

# Karst Features and Hydrogeology of the Proposed Sabal Trail Natural Gas Transmission Pipeline Withlacoochee River Crossing - Hamilton County, Florida

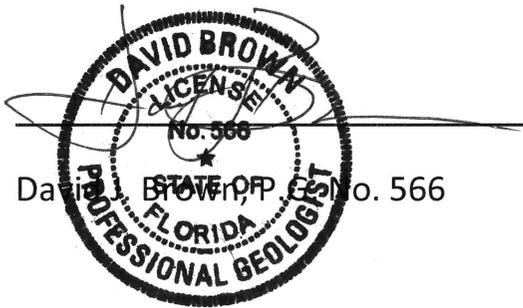


August 2014

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Sabal Trail Natural Gas Transmission Pipeline  
Withlacoochee River Crossing - Hamilton County, Florida

This report is respectfully provided to help inform the Federal Energy Regulatory Commission and other interested parties in their assessment and understanding of the potential risks to the public's health, safety and welfare; water resources; and the natural environment posed by the Sabal Trail Natural Gas Transmission Pipeline crossing of the Withlacoochee River in Hamilton County, Florida.

The findings included herein are presented on behalf of concerned landowners and are based upon sound geologic principals and hydrogeologic data available at the time the analysis was performed. The information presented is considered to be accurate and is based upon the interpretations of David J. Brown, P.G. a State of Florida Registered Professional Geologist, and is certified pursuant to Chapter 492, Florida Statutes, (FS) and Chapter 61G16, Florida Administrative Code, F.A.C.



Cover photograph: Rabbit Hole Spring (Vent No. 1) located within the Withlacoochee River channel in the vicinity of the proposed pipeline corridor taken June 28, 2014.

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## Abstract

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The Sabal Trail Natural Gas Transmission Pipeline project proposes a crossing of the Withlacoochee River in Hamilton County, Florida (Withlacoochee River Crossing). The subject site is a unique karst hydrogeologic environment, including numerous spring vents, cave and fracture systems, which make it exceptionally susceptible to adverse impacts due to the proposed pipeline both during and after construction.

It is imperative that the pipeline owner/operator, their customer base, and adjacent and nearby property owners be assured by knowledgeable professionals that underground transmission pipelines are located, designed and constructed to the highest engineering standards possible to safeguard against adverse impacts. Given this fundamental principle, areas considered highly karstic should be avoided due to their inherent instability. Karstic terrains not only present highly problematic conditions for construction, but once in operation, sinkhole development in proximity to a highly pressurized transmission pipeline could result in potentially disastrous consequences.

The unique hydrogeology of the proposed Withlacoochee River crossing site; characterized by active sinkholes, spring vents, cave systems, siphons, swallets, estavelles, and karst valleys; presents an exceptionally high potential for collapse and sinkhole activation during Horizontal Directional Drilling and related pipeline installation activities, and also exhibits a highly significant potential for future collapse during pipeline operation due to the occurrence of extensive cave and fracture systems.

Proper due-diligence in geologically unstable areas with high potential for catastrophic pipeline failure demands that such areas be eliminated from proposed pipeline corridors. Such improved planning can serve to simultaneously achieve the benefits of supporting natural gas as an alternative energy source in the State of Florida, while avoiding unnecessary risk and potential liability.

## Introduction

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The unique hydrogeology of the proposed Withlacoochee River crossing site with its numerous spring vents, cave and fracture systems, siphons, swallets, estavelles, and karst valleys not only presents an exceptionally high probability for sinkhole activation during pipeline installation, but also exhibits a highly significant potential for future sinkhole development over the operational lifetime of the pipeline. The existence of such numerous karst features clearly distinguishes the crossing site as being highly unstable and therefore must preclude the location from consideration.

It is vitally important that the Federal Energy Regulatory Commission's decision regarding the proposed transmission pipeline be made in accordance with sound engineering and geological principles and the specific goals and objectives of State and Federal regulations and environmental policies in light of the field observations, published documents, and information presented herein. The Author understands that a

geologist reporting to the Federal Energy Regulatory Commission and a professional geologist employed by Sabal Trail Transmission, LLC (Sabal Trail) were made aware of local residents' concerns during an observational field trip on March 26, 2014. To date, the high level of risk and danger associated with the proposed crossing site does not appear to have been recognized as recent field activities indicate that the proposed Withlacoochee River crossing is still being considered.

The following report is therefore provided to offer a greater understanding of the complex hydrogeologic setting and highly-altered nature of the Suwannee Limestone at the proposed Sabal Trail transmission pipeline crossing of the Withlacoochee River. As of the date of this report, the proposed pipeline's primary route is oriented in a northwest-southeast direction and crosses the Withlacoochee River approximately 14 miles south of the Florida state line, approximately 1.5 miles north of U. S. Highway 90 and approximately 1.5 miles west of County Road 141 as shown in **Figure 1**.

Sabal Trail's priority route parallels the western boundary of an existing powerline easement in Section 10, Township 1 South, Range 11 East, and transects the Withlacoochee River at the county line between Hamilton and Madison Counties. The confluence of the Withlacoochee River and the Suwannee River (an Outstanding Florida Water) is approximately 3.5 miles downstream of the proposed crossing site. As shown on **Figure 1**, the report's detailed Study Area is centered on the crossing location and is approximately 0.8 square miles in area.

## Karst Terms and Definitions

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The karst terms used in this report are in accordance with the United States Environmental Protection Agency's (EPA) 2002 report entitled "A Lexicon of Cave and Karst Terminology with Special Reference to Environmental Karst Hydrology" and several definitions from the report are provided below.

**alluvium.** A general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water as sorted or semisorted sediment in the bed of the stream or on its floodplain

**anastomotic cave pattern.** A type of maze cave consisting of tubular passages or holes in a cave or in a solution-sculptured rock. A complex of many irregular and repeatedly connected passages. Synonym: labyrinth.

**artesian flow.** Flow through a confined aquifer where the elevation of the overlying aquiclude is locally depressed so that the entire aquifer is saturated and the flow is under hydrostatic pressure. Some maze cave development in cavernous limestones may be due to artesian flow.

**base of karstification.** Level below which karstification has not occurred.

**cavern porosity.** A pore system having large, cavernous openings. The lower size limit, for field analysis, is practically set at approximately the smallest opening that an adult person may enter.

**estavelle.** An intermittent resurgence or exurgence, active only in wet seasons. May act alternatively as a swallow hole and as a rising according to ground-water conditions. Opening in karstic terrane which acts as a discharge spring during high potentiometric surface and as a swallet during low potentiometric surface.

**fracture pattern.** The spacial arrangement of a group of fracture surfaces.

**karst.** A terrane, generally underlain by limestone or dolomite, in which the topography is chiefly formed by the dissolving of rock, and which may be characterized by sinkholes, sinking streams, closed depressions, subterranean drainage, and caves.

**karst topography.** Topography dominated by features of solutional origin. Geomorphically, the dominant features usually but not always obviously present are sinkholes and caves.

**karst valley.** 1. Valleys in karst are normally distinctive due to the lack of integrated surface drainage. Most are either blind (due to being closed where the drainage sinks underground), headless or pocket (where a river emerges from a spring) or dry (where surface flow has been lost due to underground capture). 2. Elongated solution valley in limestone. 3. Valley produced by collapse of a cavern roof.

**karst window.** Depression revealing a part of a subterranean river flowing across its floor, or an unroofed part of a cave.

**leaky aquifer.** An aquifer overlain or underlain by semipermeable strata from or into which water will flow.

**potentiometric surface.** An imaginary surface representing the total static head of ground water and defined by the level to which water will rise in a piezometer or well.

**secondary porosity.** Porosity of some lithologic material that has developed after the rock was initially formed, such as joints and fractures, and may be capable of enlargement by dissolution processes.

**siphon.** Synonym for a sump, or a section of flooded cave passage, in common parlance. True siphons, where water flows first up and then down are rare in caves, as the fractures in limestone tend to disrupt the required hydraulics.

