterization (e.g.: soil type, the architecture of the bedrock, and the local hydrology among many other factors). The type of remediation is typically determined upon subsurface exploration and excavation of the karst feature and identification and characterization of the bedrock bound throat if present at the soil bedrock interface.

Specifically, for solar field facilities it may be possible to span some of the karst features with the solar arrays, depending upon the length of the arrays and the spacing of the supporting piles.

[5]The term “undisturbed natural state” means that the existing vegetation within the 25-foot buffer, and extending across the entire sinkhole, should not be cut, trimmed, thinned or disturbed in any way.

This option is limited to the low and very low risk karst features since their current characteristics do not suggest continued erosion and growth, and instead appear to have reached equilibrium naturally. It is important to note that periodic monitoring of these karst features post-construction is recommended.

It is permissible for the very low risk karst features to be graded per the construction plans, but it is imperative that the locations of these features be marked with survey grade GPS prior to grading activities. These areas should be monitored during construction in case the grading activities cause these features to reactivate.

Please note the risk rankings presented herein are based on the current condition of the site at the time of our study. Changes in the risks and changes in the karst features will occur over time. In addition, changes may occur due to changes in surface grades, surface hydrology, nearby construction activities such as blasting, installation of water supply wells, and other similar changes.

7.0 RECOMMENDATIONS REGARDING ADDITIONAL STUDIES

Prior to site development, additional studies are recommended. Non-invasive geophysical investigations should be used for any features other than very low risk. The preferred method would be electrical resistivity investigation (ERI), however other methods such as seismic and gravimetry may be utilized. The primary purpose of the ERI will be to reveal if there are any near-surface voids that could present a risk during construction or operation of the facility.

Other investigation methods including but not limited to drilling (hollow stem, air track probe, etc), test pits, direct push borings, or other appropriate methods may be utilized to investigate specific karst features. The actual investigation method to be used will be based on the site-specific conditions, access, and the type of the karst features.

8.0 CLOSURE

The information presented herein has been based on the review of both proprietary and publicly available geologic information. However, it should be noted that karst is a dynamic landform and significant changes can occur over time. We understand that a geotechnical investigation will be completed at this site which may reveal additional subsurface karst issues. As indicated herein, karst features may be present below the ground surface that were not identified by this study. These features may not be identified until during construction. Accordingly, Terracon should be engaged during the construction phase of this project to provide oversight of the karst management plan, and to address karst features encountered during construction.

As indicated in this report, the bedrock and overlying soil below the site are susceptible to sinkhole development, and there can be extensive areas of shallow bedrock and shallow groundwater that can pose a risk to the site development process. Risk associated with these factors can be minimized during development with proper planning, design, and the control of site hydrology. Nevertheless, the client must recognize that risk of sinkhole and hydrologic-related damage to foundations, site infrastructure, and pavements does exist

Terracon has conducted these services in accordance with generally accepted geologic practices. No warranties, either expressed or implied, are made as to the professional services and recommendations presented herein.

Sincerely,
Terracon Consultants, Inc.

STATE OF KENTUCKY
BENJAMIN W. TAYLOR
27823
LICENSED
PROFESSIONAL ENGINEER

For: Joshua Valentino, PhD, PG
Project Geologist

Benjamin W. Taylor, PE, PG
Principal, Regional Manager

For: Robert K. Denton Jr., CPG, LPSS
Karst SME

Appendices: Appendix A – Small Scale Maps
Appendix B – Large Scale Maps
Appendix C – Karst Feature Inventory
Appendix D – Karst Feature Description Sheets

APPENDIX A
SMALL SCALE MAPS

Legend

Project Site

DATA SOURCES:
ESRI WMS - World Aerial Imagery, OpenStreetMap
Kentucky Geologic Survey 1:24000 Geology Maps
Solar parcel data received from client (Caldwell-Golden Expansion Parcels.kmz, 4/27/2021)

