APPENDIX H - KARST AREAS

KARST HAZARDS ASSESSMENT

(DESKTOP REVIEW AND FIELD RECONNAISSANCE)

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DAA Project Number: B14188B-01

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1.0 INTRODUCTION

Mountain Valley Pipeline, LLC (Mountain Valley), a joint venture between EQT Midstream Partners, LP and affiliates of NextEra Energy, Inc., WGL Holdings, Inc. Vega Energy Partners, Ltd., RGC Midstream, LLC, and Con Edison Gas Midstream, LLC, is seeking a Certificate of Public Convenience and Necessity from the Federal Energy Regulatory Commission (FERC) pursuant to Section 7(c) of the Natural Gas Act authorizing it to construct and operate the proposed Mountain Valley Pipeline (MVP) Project located in 17 counties in West Virginia and Virginia. Mountain Valley plans to construct an approximately 301-mile, 42-inch-diameter natural gas pipeline to provide timely, cost-effective access to the growing demand for natural gas for use by local distribution companies, industrial users and power generation facilities in the Mid-Atlantic and southeastern markets, as well as potential markets in the Appalachian region.

The proposed pipeline will extend from the existing Equitrans, L.P. transmission system and other natural gas facilities in Wetzel County, West Virginia to Transcontinental Gas Pipe Line Company, LLC's (Transco) Zone 5 compressor station 165 in Pittsylvania County, Virginia. In addition to the pipeline, MVP project components will include approximately 171,600 horsepower of compression at three compressor stations along the route, as well as measurement, regulation, and other ancillary facilities required for the safe and reliable operation of the pipeline. The pipeline is designed to transport up to 2.0 million dekatherms per day (MMDth/d) of natural gas. Resource Report 1 provides a complete summary of the MVP project and a general location map of the MVP components.

This Karst Hazards Assessment (KHA) presents the results of desk top review and field reconnaissance identifying karst hazards. The KHA is part of the MVP Resource Report 6, which was prepared and organized according to the FERC Guidance Manual for Environmental Report Preparation (August 2002). Resource Report 6 describes existing geologic setting and resources, potential impacts, geologic hazards and mitigation in relation to MVP components.

Mountain Valley previously submitted interim drafts of the KHA to FERC in October 2015 and April 2016 that identified karst features and associated hazards along the initial proposed alignment and various alternatives of the MVP. The current KHA submitted herein presents an

assessment of karst features and associated hazards within 1/4-mile of the currently October 2016 proposed route.

2.0 KARST FEATURES AND ASSOCIATED HAZARDS

Figure 1 illustrates the proposed MVP alignment and alternatives (including the current October 2016 proposed route) that are underlain by karst terrain. **Figure 2** and **Figure 3** illustrate more detail in terms of MVP alignment and alternatives underlain by karst terrain in West Virginia and Virginia, respectively.

Karst features within ¼-mile (generally termed the secondary karst buffer) and within 150 feet (corresponding to the construction easement) of the October 2016 proposed route were identified through desktop review of public and proprietary data (discussed below). Field confirmation was completed on properties where landowners allowed access in order to verify the desk top review results and identify previously unmapped karst features.

Karst features identified within the secondary karst buffer (¼ mile) and the construction easement (150 feet) are summarized in Table 2, and are illustrated in Map Sheets 1 through 37 in Appendix A. Karst features associated with minor potential for impact are highlighted in yellow, and with moderate potential for impact in orange. Mountain Valley made numerous adjustments to the proposed MVP alignment to avoid significant karst features (note that there are no red highlighted karst features or concerns in Table 2). Karst features that are at negligible risk from pipeline construction, or pose negligible risk to pipeline construction and long-term operation, are not highlighted in color in Table 2.

Mountain Valley prepared a Karst Mitigation Plan (under separate cover) that provides mitigation protocols for karst features that cannot be avoided through minor variations within the construction easement. Mountain Valley will deploy Karst Specialist inspection teams during construction to monitor karst features and provide recommendations for avoidance or mitigation.

2.1 Methods for Desktop Review and Field Reconnaissance

The KHA was completed under the direction of the Project Karst Specialist, who holds qualifications of a professional geologist having direct work experience with karst hydrology and geomorphic processes. The Karst Specialist team has over 70 years of combined direct field experience evaluating karst features in southern West Virginia and Southwest Virginia (the vicinity of the proposed MVP alignment).

Desk top analysis and field reconnaissance was focused on a 1/4-mile buffer from the proposed alignment (termed herein the secondary karst buffer), which incorporated the 150-foot lateral construction easement. The secondary karst buffer was expanded beyond ¼-mile where the likelihood of karst feature occurrence was deemed to be high. Certain carbonate bedrock formations in southern West Virginia and southwest Virginia are more prone to karstification than are others, and the desktop review and field reconnaissance were focused accordingly.

Desk top analysis included review of publicly available data sources, and data provided by the Virginia Speleological Survey (VSS) or West Virginia Speleological Survey (WVASS). Location information for many karst features was taken from information collected by volunteer amateur cavers, continuously compiled since the early 1940s. Many of these historically-documented karst features, originally mapped on 15-minute USGS topographic quadrangle maps, were transcribed onto more modern 7.5-minute topographic maps and location coordinates estimated. It is noted that information included in the desk top review that was provided by the VSS or WVASS are not associated with guarantees by these sources for accuracy or correctness of any information. Field verification was conducted (where property owner permission was granted) to verify a mapped karst feature and to identify previously undocumented karst features.

The KHA greatly expanded the knowledge base regarding local karst features. More than 12 new cave features were identified. Numerous previously undocumented springs and insurgences were identified and mapped. As well, locations of previously identified features were confirmed and updated. Equally important to identifying karst features, is documenting a lack of karst features in areas that previously had little to no historic karst review. Direct interaction with property owners, commenters, and state agencies during the KHA process facilitated karst feature identification and this additional knowledge will serve as an asset to future karst research efforts. Mountain Valley adjusted the proposed alignment in numerous locations to avoid karst features and mitigate associated hazards using the information gathered through the current and previous KHA efforts.

2.2 Coordination on Geologic Formation Names

The discussion of karst-related hazards presented below includes references to specific geologic formations, and to support that discussion the generalized stratigraphic column from McDowell and Schultz (1990) is presented below, to identify the major rock types in the karst area.

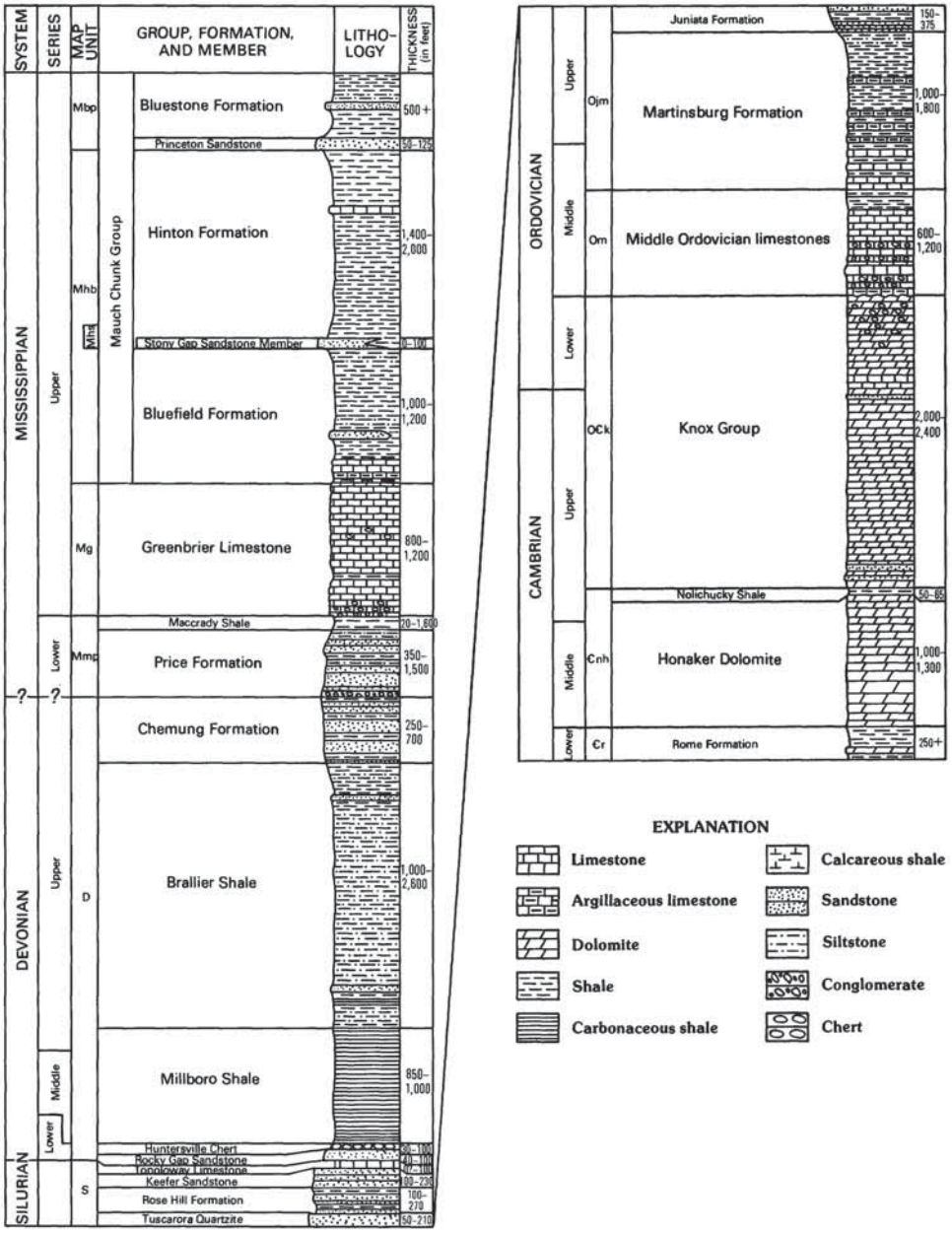

Figure 5. Generalized columnar section for rocks in the Giles County area of Virginia and West Virginia.

Structural and Stratigraphic Framework, Giles County, Virginia and West Virginia · E5

From McDowell and Schultz, 1990

For added clarity, we note that geologic formations comprising the local karst terrain are referred to by different names, particularly between practitioners in West Virginia versus Virginia. The geologic mapping work of McDowell and Schultz (1990) presented a useful correlation for formation names, as reproduced below (**Table 1**).

Table 1. Stratigraphic nomenclature used in this study and other studies in the Giles County area of Virginia and West Virginia

System	Mercer, Monroe, and Summers Counties, W. Va. (Reger, 1926, fig. 6)		Giles County, Va., and Mercer County, W.Va. (Cooper, 1961, pl. 1)	Botetourt County, Va. (McGuire, 1970)	Southwestern Virginia (Miller and Meisner, 1977)			This report	
MISSISSIPPIAN	Mauch Chunk Series	Bluestone Group	Bluestone Formation	(not exposed)	Pennington Group	Bluestone Formation	Upper red member	Mauch Chunk Group	Bluestone Formation.
							Lower member		
		Princeton Conglomerate	Princeton Formation			Princeton	Sandstone		Princeton Formation
		Hinton Group	Hinton Formation			Hinton Formation	Little Stone Gap Member		Hinton Formation
							Lower red member		
							Stony Gap Sandstone Member		Stony Gap Sandstone Member
		Bluefield Group	Bluefield Formation		Bluefield Formation				Bluefield Formation
	Greenbrier Series		"Casper" Limestone		Greenbrier Limestone			Greenbrier Limestone	
			"Ste. Genevieve" Limestone						
			Hillsdale Limestone						
			Little Valley Limestone						
	Maccrady Series		Maccrady Formation		Maccrady Shale			Maccrady Shale	
	Pocono Series		Price Formation	Price Formation	Price Siltstone			Price Formation	
DEVONIAN	Chemung Series		Parrot Formation	Chemung Formation	Chattanooga Shale			Chemung Formation	
			"Chemung" Formation						
	Portage		Brallier Formation	Brallier Formation				Brallier Shale	
	Genessee-Hamilton-Marcellus Series		Millboro Formation	Millboro Formation				Millboro Shale	
			Huntersville Formation	Needmore Formation	Wildcat Valley Sandstone			Huntersville Chert	
				Ridgely Sandstone					
				Licking Creek Formation					
	Oriskany Series Helderberg Series		Rocky Gap Sandstone	Healing Springs Sandstone				Rocky Gap Sandstone	
				New Creek Limestone					
				Keyser Formation					
SILURIAN	Clinton Series		Tonoloway Limestone	Tonoloway Formation	Tonoloway Limestone			Tonoloway Limestone	
			"Keefer" Formation	Keefer Sandstone	Rose Hill Formation			Keefer Sandstone	
			Rose Hill Formation	Cacapon Formation	Clinch Sandstone		Upper red sandstone member	Rose Hill Formation	
	White Medina Series		Tuscarora Sandstone	Tuscarora Formation			Lower white sandstone member	Tuscarora Quartzite	

From McDowell and Schultz, 1990

Table 1. Stratigraphic nomenclature used in this study and other studies in the Giles County area of Virginia and West Virginia—Continued

System	Mercer, Monroe, and Summers Counties, W. Va. (Reger, 1926, fig. 6)		Giles County, Va., and Mercer County, W.Va. (Cooper, 1961, pl. 1)	Botetourt County, Va. (McGuire, 1970)	Southwestern Virginia (Miller and Meisner, 1977)		This report
ORDOVICIAN	Red Medina Series		Juniata Sandstone	Juniata Formation	Juniata Formation		Juniata Formation
	Martinsburg Series	Lower Maysville Group	Martinsburg Formation	Martinsburg Formation	Reedsville Shale		Martinsburg Formation
		Eden Group					
		Trenton Group			Trenton Limestone		
	Moccasin Series		Eggleston Formation	Eggleston Formation	Eggleston Formation		Middle Ordovician limestone
			Moccasin Formation	Edinburg Formation	Moccasin Formation		
	Stones River (Chickamauga) Series		Witten Limestone		Lower Middle Ordovician limestone formations		
			Gratton Limestone				
			Benbolt Limestone				
			Pearisburg Limestone				
			Lincolnshire Limestone	Lincolnshire Formation			
			Five Oaks Limestone	New Market Limestone			
			Elway Limestone				
			Blackford Formation				
	Beekmantown Series		Knox Group	Beekmantown Formation	Knox Group	Beekmantown Dolomite	Knox Group
				Chepultepec Formation			
				Conococheaque Formation		Copper Ridge Dolomite	
				Copper Ridge Formation	Maynardsville Limestone		
CAMBRIAN	Elbrook? Series		Nolichucky Shale	Elbrook Formation	Nolichucky Shale		Nolichucky Shale
			Honaker Dolomite		Honaker Limestone		Honaker Dolomite
			Rome Shale	Rome Formation	Rome Formation		Rome Shale

From McDowell and Schultz, 1990

2.3 Karst Features Identified

Karst features located within the secondary karst buffer (minimum ¼-mile) and construction easement (minimum 150-feet) of the proposed MVP alignment are summarized in **Table 2**. The karst features presented in the summary table were mapped or otherwise recorded through desktop review. Features that were further characterized through field observation are specifically noted in **Table 2**. A description of the feature, potential impact to avoid or mitigate, and recommendations are included in **Table 2**. Note the color-code system for karst features (e.g., white is negligible risk; red is notable risk, etc.). The karst features identified in **Table 2** are also shown in the corresponding Map Set provided in Appendix A. Note that the karst features listed in the specific route table includes a cross-reference to the map sheet. Each karst feature listed on **Table 2** is associated with a unique identifier number for cross reference to route maps (see **Map Sheets** in **Appendix A**).