**solution subsidence.** 1. Any subsidence due to solution of underlying rock but particularly the subsidence of parts of a formation into hollows or pockets of an immediately underlying soluble formation. 2. A crater-like doline in rock other than karst limestone, formed by surface subsidence above solutionally enlarged fissures in a sub-surface karst limestone stratum.

**spongework cave pattern.** A complex maze cave pattern consisting of irregular interconnecting cavities with intricate perforation of the rock. The cavities may be large or small.

**spring.** Point where underground water emerges on to the surface, not exclusive to limestone, but generally larger in cavernous rocks.

**swallet, swallow hole.** A place where water disappears underground in a limestone region. A swallow hole generally implies water loss in a closed depression or blind valley, whereas a swallet may refer to water loss into alluvium at a streambed, even though there is no depression.

## Hydrogeology of the Study Area

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The Study Area, the southwest section of Hamilton County and parts of nearby of Madison County, is located within the Gulf Coastal Lowlands physiographic province. The Gulf Coastal Lowlands is the largest physiographic province in the State of Florida and extends along the coast of the Gulf of Mexico throughout much of the state. Elevations are generally low and range from less than 45 feet above mean sea level (msl) to approximately 100 feet msl on the landward side of the province. The tannin-stained Withlacoochee River, which originates in

Georgia, flows southerly across the Cody Scarp and intersects the Suwannee River to the south. Limestone in Hamilton County south of the Cody Scarp is thinly covered and generally not confined.

In the Study Area, the Withlacoochee River meanders in an easterly direction through an incised valley of Oligocene Age Suwannee Limestone, which is readily observed along river bank exposures. The Suwannee Limestone represents the top of the upper Floridan Aquifer, which is reported to be one of the most productive aquifers in the world (USGS) and is the primary aquifer utilized for groundwater withdrawals in the area. The potentiometric surface of the upper Floridan Aquifer varies seasonally, with elevations exceeding land surface in and around the river's incised channel resulting in numerous springs that contribute significantly to its baseflow (see report cover). Along the river banks, the Suwannee Limestone is nearly completely exposed. However, outside of the floodplain, the Suwannee Limestone is generally overlain by a thin veneer of unconsolidated siliciclastic sediments, typically less than 15 to 20 feet in thickness, composed of variable percentages of undifferentiated clays and sands. Locally, the thickness of the overlying sediments can vary due to irregularities in the upper surface of the limestone.

These unconsolidated sediments do not comprise a viable confining unit and the upper Floridan is considered a leaky aquifer within the Study Area. In the flood plain it is common to observe eroded limestone boulders and rubble (alluvium) above the limestone unit's upper contact as a result of active weathering through continuous dissolution and erosion. The upper Suwannee Limestone is highly altered and exhibits pronounced secondary porosity and in many areas cavernous porosity. The unit is extremely fractured and preferential weathering and erosion of these features most likely influences the channel's alignment and migration.

As shown below, the Suwannee Limestone outcrops nearly at land surface in the Study Area and is reported to reach thicknesses in excess of 150 feet in Hamilton County (Rupert, 1989). It is typically off-white to pale yellow-orange in color and can be highly fossiliferous with foraminifera, mollusk and echinoid fossils common. The Suwannee Limestone is also variably hard, with silicified interbeds of chert and dolomite which can have great impact on the proposed drilling operations.



**(Left) Exposed upper contact of the Suwannee Limestone (Floridan Aquifer) 300 feet west of the proposed Sabal Trail Pipeline crossing. A spongework cave pattern is clearly evident. (Right) A sample of the Suwannee Limestone obtained from the Study Area with a dense, hard, silicified (dark gray) section exposed. Scale is in inches.**

To better understand the methods used in this study, several structural geology terms must also be defined. A “*Fracture Trace*” is a line drawn on a map to denote the presence of an underlying fracture or zones of fractures

and indicates the feature's azimuth, i.e., direction or angle of bearing. Fracture traces also reflect zones of increased weathering and permeability (Diodato, 1999). In the Study Area there appears to be a strong correlation between the presence and number of adjacent karst features, whose shape and orientation denote a preferred direction, and the occurrence of enhanced permeability via fractures. Several of the karst features investigated were found to be structurally related and are excellent examples of fracture traces. Larger, more extensive fracture systems composed of multiple fracture traces or prominent karst features, i.e., karst valleys, can also be drawn on maps. Such features are often called "Lineaments" and they can extend for miles, depending on the rock type(s) and geologic history of an area. Based on the work performed as part of this study, two lineaments composed of fracture traces, fracture systems, cavern systems and springs are located in proximity to, and intersect the location of, the proposed pipeline crossing, greatly increasing the potential for adverse impacts.

"Subsidence Sinkholes" or solution subsidence features were also identified in the Study Area and are common to regions where limestone is thinly covered. Subsidence sinkholes are formed by the process of dissolution of the underlying limestone, where cavities develop below land surface resulting in a sag or collapse of overlying sediments. Cavities in underlying rock are responsible for virtually all sinkholes in Florida (USGS). Karst Windows are somewhat different than Subsidence Sinkholes and represent depressional openings that reveal subterranean groundwater flow, or the exposed portion of a cave or vertical window (FGS 2003). Based on the Author's work in the Study Area, it is possible that karst windows begin as subsidence sinkholes and developed over time through continued erosion and subsidence along preferential groundwater flowpaths.

Collectively, alignments of exposed fractures, sinkholes and karst windows can be used to infer "Fracture Traces", and since these features can often be associated with several fractures or groups of fractures, they can sometimes also be described as "Fracture Systems". Larger, more extensive Fracture Systems composed of multiple fracture traces and other prominent karst features, i.e., karst valleys, can also be drawn on maps as lineaments. Such features play an important role in groundwater flowpaths and the occurrence of springs.

## Karst Features Identified in the Study Area

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In the Study Area, the Suwannee Limestone is typically soft with a highly irregular upper surface, pockmarked with fissures, vugs (rock cavities), and solution features created by the excavating effects of water on the soluble rock. Close inspection of the exposed limestone surface reveals numerous small fractures and cracks interconnecting larger voids and cavities, resulting in cavernous porosity in many areas. Due to the minor thickness of overlying unconsolidated sediments, subsidence sinkholes dominate the Study Area. Several subsidence sinkholes were found to be active, with recently fallen trees, exposed roots and loose, raveled soils. The active subsidence observed is most likely triggered or accelerated by fluctuating river stage, whereby surface water intrudes into depressional areas and flushes loose unconsolidated sediments from cavities and solution features in the Suwannee Limestone, further weakening the feature and promoting collapse.

Karst topography, resulting from the dissolution of the Suwannee Limestone, dominates the Study Area and numerous subsidence sinkholes and dozens of depressions were identified in field inspections. Based on reports from cave divers at Morgan Spring, the base of karstification may extend throughout the thickness of the Suwannee Limestone to depths in excess of 200 feet below land surface (ft bls). This depth is most likely well below the depth for Horizontal Directional Drilling (HDD) proposed for the subterranean pipeline crossing of the

Withlacoochee River. Based on topographic information and Sabal Trail's recently drilled exploratory boreholes, the HDD will extend for approximately 2,500 lineal feet (approximately ½ mile) underneath the Withlacoochee River and will be performed at depths of shallower than 110 ft bls. If correct, this indicates, that the pipeline will be located above the base of karstification and well within the vertical range of solution features and fractures.

Two prominent elongated depressional features were identified in the Study Area and appear to be karst valleys, one of which lies directly underneath the proposed pipeline's alignment and within the section proposed for the HDD river crossing. The parallel nature of both karst valleys, that trend in a virtually identical northwest to southeast azimuth direction, may be indicative of parallel fracture systems and extensive solution activity in the underlying limestone. For the purposes of identification in this report, these features have been identified as the Thunderhole Karst Valley and the Power Line Karst Valley.