0 0.25 0.5 1 Miles

Project No.:	57205095
Date:	Jul 2021
Drawn By:	JDV
Reviewed By:	BWT

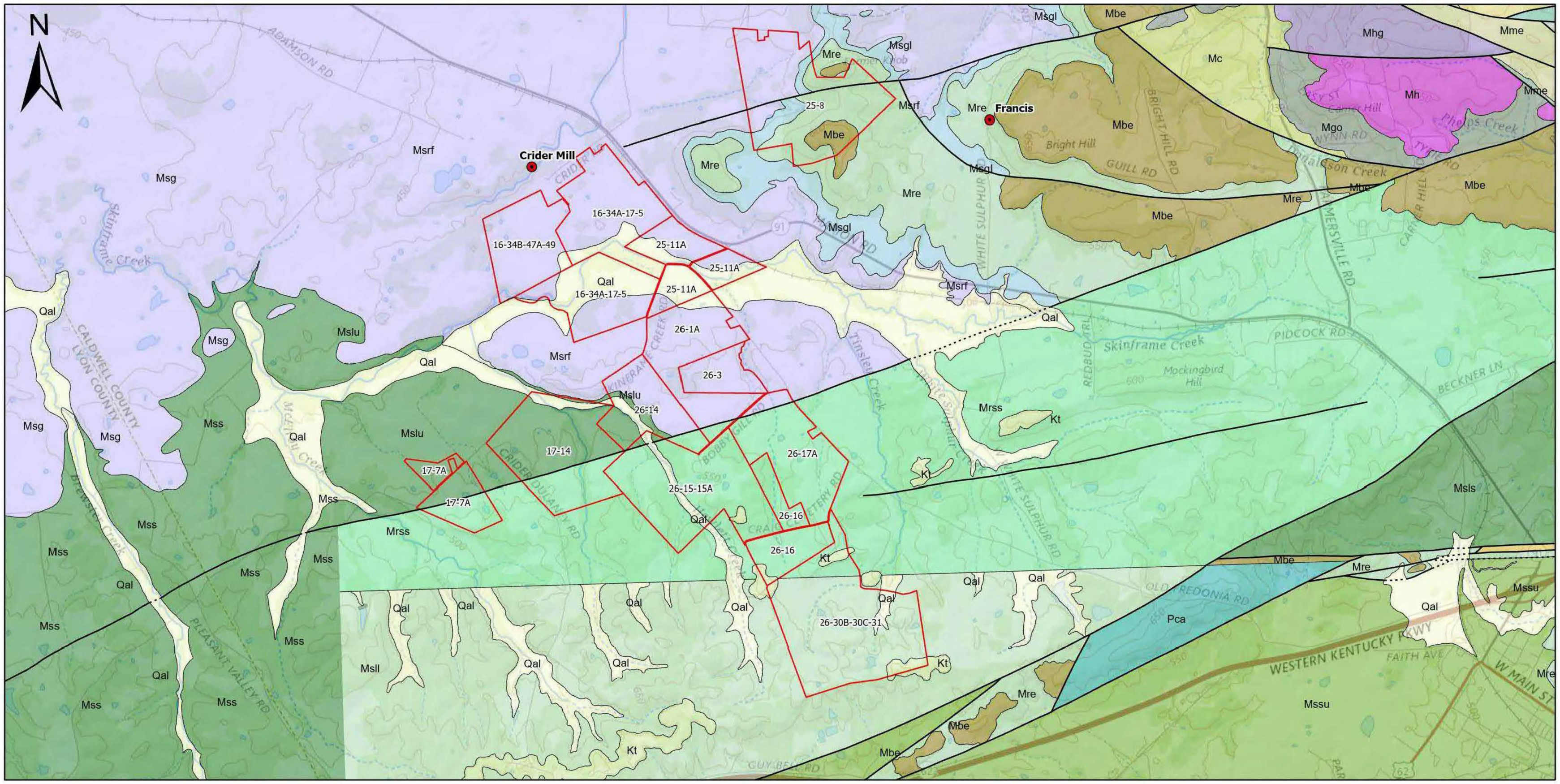
Terracon
13050 Eastgate Park Way, Suite 101
Louisville, Kentucky 40223
PH. (502) 456-1256
terracon.com

Site Map

Caldwell Solar Phase II
National Grid Renewables
Princeton, Caldwell County, Kentucky

Exhibit

1



Legend

- Project Site
- Caves
- (Qal) Alluvium
- (Kt) Tuscaloosa Formation
- (Mbe) Bethel Sandstone
- (Mre) Renault Limestone
- (Mrss) Renault Limestone, Ste. Genevieve Limestone, and St. Louis Limestone
- (Msgl) Levias Limestone Member, Ste. Genevieve Limestone
- (Msrf) Rosiclare Sandstone Member and Fredonia Members, Ste. Genevieve Limestone
- (Mslu) St. Louis Limestone, Upper Member
- (Msll) St. Louis Limestone, Lower Member
- Normal Fault
- Normal Fault (Inferred)

