# KARST MITIGATION PLAN

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1. INTRODUCTION

Sabal Trail Transmission, LLC (Sabal Trail), is proposing to design, construct and operate a natural gas pipeline (the Project) that will extend approximately 509 miles through portions of Alabama, Georgia, and Florida. Mitigation is being conducted to assess and minimize karst related issues that may arise during construction and operation of the Project. Karst conditions and sinkhole development are potential issues at various locations along the proposed pipeline alignment and at pipeline facilities.

Avoidance was used as the primary mitigation measure during the planning and selection of the proposed alignment. Where avoidance is not feasible, the karst features identified were further evaluated and remediation measures developed. In addition, field survey, testing and evaluations were conducted at each of the proposed above-ground facilities (compressor and meter stations) and horizontal directional drilling (HDD) locations to evaluate design and support of the proposed facilities and the potential for sinkhole development. Response plans for sinkholes, depressions or other karst related issues that may arise during construction or operation of the Project have also been prepared and have been included as part of the overall mitigation plan.

2. KARST RISKS ASSOCIATED WITH PIPELINE CONSTRUCTION

Sinkholes are naturally occurring phenomena in areas underlain by carbonate bedrock, such as the limestone formations associated with the Floridan aquifer, in the southeastern United States. Most sinkholes are triggered by external factors such as significant or prolonged rainfall, periods of drought, heavy groundwater pumping, or stormwater management practices. Experience with pipeline installation in the area has shown that the frequency of localized subsidence occurrences will be low and the scale of the features will be small enough to ensure that remediation efforts will not be complicated. The following addresses the risks associated with different aspects of Project construction.

2.1. Pipeline

The majority of the proposed pipeline will be constructed with conventional cut and cover techniques, where a length of trench is excavated, the pipe is placed and connected to the previous section, and the trench is backfilled with material excavated from the trench. While, there is some potential for unknown karst features to be encountered during pipeline installation, the probability that these features will be large in scale or that sinkholes or surface depressions in areas outside the immediate excavation area will be low. Exposed karst features discovered during pipeline installation can be readily identified, evaluated and remediated.

Hydrostatic testing performed during pipeline construction can introduce significant amounts of water to the area. Mitigation measures for managing hydrostatic test water in the vicinity of karst features are discussed in the Remediation Section (Section 7) of this report.
2.2. Facilities (Compressor and Meter Stations)

Above ground facilities associated with the Project include compressor and meter stations. The structures associated with these facilities will be constructed with typical and proven methods utilized throughout the project area. The majority of the structures can be supported by shallow foundations bearing within compacted in-place residual soils. Compaction of the native soil used to support the building foundations will be performed from the ground surface with conventional construction equipment.

Heavier equipment or structures with larger structural loads may require support from a deep foundation system. Driven displacement piles are the proposed deep foundation system for support of the heavier project structures. Steel sections such as pipe and H-piles are preferred over concrete sections in areas where the depth to bearing may be variable. Other methods of deep foundation support include auger cast piling and drilled shaft foundations.

As an alternative to deep foundation systems for support of Project structures, ground improvement methods such as compaction grouting and vibro-replacement (stone columns) are being considered. These methods improve the subsurface materials and allow for the use of conventional shallow foundation systems such as mats, footings and slabs-on-grade. Compaction grouting can also be used as a means to reduce the potential for sinkhole development at a given site or within a proposed building footprint.

Standard stormwater management practices will be employed during design and construction of ponds required for stormwater retention/detention. However, in karst sensitive areas, shallow ponds with larger surface areas may be considered, where feasible, to mitigate the risk of affecting aquifer confining units. Ponds will be located away from structures to the extent possible or at least the distance of typical sinkhole dimensions for the area. In addition, direct rainfall on impervious areas will be diverted away from building and equipment foundations.

2.3. HDD Crossings

Sabal Trail has consulted with nationally recognized horizontal directional drilling (HDD) contractors with experience completing HDD installation in the Project’s region, as well as other karst areas, to help evaluate the potential risks to the Project and to develop mitigation measures that may be employed during construction.

Areas of karst activity pose increased risks to the successful installation of pipelines by HDD. While the risk of impacts to the environment or a failed installation may be increased in karst areas, mitigation measures, proven on other projects, have been identified and will be employed during all phases of the project from routing through construction to lower these risks to help ensure successful pipeline installations. Although there are increased risks associated with HDD installations in karst areas, numerous HDD pipeline installations have been successfully completed at sites subject to karst activity, including in central Florida. Just a few examples are Florida
Gas Transmission multiple pipeline crossings of Santa Fe River and Suwannee River in Florida, Southern Natural and Dixie pipeline crossings of Flint River in Georgia.

The general risks associated with HDD construction methods in karst areas include difficulties arising from very loose unstable soils and open voids along the drill path. More specifically, these risks include:

- Loss of drilling fluid into open conduits and inadvertent drilling fluid returns leading to turbidity in nearby wells, springs, and rivers.
- Ground subsidence and possible sinkhole formation due to excavating zones of loose unstable soils.
- Stuck drill tooling and the possibility of the carrier pipe becoming stuck in loose unstable zones during pullback.

2.3.1. Lost Drilling Fluid Returns

Drilling fluid is circulated through the drilled hole during horizontal directional drilling operations. Water based bentonite drilling fluids are an integral part of a successful HDD operation and are used to lubricate and cool the downhole tooling, suspend and transport cuttings to the surface, and stabilize the borehole by forming a thin layer of clay on the inside of the hole (wall cake). Additionally water based bentonite drilling fluids help maintain the open hole condition by offsetting the formation’s geostatic pressure with increased hydrostatic pressure. The clay in drilling fluid utilized for HDD operations is composed of bentonite, which is a naturally occurring clay mineral that absorbs several times its weight in water. When mixed with water in measured quantity, bentonite augments and optimizes the engineering properties of the mixture to support HDD operations in specified geological conditions.