Both features are associated with and located in proximity to numerous karst features, including spring vents, estavelles, karst windows and subsidence sinkholes. Karst valleys should be considered as highly unstable and prone to collapse and sinkhole development. Due to its complex structural character there is an extremely high potential for collapse and sinkhole activation at the Powerline Karst Valley during HDD and related pipeline installation activities, but also this particular site exhibits a highly significant potential for future collapse due to the depth of karstification and occurrence of extensive cave and fracture systems in close proximity to the pipeline alignment. Thunderhole Karst Valley and Power Line Karst Valley are easily identified on **Figure 2**.



**(Left)** Cavernous solution features evident in the exposed Suwannee Limestone at land surface. This solution feature is one of several located along the power line easement, within the floodplain north of the river, and is approximately 100 feet west of the proposed HDD alignment. **(Right)** This cavernous feature is located to the west of the power line easement, near the Withlacoochee River. Such features can transmit large quantities of surface water into underlying fractures and cavern systems during higher river stages and can easily enlarge and contribute to future sinkhole development.



**(Left) Active subsidence sinkhole in the Study Area, with fallen trees, exposed roots and loose, raveled soils. (Right) Another active subsidence sinkhole within the Study Area showing recent raveling of soils into the exposed cavity. Both features were observed in close proximity to the proposed Sabal Trail gas pipeline alignment and are considered extremely unstable.**

The unique karstic terrain of the proposed Withlacoochee River crossing site presents an extremely high potential for collapse and sinkhole activation during HDD and related pipeline installation activities and should be abandoned. Conversely recent exploratory drilling activities appear to indicate a desire by Sabal Trail to move forward with this location as a means to cross the Withlacoochee River. Implementation of the proposed project at this location could provide disastrous.

## Springs Identified in the Study Area

The number of springs identified in the Study Area clearly identifies the site as hydrologically unique. As shown on **Figure 2**, there are at least 11 springs in close proximity to the proposed pipeline crossing. Some of these features flow only during a rising or falling river stage which indicates a dynamic relationship between surface water and groundwater. At times some of these features apparently act as estavelles, whereby they discharge during high potentiometric surface events and become swallets when the potentiometric surface is low. Artesian flow from the springs is facilitated by preferential flowpaths created by subsurface solution features, caves and fracture systems and based on discussions with a local cave diver; several of the springs may be interconnected by a complex series of passages over hundreds of feet in length. This interconnectivity increases susceptibility for adverse impacts from the proposed HDD drilling operation and there appears a very high probability that the interconnected cave systems would facilitate uncontrolled HDD fluid (drilling mud) discharges into the Withlacoochee River.

In an effort to increase awareness of the spring features in the Study Area, representatives from the SRWMD were notified to verify that that all features identified as part of this study were accounted for in their springs database. The Author understands that three (3) new springs were added to the database for the Study Area based on these recently-identified springs. The increased awareness and protective measures concerning safeguarding springs in Florida mandate that these features be protected from adverse impacts, especially those related to HDD.



**(Left)** Discharge from the Crack Spring located 380 feet east of the proposed HDD pipeline crossing. **(Right)** Little Spring located along the bank of the Withlacoochee River, west of the proposed pipeline alignment. A small diameter PVC pipe has been introduced into Little Spring by a nearby landowner and is presumably used to supply drinking water.

Several springs are notable in the area; however Morgan Spring is located approximately 1,000 feet west of the pipeline alignment and is within the study area. Morgan Spring is a well-known cave diving site and is listed in the Florida Springs Database and in the Cave Atlas. It is privately owned and the cavern system has been mapped by several renowned cave divers, including Tom Morris with Karst Environmental Services, Inc. and the late Wes Skyles. The landowner of Morgan Spring has copies of Mr. Skyles' original hand-drawn maps and plots of the cave system at Morgan Spring and a similar map can be found on the Cave Atlas website. A simplified cave map of Morgan Spring was obtained from the SRWMD and is included on **Figure 2**. Based on the SRWMD plot, the Morgan Spring cave system extends in a northerly direction and then angles to the east towards the pipeline alignment. The Morgan Spring cave system is reported to connect with other springs in the area and has been determined to exceed 200 feet in depth. The occurrence of extensive cave systems in the vicinity of the proposed pipeline alignment provides additional support for the pipeline's relocation. Several of the springs identified as part of this study are shown below.



**(Left)** The boardwalk located at Morgan Spring facilitates access for cave divers during variable river stage. The spring vent is located beyond the boardwalk and flows westerly towards the Withlacoochee River. **(Right)** The spring vent for Morgan Spring with several submerged logs visible below the water surface. The cave system at Morgan Spring is extensive and is reported to extend to depths in excess of 200 ft bls.



**(Left) Rabbit Hole Spring (Vent No. 2) located within the Withlacoochee River, west of the proposed pipeline alignment. (Right) Corbett Spring located along the northern bank of the Withlacoochee River, east of the proposed pipeline alignment. Corbett Spring appears to be associated with two prominent karst windows and multiple subsidence sinkholes located immediately to the north.**



**(Left) Chaplin Spring located within the Withlacoochee River, west of the proposed pipeline alignment. (Right) Sidemount Spring located downstream of Chaplin Spring, in the Withlacoochee River. Anastomotic cave pattern is clearly evident within both springs.**

Based on the field observations, it is extremely possible that drilling fluid discharges from HDD will occur at the Crack Spring and the River Vent due to their proximity to the proposed pipeline crossing. In fact, locals often refer to the River Vent as the “Power Line Spring” given its closeness to the easement. Given the alignment of the Power Line Karst Valley, the River Vent and the Crack Spring, it is exceedingly likely that the highly fractured Suwannee limestone could also collapse, resulting in sinkhole formation within or near to the river channel.



(Left) Surface boil from the spring identified as the River Vent. (Right) Underwater view from the River Vent's fractured opening looking back at the surface of the river. Several fallen logs are visible in the background. This feature is believed to be associated with Crack Spring, and is located immediately to the east of the proposed pipeline crossing.

## LIDAR Imagery

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To better understand and assist in the field investigation of topographic expressions of karst features within the Study Area, Light Detection and Ranging (LIDAR) imagery was obtained from the SRWMD. LIDAR is a remote sensing technique that uses an aircraft-mounted pulsed laser to measure variable distances (ranges) from the aircraft to land surface. The reflected laser pulses generate a well-defined, three-dimensional representation of land surface features. Due to the incredibly high number of pulses LIDAR can penetrate through and around vegetation and forest cover. The large amount of topographic data generated by LIDAR allows for the creation of highly-accurate computer generated color shaded maps depicting land surface elevations.

Gradual shifts in LIDAR imagery color represent gradual changes in land surface elevation, whereas abrupt changes in color likewise represent abrupt changes in land surface. LIDAR imagery is therefore extremely useful in the investigation of unique landforms, particularly karst features. As shown in **Figure 3**, the corresponding LIDAR image of the Study Area clearly portrays the complex coloration denoting a highly karstic terrain. LIDAR imagery has incredible value in the investigation of karst landforms, even in heavily forested areas. When georeferenced surface features such as springs, subsidence sinkholes, and fracture traces are plotted on top of the LIDAR imagery, a better understanding of complex karstic terrains is achievable.

In the Study Area, LIDAR imagery indicates land surface elevations ranging from a high of approximately 89 feet NAVD88 to a low of 34 feet NAVD88 at the river shoreline. In the LIDAR imagery included in this report, the highest land surface elevations in the Study Area are depicted as white. These same areas exhibit thicker, sandier soils and may play an important role in the recharge of down-gradient discharge areas and springs. As shown in **Figure 3**, LIDAR indicates that land surface slopes downward towards the river with the corresponding LIDAR colors ranging from red, to yellow to green and finally to light blue at river itself. LIDAR is particularly useful in identifying surface water flow channels, including those associated with springs. The Thunderhole Karst Valley and the Power Line Karst Valley are clearly seen as well as their relationships to nearby springs and subsidence features. As shown, the pipeline and HDD proposed alignment will occur along the axis of the Power Line Karst Valley. Alignment of the pipeline along this feature should be considered highly dangerous and

extremely inappropriate. Based on the LIDAR imagery, field observations, the alignment of the Withlacoochee River and the two karst valleys, two parallel lineaments have been identified within the Study Area and are located in proximity to, and at the intersection of, the proposed pipeline river crossing, greatly increasing the potential for adverse impacts. The two lineaments are shown on **Figure 3**.

