

Project No. ASF17-186-00  
January 8, 2018



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Hill Country Bible Church Austin - Brushy Creek Campus  
c/o Pastor Doug James  
Hill Country Bible Church Austin  
12124 Ranch Road 620 N.  
Austin, Texas 78750

**RE: Geophysical Survey Results  
Hill Country Bible Church – Brushy Creek Campus  
3000 Farm-to-Market Road 1431  
Round Rock, Williamson County, Texas**

Dear Pastor James:

**Raba Kistner Environmental, Inc. (RKEI)** has prepared this report to document the results of a ground geophysical survey performed to evaluate subsurface geologic conditions at the proposed building pad site for the Hill Country Bible Church – Brushy Creek Campus located in Round Rock, Williamson County, Texas (hereinafter referred to as SITE). A direct-current (DC) electrical resistivity imaging survey was conducted to evaluate the presence of significant karst or structural features that may be present in the shallow subsurface that could pose a concern with regard to planned construction activities within and immediately surrounding the proposed building footprint. Performance of a geophysical survey was recommended to supplement site characterization data previously developed as part of the geotechnical engineering study (*i.e.*, *Raba Kistner Consultants, Inc. Project No. AAA17-092-00, report dated 1/5/18*) and address concerns regarding the potential presence of additional solution cavities or caves below the pad site that could affect the design or construction of an approximate 24,500 square foot worship center (Phase 1) and future 31,200 square foot building addition and above-grade multi-level parking garage (Phase 2). A Project Location Map including the SITE location and previously installed geotechnical borings is provided on **Figure 1**.

This report was prepared for Hill Country Bible Church Austin (CLIENT) in support of the stated project objectives and may not contain sufficient information for other parties or other purposes. Project activities were conducted in accordance with the authorized scope of services described in **RKEI Proposal No. PSF17-471-00, dated December 12, 2017**. The following paragraphs present a discussion of project activities and associated geophysical survey results.

## **BACKGROUND**

Various geologic data themes including published surface geology, topography, Edwards Aquifer Recharge Zone (EARZ) boundaries, and recent aerial photography with respect to the proposed worship center property are also provided on **Figure 1**. Subsurface conditions at the SITE and surrounding vicinity consist of karst limestone terrain generally corresponding to the lower to middle portions of the Edwards Limestone (Ked), undivided. In the Austin, Texas region, the Edwards Limestone consists primarily of 60 to 350 feet of limestone and dolomite, which is prone to varying degrees of karstification or dissolution, particularly in areas adjacent to normal fault zones or along natural drainage features including Brushy Creek. On the basis of our recent project involvement and



discussions with the project team, we understand that the results of previous geologic mapping activities for the SITE in addition to the neighboring land parcel to the west along Farm-to-Market Road (FM) 1431 have indicated the presence of caves, solution cavities, and other zones of limestone dissolution (i.e., karst development).

Information developed by Horizon Environmental Services, Inc. for the proposed Enclave at Mayfield Ranch development (i.e., *Geologic Assessment Report dated July 2015*), which includes the SITE, indicates the presence of three cave features surrounding the proposed worship center building pad site designated as the Round Rock Breathing Cave, Klingon Cave, and Mangrove Cave, respectively. The caves have well-developed surface expressions and associated drainage and are formed at shallow depths within the Edwards Limestone. As presented on **Figure 1**, the lateral extents of the caves were mapped using conventional (i.e., tape and compass) methods. On the basis of cave mapping activities and pursuant to applicable Edwards Aquifer Protection Program (EAPP) rules administered by the Texas Commission on Environmental Quality (TCEQ), the caves are designated to represent sensitive recharge features for the Edwards Aquifer; therefore, the caves must be protected in conjunction with future phases of land development. To this end, protective natural buffer zones have been established and ground disturbance activities within these zones is prohibited pursuant to terms of the TCEQ-approved Water Pollution Abatement Plan.