While drilling fluid loss to conduit and cave systems is possible in karst affected areas, site characterization of the HDD sites does not suggest that cave systems will be directly encountered along the HDD profiles. In addition, there is only one spring located within 2,000 feet of HDD crossings (Suw923972, 4th Magnitude). It is recognized that small conduits feeding cave systems could be encountered along the HDD profiles; however, these conduits are not typically “open” but are filled with permeable sediments that create a preferential pathway for groundwater flow. In some instances, loss of drilling fluid from the borehole to these conduits will subside over time as the drilling fluid builds a layer of bentonite in the borehole and seals it to further flow. Drilling fluid properties will be managed, on a site specific basis, to ensure that they are optimal for the conditions being encountered.

The partial or full loss of drilling fluid may also occur as a result of encountering loose unstable zones of soil that have in-filled existing sinkholes or by intersecting conduits or voids. In zones of loose unstable soil, the properties’ of drilling fluid may be augmented to aid in stabilizing the soils.
and in maintaining drilling fluid returns to the entry and/or exit pits. If open voids are encountered along the HDD path, a temporary loss of drilling fluid returns can be expected until the fluid being pumped into the borehole fills the cavity and drilling fluid returns are restored. In the event that conduits intersect the HDD path, lost circulation materials (LCMs) may be used to attempt to seal the conduits and allow for the reestablishment of drilling fluid returns to the entry and/or exit pits. Many types of LCMs are available for use during HDD operations that are inert and environmentally benign. These can include wood fibers, cotton seed husks, ground walnut shells and other natural materials.

Special polymers that swell to several times their original size when introduced to water can also be used. These polymers are industrial grade equivalents of food grade polymers that are used to swell and absorb fluids in the food industry. The type of products used is typically left to the discretion of the HDD Superintendent and the Environmental Inspector. These products are readily available should the need arise.

Grout and concrete plugs have been successfully utilized to fill subsurface voids and conduits to restore drilling fluid returns and stabilize the borehole during HDD operations. The details of how grout plugs are installed are highly dependent on conditions encountered during HDD operations. There are many types of equipment, methods and materials to successfully install a grout plug and their use will be determined on a case by case basis by a specialty grouting contractor. Potential short-term impacts to groundwater quality resulting from grout plug installation would be negligible because the grout will set up after a short time.

2.3.2. Fracture and Conduit Size Limitations for HDD

Successful installation of pipelines using HDD methods requires sufficient stability of the borehole to allow the passage of the pipe during pullback operations. In mature karst areas, fractures and conduits can be present within the limestone bedrock units that could pose risks to the successful completion of the pipeline installation. When designing HDD installations in rock formations, the key characteristic of the bedrock which determines how stable the formation will be during drilling and pullback operations is the rock quality designation (RQD). Rock core samples are typically recovered from exploratory hole in 5 to 10-foot intervals referred to as core runs. RQD is a measure of the fracture spacing of the formation and is expressed as a percentage value. RQD is calculated by dividing the total length of rock core pieces over 4 inches in length recovered from a core run by the total length of the core run.

In competent rock formations, RQD values less than 50 percent provide evidence that borehole stability during HDD operations may be compromised, which introduces risk of difficulties during construction. In the karst limestone formations expected along sections of the pipeline
alignment, RQD values less than 50 percent do not necessarily present a large risk of borehole instabilities. The lower RQD values in these formations, which may be due to reduced core recovery in weathered and poorly cemented/in-filled zones of the formation that wash away or are broken during the coring process are not necessarily detrimental to borehole stability during HDD operations. The identified fracture traces that intersect the HDD crossings of the pipeline alignment may be zones where more weathering of the limestone has occurred. The weathered state of the formation does not negate the feasibility of successfully completing the installations.

Open conduits can present a risk of stuck and/or lost tooling in the borehole during HDD operations. In karst-sensitive areas, conduits in the limestone formations feed groundwater to springs in the region. Near the mouth of these springs, the conduits can be large enough to be explored by divers. Essentially, the springs are fed by irregular networks of smaller conduits that become increasingly smaller with distance from the spring. Because of the distance the HDD sites are from the nearest documented springs, as discussed in Resource Report 2, it is anticipated that any conduits encountered will be less than a few feet in size. Additionally, evidence of large open voids or conduits was not observed during site characterization activities.

When estimating the type and width of subsurface voids that can be successfully spanned, consideration must be given to the type, strength and rigidity of drilling tooling and mainline pipe. During consultations with HDD contractors experienced in karst-sensitive areas, it has been determined that open conduits or voids of approximately 15 feet or less in diameter have been successfully spanned utilizing similar tooling and in similar conditions as those expected on the proposed Sabal Trail Project. Voids of this nature can be successfully spanned because the stiffness/strength of the downhole tooling and mainline pipe is sufficient to allow drilling operations to continue without compromising the geometry of the hole, the integrity of the tooling or mainline pipe.

2.3.3. Sinkhole Development from HDD Operations

HDD operations could trigger or reactivate sinkhole activity where the borehole passes through loose, unstable soils that have in-filled existing sinkholes, where the borehole passes through the throat of an in-filled sinkhole, or where soil in-filling in conduits is removed by circulation of drilling fluid. This occurs through a process of over-mining where the loose soil continues to ravel into the drilled hole, similar to how sand passes through the constriction in an hourglass. As drilling fluid is circulated through the borehole, loose soils are entrained into the drilling fluid and carried out of the hole. This process can eventually lead to the activation or reactivation of ground settlement. Proven techniques, used throughout the HDD industry, will be implemented on a site specific basis.
3. **IDENTIFICATION OF KARST FEATURES**

Sabal Trail assembled a team of Georgia and Florida karst experts to identify and investigate karst features in proximity to the proposed pipeline alignment, above-ground facilities, and HDD crossings. The team is led by Ian Kinnear of PSI and Gregg Jones of Cardno ENTRIX. Ian Kinnear, P.E., has 36 years of geotechnical experience in and around the pipeline alignment specializing in ground improvement techniques and procedures to repair and restore areas where sinkholes have occurred. Gregg Jones, P.G., is a karst hydrogeologist with 28 years of experience investigating springs, sinkholes, fractures, and the flow system of the Floridan aquifer in north and central Florida.

The karst team contacted numerous agencies to obtain information and data including the Florida Geological Survey, the Georgia Environmental Protection Division, the Suwannee River Water Management District, and the Southwest Florida Water Management District. Potential karst features including sinkholes, fracture traces, springs and springsheds were identified by reviewing regional published geologic and geotechnical data; aerial photography; and sinkhole, closed depression, and springs databases. In addition, training of field and survey crews was conducted to assist them in identifying topographic or other indicators of possible sinkhole activity. Several features were identified during survey of the proposed alignment and facilities.