The close-up LIDAR images portrayed in **Figure 4** clearly show several subsidence sinkholes that are located to the west and immediately east of the proposed HDD alignment. The features indicate a preferred alignment as shown by the linear groupings. Using the observations made in the field and a similar analysis of LIDAR imagery allows for the fracture trace analysis presented in **Figure 3**. As shown, the Study Area has a complex system of sinkholes, fracture traces, and lineaments that further indicate the instability of the area and the high potential for sinkhole activity during pipeline installation and during the pipeline's operational lifetime.

## Geologic Considerations Supporting Pipeline Relocation

It is the author's understanding that in July 2014, a geotechnical drilling contractor performed a total of four (4) test borings to depths of approximately 110 ft bls, with three (3) test borings located on the north side of the Withlacoochee River and one (1) test hole performed on the south as shown on **Figure 5**. Using the borehole locations and land surface elevations derived from LIDAR, it appears that HDD will occur over approximately 2,500 feet (approximately 0.5 miles) in order to cross underneath the river, including lands owned by the SRWMD. Landowners' conversations with the drilling foreman indicated that many difficulties were encountered within the Power line Karst Valley and one of the test boreholes near the river collapsed and resulted in the drill rods being temporarily stuck at a depth of approximately 90 ft bls. Similar conversations made with the driller indicated that the site included some of the most difficult drilling conditions he has ever experienced.

The landowner's comments regarding the difficulties reportedly encountered by the drill crew are not surprising given the highly fractured and silicified nature of the Suwannee Limestone which can result in lost, or poor, drilling fluid circulation and borehole collapse. Given that the test holes represent a vertical sample of subsurface formations and do not horizontally cross the highly unstable section of the upper Suwannee Limestone, the difficulties encountered during vertical test drilling are predicted to be much more severe and problematic during HDD. Such difficulties will most likely affect the drilling fluids (drilling muds) used to stabilize the HDD borehole. Inadvertent HDD fluid returns are expected to occur and are often referred to as "hydrofractures" or "frac-outs". Given the highly karstic nature of the proposed HDD alignment, the possibility of a hydrofractures is considered extremely high.

Such difficulties during drilling are also proportional to the diameter of the borehole. The test boring diameters are small and represent a mere fraction (potentially less than 0.5%) of the diameter of the HDD borehole. Since borehole diameter has a great impact on drilling advancement, the large diameter of the HDD borehole is predicted to experience much more severe collapse issues and loss of drilling fluids. Given the highly fractured nature of the limestone, it is likely that a HDD borehole collapse or hydrofracture could occur in close proximity, or even underneath, the Withlacoochee River.

Once drilling fluid circulation is lost, the HDD borehole will become unstable and will have a very high potential for collapse. Also, it is important to note the test borings appear not to have penetrated to the depths of the local cave system mapped by divers at Morgan Spring. The cave passage depths determined by divers indicates

that cavernous voids extend to depths in excess of 200 ft bls. Over the lifetime of the pipeline, these cavernous voids could result in future sinkhole development potentially causing a catastrophic pipeline failure.

A review of the *ASTM Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit under Obstacles, Including River Crossings* (F1962-11) indicates that such crossings are major events and require extensive and thorough surface and subsurface investigations including bottom contours of the river to characterize stability and suitability for the design life of the pipeline. Such investigations are also recommended to extend both upstream and downstream of the proposed crossing to better understand the geologic setting. According to the ASTM standard, the overall technical and economic feasibility of a HDD project is dependent upon the nature of sediments at the crossing site and is a major factor in the consideration of such a crossing.

The ASTM guide goes on to state that in cases where substantial problems may occur, including areas with transitions from non-lithified material or cavities into rock (i.e. limestone), an alternative drilling location should be chosen. Given the high number of karst features, caverns, fracture systems and the difficulties reported to be experienced by test drilling, it is imperative that an alternate location be identified since the proposed site fails on all aspects of sound geologic principles.



**(Left) Track-mounted drill rig performing geotechnical drilling north of the Withlacoochee River. (Right) A second exploratory drill hole being performed along the HDD alignment, north of the Withlacoochee River.**

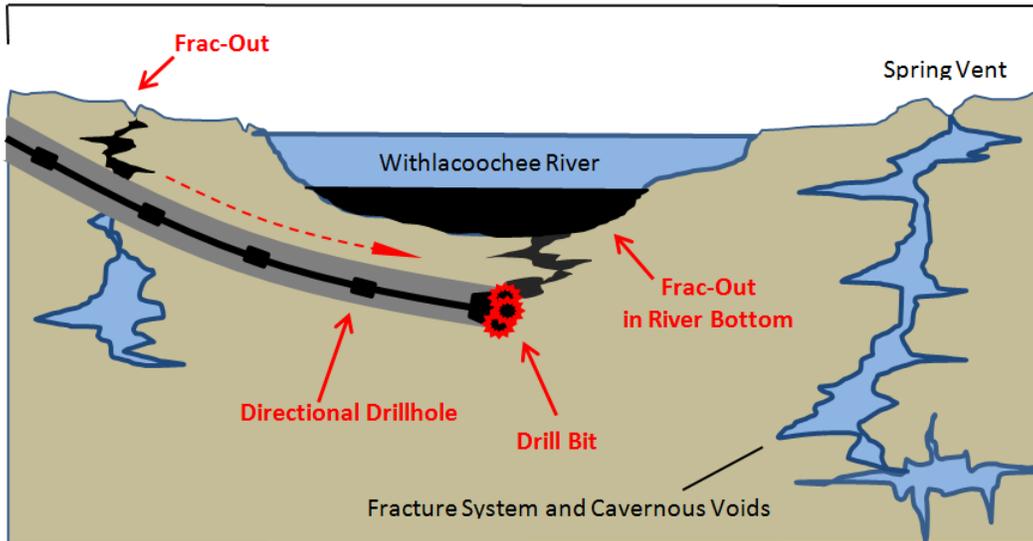
## Conclusions and Recommendations

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The Sabal Trail transmission pipeline is proposed to be installed in an area that is clearly unsuitable and incompatible. The crossing site is highly karstic and is characterized by active sinkholes, spring vents, cave systems, siphons, swallets, estavelles, and karst valleys. These features are clear evidence of the exceptionally altered and weathered nature of the site and are indicative of the active and continuous dissolution of the Suwannee Limestone and subsequent formation and enlargement of sinkholes. Construction and operation of a natural gas pipeline in this area introduces a much greater likelihood of failure and a significant potential to

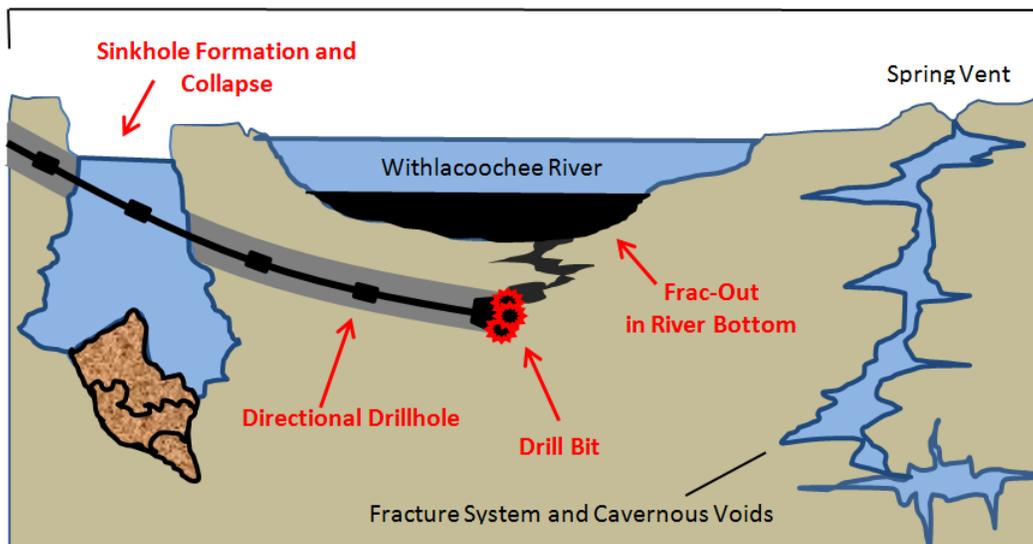
cause ground and surface water contamination, alter natural flow regimes, and cause adverse impacts to existing legal water users, natural systems and the environment.