2.4 Karst Feature Mitigation

Refer **to the MVP Karst Mitigation Plan** for a detailed discussion on karst hazard mitigation where an identified feature cannot be reasonably avoided within a proposed construction easement, or where an unidentified feature is encountered during construction.

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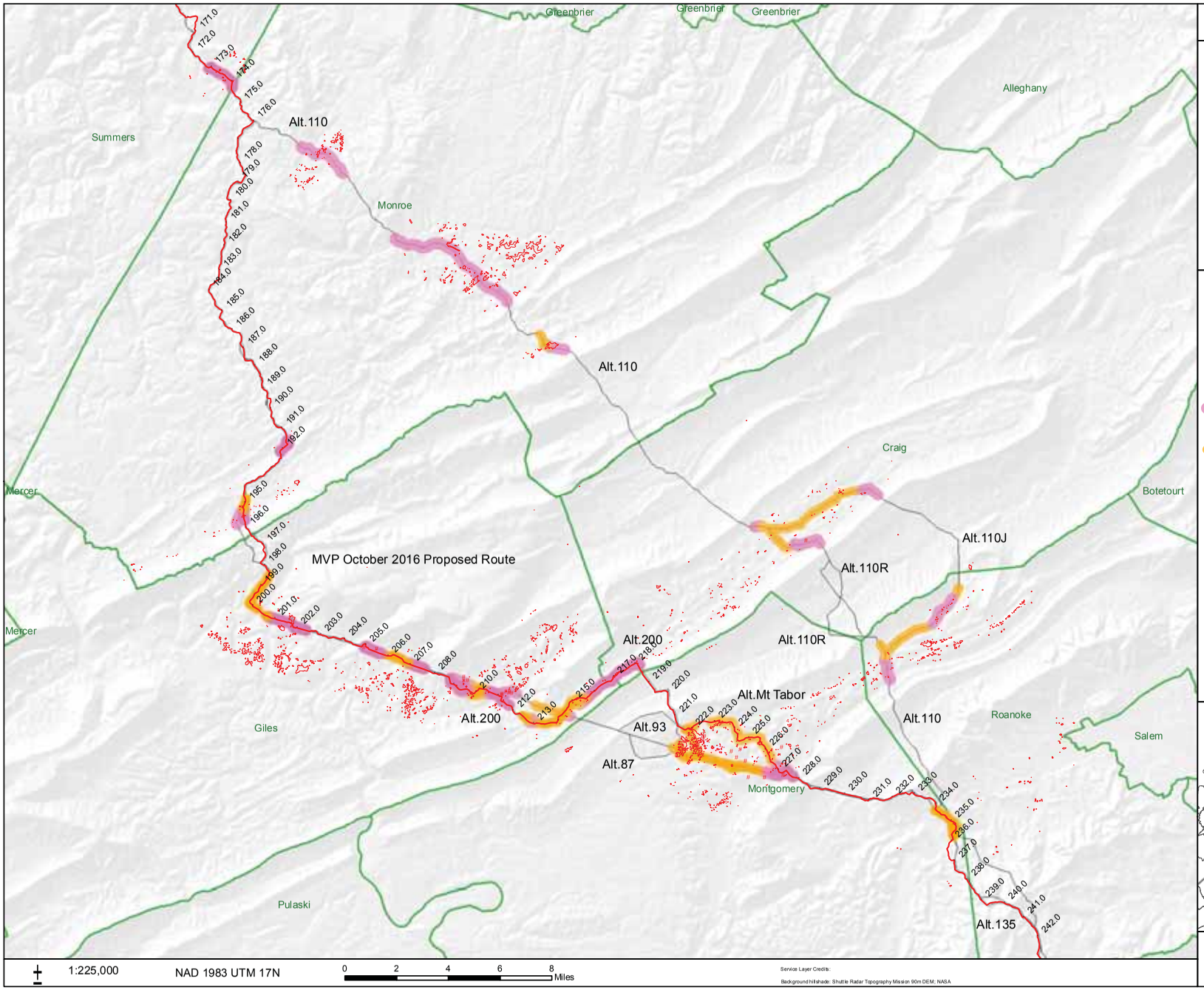
2.6 Figures 1 Through 3



1:225,000 NAD 1983 UTM 17N 0 2 4 6 8 Miles

Service Layer Credits:

Background hillshade: Shuttle Radar Topography Mission 90m DEM; NASA

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

FIGURE NUMBER 1
Karst Zones

09-30-16

Draper Aden Associates
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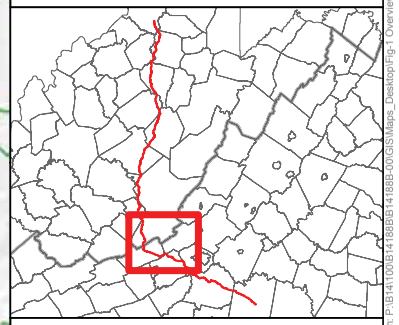
Legend

- MVP October 2016 Proposed Route with Mile Posts
- MVP Alternates / Previous Variations
- Limestone
- Dolomite
- Karst Features



Karst Regions adapted from 1968 Geological Map of West Virginia, 1:250,000, West Virginia Geological and Economic Survey.
Digital Representation of the 1993 Geologic Map of Virginia; 1:500,000
U.S. Geological Survey, 2003; (Virginia Division of Mineral Resources Publication 174)
Geologic Map of Giles County, Virginia, 1986, Ed. E.K.Rader and T.M.Gathright II

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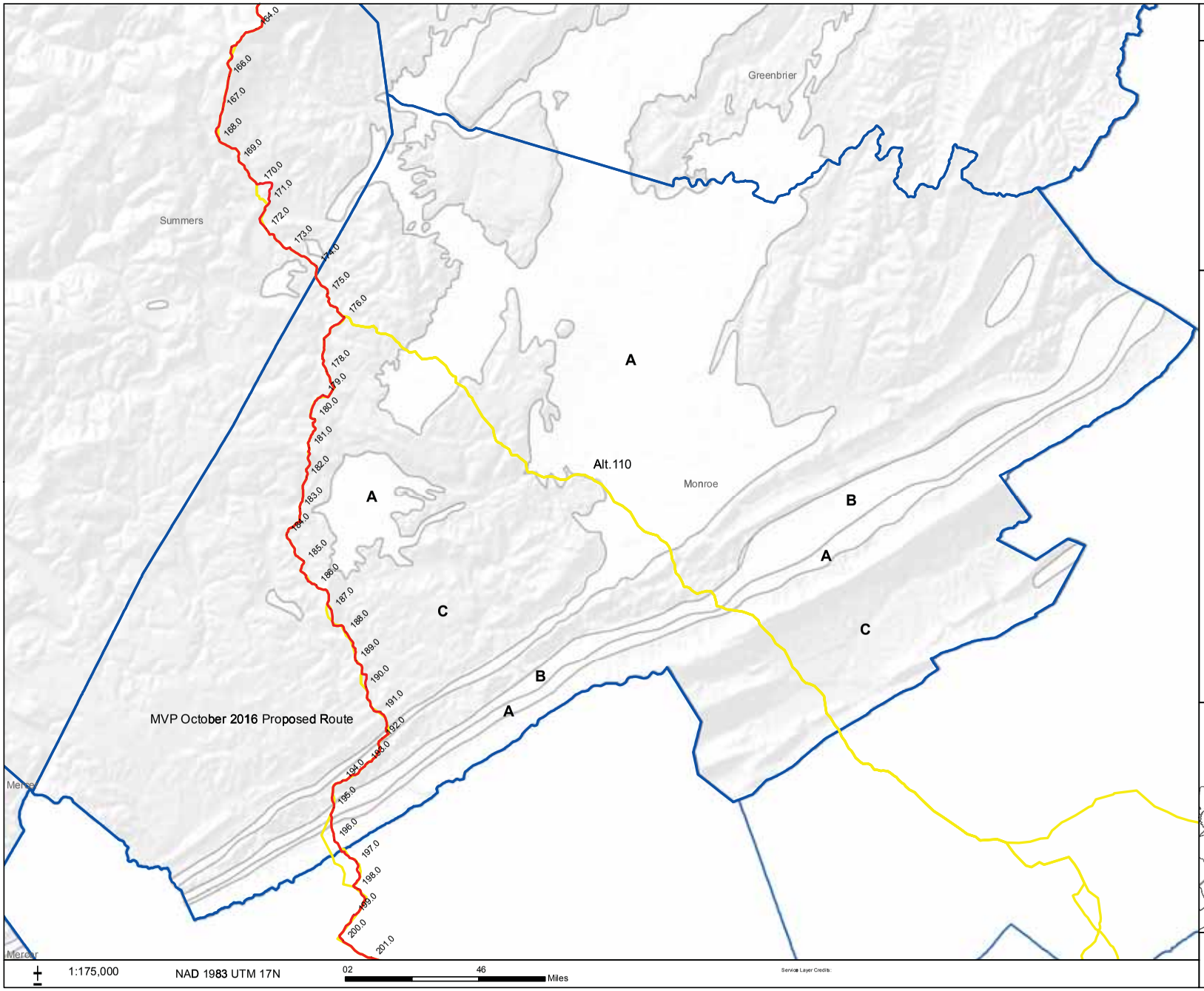

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

FIGURE NUMBER 2
Karst in West Virginia

09-30-16

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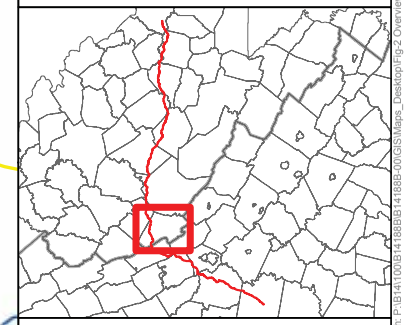
Legend

- MVP October 2016 Proposed Route with Mile Posts
- MVP Alternates / Previous Variations

A - Limestone
B - Dolostones
C - Non-carbonates



Karst Regions adapted from 1968 Geological Map of West Virginia. 1:250,000. West Virginia Geological and Economic Survey.

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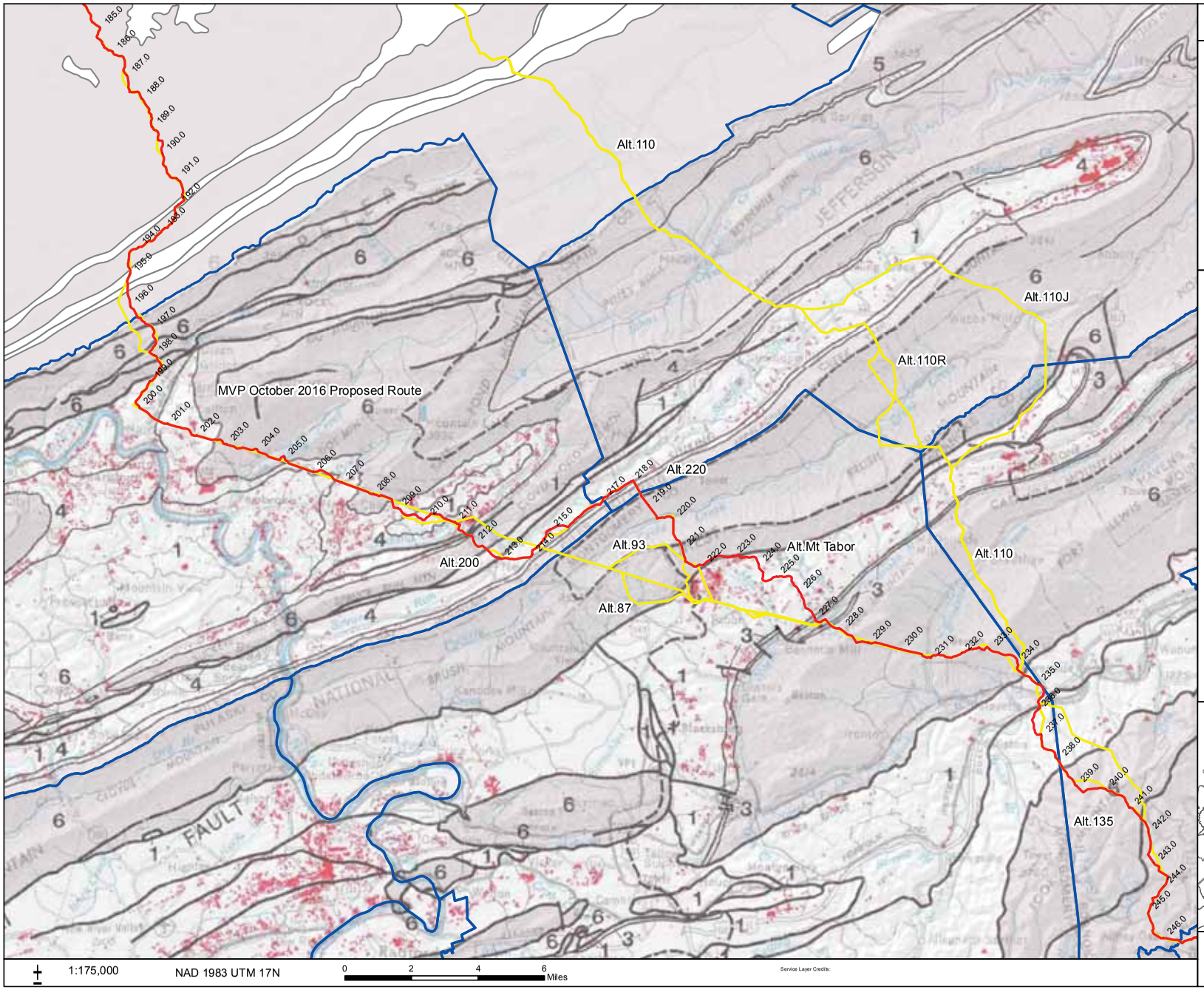