DATA SOURCES:
ESRI WMS - World Aerial Imagery, OpenStreetMap
Kentucky Geologic Survey 1:24000 Geology Maps
Solar parcel data received from client (Caldwell-Golden Expansion Parcels.kmz, 4/27/2021)

0 0.25 0.5 1 Miles

Project No.:	57205095
Date:	Jul 2021
Drawn By:	JDV
Reviewed By:	BWT

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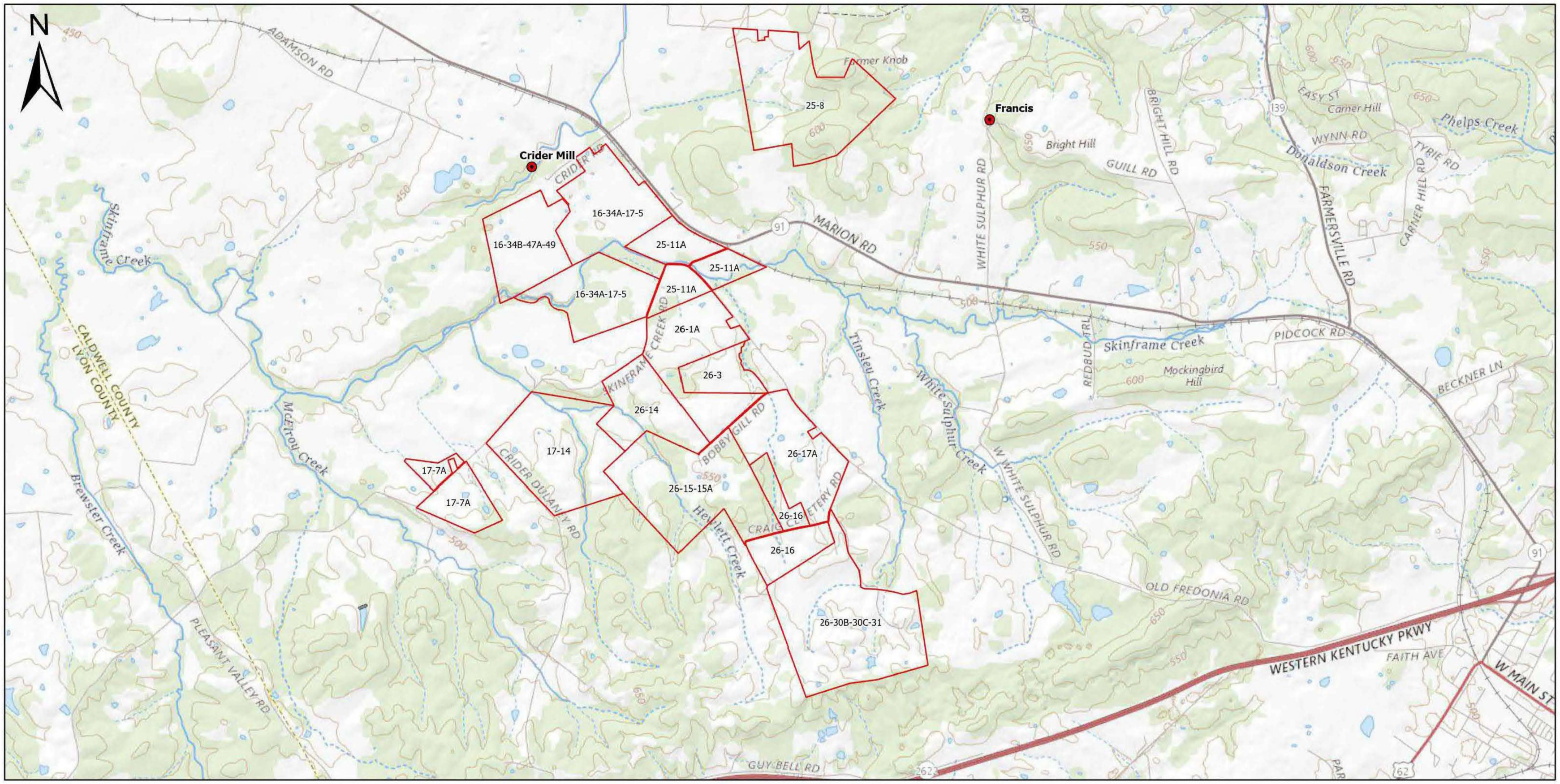
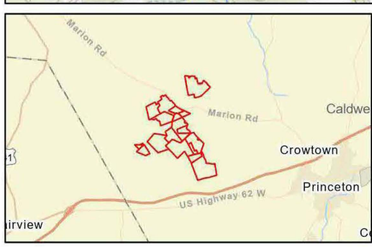
Geology Map