The results of exploratory drilling activities conducted to date in conjunction with the current (November-December 2017) geotechnical engineering study confirm the occurrence of small karst features or solution cavities throughout the development footprint for the project generally associated with bedding unit contacts and ranging in vertical extent from approximately 0.5 to 5.5 feet. Limestone core recovery data corroborates drilling observations and indicates weathered or dissolved limestone intervals, respectively, but has not revealed the presence of large void features or sample gaps interpreted to represent caves or large solution cavities in the shallow subsurface. As further discussed herein with respect to geophysical survey results, a potential void or solution cavity was reported by the drilling team from 10.5 to 16 feet at boring B-2 on the basis of poor core sample recovery.

## **PURPOSE AND OBJECTIVES**

In light of recent assessment data and our past experience with construction activities in the Edwards Limestone in the immediate project vicinity, it is possible that other karst features are present in the shallow subsurface below the proposed development property. Consequently, performance of a phased field study was recommended, involving geophysical survey methods to further evaluate rock conditions below the building pad site for indications of large voids that could adversely impact proposed development activities (i.e., "Phase A"). As further discussed herein, it is generally recommended that potential voids and/or other karst features indicated by the nonintrusive electrical resistivity study be further explored by core borings (i.e., "Phase B") to better evaluate the implications of the feature(s) with respect to performance criteria for the building foundation system. This report was prepared specifically to document completion of Phase A study activities.

Information generated as the result of the geophysical survey was initially presented for consideration by CLIENT and our geotechnical engineering staff in email correspondence submitted on

January 3, 2017. This report was prepared to formally document geophysical survey results for use in conjunction with next phases of construction project planning.

## **GEOPHYSICAL SURVEY METHODS**

### **Selection of Electrical Earth Resistivity Survey Method**

A DC electrical resistivity imaging (DC-ERI) survey was performed because this technique can delineate areas in the subsurface where large air-filled voids or zones of weathering (i.e., limestone dissolution) may be present. Air-filled voids, which can vary in size from caves (i.e., large enough for a person to enter) to solution cavities (i.e., sub-centimeter to approximately 1 meter in scale), have a distinctly different electrical signature (e.g., more resistive) relative to the surrounding competent limestone rock mass. Clay-filled voids also have a distinctly different electrical signature (e.g., more conductive) relative to the surrounding limestone. The electrical contrasts between the karst features (i.e., evidenced by electrically conductive or resistive anomalies) and surrounding rock and soils usually create conditions favorable for geological interpretation of electrical resistivity data.

### **Geophysical Data Collection**

In accordance with the authorized scope of work, **RKEI** conducted geophysical survey activities at the SITE on December 20-21, 2017. As indicated by overlays (blue lines) on the aerial imagery presented on **Figure 1**, continuous geophysical data was collected along interconnected closely-spaced parallel survey lines (or grid boxes) positioned throughout the extent of the proposed building pad construction footprint in order to facilitate 3-D data processing. In an effort to survey the majority of the building pad area (i.e., both Phase 1 and 2 areas), individual survey grids designated as “HCBC-1 through HCBC-5”, each measuring 55 meters (180 ft) by 35 meters (115 ft), were arranged as indicated on the referenced figures. Owing to the irregular geometry of the building pad footprint, contiguous grids were oriented roughly NE-SW along the building’s long axis, as necessary to facilitate combined data reduction and modeling.

In conjunction with survey efforts, continuous measurements at a 16.4-ft (5-meter) electrode spacing were collected along survey grid lines utilizing a Syscal Pro electrical resistivity system and corresponding multi-electrode array manufactured by IRIS Instruments. The electrical properties of the geologic section beneath long survey (screening) transects the electrode grid were measured to approximate (maximum) depths of 30-40 ft below existing grade using these methods.