Service Layer Credits:

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FIGURE NUMBER 3
Karst and Karst Features in Virginia

09-30-16

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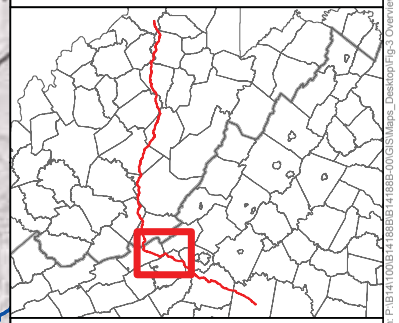
Legend

- MVP October 2016 Proposed Route with Mile Posts
- MVP Alternates / Previous Variations
- # Karst Features

1,3 - Dolostones
4 - Limestones
6 - Non-carbonates



Publication 083; Selected Karst Features of the Central Valley and Ridge Province, Virginia. 1:250,000-scale map and text. D. A. Hubbard. Virginia Department of Mines Minerals and Energy, 1988

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Table 2 – Karst Features and Hazards Analysis

Table 2 Karst Features and Hazards Analysis - Proposed FERC 5.0.0 Alignment (Refer to Karst Review FERC 5.0.0 Sheets 1-37 that are referenced in this Table).
Updated for MVP October 2016 Proposed Route

Key:

= Significant potential for impact - Alignment adjustments to avoid karst features removed all areas of significant concern
= Moderate potential for impact - Additional evaluation during construction may be required
= Minor potential for impact - Highlighted for construction inspection
= Negligible potential for impact

Mile Post	Sheet #	Feature Identification	Field Confirmed?	Description (Note, left and right location references are relative to increasing milepost on proposed alignment)	Potential Impacts and Recommendations for Avoidance / Mitigation	County
172.90	1 of 37	Contact - begin limestone	Yes	Northern extent of karst terrain (approximate).	n/a	Summers
172.38	1 of 37	Sinkhole	Yes	Sinkhole mapped approximately 240 feet to right (Southwest).	See Note (1) at bottom of table	Summers
172.34	2 of 37	Sinkhole	Yes	Sinkhole approximately 280 feet left (Northeast). Proposed MVP crosses surface drainage leading to sinkhole.	See Note (1) at bottom of table	Summers
173.62	2 of 37	Sinkhole	Yes	Sinkhole approximately 400 feet right (Southwest). Proposed MVP crosses surface drainage leading to sinkhole.	See Note (2) at bottom of table	Summers
173.60	2 of 37	Spring	Yes	Small spring approximately 260 feet right (west).	Proposed alignment is topographically above the spring. In general, uncontrolled storm water or other construction-related fluid from the Limit of Disturbance could impact the spring and stream. Field reconnaissance indicates negligible risk for impact to the karst feature and BMPs will prevent incidental impacts. Construction may encounter pinnacled bedrock or unstable soil. See Note (2) for recommendations. Construction may encounter shallow groundwater and bedrock. See Note (2) for recommendations, with particular emphasis on enhanced BMPs to prevent fluid and sediment migration to spring and stream.	Summers
173.78	2 of 37	Sinkhole	Yes	Compound sinkhole approximately 500 feet right (southwest) of the proposed alignment.	See Note (1) at bottom of table	Summers
174.02	2 of 37	Sinkhole	Yes	Sinkhole edge approximately 30 feet to left (east) of proposed MVP alignment.	See Note (2) at bottom of table	Summers
174.22	2 of 37	Contact - end limestone	Yes	End of limestone area (approximate).	n/a	Summers
191.60	3 of 37	Contact - begin limestone	Yes	Short section of Union Limestone.	n/a	Monroe
191.86	3 of 37	Losing Stream, Insurgence	Yes	Below the pond there is an area where a minor stream sinks into the ground. Elevation of sink is about 30 feet above creek base level.	See Note (2) at bottom of table	Monroe
192.04	3 of 37	Springs (2)	Yes	440 feet left (southeast), and 105 feet southwest of Access Road MVP-MO-230, is a small wet weather seep. 705 feet left (southeast), and 370 feet southwest of Access Road MVP-MO-230, is a spring.	n/a	Monroe
194.84	4 of 37	Contact - begin dolomite	No	Begin dolomite area (approximately). St. Clair thrust fault (ancient, inactive fault). This area historically known to have extensive and well documented cave and karst development. High karst potential with significant cave and karst feature development.	n/a	Monroe
195.18	4 of 37	Sinkhole	No	Sinkhole mapped by desktop review approximately 100 feet to right (west) of the proposed alignment. An additional sinkhole is located approximately 150 feet to the right (west).	See Note (3) and Note (2) at bottom of table	Monroe
195.30	4 of 37	Sinkhole	No	Sinkholes mapped by desktop review more than approximately 800 feet right (west) of alignment	See Note (3) and Note (1) at bottom of table	Monroe
195.30	4 of 37	Contact - begin limestone	No	Begin limestone area (approximately). High karst feature potential.	n/a	Monroe
195.35	4 of 37	Sinkhole and Cave	No	Bobcat Cave, described as a small room located in a large sinkhole, location uncertain, approximately 1100 feet to right (west). Mapped by desktop review.	See Note (3) and Note (1) at bottom of table	Monroe
195.41	4 of 37	Sinkhole	No	Open throat sinkhole located approximately 600 feet right (west) of the proposed alignment. Mapped by desktop review.	See Note (3) and Note (1) at bottom of table	Monroe
195.42	4 of 37	Spring and Cave	No	Rich Creek Spring (headwaters of Rich Creek, water supply for Red Sulphur PSD and Town of Peterstown, WV), Rich Creek Cave, and Rich Creek Fish Hatchery were mapped approximately 1,500 feet right (west) of the proposed alignment. The proposed alignment is at a higher elevation than the spring which distances it from potential impact. However, the presence of sinking streams and open throat sinkholes could provide direct conduit to the subsurface flow.	MVP contacted the Red Sulphur Public Service District and is providing support to the PSD to develop a contingency plan to ensure no interuption of water service during construction. Also, see Note (2) and Note (3) at bottom of this table	Monroe
195.52	4 of 37	Sinkhole	No	Sinkhole located approximately 80 feet left (east) of the proposed alignment	See Note (2) and Note (3) at bottom of table	Monroe
195.56	4 of 37	Sinkhole	No	Several sinkholes mapped by desktop review approximately 250 feet to the right (west) of the proposed alignment.	See Note (1) and Note (3) at bottom of table	Monroe
195.72	4 of 37	Contact - limestone	No	End of limestone area (approximately)	n/a	Monroe
196.80	5 of 37	Contact - Tonoloway limestone	No	Several short sections of Tonoloway limestone.	n/a	Giles
198.48	6 of 37	Contact - limestone to dolomite	Yes	Begin dolomite area (Knox Group). Medium karstification potential. Complex structural disconformity due to ancient thrust faulting (Narrows Fault), preferential hydrology, possible voids.	n/a	Giles
200.20	8 of 37	Sinkhole	No	Sinkholes located greater than 1,000 feet left (Northeast) of alignment	See Note (1) and Note (3) at bottom of table	Giles
200.73	9 of 37	Contact - dolomite to limestone	Yes	End dolomite area (Knox Group). Begin limestone (undivided) area. High karst feature potential.	n/a	Giles
200.85	9 of 37	Lhoist Cave	Yes	Lhoist Cave is located approximately 370 feet right (southwest) of the proposed alignment.	See Note (1) at bottom of table	Giles
201.00	9 of 37	Several sinkholes	Yes	Several sinkholes approximately 400 to 1,000 feet to left (northeast) of proposed alignment, distributed approximately linearly along a southwest trending surface drainage.	See Note (1) at bottom of table	Giles
201.40	9 of 37	Sinkhole complex	Yes	Sinkhole complex approximately 1,000 feet right (southwest) and on the other side of a topographic high from the proposed alignment. Spring and swallet associated with sinkhole.	See Note (1) at bottom of table	Giles
201.66	10 of 37	Sinkholes	Yes	Sinkholes observed approximately 80 feet left and 60 feet right of proposed MVP alignment. Another cluster of sinkholes further to the right (southwest) prevents avoidance of sinkholes altogether.	See Note (2) at bottom of table	Giles
202.05	10 of 37	Sinkhole	Yes	A small natural opening is within 50 feet left (northeast) of alignment in an area of cutter and pinnacle karst. Possible cutter or even animal hole.	See Note (2) at bottom of table	Giles
202.08	10 of 37	Cave	Yes	Crooks Crevice, 50-foot pit along roadside approximately 800 feet right (southwest) of proposed alignment.	See Note (1) at bottom of table	Giles
202.32	10 of 37	Contact - limestone	Yes	End of limestone (undivided) area	n/a	Giles
202.73	11 of 37	Spring	Yes	Small spring approximately 830 feet left (northeast) of alignment that serve as livestock watering sources.	See Note (1) at bottom of table	Giles
204.06	12 of 37	Spring	No	Little Stoney Spring is located approximately 1,100 feet right (south) of proposed MVP alignment.	See Note (1) and Note (3) at bottom of table	Giles
205.02	13 of 37	Contact - begin limestone	Yes	Begin limestone (undivided) area. Upper limestone contact in drainage swale with high potential for voids in bedrock. High karst potential with significant cave and karst feature development.	Karst Specialist Team to provide more intensive inspection during construction	Giles
205.02	13 of 37	Cave	Yes	Eight Point Pit entrance is approximately 250 feet right (West).	See Note (1) at bottom of table	Giles
205.04	13 of 37	Cave	Yes	Williams Contact Shaft entrance is approximately 500 feet right (west).	See Note (1) at bottom of table	Giles
205.20	13 of 37	Cave	Yes	High Voltage Cave is located approximately 140 feet left (east), in APCO high voltage electric transmission easement clearing. The area southwest of the electric line has large bedrock benches and pinnacles.	See Note (2) at bottom of table	Giles
205.20	13 of 37	Note	Yes	Exposed bedrock, heavy benches, thin overburden mantle. This observation is characteristic of the relatively near vicinity of the proposed alignment and not limited to the specific mile post.	n/a	Giles
205.45	13 of 37	Sinkhole	Yes	Shallow sinkhole approximately 250 feet left (northeast) of proposed alignment.	See Note (1) at bottom of table	Giles
205.48	13 of 37	Sinkhole and cave	Yes	Sinkhole is approximately 150 feet left (northeast) of MVP alignment. Conklin Sink Cave entrance is approximately 440 feet left (east) of alignment. Proposed MVP alignment crosses watershed surface drainage to Conklin Sink Cave.	See Note (2) at bottom of table	Giles
205.69	14 of 37	Contact - limestone to dolomite	Yes	End of undivided limestone area. Begin dolomite area (Knox Group). Moderate karst feature potential.	n/a	Giles
205.89	14 of 37	Sinkhole	Yes	Sinkhole observed approximately 50 feet left (northeast).	See Note (2) at bottom of table	Giles
206.90	15 of 37	Contact - dolomite to limestone	Yes	End of dolomite area. Begin limestone (undivided) area. Exposed bedrock, benches, pavement, pinnacles, thin overburden mantle.	n/a	Giles
207.55	16 of 37	Contact - end limestone	Yes	End of limestone (undivided) area. Exposed bedrock, benches, pavement, pinnacles, thin overburden mantle.	n/a	Giles
207.72	16 of 37	Swallet	No	Sinking stream dye traced to Doe Creek Spring on New River by VaDCR. Approximately 430 feet to right (south) of proposed alignment. No sink point was identified during field review (wet weather).	See Note (1) and Note (3) at bottom of table	Giles
208.67	17 of 37	Contact - begin limestone	Yes	Begin limestone (undivided) area. High karst feature potential.	n/a	Giles

Table 2 Karst Features and Hazards Analysis - Proposed FERC 5.0.0 Alignment (Refer to Karst Review FERC 5.0.0 Sheets 1-37 that are referenced in this Table).
Updated for MVP October 2016 Proposed Route

Key:

= Significant potential for impact - Alignment adjustments to avoid karst features removed all areas of significant concern
= Moderate potential for impact - Additional evaluation during construction may be required
= Minor potential for impact - Highlighted for construction inspection
= Negligible potential for impact