Caldwell Solar Phase II
National Grid Renewables
Princeton, Caldwell County, Kentucky

Exhibit

2





Legend

Project Site

Caves

DATA SOURCES:
ESRI WMS - World Aerial Imagery, OpenStreetMap
Solar parcel data received from client (Caldwell-Golden Expansion Parcels.kmz, 4/27/2021)

0 0.25 0.5 1 Miles

Project No.:	57205095
Date:	Jul 2021
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Topography Map

Caldwell Solar Phase II
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Princeton, Caldwell County, Kentucky

Exhibit

3

APPENDIX B
LARGE SCALE MAPS

Legend

- Caldwell Solar Phase II
- Index Map

DATA SOURCES:
ESRI WMS - World Aerial Imagery, OpenStreetMap
Parcel information based on "Caldwell-Golden Expansion Parcel.kmz" dated 4/27/2021

0 0.25 0.5 1 Miles

Project No.:	57215036
Date:	Jun 2021
Drawn By:	JDV
Reviewed By:	BWT

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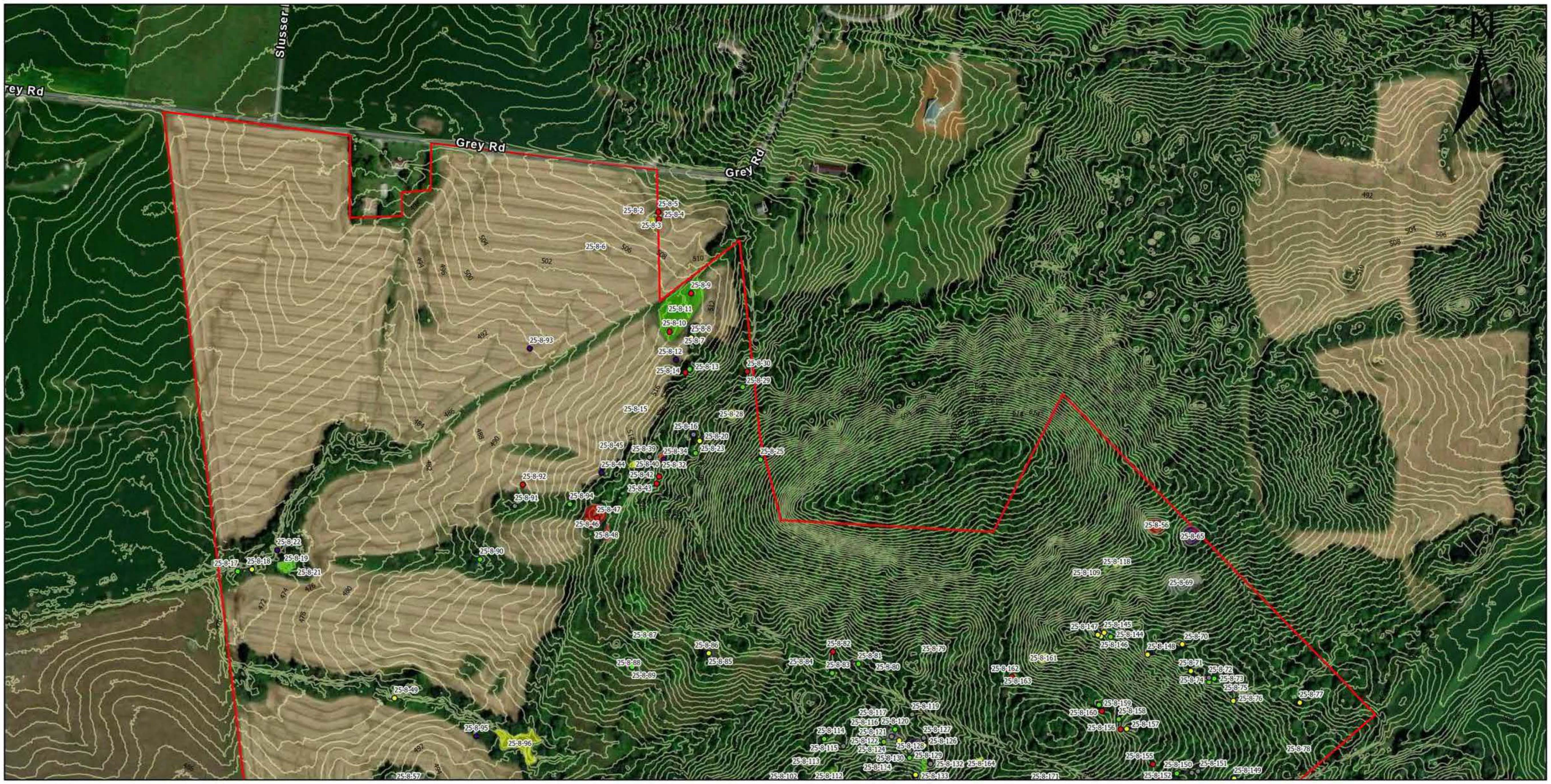
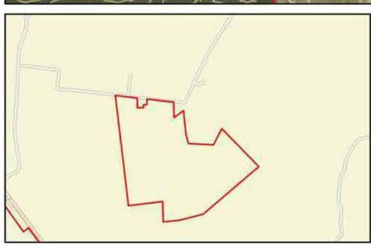
Index Map