3.1. Sinkholes

Within a 0.5 mile-wide corridor centered on the proposed pipeline centerline, more than 1,500 closed depression features were identified in Florida and more than 150 were identified in Georgia. The proposed alignment in Alabama does not cross limestone formations so no karst features were identified there. Many of the closed depression features may be quarries and excavations and many are true karst sinkholes. However, the majority of these features are relatively small and located at significant distances from the centerline of the proposed pipeline.

3.2. Fracture Traces

Fracture traces were located by identifying large-scale parallel lines of sinkholes and river segments on aerial photographs. Fracture traces of significant scale that intersected the proposed pipeline alignment were identified in Florida (Hamilton, Madison, Suwannee, Gilchrist, Alachua and Levy Counties) and in the counties in Georgia where the Floridan aquifer was mostly unconfined (Terrell, Dougherty, Brooks, and Lowndes Counties).

3.3. Springs

A search of the Florida Department of Environmental Protection springs database for springs located within 2000 feet of HDD crossings was conducted. Only one spring, Suw923972, a 4th magnitude spring located approximately 1,040 feet from the HDD crossing of the Suwannee River, fit these criteria.
4. EVALUATION OF THE POTENTIAL FOR SINKHOLE DEVELOPMENT

The general geologic conditions in each county traversed by the alignment were evaluated and assigned a risk ranking (low, medium, or high) regarding the potential for sinkhole development. Due to the varied geologic conditions in some counties, they were assigned more than one category. In general the risk criteria for the three rankings are as follows:

LOW The probability of an occurrence is unlikely. Although historical occurrences may have been reported or documented in the area, they are infrequent and recent activity is low or insignificant.

MEDIUM Historical occurrences are well documented and conditions favorable to development are believed to be present.

HIGH Historical occurrences are common and frequent and conditions favorable to development are present and well documented.

Natural factors that influence sinkhole risk in any given area include the depth to rock, the composition of the overburden soils above the rock (confined with clayey soils present over the rock or unconfined with essentially sands from the ground surface to top of rock), recharge potential, presence and concentration of fractures, and the potentiometric surface elevation of the aquifer. These factors were taken into consideration while assessing the sinkhole risk in each county. The most significant human-caused influence that can significantly increase sinkhole collapse/risk in any given area is water management; either through heavy pumping of groundwater or directing significant stormwater run-off to isolated ponds.

In addition, the most common types and dimensions of surface depressions formed by sinkholes within the general area were identified. The assigned risk rankings, general geologic conditions and most common sinkholes on a county by county basis along the entire alignment are summarized in Resource Report 6.

5. EVALUATION OF KARST FEATURES

From the list of closed depression and fracture-related sinkholes in Georgia and Florida discussed previously, a subset of features thought to be representative of the types of sinkhole features that would be encountered along the alignment, were selected for further investigation and analysis. The karst features selected as being representative span sections of the pipeline alignment in Georgia and Florida and encompass cover-collapse, subsidence, and solution sinkhole-type features and various depths of aquifer confinement and cover expected along the alignment. These representative sinkholes, possible sinkhole activity identified by field crews, proposed above-ground facilities, and HDD river crossings were investigated using geophysical and geotechnical techniques to provide data that will assist with pipeline design and evaluation of karst features or activity that may affect pipeline construction or operation. These features, facilities, and river crossings are listed and discussed in greater detail in Tables 1, 2, and 3.
From the results of these investigations, mitigation measures were developed that will be utilized to insure the stability of these features if they cannot be avoided during pipeline construction. Mitigation measures are included in Section 7.

5.1. Description of Geophysical and Geotechnical Evaluations

Geophysical testing involves the subsurface site characterization of the geology and geological structure beneath the surface based on the lateral and vertical mapping of physical property variations that are remotely sensed using non-invasive technologies. Geophysical techniques are typically not utilized in more traditional geotechnical studies for pipeline construction outside of karst areas, but are considered a necessary inclusion to support mitigation measures in karst-sensitive areas.

Ground penetrating radar (GPR) and electro-resistivity imaging (ERI) surveys were used at the representative karst features selected along the proposed alignment, proposed facility sites, HDD crossings, and possible sinkhole features identified by field personnel.

When using geophysical tools, variations in properties of subsurface materials cause man-made energy wave speed changes and partial energy reflections. Variations in soil resistivity are measured and these reflections or changes are mapped to create a two-dimensional profile. Down-warping of the profile, variations in reflection depth or changes in resistivity are indications of possible raveling or sinkhole activity. These indicators are identified as anomalies in the general or typical soil profile. The term anomaly describes a layer or pocket of subsurface material that has properties different than the surrounding soil.

Advantages of geophysical testing include the ability to evaluate large areas in a short timeframe while limiting destructive or intrusive conventional sampling methods. Once anomalies, which may be indicative of deeper geologic problems, are identified by the geophysical testing, the subsurface conditions can be confirmed and further evaluated by geotechnical assessment by drilling and sampling conventional soil borings.

The geotechnical evaluation used for Sabal Trail involved the performance of soil test borings to further investigate anomalous conditions identified by the geophysical testing. The borings were carried out using rotary wash procedures and sampled using standard penetration test (SPT) procedures. The borings were extended at least 10 feet into competent limestone or a minimum of 10 feet below the deepest pipeline element or construction depth, whichever was greater, to evaluate foundation support requirements and sinkhole risk. The field data was then reviewed and an assessment was made as to whether ground improvement/modification is needed to remediate potential sinkhole formation or reduce sinkhole risk.

Used together, geophysical and geotechnical assessments provide Sabal Trail with a strong understanding of subsurface conditions and the ability to develop a confident design and construction strategy.
5.2. Pipeline Construction - Evaluation of Representative Karst Features

Each of the representative karst features was given an initial risk ranking (low, medium, or high) in general accordance with the definitions and procedure for the county rankings discussed previously. A two phase testing program was developed for each feature to further define the potential risk. The initial phase, which included geophysical testing using GPR and/or ERI, provided further insight into the depth, extent and morphology of the features and anomalous conditions that require further evaluation. The second phase included the performance of soil test borings to better define subsurface conditions and evaluate site specific conditions or indicators of current karst activity and sinkhole risk. Following completion of the geophysical and geotechnical testing, the features were given an updated risk ranking and recommendations for remediation of the feature were developed.