The data generated as the result of DC-ERI survey activities was analyzed using computerized methods to produce a 3-D block model depicting subsurface conditions below the survey grid stations. In general, deeper resistivity survey results, and results obtained along the perimeter of data collection grids were generated from fewer data points and, therefore, provide for less certainty in interpretation than results from shallower depths throughout the center of the survey areas. The decrease in resolution and certainty is also a function of diffusion of the electrical signal at depth or along the edges of the data collection grids, which is inherent to all types of surface geophysical surveys. Various color-coded renderings of the block model depicting variations in electrical resistivity were generated and interpreted with respect to areas of inferred competent rock versus areas of suspected clays, voids, or

other subsurface features of interest. Potentially significant high-resistivity anomalies considered most likely to represent discrete karst features or zones of less-competent (dissolutioned) limestone are designated in plan view on **Figures 2A through 2C – Composite and Plan View 3-D Resistivity Plots** (i.e., designated by recommended boring locations). As presented on **Figure 2D – Additional Areas of Concern**, based on calibration of geophysical survey outputs to the known occurrence of the small karst feature/void identified at boring B-2 (10.5-16 feet), three additional areas of concern were identified in resistivity data that may also correspond to small (discrete) features of concern.

### **INTERPRETATION OF GEOPHYSICAL SURVEY DATA**

Survey results were interpreted and modeled as a combined 3-D block models depicting spatial variations in subsurface resistivity. As depicted on **Figures 2A through 2D**, the block models graphically summarize and illustrate the geo-electric properties of the shallow subsurface below the proposed building pad site. The survey results are presented in units of ohm-meters (ohm-m), a measure of the electrical resistivity of the geologic section to an induced current. Measured electrical resistivity values in the shallow subsurface at the SITE range from less than 300 to over 5,000 ohm-m, which demonstrates the heterogeneity of the rock mass, but are consistent with values obtained at other project sites located over the Edwards Limestone.

As presented on **Figures 2A through 2C**, high resistivity values are generally indicated by warm colors (i.e., yellow, orange, and red) in contrast to low to intermediate values, which are generally indicated by cool colors (i.e., blue to green) on graphical data plots. The results presented on the referenced figures are displayed in different perspectives to illustrate geologic structure/conditions detected as the result of the collective survey effort. Perspectives include: 3-D block diagram with horizontal (2-D) slices, 3-D contour plot, in addition to isosurface plots in both 3-D perspective and plan view depicting areas of relatively high and low resistivity values. As indicated on **Figure 2D**, discrete features like the one identified at boring B-2 are apparently associated with isolated areas of intermediate resistivity encased in zones of low resistivity.

In order to facilitate direct comparison of measured resistivity data to the building pad footprint, plan-view plots of inverted resistivity were developed from block-model renderings of maximum and minimum resistivity data (i.e., high and low resistivity anomalies) to illustrate discrete areas considered most likely to contain significant karst features within the shallow subsurface (i.e., <30-40 feet below existing grade). As presented on **Figure 3 – Supplemental Geotechnical Boring Location Map**, based on our interpretation of collective data, areas exhibiting values greater than 2,678 to 3,405 ohm-m, respectively, are generally considered to represent primary areas of concern for the building pad area at the SITE.

Based on calibration of geophysical data to the discrete karst feature at B-2, three additional areas of concern were identified and plotted on **Figure 3**. It should be noted that geotechnical borings B-1, B-4, and B-7 were installed in close proximity to these suspected features within the plotted areas of concern, but did not encounter open voids. The absence of significant karst features in these borings supports the interpretation that karst features at these locations, if present, are discrete and not laterally-continuous.