Mile Post	Sheet #	Feature Identification	Field Confirmed?	Description (Note, left and right location references are relative to increasing milepost on proposed alignment)	Potential Impacts and Recommendations for Avoidance / Mitigation	County
208.85	17 of 37	Sinkhole	Yes	Sinkhole on east side of access road, approximately 1,000 feet right (southwest) of alignment.	See Note (1) at bottom of table	Giles
209.00	17 of 37	Swallet, Losing stream	Yes	Crossing a losing stream. Multiple stream sink points mapped by desktop review approximately 760 feet left (northeast) of proposed alignment.	See Note (1) at bottom of table	Giles
209.10	17 of 37	Sinkhole	Yes	Proposed MVP alignment is on edge of sinkhole, to left (northeast).	See Note (2) at bottom of table	Giles
209.30	17 of 37	Cave	Yes	Pighole cave system located more than 1/4-mile left (northeast) of proposed alignment.	n/a	Giles
209.33	17 of 37	Cave	Yes	Echols Cave approximately 970 feet right (southwest) of alignment, and 150 feet above proposed access road.	n/a	Giles
209.62	18 of 37	Contact - end limestone	Yes	End of undivided limestone area. Begin dolomite area (Knox Group). Moderate karst potential.	n/a	Giles
209.75	18 of 37	Sinkhole	Yes	Compound sinkhole approximately 150 feet right (south). Additional sinkholes in vicinity farther away.	See Note (2) at bottom of table	Giles
209.95	19 of 37	Sinkhole	Yes	Sinkhole approximately 660 feet to right (southeast).	See Note (1) at bottom of table	Giles
210.54	19 of 37	Sinkhole	Yes	Sinkhole approximately 80 feet to left (north).	See Note (2) at bottom of table	Giles
210.62	19 of 37	Sinkhole	Yes	Several sinkholes to left (south) approximately 170 feet or more.	See Note (1) at bottom of table	Giles
210.65	19 of 37	Contact - dolomite to limestone	Yes	Begin limestone (undivided) area. This area has been historically known to contain caves and karst features. High karst feature potential.	n/a	Giles
211.05	19 of 37	Cave, Spring	Yes	Tawneys Cave and Spring at base of hill and road embankment. Two cave entrances approximately 800 feet to left (northeast) of alignment. Extent of Tawney's cave does not extend beneath the alignment.	n/a	Giles
211.39	19 of 37	Sinkholes	Yes	Two sinkholes approximatley 200 feet and 350 feet left (northeast) of the alignment.	See Note (1) at bottom of table	Giles
211.45	19 of 37	Contact - end limestone	Yes	Undivided limestone ends, Martinsburg siliciclastics begin.	n/a	Giles
211.66	20 of 37	Cave	Yes	Hog Hole No. 2. A small cave approximately 140 feet to right (southwest).	See Note (2) at bottom of table	Giles
211.67	20 of 37	Contact	Yes	Narrow band of limestone. Hog Hole Cave associated with this formation.	n/a	Giles
212.43	20 of 37	Contact - begin dolomite	Yes	Saltville thrust fault (ancient, inactive fault) disconfomity. Preferential hydrology, possible voids	n/a	Giles
212.89	21 of 37	Contact	Yes	Narrow band of undivided limestone and Honaker / Nolichucky dolomite.	n/a	Giles
213.08	21 of 37	Sinkhole	Yes	Sinkhole approximately 350 feet left (northeast) of alignment.	See Note (1) at bottom of table	Giles
214.03	22 of 37	Sinkholes	Yes	Several sinkholes between 50 and 150 feet left (northwest) of the proposed alignment	See Note (2) at bottom of table	Giles
214.26	22 of 37	Spring	Yes	Proposed alignment cuts immediately above and approximately 100 feet left of a large spring at the convergence of two topographic drainage features.	Primary concern is the potential to disrupt the spring hydrology and compromising the spring water flow. See Note (2) at bottom of this table	Giles
214.39	22 of 37	Sinkholes	Yes	Several sinkholes in vicinity of a proposed access road.	n/a	Giles
214.67	23 of 37	Sinkholes	Yes	Two (2) sinkholes in vicinity of proposed access road.	n/a	Giles
214.86	23 of 37	Spring	Yes	Large spring located approximately 360 feet right (east) and upstream of the proposed alignment. Alignment crosses the spring's stream. The source is most likely from the flank of the mountain to the northeast.	See Note (2) at bottom of table	Giles
214.98	23 of 37	Cave	Yes	Canoe Cave is located approximately 1,000 feet right (southeast) of the alignment.	See Note (1) at bottom of table	Giles
215.01	23 of 37	Sinkhole	Yes	Sinkhole containing debris approximately 240 feet right (southeast) of proposed alignment.	See Note (1) at bottom of table	Giles
215.24	23 of 37	Sinkhole	Yes	Sinkhole approximately 50 feet right (southeast) of proposed alignment.	See Note (2) at bottom of table	Giles
215.35	23 of 37	Sinkhole	Yes	Sinkhole approximately 440 feet right (southeast) of the proposed alignment.	See Note (1) at bottom of table	Giles
215.59	24 of 37	Contact - begin limestone	Yes	End of dolomite area (Knox). Begin limestone (undivided) area. High karst feature potential.	n/a	Giles
215.60	24 of 37	Sinkholes	Yes	Two sinkholes approximately 410 feet right (southeast) of proposed alignment.	See Note (1) at bottom of table	Giles
215.91	24 of 37	Sinkhole	Yes	Sinkole approximately 280 feet left (northwest) of proposed alignment.	See Note (1) at bottom of table	Giles
216.22	24 of 37	Cave, Stream insurgence	Yes	A possible cave with stream insurgence approximately 240 feet right (southeast) of the proposed alignment. The alignment is in the vicinity of the insurgence drainage and karst related features may be relatively near the surface.	See Note (2) at bottom of table	Giles
216.52	25 of 37	Cave, spring, stream insurgence and sinkholes	Yes	Jones Cave, a large spring, and sinkholes, one with a stream insurgence are 400 to 600 feet left (northwest) of the proposed alignment. The proposed alignment also crosses the watershed leading to the sinkholes and crosses the conveyance of a spring-fed stream where the spring is located upslope of the proposed alignment. A proposed access road along existing private and farm roads is located near the sinkholes and Jones Cave.	See Note (2) at bottom of table	Giles / Craig
216.65	25 of 37	Spring	Yes	A spring that serves three (3) houses, located approximatley 800 feet right (southeast) of proposed alignment	See Note (1) at bottom of table	Giles
216.89	25 of 37	Sinkholes	Yes	Two (2) sinkholes just left (west) and along workspace of the proposed alignment, and a historic report of a filled sinkhole approximately 300 feet left (northwest) of the proposed alignment.	See Note (2) at bottom of table	Giles
217.03	25 of 37	Sinkhole	Yes	Sinkhole approximately 120 feet right (east) of the proposed alignment.	See Note (2) at bottom of table	Craig
217.13	25 of 37	Sinkholes	Yes	Sinkhole approximately 50 feet left (northwest) of the proposed alignment. Additional sinkholes approximately 320 and 370 feet left.	See Note (2) at bottom of table	Craig
217.24	25 of 37	Sinkhole	Yes	Sinkhole 180 feet left (northwest) of the proposed alignment.	See Note (1) at bottom of table	Craig
218.09	26 of 37	Sinkhole	Yes	A sinkhole is located approximately 230 feet left (north) of the proposed alignment.	See Note (1) at bottom of table	Craig

Table 2 Karst Features and Hazards Analysis - Proposed FERC 5.0.0 Alignment (Refer to Karst Review FERC 5.0.0 Sheets 1-37 that are referenced in this Table).
Updated for MVP October 2016 Proposed Route

Key:

= Significant potential for impact - Alignment adjustments to avoid karst features removed all areas of significant concern
= Moderate potential for impact - Additional evaluation during construction may be required
= Minor potential for impact - Highlighted for construction inspection
= Negligible potential for impact

Mile Post	Sheet #	Feature Identification	Field Confirmed?	Description (Note, left and right location references are relative to increasing milepost on proposed alignment)	Potential Impacts and Recommendations for Avoidance / Mitigation	County
218.15	26 of 37	Cave and stream insurgence sinkhole	Yes	Possible cave entrance and stream insurgence within an open throat sinkhole approximately 140 feet left (northeast), and about 40 feet down a very steep hill from the proposed alignment. The alignment is likely downstream of the insurgence drainage and karst related features may be relatively near the surface.	See Note (2) at bottom of table	Craig
218.27	26 of 37	Contact	Yes	End of limestone area (approximate).	n/a	Craig
221.70	27 of 37	Contact - Pulaski Fault, begin dolomite. Begin Mount Tabor sinkhole plain	No	Approximate beginning of Mt Tabor sinkhole plain (MP 221.70). Approximate location of Pulaski Fault. Geology is poorly mapped in this area. This area is historically known to have extensive and well documented cave and karst development. A DCR dye trace study conducted in 2004 in the Mount Tabor sinkhole plain indicated that karst water flow from sinkhole toward Slussers Chapel Cave and further on to Mill Creek Cave and spring in the TNC-DCR natural area preserve.	See Note (2) and Note (3) at bottom of table. MVP is evaluating an alternate alignment to avoid the sinkhole plain to the extent practical. The desk top review of the alternate route suggests less karstification; field work is underway to verify. See Note (3) at bottom of table for certain properties.	Montgomery
221.86	27 of 37	Note	No	Alignment stream crossing in vicinity of Pulaski Fault, edge of karst area.	n/a	Montgomery
221.93	27 of 37	Cave, Stream insurgence	No	Slusser Chapel Cave and stream insurgence are approximately 3,000 feet downstream of the proposed alignment.	n/a	Montgomery
222.26	27 of 37	Sinkhole	No	Sinkhole approximately 430 feet right (southeast).	See Note (1) and Note (3) at bottom of table	Montgomery
222.84	28 of 37	Note	Yes	Alignment stream crossing in vicinity of Pulaski Fault, edge of karst area.	See Note (2) at bottom of table	Montgomery
223.25	28 of 37	Sinkhole	Yes	Sinkhole approximately 90 feet right (southwest). Several sinkholes trend to the southwest and appear to be distributed along a lineament.	See Note (2) at bottom of table	Montgomery
223.33	28 of 37	Sinkhole	Yes	Sinkholes along alignment workspace.	See Note (2) at bottom of table	Montgomery
223.34	28 of 37	Sinkhole	Yes	Open throat sinkhole approximately 70 feet left (north).	See Note (2) at bottom of table	Montgomery
223.47	28 of 37	Sinkhole	Yes	Sinkhole along alignment workspace.	See Note (2) at bottom of table	Montgomery
223.70	29 of 37	Sinkhole	Yes	Sinkhole approximatley 310 feet right (southwest).	See Note (1) at bottom of table	Montgomery
224.00	29 of 37	Sinkhole	Yes	Sinkhole along alignment workspace.	See Note (2) at bottom of table	Montgomery
224.06	29 of 37	Sinkhole	Yes	Sinkhole approximately 125 feet right (west).	See Note (2) at bottom of table	Montgomery
224.33	29 of 37	Sinkhole	Yes	Sinkhole approximately 720 feet left (northeast), and approximately 150 feet below access road.	See Note (1) at bottom of table	Montgomery
224.59	29 of 37	Sinkhole	Yes	Sinkhole approximately 40 feet right (southwest).	See Note (2) at bottom of table	Montgomery
225.02	30 of 37	Sinkhole	No	Sinkhole approximately 470 feet right (south).	See Note (1) and Note (3) at bottom of table	Montgomery
225.61	30 of 37	Sinkhole	Yes	Sinkhole approximately 195 feet right (west).	See Note (1) at bottom of table	Montgomery
226.03	31 of 37	Cave	Yes	Orr Pit No.1, No.2. Located along proposed access road MVP-MN-266. The immediate area contains several very small sinkholes likely indicating cutter and pinnacle bedrock surface.	Adjust access road alignment.	Montgomery
226.18	31 of 37	Sinkhole	Yes	Sinkhole approximately 165 feet right (southwest).	See Note (1) at bottom of table	Montgomery
226.20	31 of 37	Sinkhole	Yes	Sinkhole approximately 95 feet left (northeast).	See Note (2) at bottom of table	Montgomery
226.39	31 of 37	Sinkholes	Yes	Several sinkholes approximately 240+ feet left (northeast).	See Note (1) at bottom of table	Montgomery
226.51	31 of 37	Sinkholes	Yes	Several sinkholes approximately 145 feet left (northeast) along a lineament.	See Note (2) at bottom of table	Montgomery
226.55	31 of 37	Sinkholes	Yes	Several sinkholes approximately 150 feet right (southwest) along a lineament.	See Note (2) at bottom of table	Montgomery
226.89	32 of 37	Sinkhole	Yes	Sinkhole approximately 160 feet right (southwest) along a lineament.	See Note (2) at bottom of table	Montgomery
226.83	32 of 37	Contact - limestone	Yes	Approximate section of Lincolnshire New Market, and Edinburg Limestones. High potential for karst development.	n/a	Montgomery
226.89	32 of 37	Sinkhole lineament	Yes	Several sinkholes are mapped by desktop review within a linear cluster roughly perpendicular to the proposed MVP pipeline, ranging from approximately 160 to 2,000 feet to the northeast and southwest. This lineament may represent a fracture or zone of weakness in the bedrock. There is a possibility of unconsolidated bedrock along this lineament extended. The access road also passes in the vicinity of these sinkholes.	See Note (2) at bottom of table	Montgomery
227.23	32 of 37	Spring, Cave	Yes	Johnsons spring, water probably from the hollow to (northeast). Johnsons Cave carries a small stream and is approximately 430 feet right (southwest) of proposed MVP alignment. Several sinkholes located near Johnsons Cave and spring.	See Note (1) at bottom of table	Montgomery
227.53	32 of 37	Sinkhole lineament	Yes	Sinkholes observed right (west). This lineament may represent a fracture or zone of weakness in the bedrock. There is a possibility of unconsolidated bedrock along this lineament extended.	See Note (1) at bottom of table	Montgomery
227.57	32 of 37	Losing Stream, Insurgence	Yes	Losing stream and wet weather insurgence was observed approximately 100 feet right of proposed MVP alignment. May be associated with sinkhole lineament along ridge. Very likely contributes to the water flowing through Johnsons Cave and spring.	See Note (2) at bottom of table	Montgomery
227.70	32 of 37	Stream insurgence	Yes	Stream insurgence was observed approximately 600 feet left the proposed alignment.	See Note (1) at bottom of table	Montgomery
227.70	32 of 37	Contact - end Limestone	Yes	Limestone ends.	n/a	Montgomery
234.21	34 of 37	Contact - begin dolomite	No	Elbrook dolomite begins.	n/a	Montgomery
234.43	34 of 37	Stream insurgence	Yes	A minor stream sinks approximately 140 feet right (southwest).	See Note (2) at bottom of table	Montgomery
234.53	34 of 37	Sinkhole	Yes	Numerous small sinkholes (about 6 feet diameter) likely indicate a cutter and pinacle bedrock surface between MP-234.50 and MP-234.70. These are along and to the left (east) of the alignment.	See Note (2) at bottom of table	Montgomery
234.73	34 of 37	Sinkhole	Yes	Proposed alignment along steep edge of a 1.0 Ac., 34 foot deep sinkhole.	See Note (2) at bottom of table	Montgomery
235.09	34 of 37	Sinkhole	Yes	Sinkhole approximately 160 feet left (east) of the proposed alignment.	See Note (1) at bottom of table	Montgomery
235.13	34 of 37	Sinkholes	Yes	Two sinkholes approximately 65 feet right (southwest) of the proposed alignment.	See Note (2) at bottom of table	Montgomery
235.79	35 of 37	Contact	Yes	Begin Rome Formation. Very limited karst potential.	n/a	Montgomery
235.79	36 of 37	Note	Yes	No karst features identified in this proposed alignment.	n/a	Montgomery
238.67	37 of 37	Contact	Yes	End Rome Formation. Karst assessment ends.	n/a	Montgomery