5.3. Evaluation of Above-Ground Facilities (Compressor and Meter Stations)

Geophysical testing was completed at each of the proposed above-ground facility sites. Subsurface conditions within the facility sites were also evaluated by drilling/sampling site specific borings. This included the performance of borings in identified anomalous areas determined from the geophysical survey as well as in proposed building footprints and areas of equipment support. The borings were carried out using rotary wash procedures and sampled using standard penetration test (SPT) procedures. The borings were extended to depths sufficient to evaluate foundation support requirements and sinkhole risk with several of the facility explorations extending into the underlying rock formation. The field data was then reviewed to determine the sinkhole risk/potential at the site with an assessment being made as to whether ground improvement/modification is needed to reduce sinkhole risk.

5.4. Evaluation of HDD Sites

At each HDD site located in karst terrain, geophysical and geotechnical investigations were conducted to characterize subsurface conditions that could be experienced during HDD operations. The geotechnical investigations consisted of completing borings offset from the pipeline alignment utilizing rotary wash and rock coring techniques to advance the borings and sample the subsurface strata. The interval between samples was reduced where deemed necessary. Geophysical investigations consisted of ERI surveys along the alignment of each HDD. Areas identified as potential karst features by the ERI surveys were targeted for further investigation by completing additional geotechnical borings. Data collected during the site investigation phase of the project was utilized during the design phase to design the HDD geometry to maximize the likelihood of successful installation and reduce the risk of impacting areas along the alignment of the HDDs.

More specifically, the following methodologies, where possible, were employed during the design phase:
The depth of HDD was designed to avoid zones that were interpreted to represent the largest potential risk to the successful installation of the pipeline while minimizing the risk of inadvertent drilling fluid returns to the surface.

The length of each HDD was developed to ensure that its associated surface work space would avoid impacts to environmentally sensitive areas while minimizing the length of the HDD drill path.

Workspace has been identified for fabrication of the pipe pull section in one continuous section so that intermediate tie-in welds will not be required during pullback operations.

6. EVALUATION OF RESULTS

The results of geophysical and geotechnical investigations are included in Table 1 for the representative karst features, Table 2 for the above ground facilities, and Table 3 for the HDD crossings. The results of these investigations were used to assist with the development of the mitigation measures outlined in section 7.

Table 1. Results of Geophysical and Geotechnical Testing of Representative Karst Features.