Interpretation of resistivity data supports the following statements:

- As presented on **Figures 2A through 2C**, variations and orientations of subsurface electrical properties at the SITE are indicative of a fractured and heterogeneous limestone terrain containing subsurface zones of limestone dissolution or karstification, which is typical of the Edwards Limestone formation. The following general interpretation of geophysical data is offered based on known relationships between rock or soil type, our understanding of the specific geologic setting for this project site, and 3-D resistivity data presented on the referenced figure:
  - Low resistivity values less than about 633 ohm-m (blue colors) are generally interpreted to be associated with surface soil cover and uppermost limestone strata exhibiting relatively significant fracture development and weathering.
  - Intermediate resistivity values ranging from about 633 to 2,678 ohm-m (green to yellow colors) are generally interpreted to be associated with uniform and generally competent rock conditions within the Edwards Limestone. Although it is possible that zones with intermediate electrical resistivity values may contain (relatively small) discrete karst features (similar to the feature identified at B-2), it is not considered likely that such features are laterally-continuous over areas greater than about 2.5 meters in one direction.
  - High resistivity values greater than 2,678 ohm-m (orange to red colors) are generally interpreted to be associated with zones containing less-competent and dissolutioned limestone strata, but may also host (relatively larger) karst features that would pose a concern with respect to construction of the building foundation system (i.e., open voids including solution cavities or caves).
- As represented on **Figure 3**, potential karst zones (areas of concern) are interpreted to correspond to zones of anomalously high resistivity values. As presented on the referenced figure, areas of high resistivity (greater than ~2,678 ohm-m) depicted by yellow colors may be indicative of partially-dissolved or karst limestone containing open voids. Results indicate the presence of several high-resistivity anomalies that could be further investigated as part of the current geotechnical engineering study. It is important to note that areas of high resistivity likely do not represent large open voids, but may correlate to zones of dissolution within the same limestone bedding units that host cave features at the SITE; similar to what was observed at some locations during the drilling and sampling of past geotechnical borings.
- As indicated by the preceding discussion, inspection of the resistivity survey results in **Figure 3** generally reveals that the “uniform” host rock (i.e., the Edwards Limestone formation) has electrical resistivity values that vary by more than 2,000 ohm-m. This is interpreted to be due to changes in the lithologic characteristics of the Edwards Limestone (i.e., physical changes between limestone bedding units and attributed to post-depositional weathering processes). Despite this variability, review of the plotted 3-D resistivity block model does not indicate linear features within the dataset that would be indicative of primary geologic contacts or structural

features including normal faults or fracture zones. This is significant because development of solution cavities or cave systems within the Edwards Limestone is often associated with groundwater movement along subsurface drainage pathways or flow conduits that follow structural features or geologic contacts.

- Areas of high to very high resistivity measured throughout the study segments are considered to represent the greatest potential for significant karst development within the construction depth interval for the project. Review of 3-D block diagrams indicate that karst prone zones appear to be planar, occurring mainly at depths between 3-10 and 16-25 feet below existing grade, following individual bedding units within the Edwards Limestone. Based on similar experience, these features are likely associated with dissolution along bedding surfaces. High resistivity values are typically indicative of increased air (void) space per unit rock mass.

The inferences of the subsurface presented herein are based solely on the results of the surface-based DC-ERI survey. As further discussed in the following section, correlation with borehole data (i.e., Phase B) is one recommended approach to further substantiate the interpretations and calibrate reported resistivity data to existing conditions below the building pad site.

## RECOMMENDATIONS

On the basis of collective geophysical survey data and our understanding of the project at this time, **RKEI** offers the following recommendations:

- Consideration should be given to the installation of additional geotechnical borings in areas of concern to confirm the absence of large or otherwise significant karst conditions in the shallow subsurface below the building pad site. In order to further evaluate geophysical interpretations in conjunction with initial stages of construction, it may be advisable to install a total of 8 exploratory borings within primary area(s) of concern identified as the result of this study as indicated on **Figure 3** (i.e., designated as “geophysical borings” GB-1 through GB-8). As the inferences of the subsurface presented herein are based solely on the results of the surface-based electrical resistivity survey. Correlation with borehole data is often recommended to substantiate interpretations.
- As an alternative to the installation of additional geotechnical (GB) borings described above, consideration should be given to an initial pilot-hole program in advance of pier-shaft drilling activities. Pilot holes should be installed in an appropriate manner to supplement existing geotechnical engineering data and to establish whether areas of concern correspond to presence of significant karst features (e.g., caves or solution cavities), or possibly, fractured zones exhibiting enhanced limestone weathering or dissolution. For the purposes of this reporting, weathered or karst intervals should be interpreted as zones or layers of weak, weathered, and/or poor quality rock or containing clay-filled voids. Assuming that pilot hole program is implemented, the following additional recommendations are offered:
  - Assuming that a deep foundation system is planned for the worship center building, at a minimum, it is recommended that pilot holes be drilled at all pier shaft locations that