Caldwell Phase II
National Grid Renewables
Princeton, Caldwell County, Kentucky

Exhibit

A





Legend

- Property Limit
- 2 Foot Contour

Point Karst Risk

- Very High
- High
- Moderate
- Low
- Very Low

Area Karst Risk

- Very High
- High
- Moderate
- Low
- Very Low

DATA SOURCES:
ESRI WMS - World Aerial Imagery, OpenStreetMap
Parcel information based on "Caldwell-Golden Expansion Parcel.kmz" dated 4/27/2021

0 250 500 1,000
Feet

Project No.:	57215036
Date:	Jul 2021
Drawn By:	JDV
Reviewed By:	BWT

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Karst Risk Map - Imagery

Caldwell Phase II
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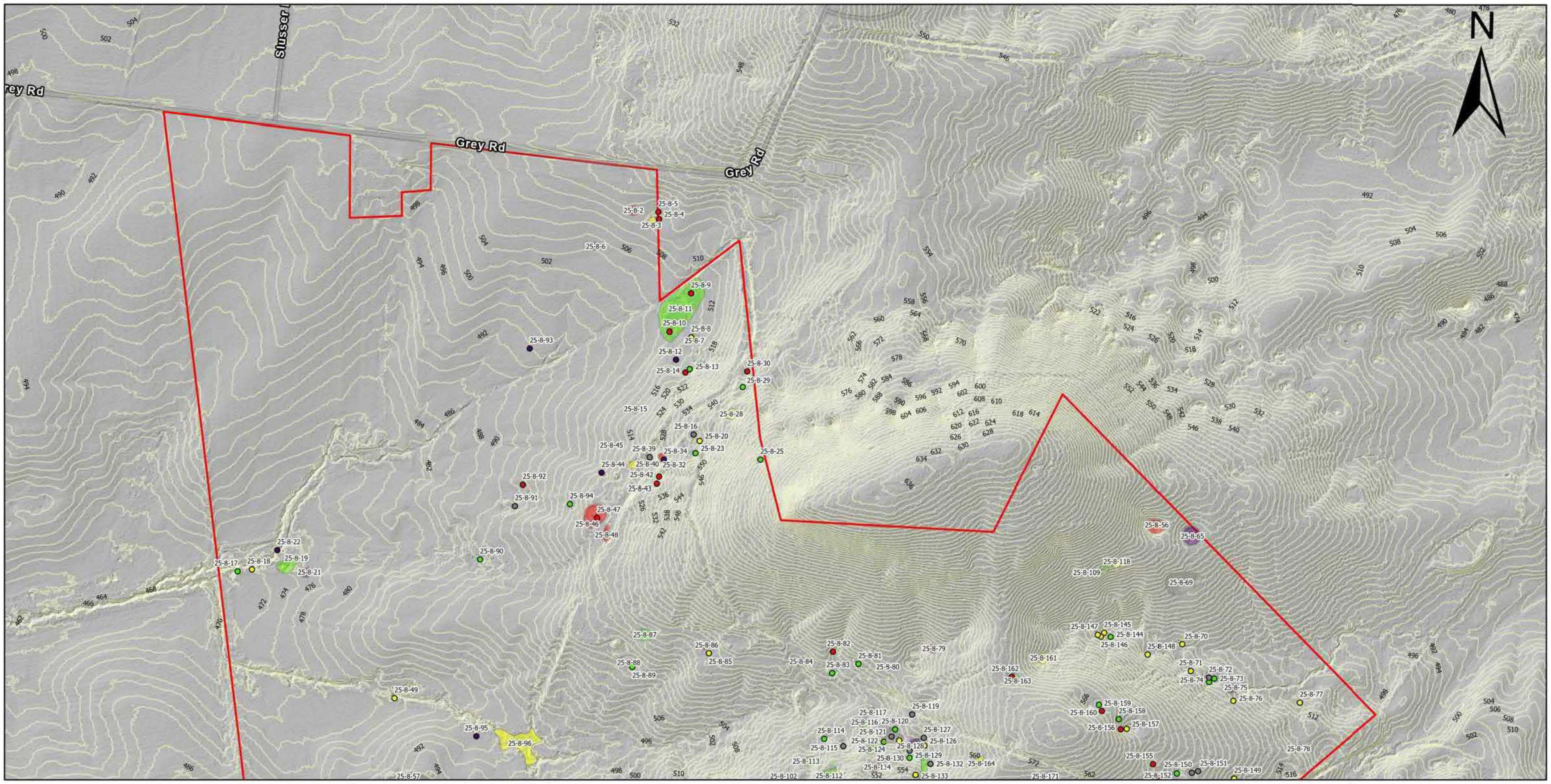
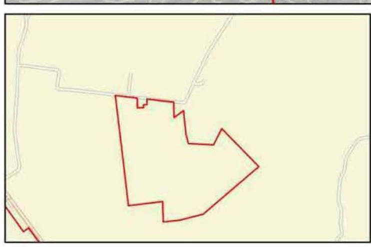
Princeton, Caldwell County, Kentucky

Exhibit
B1

Filed per 3-30-2022 ESB Order
Response to 2 ESB 01





Legend

- Property Limit
- 2 Foot Contour

Point Karst Risk

- Very High
- High
- Moderate
- Low
- Very Low

Area Karst Risk

- Very High
- High
- Moderate
- Low
- Very Low

DATA SOURCES:
ESRI WMS - World Aerial Imagery, OpenStreetMap
Parcel information based on "Caldwell-Golden Expansion Parcel.kmz" dated 4/27/2021