<table>
<thead>
<tr>
<th>Location</th>
<th>Initial Risk Ranking</th>
<th>Geophysical Results</th>
<th>Geotechnical Results</th>
<th>Current Risk Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Milepost 148.7 Spread 2 Dougherty County, Georgia Parcel Ga-DO-007</strong></td>
<td>MEDIUM</td>
<td>A closed circular depression was identified just west of proposed pipeline alignment</td>
<td>Cover-collapse sinkholes most common type in Dougherty Co. Range from 10-30 ft. in diameter.</td>
<td>None</td>
</tr>
<tr>
<td><strong>Milepost 159.8 - 161.3 Spread 2 Dougherty County, Georgia Parcel GA-DO-044.004</strong></td>
<td>MEDIUM</td>
<td>Alignment parallels well field with documented sinkholes</td>
<td>Cover-collapse sinkholes most common type in Dougherty Co. Range from 10-30 ft. in diameter.</td>
<td>ERI and GPR One anomaly identified by ERI</td>
</tr>
<tr>
<td><strong>Milepost 260.5 Spread 3 Hamilton County, Florida Parcel Fl-HA-043.000</strong></td>
<td>MEDIUM</td>
<td>Closed circular depression was identified west of proposed alignment in existing power-line easement.</td>
<td>Solution sinkholes most common type in Hamilton Co. Range from 10-30 ft. in diameter.</td>
<td>GPR Two anomalies identified</td>
</tr>
</tbody>
</table>
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</tr>
</thead>
<tbody>
<tr>
<td>Milepost 335.3 Spread 5 Gilchrist County, Florida Parcel FL-GI-078.000</td>
<td>MEDIUM</td>
<td>Several small circular depressions were identified in the vicinity of the proposed alignment. The depressions appeared to be approximately 10-15 ft. in diameter.</td>
<td>Three soil borings performed, 15-25 ft. loose-medium dense clean to silty sands underlain by fat clay (CH). Limestone formation is 33-38 ft. below grade. The upper limestone encountered was weathered to 45-50 ft. where SPT resistance values indicated hard materials. No voids or cavities in limestone formation.</td>
<td>LOW</td>
</tr>
<tr>
<td>Milepost 340 Spread 5 Alachua County, Florida Parcel FL-AL-016.000</td>
<td>MEDIUM</td>
<td>Two circular depressions identified just east of proposed alignment.</td>
<td>One soil boring performed. Encountered clean to silty fine sands to 100 ft. bls. SPT resistance values increased with depth to approx. 50-55 ft. No loss of drilling fluid.</td>
<td>LOW</td>
</tr>
<tr>
<td>Milepost 363.8 Spread 5 Levy County, Florida Parcel FL-LE-104.000</td>
<td>HIGH</td>
<td>Line of several small circular depressions identified in vicinity of pipeline centerline. Depressions generally 3-4 ft. in diam. &amp; approx. 2-3 ft. in depth.</td>
<td>Three soil borings. Alternating strata of clean fine sand, clayey sand &amp; silty fine sands to approx. 23-43 ft. underlain by clay. Limestone formation was approx. 43-48 ft. below ground surface. Losses of drilling fluid at limestone interface in borings at central &amp; northern anomalous areas.</td>
<td>HIGH</td>
</tr>
<tr>
<td>Location</td>
<td>Initial Risk Ranking</td>
<td>Geophysical Results</td>
<td>Geotechnical Results</td>
<td>Current Risk Ranking</td>
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<tr>
<td>Milepost 422 Spread 6 Sumter County, Florida Parcel GSA-FL-SUM-109.000</td>
<td>MEDIUM Two small circular ponds and a depression along possible reroute alignment. Ponds approx. 60 and 150 ft. in diam. and in line with other depressions.</td>
<td>Cover-subsidence and solution sinkholes most common types in Sumter Co. Range from 10-30 ft. in diam.</td>
<td>GPR 25 anomalies identified primarily surrounding northern pond</td>
<td>HIGH Northern pond believed to be relic sinkhole. Based on elevated risk ranking, reroute of pipeline in area abandoned. Because feature will be avoided, no mitigation necessary.</td>
</tr>
<tr>
<td>Milepost 427.4 Spread 6 Sumter County, Florida Parcel GSA-FL-SUM-119.050</td>
<td>MEDIUM Closed circular depression identified</td>
<td>Cover-subsidence and solution sinkholes most common types in Sumter Co. and typically range from 10-30 ft. in diam.</td>
<td>GPR No anomalies identified</td>
<td>LOW No indicators of potential sinkhole activity identified in geophysical or geotechnical testing</td>
</tr>
<tr>
<td>Milepost 433.3 Spread 6 Sumter County, Florida Parcel A4-FL-SUM-132.000</td>
<td>MEDIUM Series of circular depressions identified, two of which appeared to be approx. 50-60 ft. in diam.</td>
<td>Cover-subsidence &amp; solution sinkholes most common types in Sumter Co. Range from 10-30 ft. in diam.</td>
<td>GPR Three anomalies identified</td>
<td>Pending First Quarter 2015 Pending interpretation of results</td>
</tr>
<tr>
<td>Milepost 438.8 - 439.3 Spread 6 Lake County, Florida Parcel FL-LA-030.000</td>
<td>MEDIUM Series of circular depressions identified that appear to be approx. 60-150 ft. in diam., but none are directly on alignment.</td>
<td>Solution sinkholes most common type in Lake Co. and can range from 10 to 80 ft. in diam.</td>
<td>GPR Eight anomalies identified</td>
<td>Pending/ First Quarter 2015 Pending interpretation of results</td>
</tr>
<tr>
<td>Milepost 452.2 Spread 6</td>
<td>MEDIUM Solution sinkholes</td>
<td></td>
<td>GPR</td>
<td>Pending/ First Quarter 2015 Pending interpretation of results</td>
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<tbody>
<tr>
<td>Lake County, Florida Parcel FL-LA-097.000</td>
<td>Circular depression identified on alignment. Ponds located north and south of alignment &amp; identified depression.</td>
<td>most common type in Lake Co. Range from 10-80 ft. in diam.</td>
<td>One anomaly identified</td>
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Table 2. Results of Geophysical and Geotechnical Testing of Above-Ground Facilities.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>COMPRESSOR STATION</strong></td>
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<tr>
<td>Alexander City, Georgia (MP 0.0)</td>
<td>LOW Alabama Sinkhole Map (Nov. 2011), shows nearest sinkhole more than 8 miles from site. “Hackneyville, Alabama” &amp; “Alexander City, Alabama” topo. maps, show no closed depressions within 1 mile of site.</td>
<td>Sinkholes are uncommon</td>
<td>None performed</td>
<td>LOW Borings encountered clay soils underlain by silty soils to 23-42 ft. where very hard metasedimentary rock was encountered.</td>
</tr>
<tr>
<td>Albany, Georgia (MP 159.2)</td>
<td>MEDIUM Facility located adjacent to well field with documented sinkholes</td>
<td>Cover-collapse sinkholes are the most common type in Dougherty County and generally range from 10 to 30 feet in diameter.</td>
<td>None performed</td>
<td><strong>MEDIUM</strong> Borings encountered overburden of predominantly sands/clays atop continuous limestone frm. Upper few feet of sand silty becoming more silty &amp; clayey with depth. Sands grade from very loose to medium dense. Very loose to very soft conditions in borings above limestone interface. Some small voids in</td>
</tr>
<tr>
<td>Location</td>
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<td>Geophysical Results</td>
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</tr>
<tr>
<td>Hildreth, Florida (MP 269.2)</td>
<td>MEDIUM to HIGH Sinkhole potential higher in southern part of county</td>
<td>Solution sinkholes are most common in Suwanee County and typically less than 10 feet in diameter</td>
<td>limestone frm. In boring B-1, drill rods fell under own weight from approx. 93-98.5 ft. bls. Losses in drilling fluid noted between 70-95 ft. bls.</td>
<td>LOW to MEDIUM At this time, based on the results of the project specific borings, we do not consider it necessary to carry out any grouting below buildings or equipment foundations.</td>
</tr>
<tr>
<td>Dunnellon, Florida (MP 389.8)</td>
<td>LOW to MEDIUM</td>
<td>Cover-subsidence and solution sinkholes most common &amp; can be 10-30 ft. in diam.</td>
<td>Pending</td>
<td>Pending/ First Quarter 2015 Pending interpretation of results</td>
</tr>
<tr>
<td>Reunion, Florida (MP 474.4)</td>
<td>LOW</td>
<td>Cover-subsidence sinkholes are most common and</td>
<td>GPR and ERI Three anomalies identified by Borings indicate overburden of interbedded clean fine sands &amp; silty fine sands. Clay</td>
<td>LOW to MEDIUM Given difficulties experienced in completing deep borings &amp; presence of</td>
</tr>
</tbody>
</table>
# KARST MITIGATION PLAN

<table>
<thead>
<tr>
<th>Location</th>
<th>Initial Risk Ranking</th>
<th>Geophysical Results</th>
<th>Geotechnical Results</th>
<th>Current Risk Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transco Hillabee</td>
<td>LOW</td>
<td></td>
<td>layers encountered in some borings at 33.5 ft. b.s. &amp; just above limestone from. Sand &amp; clay soils extend to 65-70 ft. b.s. Zones of wt. of hammer material in overburden soils in borings BH-2 and BH-8/BH-8A. In several deeper borings, shells encountered. Circulation lost in these materials and localized ground collapse during initial drilling. Below overburden soils limestone present. &amp; is sandy silty, very hard &amp; well-cemented. SPT blow counts in limestone ranged from 9-50 bpf for no sample spoon penetration.</td>
<td>very loose/soft zone at 20-35 ft. b.s, some ground improvement may be necessary to support the proposed structures on conventional shallow foundations.</td>
</tr>
<tr>
<td>Tallapoosa County, Alabama (MP 0.0)</td>
<td>LOW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FGT Suwanee Suwannee</td>
<td>MEDIUM to HIGH</td>
<td>Solution sinkholes</td>
<td>GPR</td>
<td>LOW to MEDIUM</td>
</tr>
</tbody>
</table>