are planned within areas of concern (high resistivity zones) identified on **Figure 3**. Pilot holes at pier shaft locations should be installed to minimum depths on the order of 25-30 feet below existing grade.

- If a deep foundation system is planned, it is additionally recommended that pier shaft drilling activities in high-resistivity areas (comprising the area of concern) be accomplished first to more rapidly identify potentially significant karst features and/or zones of less competent rock, the presence of which would require extension of straight-shaft piers to obtain necessary skin friction values. Based on our similar experience, the early identification of potential problem areas will help to minimize long-term construction delays and facilitate a proactive as opposed to reactive approach to potential foundation design modifications.
- If a shallow foundation system comprised of spread and/or continuous footings is considered, a pilot hole program is also recommended to ensure solid bearing conditions beneath the footings at significant point load locations. In this situation, pilot holes should be installed at locations recommended by the project design team to depths on the order of 10-16 feet below existing grade.
- The results of any additional exploratory drilling and sampling (i.e., additional geotechnical or pilot hole program) should be reviewed by the geotechnical engineer in conjunction with previous assessment data for the project and considered to refine recommendations for installation of the proposed building foundation system(s) and pavements, if warranted. It is recommended that additional geotechnical engineering recommendations be provided as a supplement to the geotechnical engineering study report prepared by Raba Kistner Consultants, Inc. dated 1/5/18.

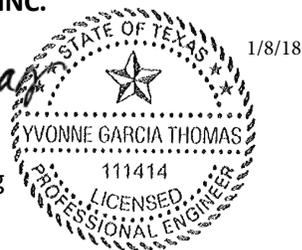
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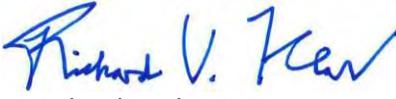
We appreciate the opportunity to have been of service on this important project and look forward to assisting the construction team with future phases of this project. Please do not hesitate to call either of the undersigned if you have any questions regarding the information provided herein.