### Approximately 2,500 Lineal Feet Horizontal Directional Drill Hole



Schematic showing cross-section of the proposed HDD crossing of the Withlacoochee River and hypothetical karst features that could result in a hydrofracture (frac-out), significant loss in drilling fluid and potential loss of the borehole.

### Sinkhole Formation and Collapse



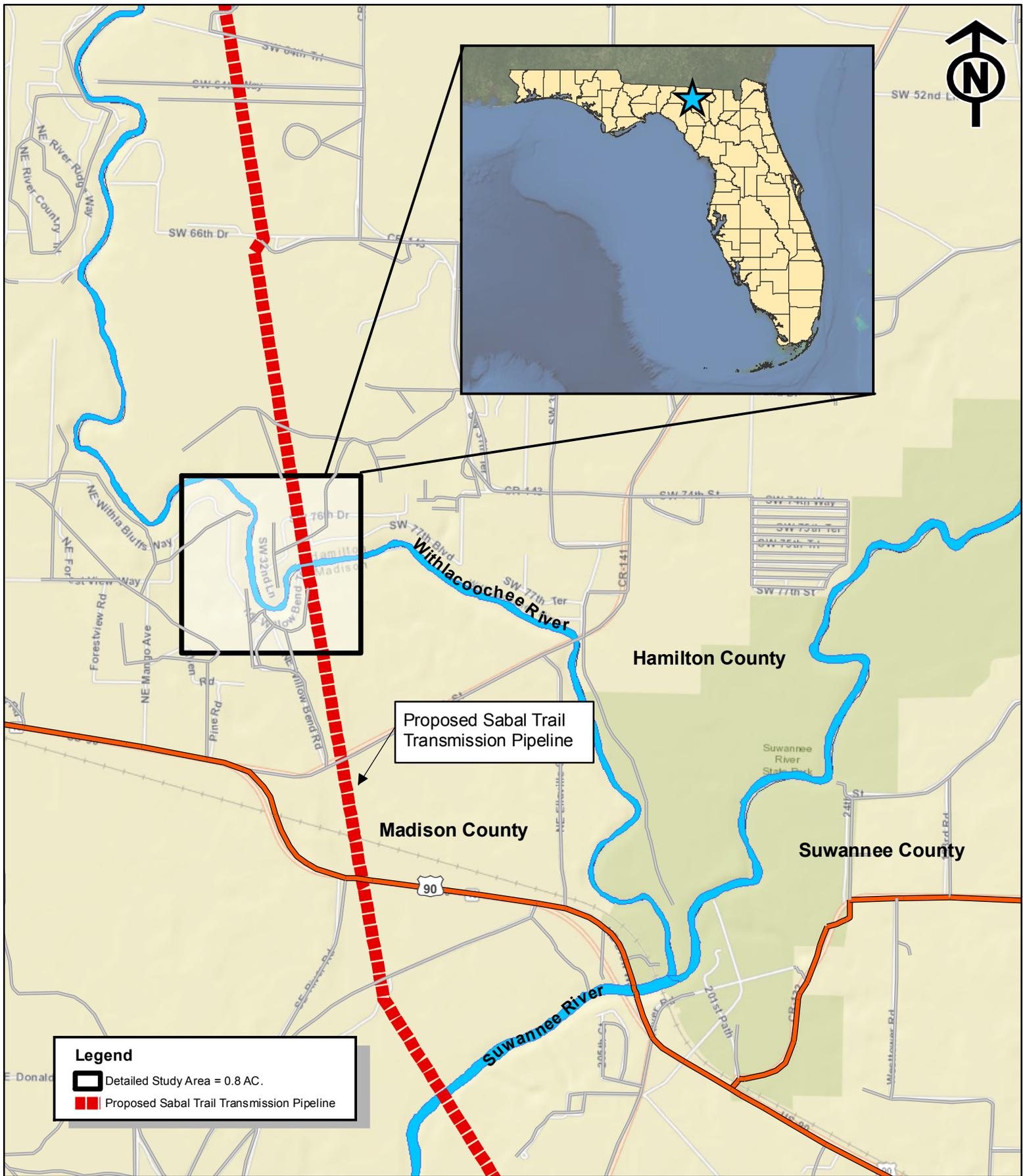
Schematic showing potential sinkhole or collapse feature forming as a result of the proposed HDD crossing of the Withlacoochee River. A collapse, such as that shown, would result in the loss of the HDD borehole, drilling fluids and result in adverse impacts to environmental features and the water resources.

The directional drilling techniques used to install the transmission pipeline under the river channel will transect the highly weathered limestone and potentially short-circuit the preferential flow paths and fracture systems as depicted in the schematics provided above. The disruptive nature of the drilling and reaming processes will have a high probability of creating hydrofractures, sinkholes, or possibly swallets during construction and may also activate the raveling of overlying sediments resulting in subsequent sinkhole development after completion of drilling activities. The destruction of preferential flow paths along existing fracture and cave systems could adversely affect the local groundwater gradient and reduce or eliminate groundwater flow to several springs that provide critical baseflow to the Withlacoochee River.

As shown on **Figure 6**, the Suwannee River and Withlacoochee River confluence regional topography is an extremely complex karstic terrain with a highly “pock-marked” land surface indicating a very high frequency of sinkhole occurrence and activity. A review of this LIDAR image clearly portrays the complex hydrogeology of both the study area and the surrounding region.