## M&R STATIONS

**Transco Hillabee**

- Sinkholes are uncommon
- None performed

**Tallapoosa County, Alabama (MP 0.0)**

- Solution sinkholes
- Not Applicable ("N/A")

**FGT Suwanee Suwannee**

- Borings indicate overburden of
- LOW to MEDIUM

Based on results of Alexander City Compressor Station.
<table>
<thead>
<tr>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>County, Florida (MP 299.7)</td>
<td>most common and typically less than 10 feet in diameter</td>
<td>11 anomalies identified</td>
<td>inter-bedded layers of clean fine sands, slightly silty fine sands, silty fine sands, clayey sands, and clays. Overburden soils extend to 60-105 ft. bsls. Based on SPT blow counts, sands graded in very loose to medium-dense condition. Clays varied from soft to medium-stiff consistency. Wt. of rod materials encountered in boring B-1 between 80-95 ft. bsls. Below overburden soils, limestone present at 60-105 ft. bsls. Variation in depth to limestone fairly typical for Suwannee Co. Limestone is sandy silty rock, locally very hard and well-cemented. Material is porous and part of Floridan Aquifer. Blow counts in limestone typically 50 blows for no sample spoon penetration. Loss of drilling fluid in boring B-1 at approx. 98 ft. bsls and in boring B-2 at approx. 60 ft. bsls near depths at which overburden soils contact limestone. Borings drilled without need for temp. casing.</td>
<td>the results of the project specific borings, we do not consider it necessary to carry out any grouting below buildings or equipment foundations.</td>
</tr>
<tr>
<td>Location</td>
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<td>Geophysical Results</td>
<td>Geotechnical Results</td>
<td>Current Risk Ranking</td>
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<tr>
<td>FSC Osceola County, Florida (MP 474.4)</td>
<td>LOW</td>
<td>Sinkholes that do develop are typically shallow, small to large in diameter (10'-80') and develop gradually. Cover-subsidence type sinkholes are most common.</td>
<td>Borings indicate overburden of layers of clean fine sands, slightly silty fine sands, silty fine sands, silts and clays. Overburden extended to 60-65 ft. bls. Sands varied from very loose to medium-dense with occasional dense to very dense layers. Dense &amp; very dense layers consisted of slightly silty sand or silty sand &quot;hardpan&quot;. Silts and clays encountered beginning at 35-40 bls &amp; stiff to very stiff. Shell at 60-62 ft. just above limestone. Circulation lost in this strata. Upper limestone at site is sandy silty, locally very hard and well-cemented, porous &amp; part of Floridan Aquifer. In boring FSC-1, SPT blow counts in limestone &gt; 50 blows for no sample spoon penetration. In boring FSC-2, wt of rod material was 65 ft. bls. The other N-values in limestone ranged between 13-50 bpf.</td>
<td>LOW to MEDIUM Given the indicated presence of an anomaly and our experience with conditions at the adjacent Reunion Compressor Station Site, some ground improvement may be necessary to support the proposed structures on conventional shallow foundations.</td>
</tr>
<tr>
<td>Gulfstream Osceola County, Florida (MP 474.4)</td>
<td>LOW</td>
<td>Sinkholes that do develop are typically shallow, small to</td>
<td>GPR Two anomalies were identified</td>
<td>LOW to MEDIUM Given the indicated presence of an anomaly and our experience with conditions at the adjacent Reunion</td>
</tr>
</tbody>
</table>
## KARST MITIGATION PLAN

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</thead>
<tbody>
<tr>
<td>FGT Hunters Creek Orange County, Florida (MP 13.1)</td>
<td>LOW</td>
<td>large in diameter (‘10’-’80’) and develop gradually. Cover-subidence type sinkholes are most common.</td>
<td>Sands extend to 65 ft. bsl and varied from very loose to medium-dense with occasional dense to very dense layers. Dense and very dense layers consisted of a slightly silty sand or silty sand hardpan. Shell layer was encountered at 60 ft. bsl just above limestone. Circulation lost within shell strata. Limestone is sandy silty, locally very hard, well-cemented, porous &amp; part of Floridan Aquifer. SPT blow counts in limestone &gt; 50 blows for no sample spoon penetration to about five inches of penetration. Borings did not encounter open voids or weight of rod material.</td>
<td>Compressor Station Site, some ground improvement may be necessary to support the proposed structures on conventional shallow foundations.</td>
</tr>
<tr>
<td>DEF Citrus County Citrus County, Florida (MP 21.4)</td>
<td>MEDIUM</td>
<td>Solution sinkholes most common and typically are less than 10 feet in diameter</td>
<td>Pending/First Quarter 2015 Pending/First Quarter 2015 Pending/First Quarter 2015 Pending/First Quarter 2015</td>
<td>Pending interpretation of results</td>
</tr>
</tbody>
</table>
Table 3. Results of Geophysical and Geotechnical Testing for HDD Crossings.