Very truly yours,

**RABA KISTNER ENVIRONMENTAL, INC.**

  
Yvonne Garcia Thomas, P.E.  
Manager, Geotechnical Engineering

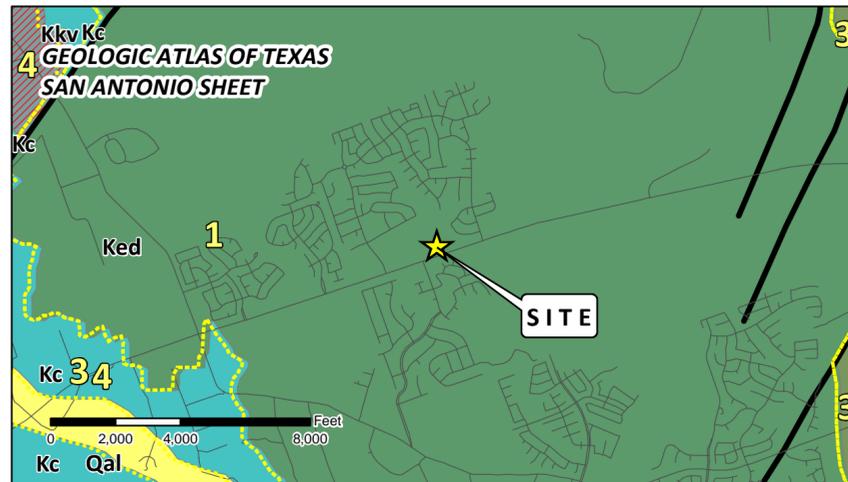