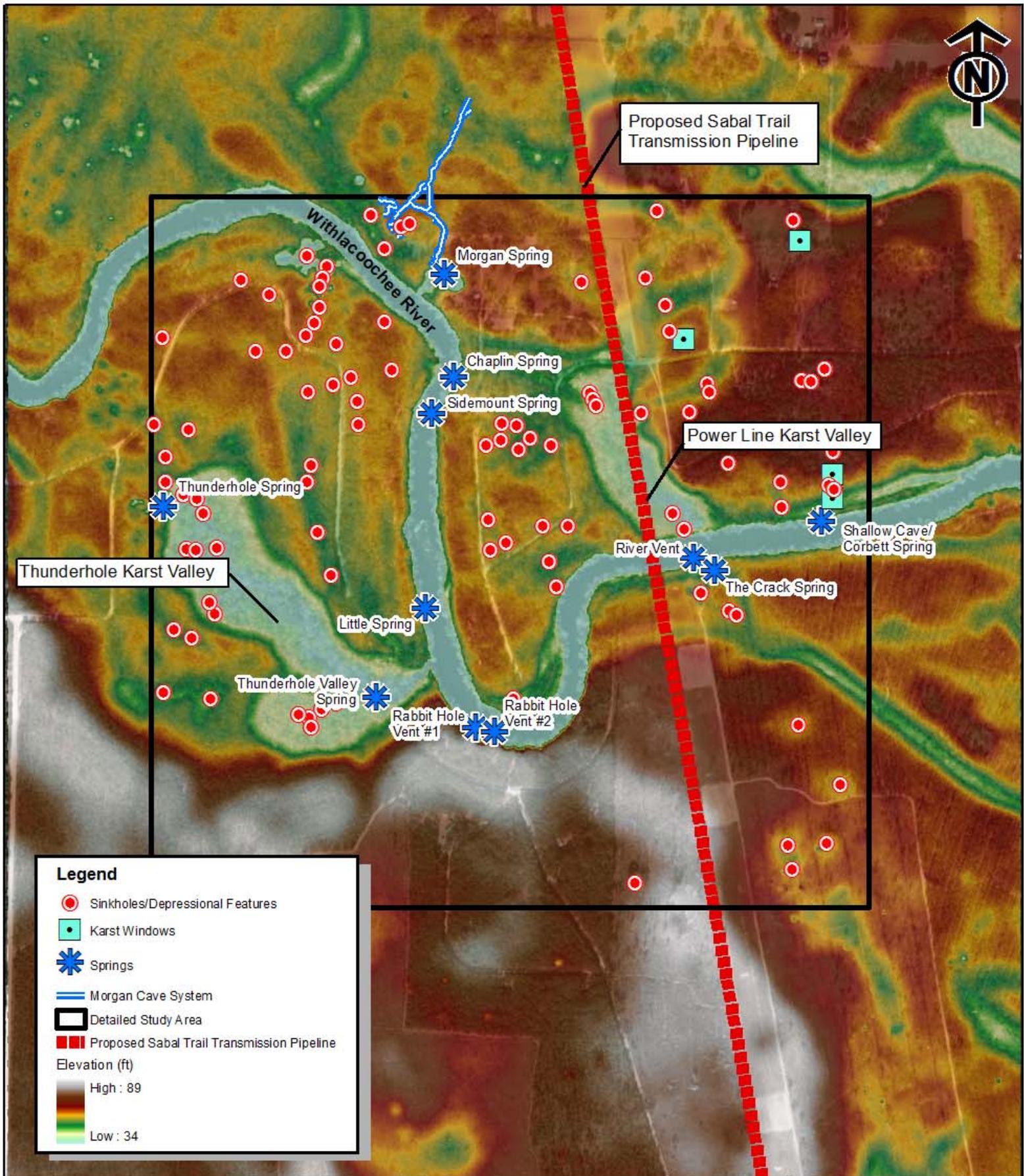
It is vitally important that technical decisions regarding the placement and construction of the Sabal Trail underground transmission pipeline be based on site-specific hydrogeologic information and be sensitive to the potential for adverse impacts. It is the author’s belief that a comprehensive due diligence assessment of the proposed pipeline crossing site demonstrates that the site does not meet these requirements, presents significant potential for structural failure and adverse impacts. As such, the site should be abandoned from further consideration in order to safeguard the public, the natural environment, and the owner/operator.

Given the highly unstable nature of the Withlacoochee River crossing, attempts to directionally drill and operate the pipeline could have disastrous consequences and in turn potentially jeopardizing the public’s support for development of natural gas as an alternate energy resource for the State of Florida.



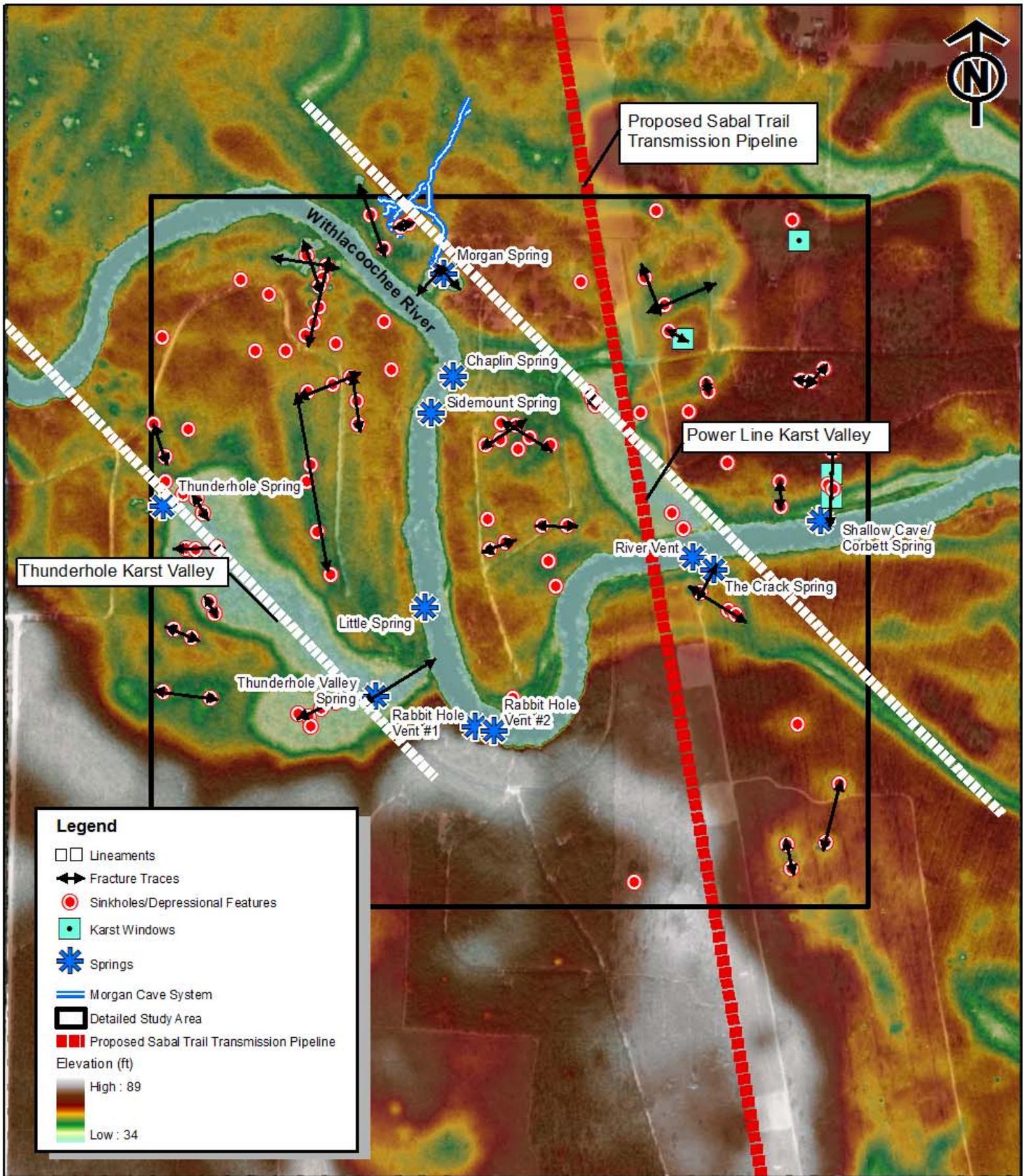
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**Figure 1**  
**Detailed Study Area**  
**General Location Map**



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**Figure 2**  
**Withlacoochee Crossing**  
**Topography**