<table>
<thead>
<tr>
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<th>Geotechnical Results</th>
<th>Current Risk Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Withlacoochee CCL MP 1.27</td>
<td>LOW</td>
<td>Solution sinkholes most common and typically are less than 10 feet in diameter</td>
<td>ERI and SBP Six anomalies were identified</td>
<td>Borings indicate very loose to medium dense silty and clayey sands and very soft to medium stiff clays overlying poorly to moderately indurated limestone and wackestone. Top of limestone at 20-28 ft bls. Borings did not encounter voids or wt of rod materials. LOW – Installation of pipeline at site feasible but some construction difficulties expected with loss of drilling fluid returns during HDD operations being greatest. Large voids not anticipated along HDD path, but drilling fluid loss to smaller voids or zones of loose material expected. Mitigation measures outlined in this document will increase likelihood of successful installation.</td>
</tr>
<tr>
<td>Withlacoochee MP 229</td>
<td>LOW</td>
<td>Solution sinkholes most common and typically are less than 10 feet in diameter</td>
<td>ERI and GPR Three anomalies were identified</td>
<td>Borings indicate loose to medium dense sands with variable silt content &amp; stiff to hard clays overlying poorly to moderately indurated limestone. Top of limestone 25- 45 ft bls. Drilling fluid returns lost at approx 61, 55, 22, &amp; 51 ft in WRH-B-1, WRH-B-2, WRH-B-3 &amp; WRH-B-5, respectively. Voids ranged from 1-3 ft thick vertically. MEDIUM – Installation of pipeline at site feasible but construction difficulties expected with loss of drilling fluid returns during HDD operations being greatest. Large voids not anticipated along HDD path, but drilling fluid loss to smaller voids or zones of loose material such as those encountered in borings expected. Mitigation measures outlined in this document will increase likelihood of a successful installation.</td>
</tr>
<tr>
<td>Flint River</td>
<td>MEDIUM</td>
<td>Solution sinkholes most common and typically are less than 10 feet in diameter</td>
<td>ERI and SBP 14 anomalies were identified</td>
<td>Borings on west side of crossing indicate soft to very stiff clay, loose to medium dense clayey sand, medium dense sand, &amp; hard sandy clay overlying very loose to very dense sand. Boring B-1 encountered wt of rod material at approx 68 &amp; 88 ft bls &amp; possible void at approx 108 ft bls. Approx 70 ft of MEDIUM – Installation of pipeline at site feasible but construction difficulties expected with loss of drilling fluid returns during HDD operations &amp; localized ground settlement being greatest. Large voids not anticipated along HDD path, but drilling fluid loss to smaller voids or zones of loose material such as those encountered in borings expected. Mitigation measures outlined in this document</td>
</tr>
</tbody>
</table>
7. MITIGATION OF CONSTRUCTION RELATED KARST ISSUES

The following is a discussion of mitigation measures that will be employed to reduce the frequency, magnitude, and severity of karst related issues that may arise during construction of the pipeline and above ground facilities and during HDD operations.

7.1. Pipeline Construction

7.1.1. Hydro –Testing

To reduce the potential for sinkhole development during hydrostatic testing, the test water from a new pipe will not be discharged directly into the vicinity
of a known karst feature open to the surface. The water will be discharged down-gradient of identified karst features. If site conditions prevent a down-gradient discharge, the water will be discharged as far from the karst feature as practicable with a discharge and sediment and erosion control features detailed in the Project Erosion and Sediment Control Plan (ESCP). Post-construction monitoring will ensure proper re-vegetation and restoration of these areas.

7.1.2. Ground Subsidence or Sinkhole Formation

As required by Code 49 of Federal Regulations, Part 192.613, route surveillance will be conducted during construction and operation of the facilities, along with training of surveillance personnel, to monitor the pipeline alignment for evidence of subsidence, surface cracks, or depressions which could indicate sinkhole formation. Signs of sinkhole formation, ground subsidence or surface depressions will be immediately and clearly marked. Work will be temporarily halted and the immediate area around the depression evacuated until it is deemed safe and stable. The project geotechnical engineer will also be notified of the occurrence.

Based on the direction of the geotechnical engineer, the area may be backfilled with clean sand fill to temporarily stabilize the area until further evaluation can be conducted. This may include geophysical and/or geotechnical testing.

In some cases, pipeline construction will necessitate the backfilling of closed depressions without visible openings/voids at the ground surface and depressions with karst voids or openings exposed to ground surface. A common approach is to infill these features with clean sand. Backfill activity would consist initially of vegetation removal and placement of a clean sand fill. If it is an “open hole” with no readily visible bottom, an effort should be made to use water to aid in the filling process.

If sand infill does not provide for a stable subgrade for pipe support, compaction grouting may be required. Compaction grouting is a common method of remediating ongoing active or potential sinkhole formation. The process involves installing pipe by driving or drilling into the area of concern and injecting grout under pressure to fills voids, cavities and soft zones within the limestone formation. As the pipe is withdrawn, grout is continually pumped to stabilize any loose or raveled soils in the overburden by compression and compaction. To effectively stabilize the feature without pumping excessive amounts of grout, a volume limit is typically established for each hole. If the limit is reached, secondary or tertiary points are added to ensure the feature is stabilized.

Based upon the final remediation method the alignment of the pipe maybe modified.
7.2. Above-Ground Facilities (Compressor and Meter Stations)

Site specific measures to assure structural integrity in the facility areas will be used. Similar to other industrial facilities in the immediate area founded over karst conditions, reinforced grade beams and slabs capable of spanning small drop outs, or utilizing deep foundations (piles or drilled shafts) that extend into competent rock may be used. In the event of a drop out, heavily reinforced grade beams and slabs can be placed after the completion of hole in-filling and compaction grouting.

7.3. HDD Crossings

During construction, the Chief Inspector, HDD Superintendent and other members of Sabal Trail’s inspection staff will maintain close communication regarding daily progress and any potential karst features (zones of concern) that may have been encountered. Close communication between all members of the construction staff will be important to ensure that all possible risks are addressed and accounted for in the drill plan. The following sections outline methods that will be employed during construction to minimize negative impacts associated with HDD activities in karst-sensitive areas.

7.3.1. Pilot Hole

During pilot hole operations, the following measures will be employed to help determine if the condition of the formation along the HDD drill path indicates that a zone of concern has been encountered.

- Rates of penetration and resistance to forward progress will be monitored for zones of loose soils or open voids indicating that zones of concern may be present. A decrease in the resistance required to advance the bottom hole assembly could indicate a zone of loose, unstable soils or open voids.
- The pilot hole driller/surveyor will monitor the steering inputs required to advance the pilot hole along the alignment and profile of the HDD path. Zones where larger steering inputs are required to advance the pilot hole within acceptable tolerance could indicate a zone of loose, unstable soils or open voids.
- Drilling fluid returns will be monitored. A loss of drilling fluid returns may indicate where loose, unstable zones or open voids and/or conduits are located along the drill path and that the bottom hole assembly is entering a karst feature.