Notes:

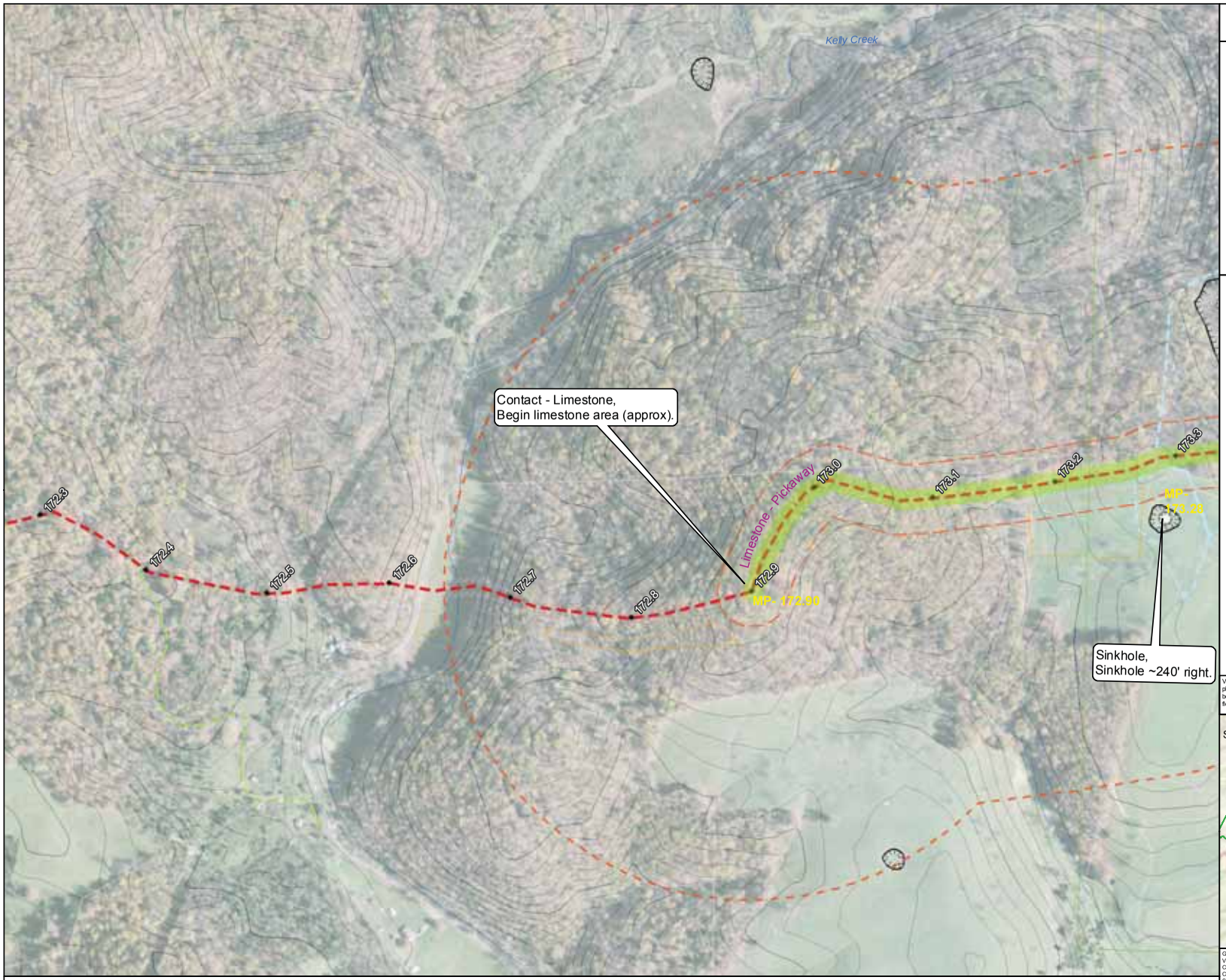
(1) - In general, uncontrolled storm water or construction-related fluid release from the Limit of Disturbance could potentially impact groundwater or surface water via the karst feature(s) or spring, and/or accentuate soil raveling and sinkhole formation. Field reconnaissance indicates negligible risk for impact to the karst feature or spring and BMPs will prevent incidental impacts. Construction may encounter pinnacled bedrock or unstable soil or shallow groundwater. Recommendations: Do not convey stormwater or discharge construction-related fluid to a karst feature or drainage leading thereto; Implement Project-specific Erosion Sediment Control Plan and Spill Prevention Control and Countermeasures Plan.

(2) - The karst feature(s) and/or drainage is proximal to the Limit of Disturbance. In general, uncontrolled storm water or construction-related fluid release from the Limit of Disturbance could potentially impact groundwater or surface water via karst feature(s) or spring, and/or accentuate soil raveling and sinkhole formation. Field reconnaissance indicates negligible risk for impact to the karst feature or spring and BMPs will prevent incidental impacts. Construction may encounter pinnacled bedrock or unstable soil or shallow groundwater. Recommendations: Adjust the construction right-of-way to the extent practical to avoid a karst feature. If avoidance is not possible, refer to Karst Mitigation Plan for mitigation and stabilization; Do not convey stormwater or discharge construction-related fluid to a karst feature or drainage leading thereto; Implement Project-specific Erosion Sediment Control Plan and Spill Prevention Control and Countermeasures Plan.

(3) - The primary concern is that MVP was not permitted access to the property to field verify karst feature(s). See Note (1) or Note (2) above for recommendations. Further recommendations: Provide MVP permission to conduct field verification of the property for potential karst feature(s).

Appendix A

Map Sheets (1-37) for Karst Hazards Assessment



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Aerials: USGS NAIP Series. Monroe Co. 10/27/2014; Giles Co. 10/02/2014; Montgomery Co. 10/25/2014.

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Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Karst Features and Hazards Assessment MVP October 2016 Proposed Route

Sheet 1 of 37

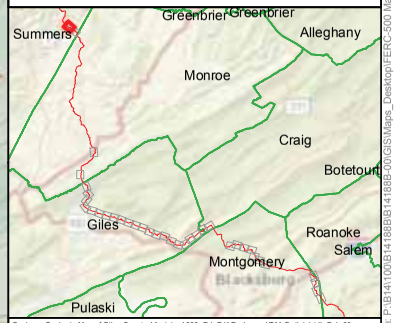
09-30-16

Draper Aden Associates
Engineering • Surveying • Environmental Services

Legend

- Cave (Length, Depth)
- Spring
- Swallet
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Sinkholes VGIN-5ft
- Sinkholes VaDMME
- Select Sinkhole Watersheds
- Fault
- Lineament
- 150' Buffer, Primary Karst Review Zone
- 1320' Buffer, Secondary Karst Review Zone
- MVP October 2016 Proposed Route
- MVP October 2016 Proposed Route Milepost
- MVP October 2016 Proposed Access Roads
- MVP October 2016 Proposed Permanent Easement
- MVP October 2016 Proposed Temporary Work Space
- MVP October 2016 Proposed Ancillary and ATWS

VGIN Contour Disclaimer: "Any determination of topography or contours, or any depiction of physical improvements, property lines or boundaries is for general information only and shall not be used for the design, modification, or construction of improvements to real property or for flood plain determination."



Geology: Geologic Map of Giles County, Virginia. 1986. Ed. E.K.Rader and T.M.Gathright II. Pub.69, Virginia Dept. of Mines, Minerals and Energy
Caves: Douglas (1964); Holsinger (1975); Zokaites (1995). Va and WVa Speleological Surveys.
Contours: VA: VGIN 2007/2011 Terrain Models, WV: USGS 1/9 NED. For Visualization Only.
Sinkholes: VaDMME, http://dmme.virginia.gov/webmaps/DGMR
Appalachian Trail: https://www.appalachiantrail.org/about-the-trail/mapping-gis-data

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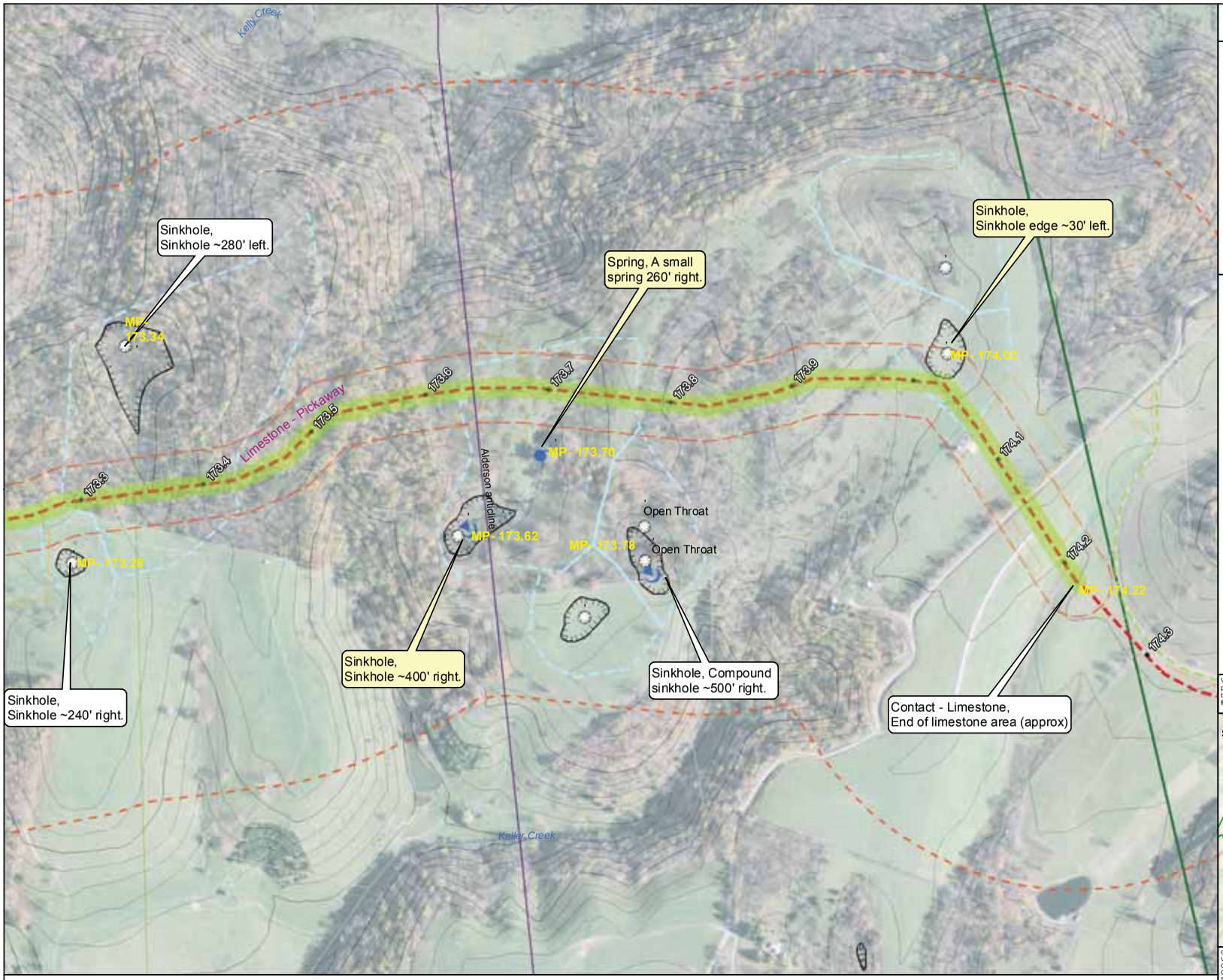

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Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Karst Features and Hazards Assessment MVP October 2016 Proposed Route

Sheet 2 of 37

09-30-16

Draper Aden Associates
Engineering • Surveying • Environmental Services

Legend

- Cave (Length, Depth)
- Spring
- Swallet
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Sinkholes VGIN-5ft
- Sinkholes VaDMME
- Select Sinkhole Watersheds
- Fault
- Lineament
- 150' Buffer, Primary Karst Review Zone
- 1320' Buffer, Secondary Karst Review Zone
- MVP October 2016 Proposed Route
- MVP October 2016 Proposed Route Milepost
- MVP October 2016 Proposed Access Roads
- MVP October 2016 Proposed Permanent Easement
- MVP October 2016 Proposed Temporary Work Space
- MVP October 2016 Proposed Ancillary and ATWS

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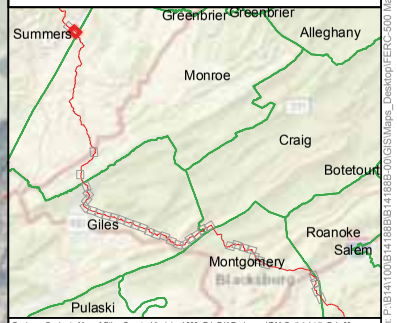

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Appalachian Trail: https://www.appalachiantrail.org/about-the-trail/mapping-gis-data