Scale: 1:10,000

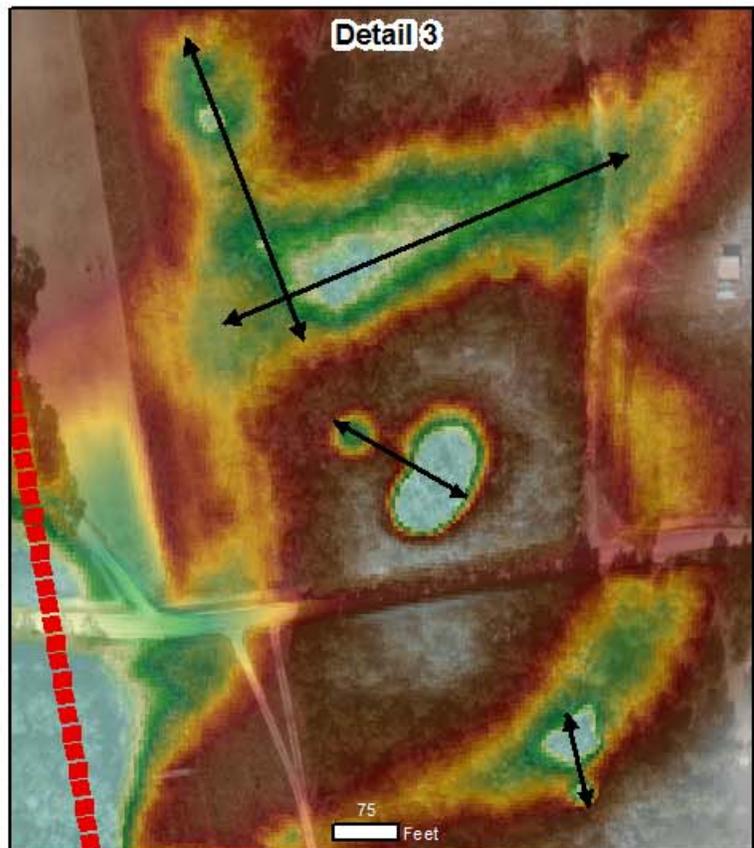
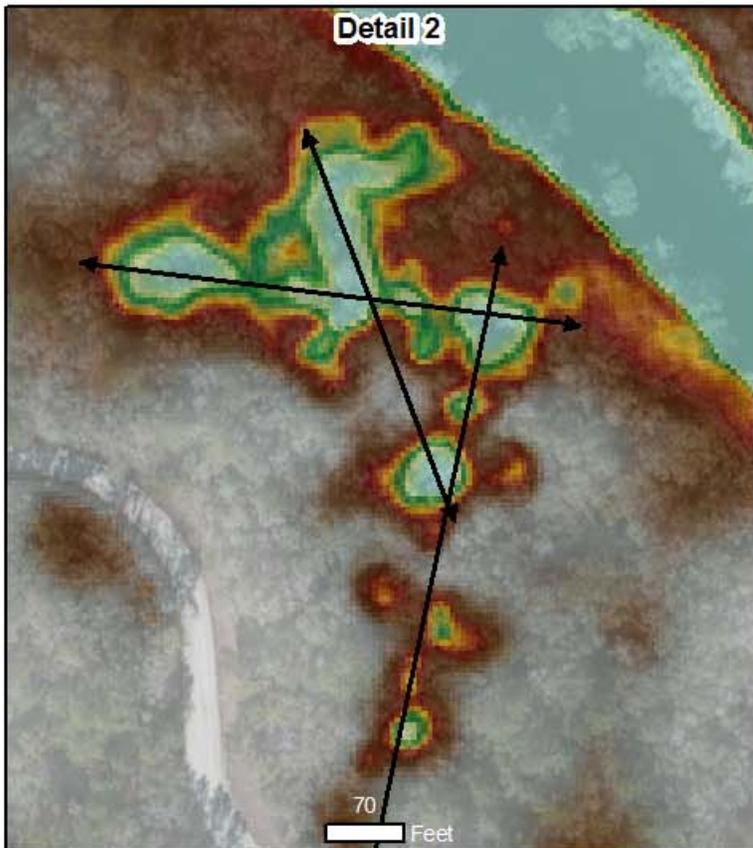
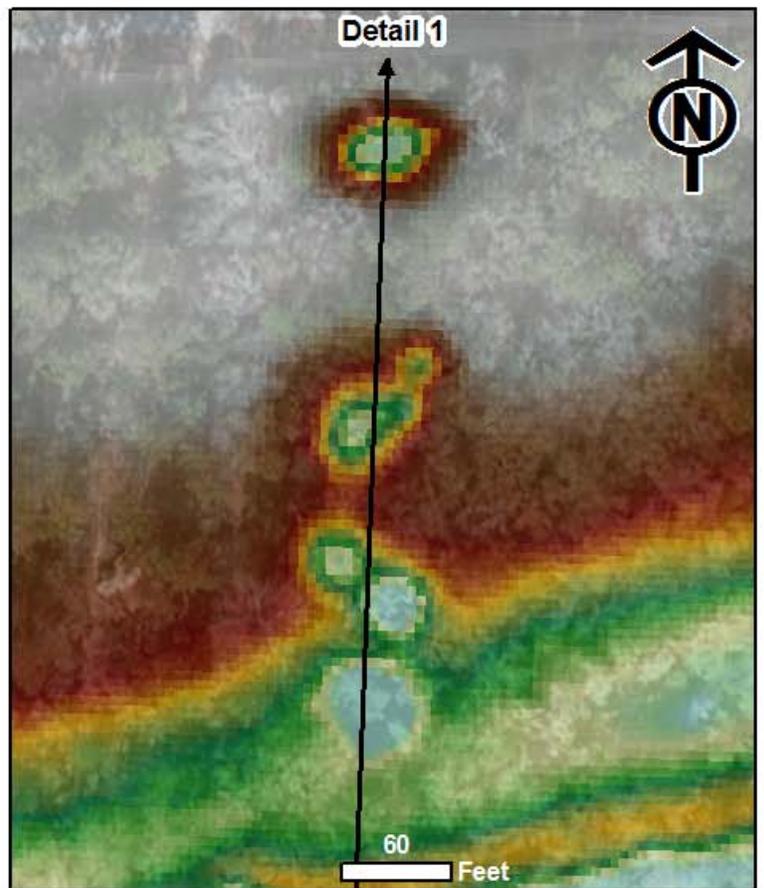
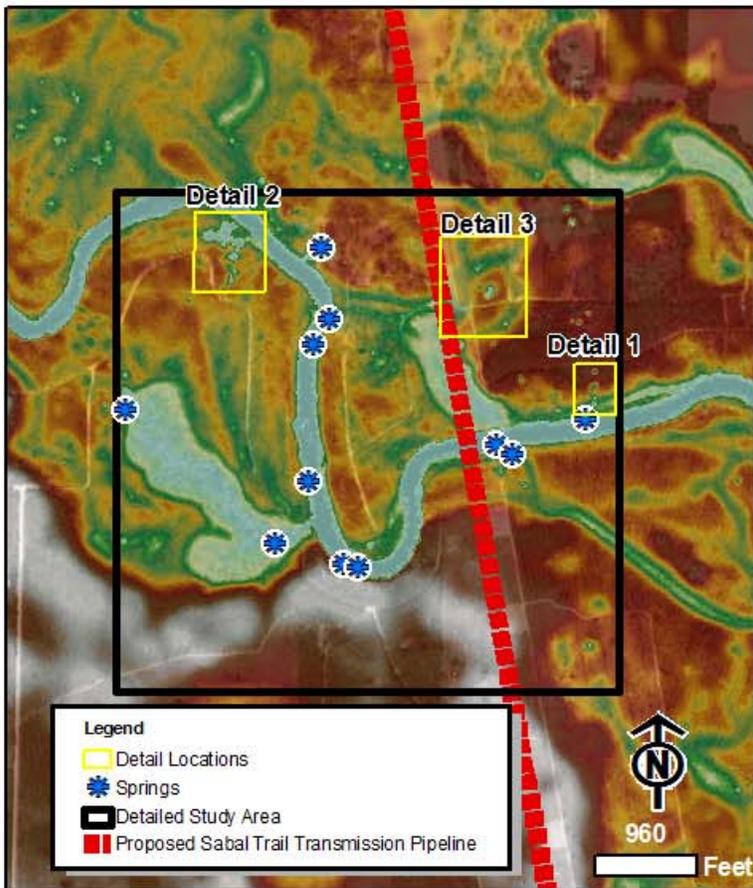
7/16/2014

Image: World Street Basemap

0 240 480 960 1,440 Feet

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**Figure 3**  
**Withlacoochee Crossing**  
**Karst Features, Fracture Traces**  
**and Lineaments**