The following actions will be taken if, based on the above observations, it is believed that zone of concern has been encountered along an HDD drill path.
The location and extent of the zone of concern will be documented so that it can be considered relative to subsequent drilling activities.

The zone of concern will be targeted for surface monitoring along the HDD alignment during drilling operations.

Observations made during pilot hole operations will be used to modify the original drill plan for subsequent HDD operations.

The HDD contractor will make all reasonable attempts to maintain drilling fluid returns. If the integrity of the borehole or the HDD profile geometry becomes compromised through attempts to restore drilling fluid returns, the HDD contractor will notify Sabal Trail. If it is determined that further attempts to restore drilling fluid returns may compromise the HDD installation or are unlikely to be successful, the HDD contractor will proceed with modified drilling procedures to reduce the risk of inadvertent drilling fluid returns.

In the event of inadvertent drilling fluid returns, the Best Drilling Practices Plan for the Sabal Trail Project will be followed.

In the event of ground subsidence, the area will be monitored and backfilled with sand if feasible. Topographic surveys will be conducted if nearby structures may be impacted.

If drilling fluid loss downhole affects nearby springs or rivers and complete drilling fluid loss to the formation cannot be prevented, all or a portion of pilot hole would be abandoned and a new pilot hole started at an alternate depth. Drilling will continue and the affected waterbody will be monitored in accordance with the Best Drilling Practices Plan for the Sabal Trail Project

If practical, an increased rate of penetration through zones of loose, unstable soils will be used to limit the risk of inadvertent returns.

Twenty four hour HDD operations may be implemented to help maintain stability of the hole within zones of concern.

7.3.2. Reaming and Swabbing

During reaming operations, the following measures will be employed to help determine if the condition of the formation along the HDD drill path indicates that a zone of concern has been encountered.

Rates of penetration and rotary torque on the downhole drill pipe string can be monitored for zones of loose material indicating where zones of concern may be present.

Drilling fluid returns will be monitored. A loss of drilling fluid returns may indicate where loose, unstable zones or open voids
and/or conduits are located along the drill path and that the reaming assembly is entering a karst feature.

The following actions will be taken if, based on the above observations it is believed that zone of concern is encountered along an HDD drill path.

- The location and extent of the zone of concern will be documented so that it can be considered relative to subsequent drilling activities.
- The zone of concern will be targeted for surface monitoring along the HDD alignment during drilling operations.
- The observations made during reaming operations will be used to modify the original drill plan for subsequent HDD operations.
- The HDD contractor(s) will make all reasonable attempts to maintain drilling fluid returns. If the integrity of the drilled hole becomes compromised through attempts to restore drilling fluid returns, the HDD contractor shall notify Sabal Trail or their authorized representative. If it is determined that further attempts to restore drilling fluid returns may compromise the HDD installation or are unlikely to be successful, the HDD contractor should proceed with modified drilling procedures to reduce the risk of inadvertent drilling fluid returns.
- In the event of inadvertent drilling fluid returns, the Best Drilling Practices Plan for the Sabal Trail Project will be followed.
- In the event of ground subsidence, the area will be monitored and backfilled with sand if feasible. Topographic survey will be conducted if nearby structures may be impacted.
- If drilling fluid loss downhole affects nearby springs or rivers and complete drilling fluid loss to the formation cannot be prevented, reaming operations will continue and the affected waterbody will be monitored in accordance with the Best Drilling Practices Plan for the Sabal Trail Project.
- Increased rate of penetration through zones of loose, unstable soils will be used to limit the risk of inadvertent returns and over-mining of loose soils.
- Twenty four hour HDD operations may be implemented to help maintain stability of the hole within zones of concern.
- The HDD contractor will employ modified reaming practices to limit impacts and maximize the chances for a successful installation.

7.3.3. Pullback

To maximize the chances of a successful installation, pullback operations will commence immediately following one or more acceptable swab passes.
which indicate that the hole is in a condition to accept the carrier pipe. The HDD Superintendent, in consultation with the STT Inspection Team, will make the determination as to when the reamed borehole has been adequately prepared for installation of the pipeline. Pullback operations will be carried out on a 24-hour basis until the completion of pipe installation.
8. GLOSSARY

- BLS or BGS – an abbreviation for below surface or below ground surface.
- Carrier Pipe – pipe designated to contain and carry the product, in this context - natural gas
- Compaction Grouting – a grouting technique that displaces and densifies loose granular soils, reinforces fine grained soils and stabilizes subsurface voids or sinkholes, by the staged injection of low-slap, low mobility aggregate grout.
- Cut and Cover – a pipeline construction technique where a trench is excavated, the pipeline is laid in the trench then the trench is backfilled.
- Drill Tooling – HDD tooling used to drill a pilot hole or ream (increase the diameter of) the hole for the carrier pipe installation. This tooling includes the drill pipe, drill bit and or reaming tools and stabilizers.
- Drilling Fluid - a water-based drilling fluid consisting of water and bentonite (a naturally occurring clay mineral). The drilling fluid is pumped downhole during drilling operations to remove soil and rock cuttings from the hole, stabilize the hole and cool and lubricate the downhole tooling.
- Drilling Fluid Returns – Drilling fluid that is pumped downhole through the drill pipe to the drill bit or reaming tool and travels to the entry and/or exit sides of the crossing via the annulus of the drilled hole.
- Electric Resistivity Imaging (ERI) – also known as electric resistivity tomography (ERT), a geophysical technique for imaging sub-surface structures from electrical resistivity measurements made at the surface, or by electrodes in one or more boreholes.
- Ground Penetrating Radar (GPR) - a geophysical method that uses radar pulses to image the subsurface.
- HDD pullback – A process of pulling the carrier pipe through a previously reamed hole.
- Magnitude – in case with natural springs, a classification method based on the volume of water the spring discharges; the 1st magnitude springs discharge more than 100 cubic feet of water per second, 2nd magnitude springs discharge between 10 and 100 cubic feet of water per second
- Mitigation – the action of reducing severity or seriousness of something. In the context of this plan, karst mitigation is a set of actions intended to reduce a probability and/or impacts associated with karst terrain.
- Standard Penetration Test (SPT) - an in-situ dynamic penetration test designed to provide information on the geotechnical engineering properties of soil.