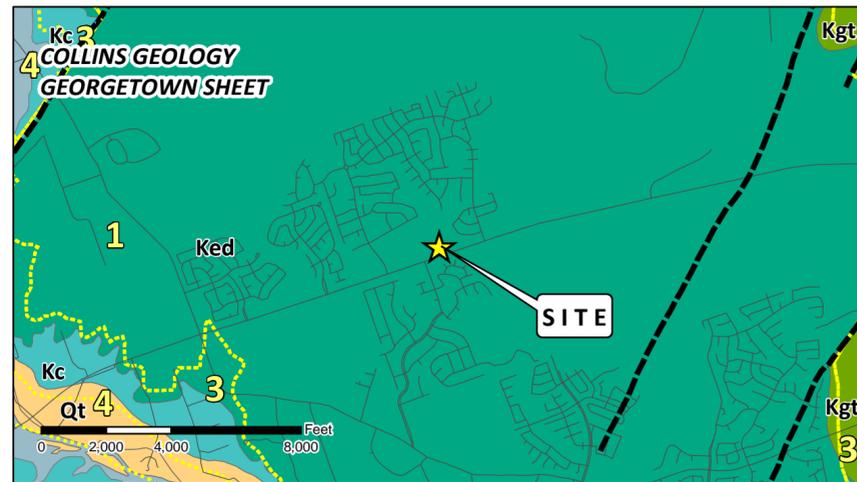
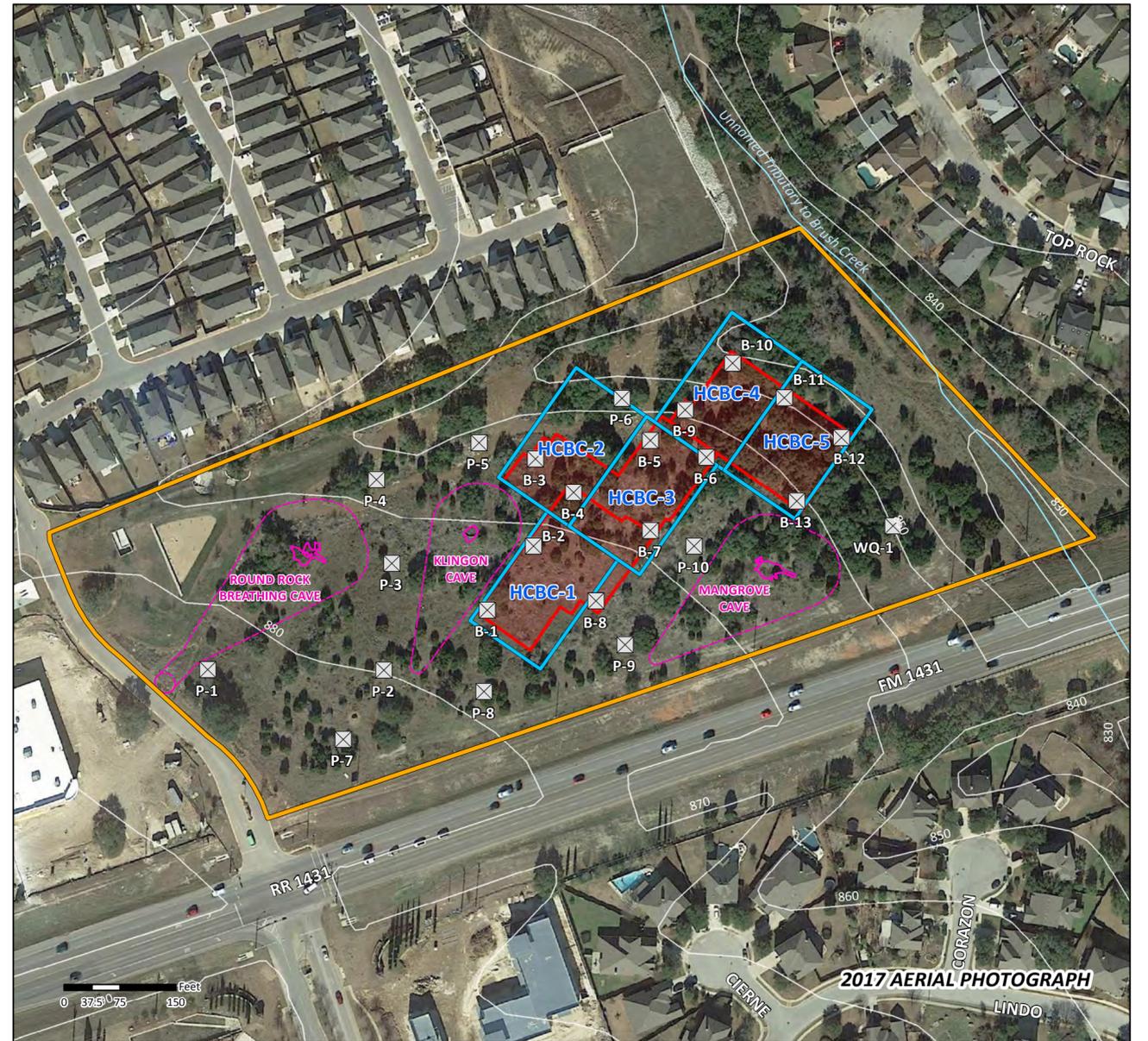
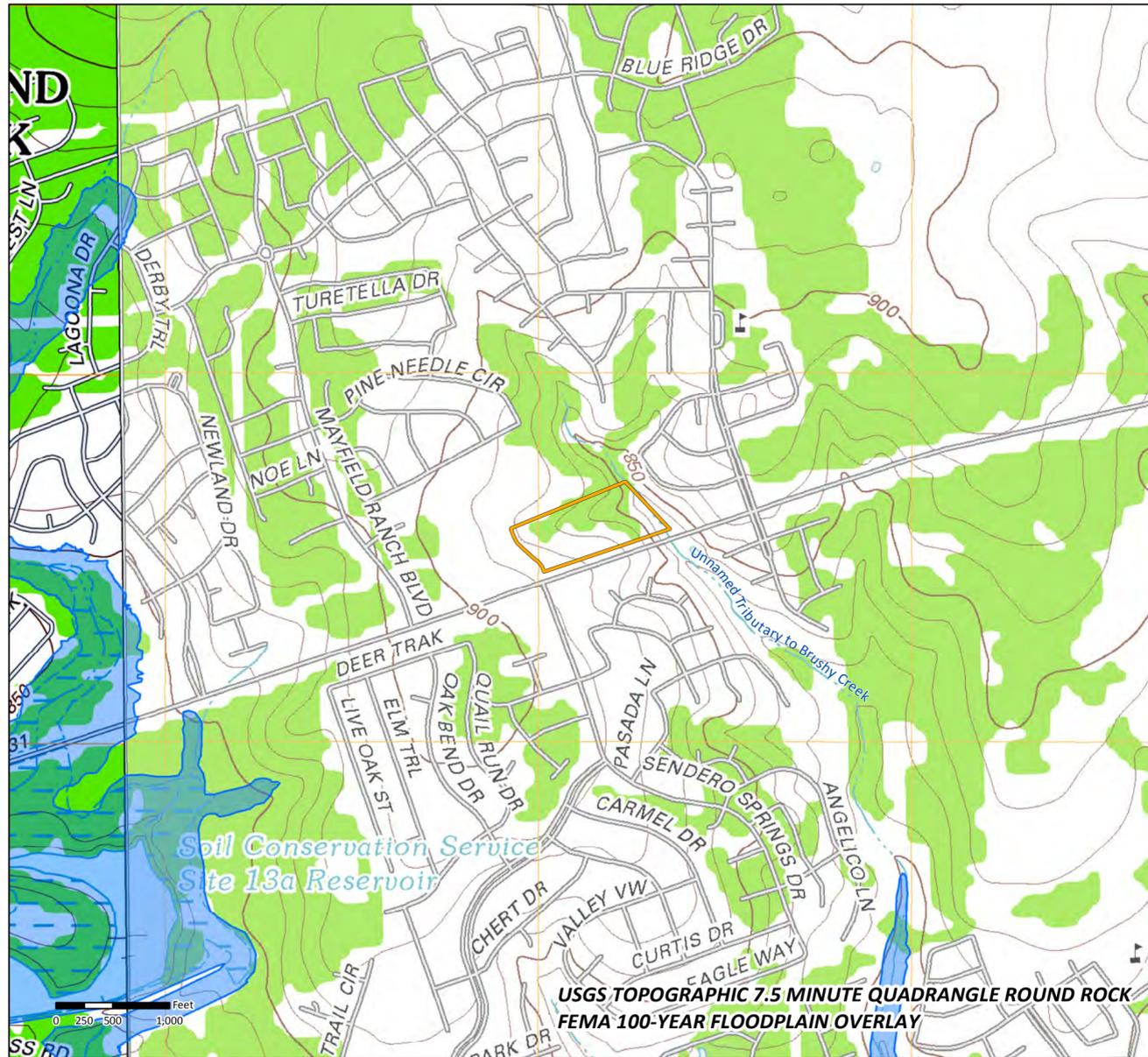