Scale: See Insets

7/16/2014

Image: SRWMD LIDAR



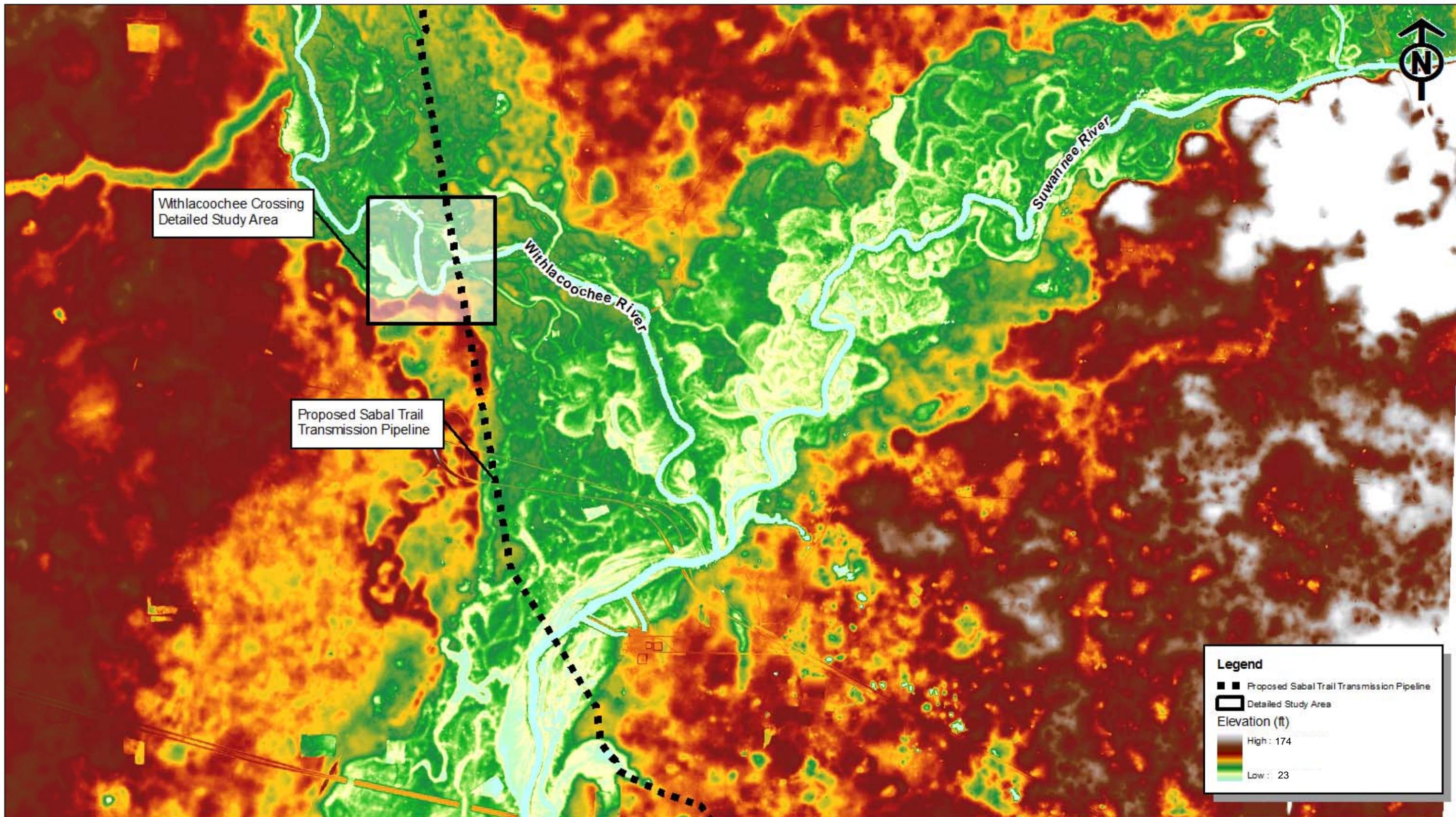
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**Figure 4**  
**Withlacoochee Crossing**  
**LIDAR Topographic Detail**



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**Figure 5**  
**Withlacoochee Crossing**  
**Parcel Map and Drill Locations**



Withlacoochee Crossing  
Detailed Study Area

Proposed Sabal Trail  
Transmission Pipeline

**Legend**

- Proposed Sabal Trail Transmission Pipeline
- Detailed Study Area

**Elevation (ft)**

High: 174

Low: 23

Scale: 1:40,000      8/8/2014

Image: SRWMD LIDAR



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**Figure 6**  
**Suwannee River & Withlacoochee River Confluence Regional Topography**

## References Cited

- *Karst Features and Hydrogeology in West-Central Florida – A Field Perspective*  
Authors: Ann B. Tihansky and Lari A. Knochenmus  
2001 U.S. Geological Survey Karst Interest Group Proceedings, Water Resources Investigation Report 01-4011, p. 198-211
- *The Influence of Joints and Micro-Fractures on the Limestone Aggregate Shape and Quality*  
Authors: Beata Figarska-Warchol and Jan Bromowicz  
AGH University of Science and Technology, Faculty of Geology, Geophysics and Environment Protection, Krakow, Poland, 2010
- *Karst Geomorphology and Relation to the Phreatic Surface: Briar Cave, Marion County, Florida*  
Authors: Lee Florea, Kristin Kelley, Tomoyuki, David Miller and Robert Mrykalo  
Department of Geology, Univeristy of South Florida  
Department of Environmental Science and Policy, University of South Florida
- *Sinkholes*  
Author: James E. Kaufmann  
U.S. Geological Society – Fact Sheet 2007-3060, July 2007
- *Induced Sinkhole Formation Associated with Installation of a High-Pressure Natural Gas Pipeline, West-Central Florida*  
Authors: Ted J. Smith, P.G., C.P.G. and George C. Sinn, Jr., P.E.  
Earth & Water Resources, LLC and Central Florida Testing Laboratories, Inc.  
13<sup>th</sup> Sinkhole Conference, NCKRI Symposium 2
- *Laboratory 8: Karst (and Campus Karst Excursion)*  
GLY1150L: Florida Geology Laboratory, University of Florida, Spring 2011
- *Factsheet About Outstanding Florida Waters (OFW)*  
Florida Department of Environmental Protection, April 2011
- *Fracture Trace Mapping of the Eldridge-Wilde Well Field, Pinellas County, Florida*  
Author: D.M. Diodato  
U.S. Geological Survey, Open-File Report 99-235, 1999
- *Simulation of Groundwater flow in North Florida and South-Central Georgia*  
Author: James W. Schneider, Ph.D.; Sam B. Upchurch, Ph.D., P.G.; Jian Chen, P.G.; Crystal Cain  
Suwannee River Water Management District, March 2008 (Revised August 2008)
- *Florida Spring Classification System and Spring Glossary*  
Compiled By: Rick Copeland  
Florida Geological Survey Special Publication No. 52, 2003
- *Special Publication No. 29 – Karst in Florida*  
Author: Ed Lane  
Florida Geological Survey, Tallahassee, 1986

- *Florida's Springs – Strategies for Protection and Restoration*  
The Florida Springs Task Force, November 2000
- *General Highway Map - Hamilton County, Florida*  
Created By: Surveying and Mapping Office for the State of Florida Department of Transportation  
March 2003
- *Transmissivity of the Upper Floridan Aquifer in Florida and Parts of Georgia, South Carolina and Alabama*  
Created By: Eve L. Kuniansky, Jason C. Bellino and Joann F. Dixon  
U.S. Geological Survey Groundwater Resources Program, 2012
- *Using State-Wide GIS Data to Identify the Coincidence Between Sinkholes and Geologic Structures*  
Author: Lee Florea  
Journal of Cave and Karst Studies, Version 67, No. 2, Pages 120-124, August 2005
- *Open File Report 86 – Geology of Suwannee County, Florida*  
Author: Frank R. Rupert  
Florida Geological Survey, Tallahassee, Florida, 2003 (ISSN 1058-1391)
- *Southeastern Geological Society Guidebook No. 23 – Karst Hydrogeology and Miocene Geology of the Upper Suwannee River Basin, Hamilton County, Florida*  
Published by: Southeastern Geological Society, Tallahassee, FL 32302  
October 23-24, 1981
- *Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings*  
Published by: ASTM International, West Conshohocken, PA 19428  
June 30, 2014
- *A Lexicon of Cave and Karst Terminology with Special Reference to Environmental Karst Hydrology*  
U.S. Environmental Protection Agency, National Center for Environmental Assessment (Washington Office) – Office of Research and Development, Washington, D.C. 20460  
February 2002
- CaveAtlas.com – United States (<http://caveatlas.com>)