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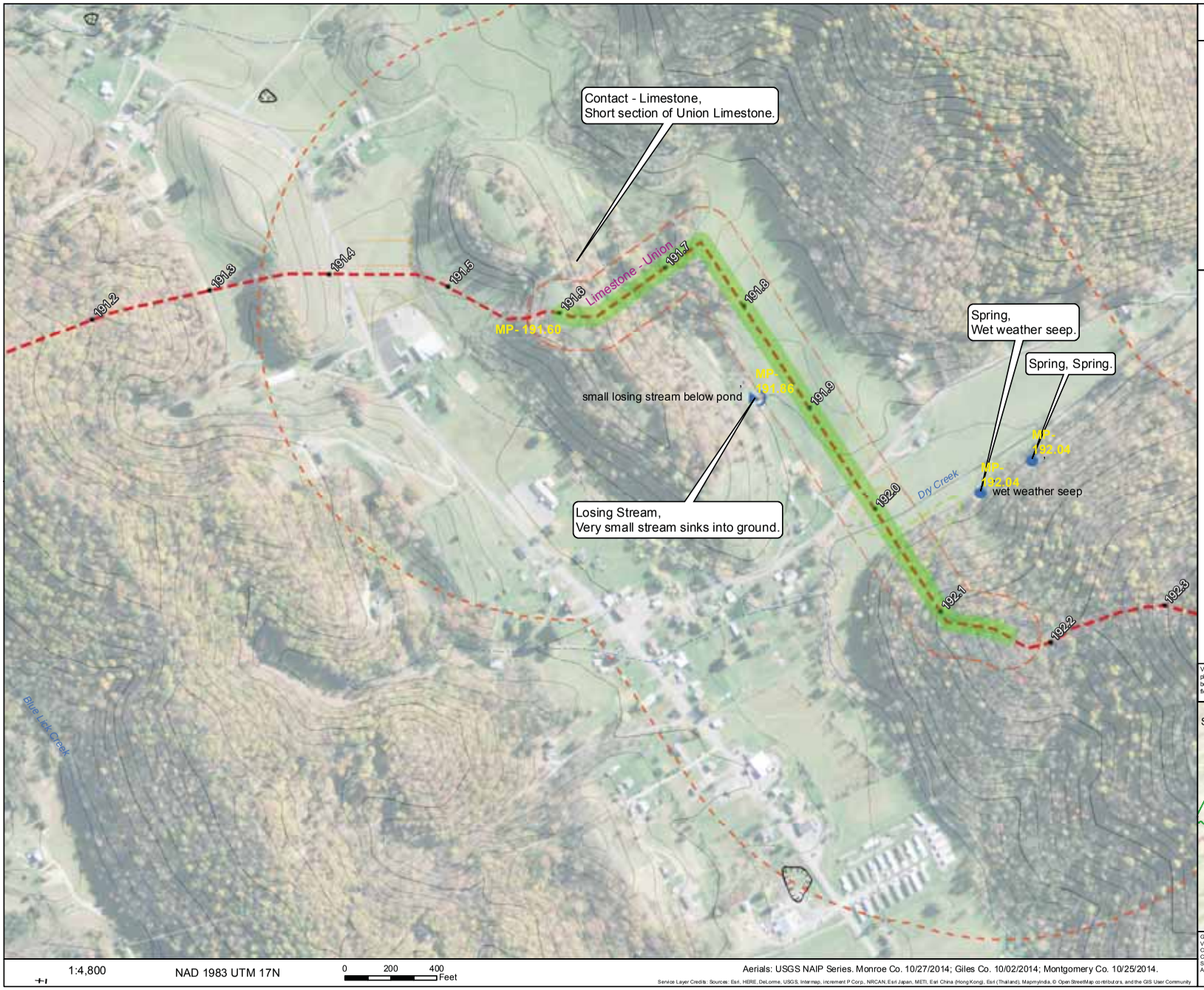

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Legend

- Cave (Length, Depth)
- Spring
- Swallet
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Sinkholes VGIN-5ft
- Sinkholes VaDMME
- Select Sinkhole Watersheds
- Fault
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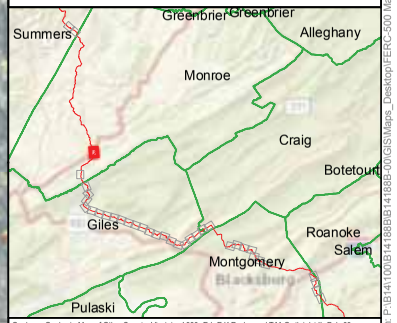

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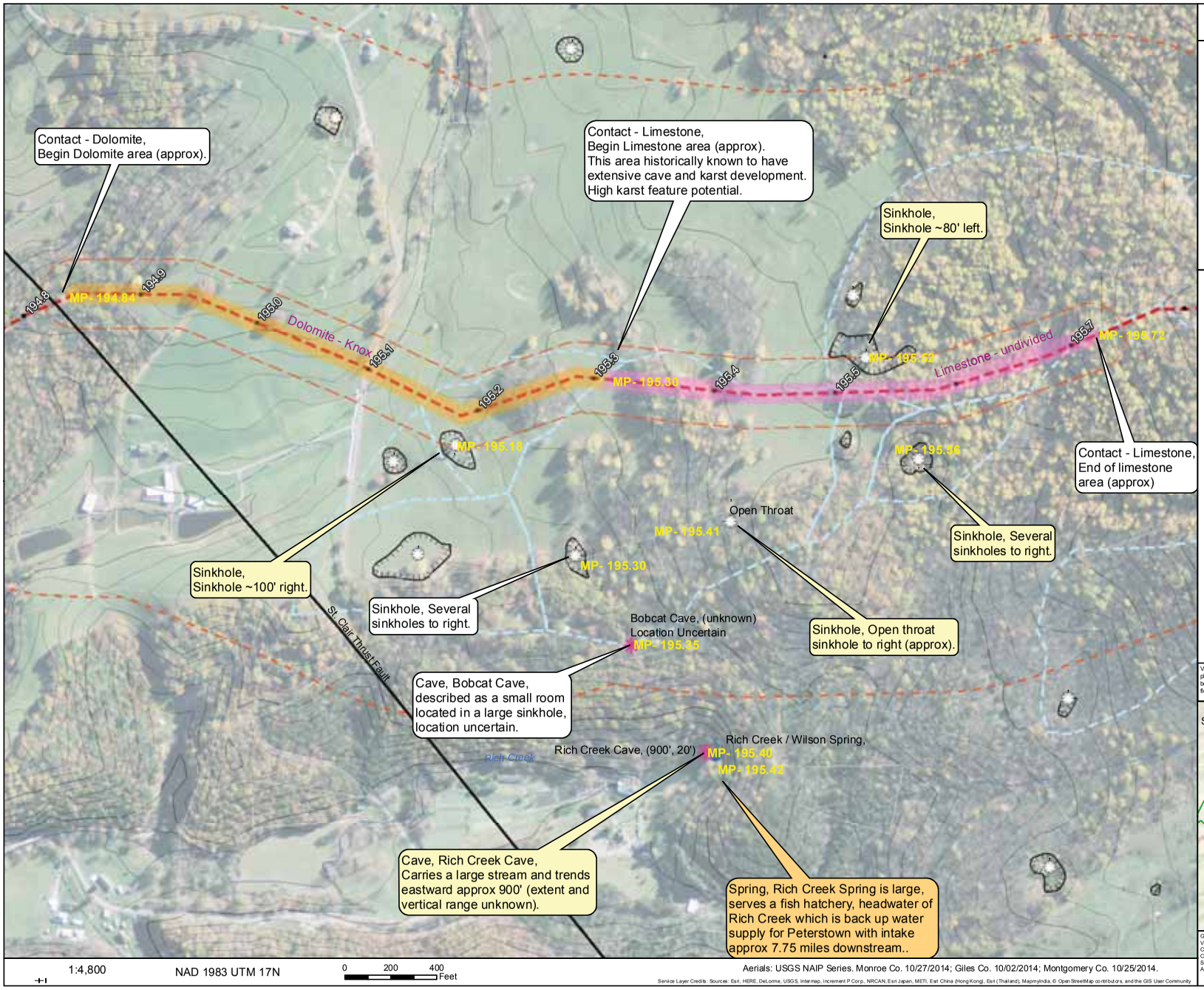

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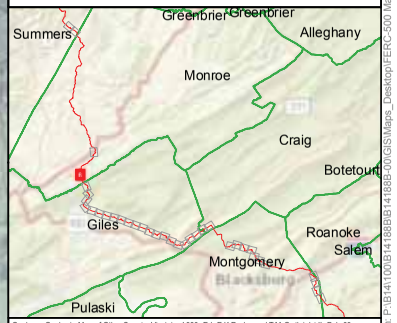

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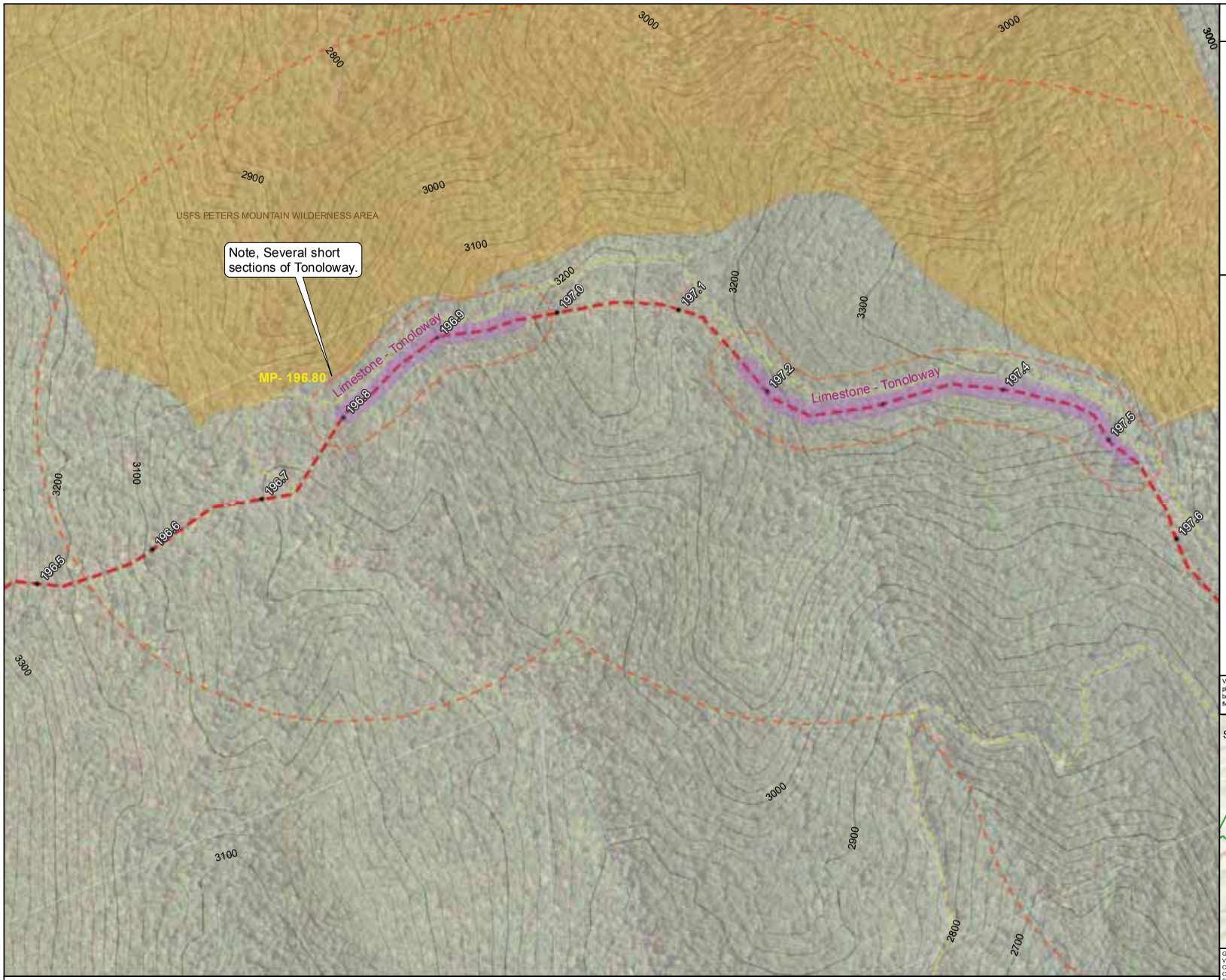

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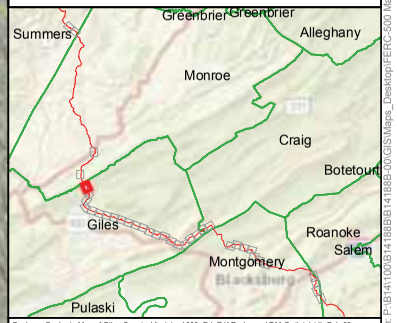