  
Richard V. Klar, P.G.  
Vice President

YGT/RVK/srw  
Attachments

Copies Submitted:      Above (1 Electronic PDF Copy)

# FIGURES



**Legend**

- ⊗ Previous Geotechnical Soil Boring (RKEI-2017)
- 10-Foot Topographic Contour
- Geologic Fault (BEG)
- Geologic Fault (GAT)
- Approximate Site Boundary
- Approximate Cave Footprint (Horizon-2015)
- Cave Buffer
- Geophysical Survey Grid
- Karst Zone
- Edwards Aquifer Boundary
- Proposed Structure
- 100-Year Floodplain

**Geologic Formation**

- Comanche Peak Limestone (Kc)
- Del Rio Clay & Georgetown Formation (Kdg)
- Edwards Limestone (Ked)
- Keys Valley Marl (Kkv)
- Alluvium (Qal)
- Georgetown Formation (Kgt)
- Terrace Deposits (Qt)



**PROJECT LOCATION MAP**  
HILL COUNTRY BIBLE CHURCH  
3000 FARM TO MARKET ROAD 1431  
ROUND ROCK, WILLIAMSON COUNTY, TEXAS

PROJECT NUMBER:	ASF17-186-00	 <b>FIGURE</b> <b>1</b>
DRAWN BY:	LAW/CCL	
CHECKED BY:	RVK	
DATE:	January 8, 2018	

SOURCE: 1) USGS 7.5 Minute Topographic Quadrangle Round Rock Provided by the Perry-Casteneda Map Collection, University of Texas at Austin - 2013  
 2) Aerial Photograph Provided by Google Earth - 2017  
 3) Geology Provided by Bureau of Economic Geology (BEG) - 2000, Geologic Atlas of Texas (GAT), Austin Sheet - 1983  
 4) Basemaps Provided by Environmental Systems Research Institute (ESRI) - 2010  
 5) 100-Year Floodplain Data Provided by FEMA Panel No. 48491C0490E - 09/26/2008  
 6) Karst Zone Data Provided by Veni - 2002  
 7) Edwards Aquifer Data Provided by TCEQ - 2005