0 250 500 1,000
Feet

Project No.:	57215036
Date:	Jul 2021
Drawn By:	JDV
Reviewed By:	BWT

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Karst Risk Map - Hillshade

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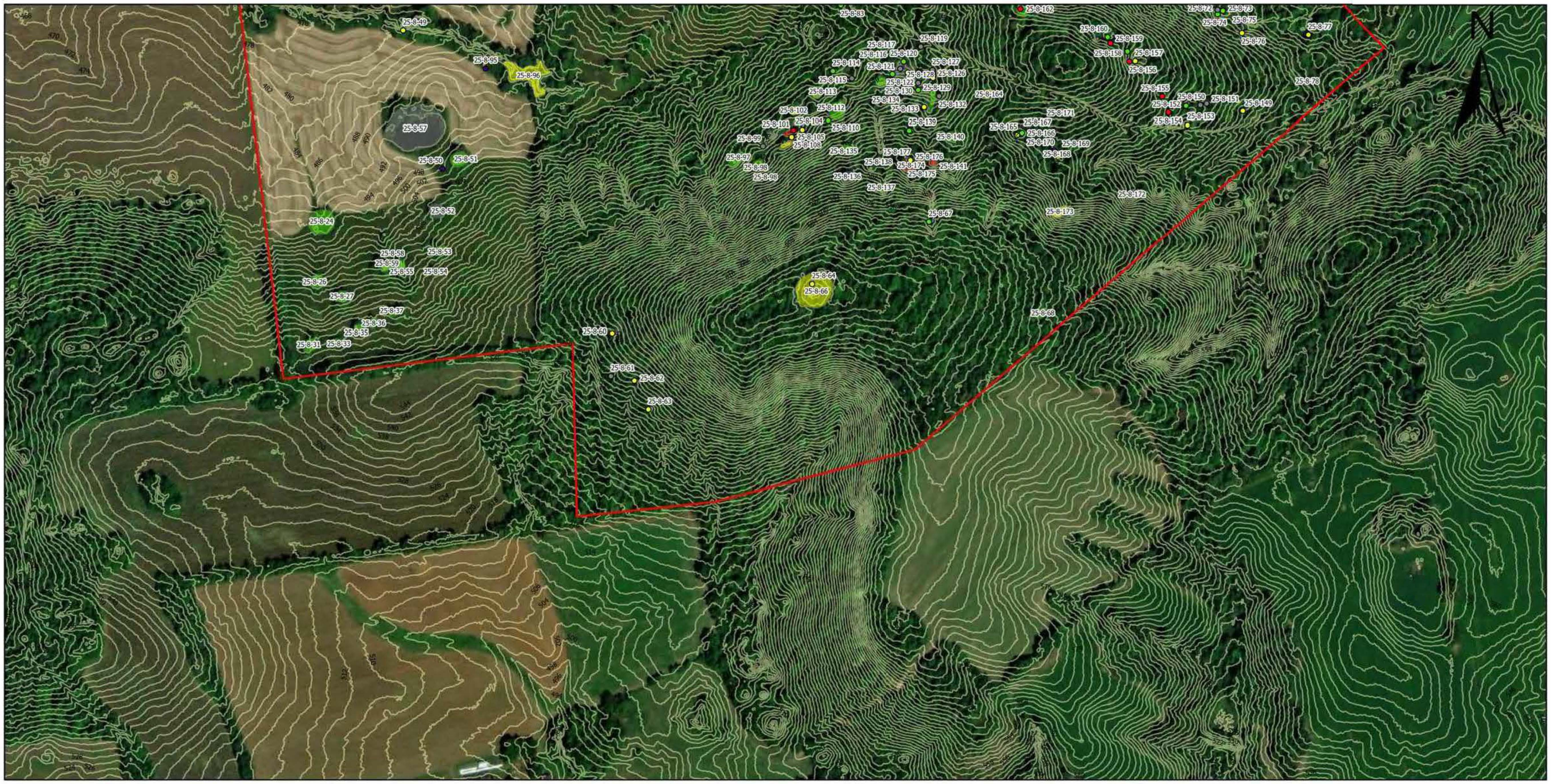
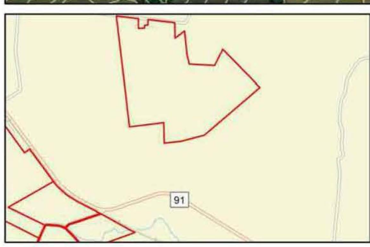
Exhibit

C1





Legend

- Property Limit
- 2 Foot Contour

Point Karst Risk

- Very High
- High
- Moderate
- Low
- Very Low

Area Karst Risk

- Very High
- High
- Moderate
- Low
- Very Low

DATA SOURCES:
ESRI WMS - World Aerial Imagery, OpenStreetMap
Parcel information based on "Caldwell-Golden Expansion Parcel.kmz" dated 4/27/2021