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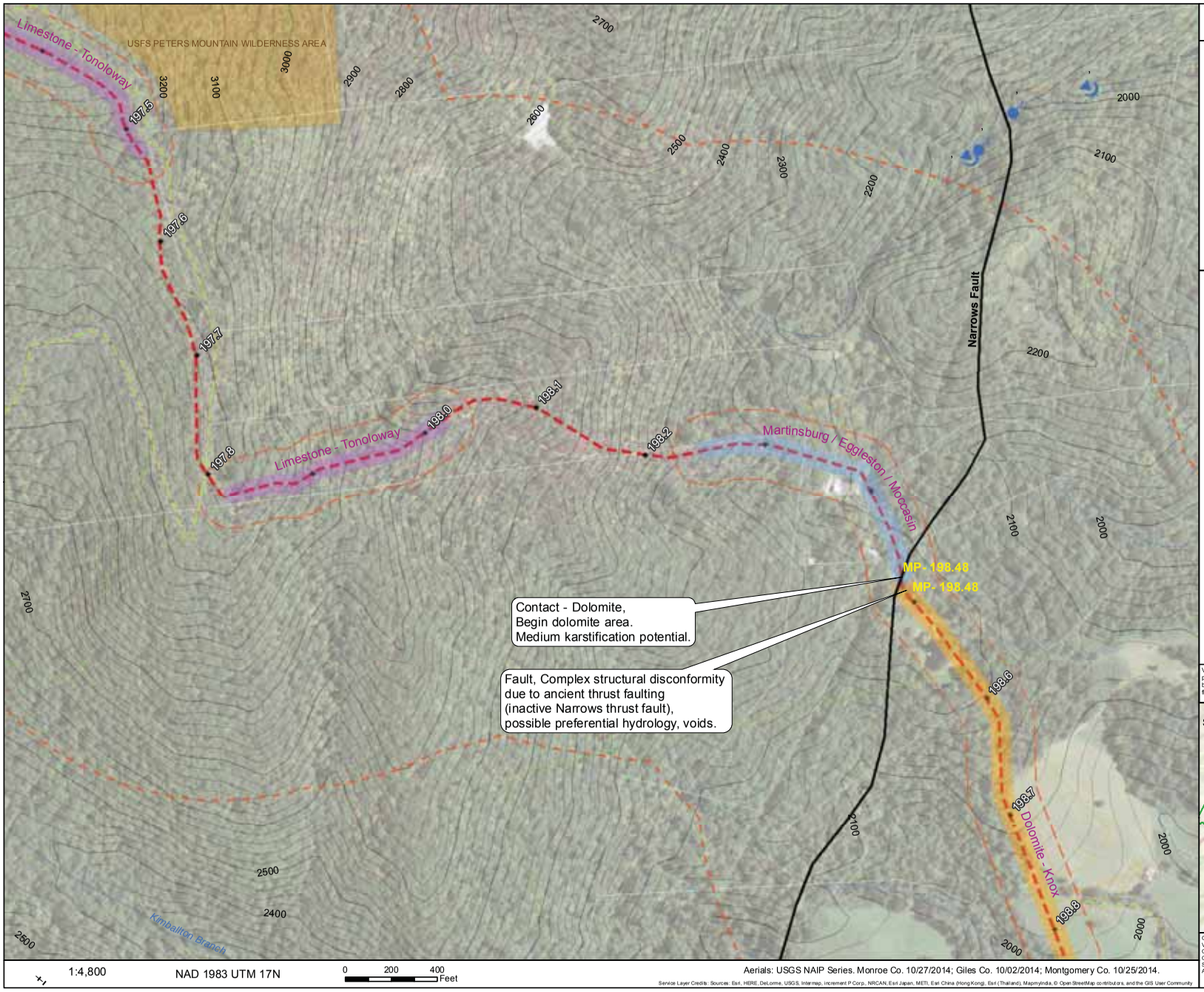

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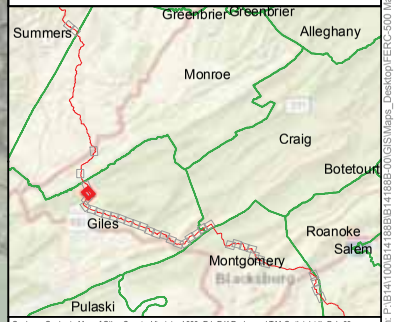

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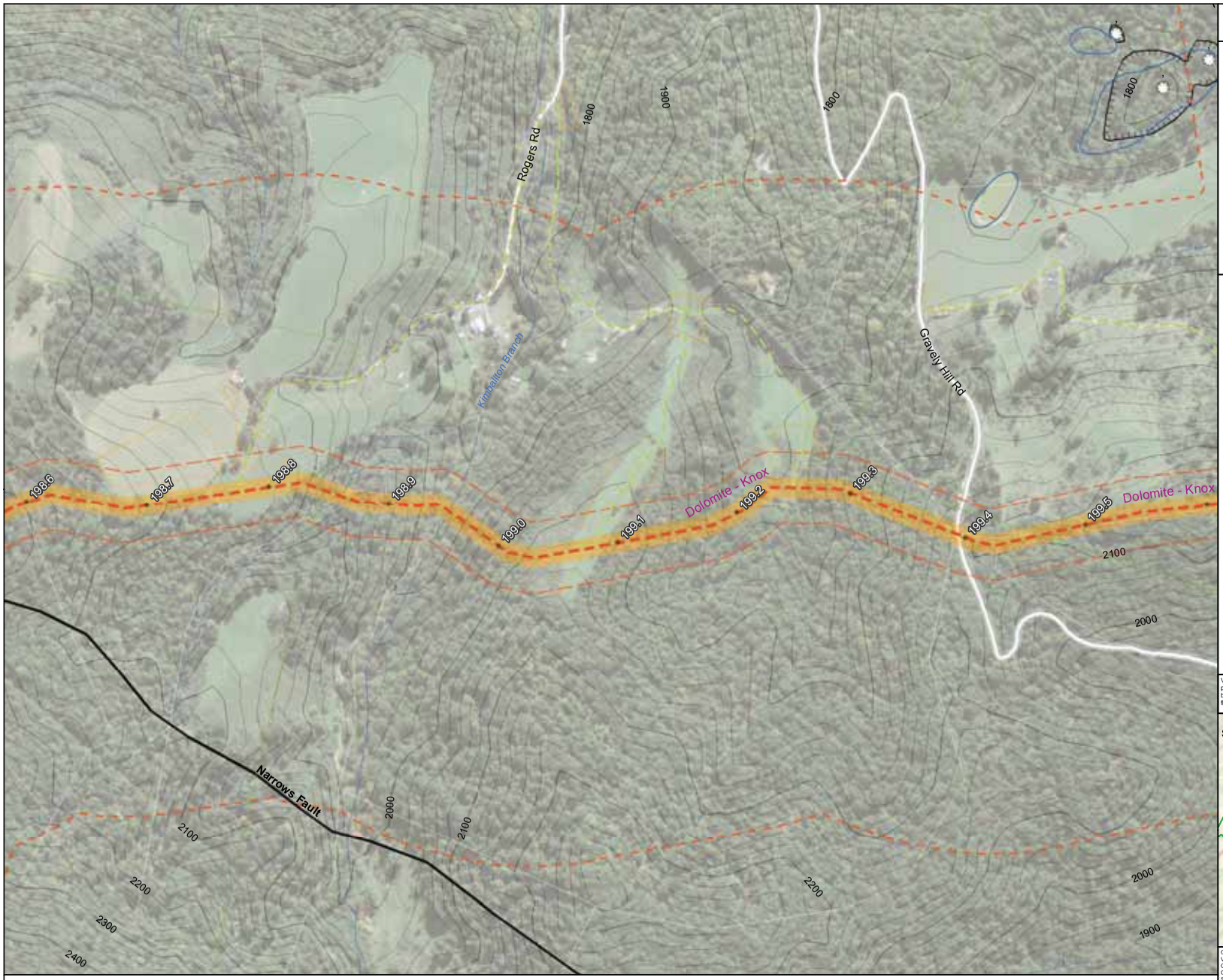

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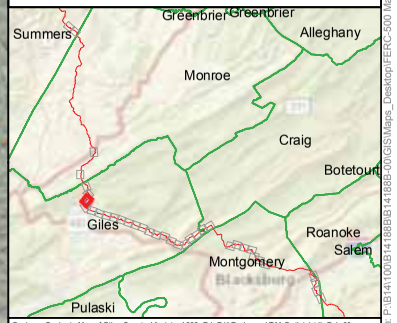

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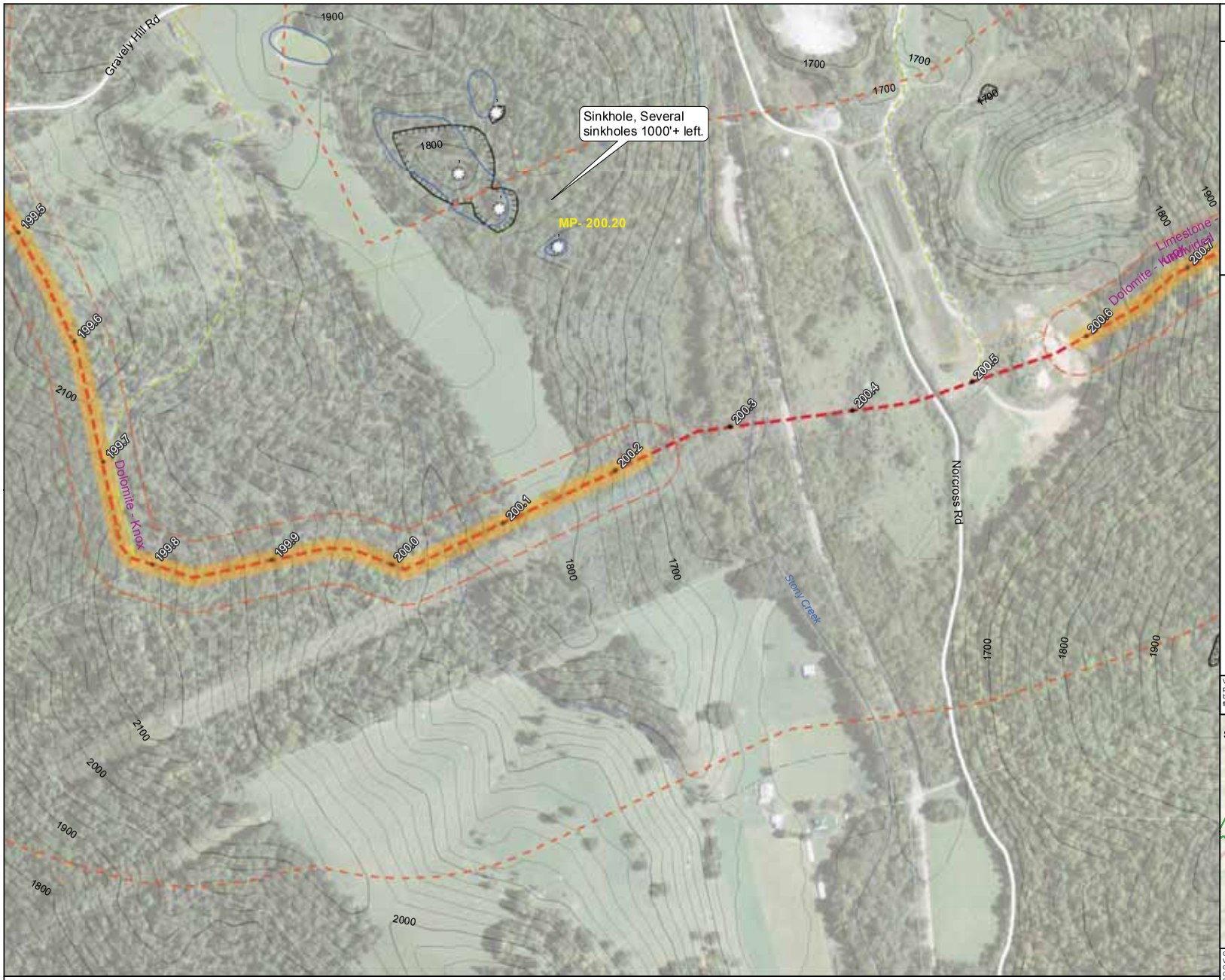

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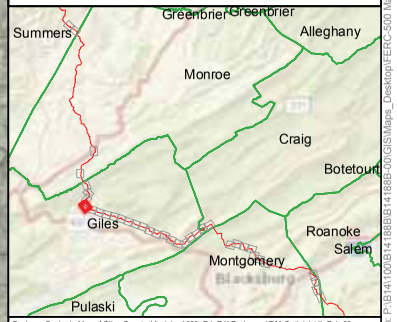

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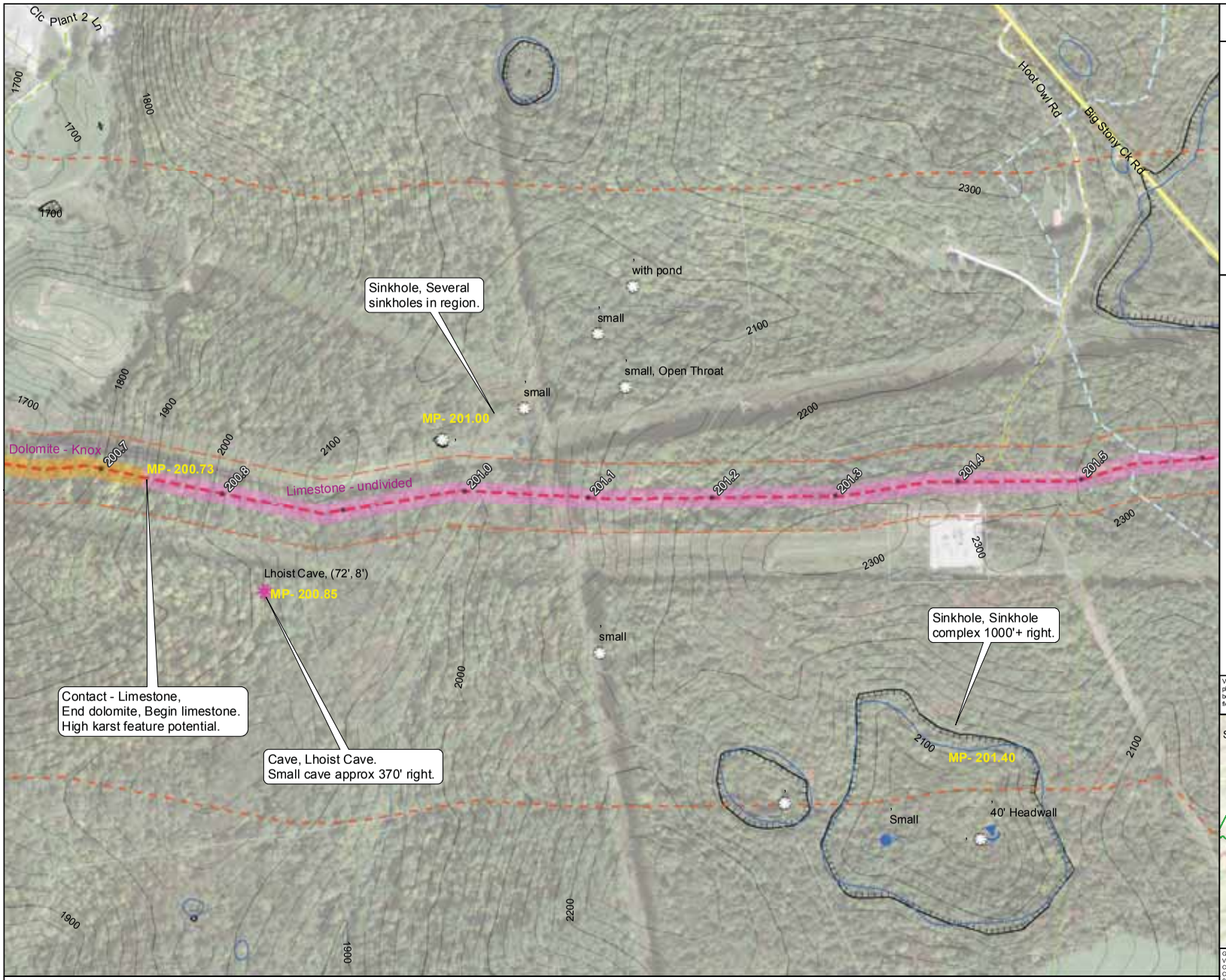