0 250 500 1,000 Feet

Project No.:	57215036
Date:	Jul 2021
Drawn By:	JDV
Reviewed By:	BWT

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Karst Risk Map - Imagery

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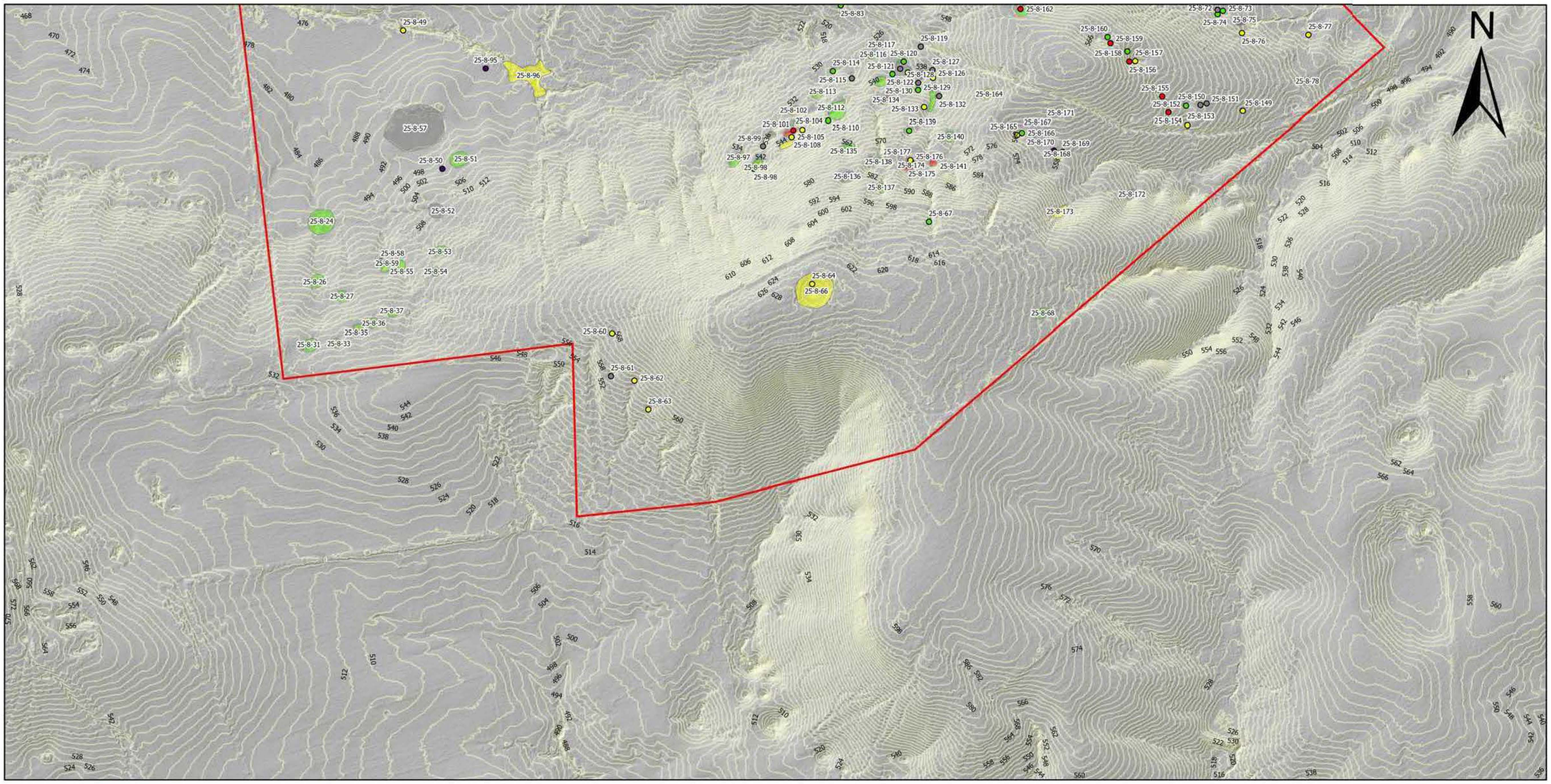
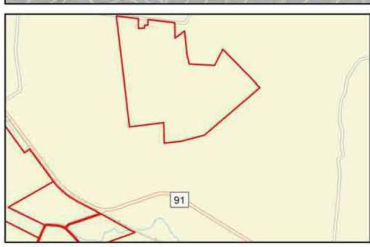
Princeton, Caldwell County, Kentucky

Exhibit
B2

Filed per 3-30-2022 ESB Order
Response to 2 ESB 01





Legend

- Property Limit
- 2 Foot Contour

Point Karst Risk

- Very High
- High
- Moderate
- Low
- Very Low

Area Karst Risk

- Very High
- High
- Moderate
- Low
- Very Low

DATA SOURCES:
ESRI WMS - World Aerial Imagery, OpenStreetMap
Parcel information based on "Caldwell-Golden Expansion Parcel.kmz" dated 4/27/2021

0 250 500 1,000 Feet

Project No.:	57215036
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Karst Risk Map - Hillshade

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Princeton, Caldwell County, Kentucky

Exhibit

C2