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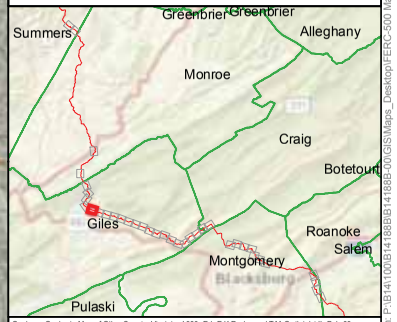

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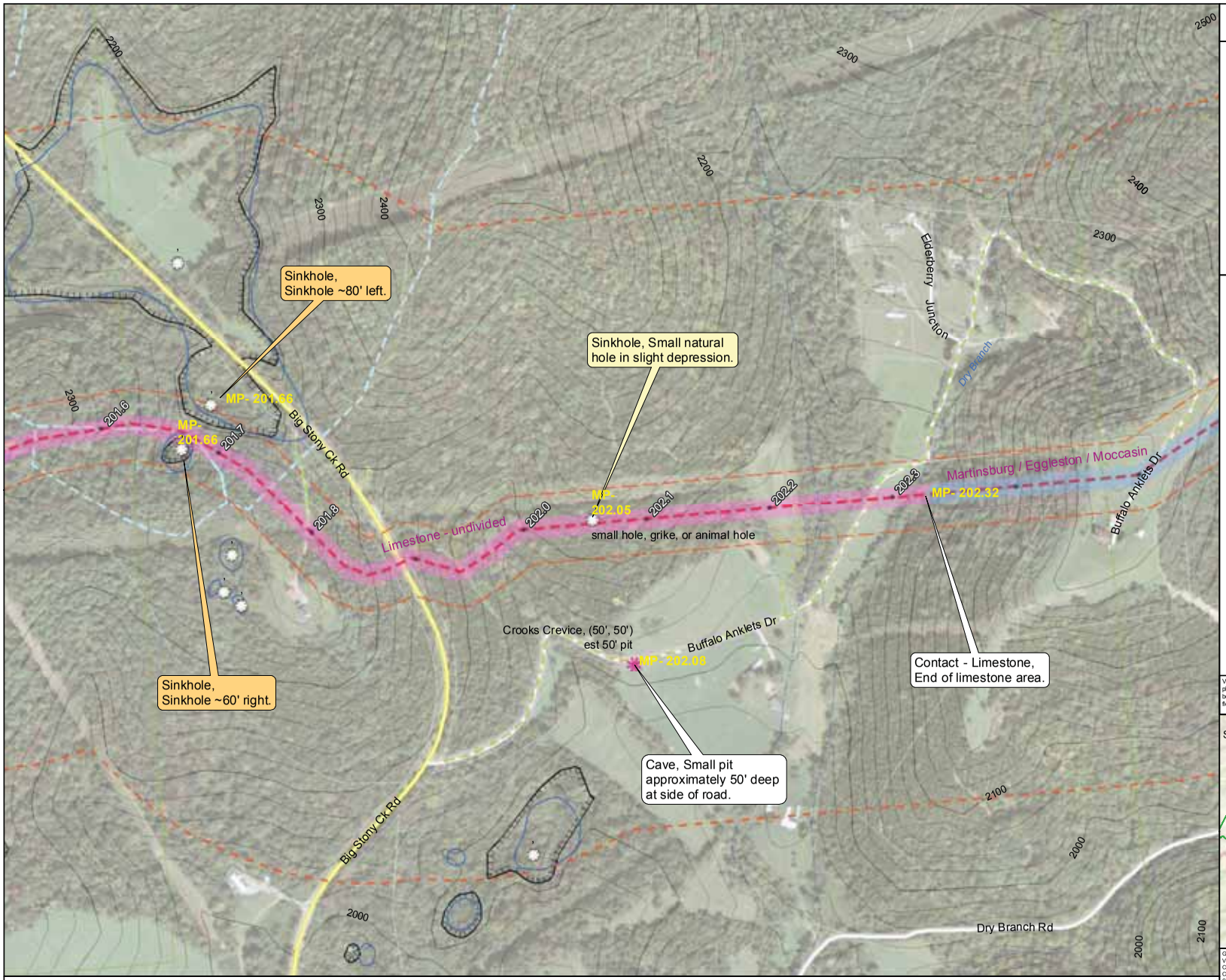

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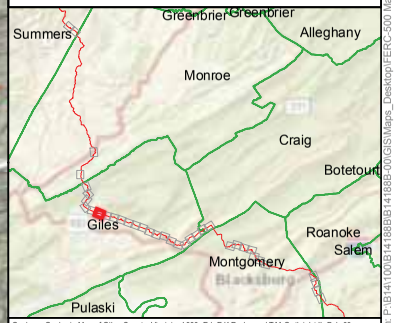

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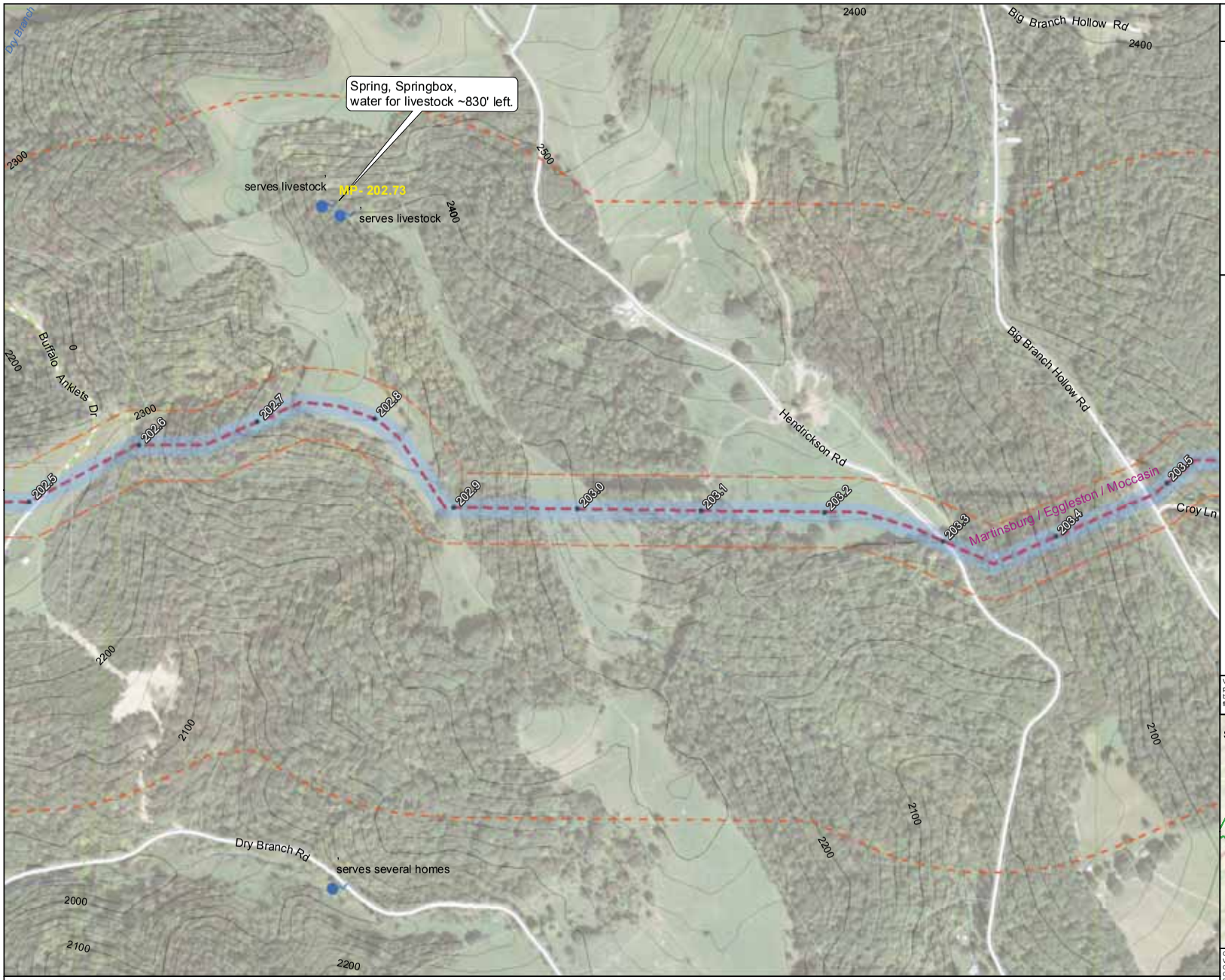

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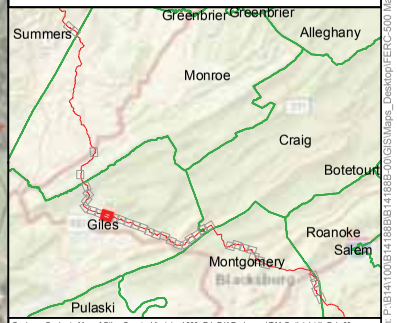

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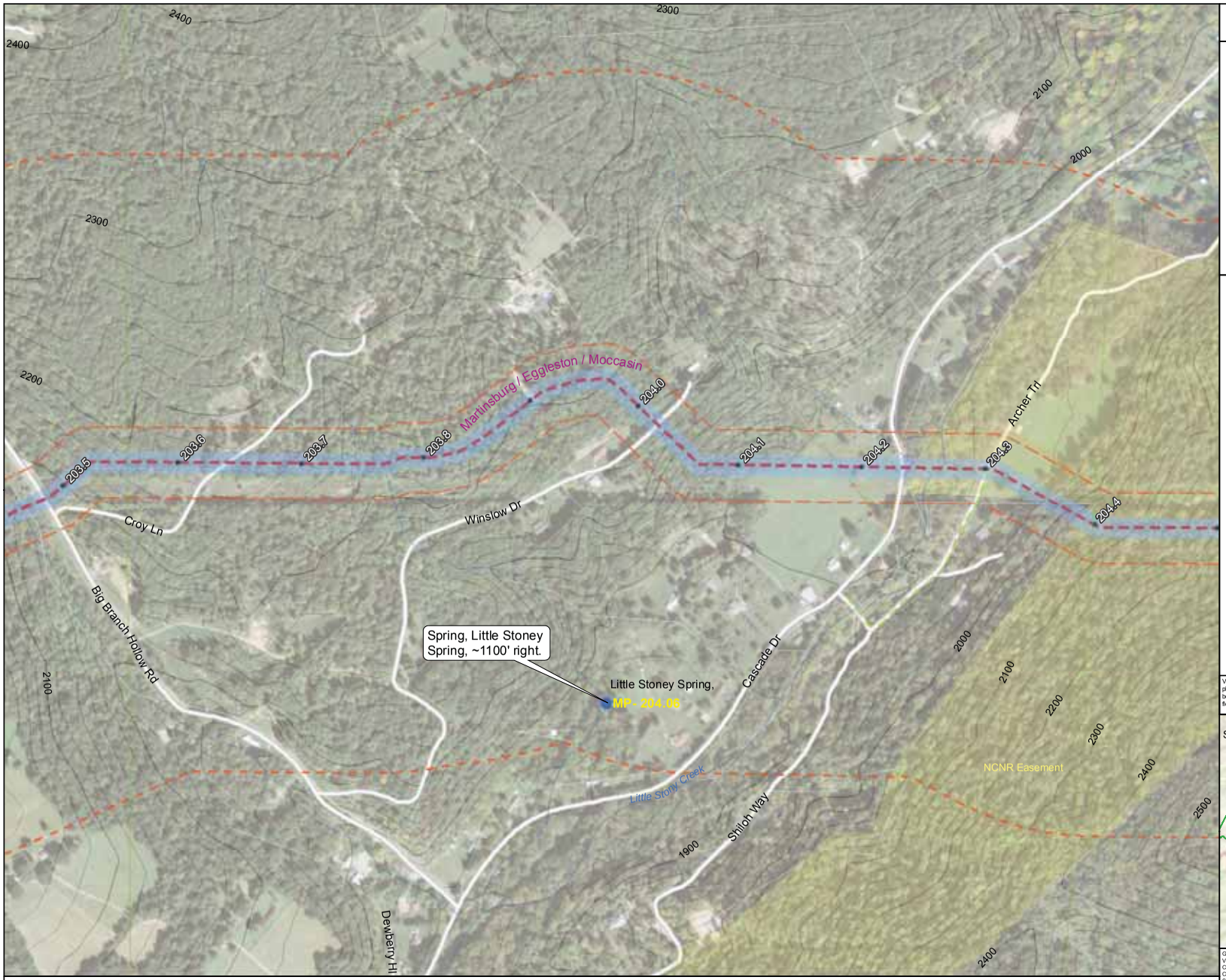

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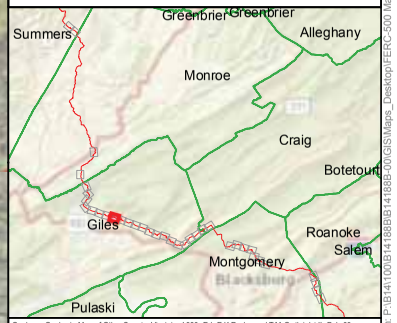

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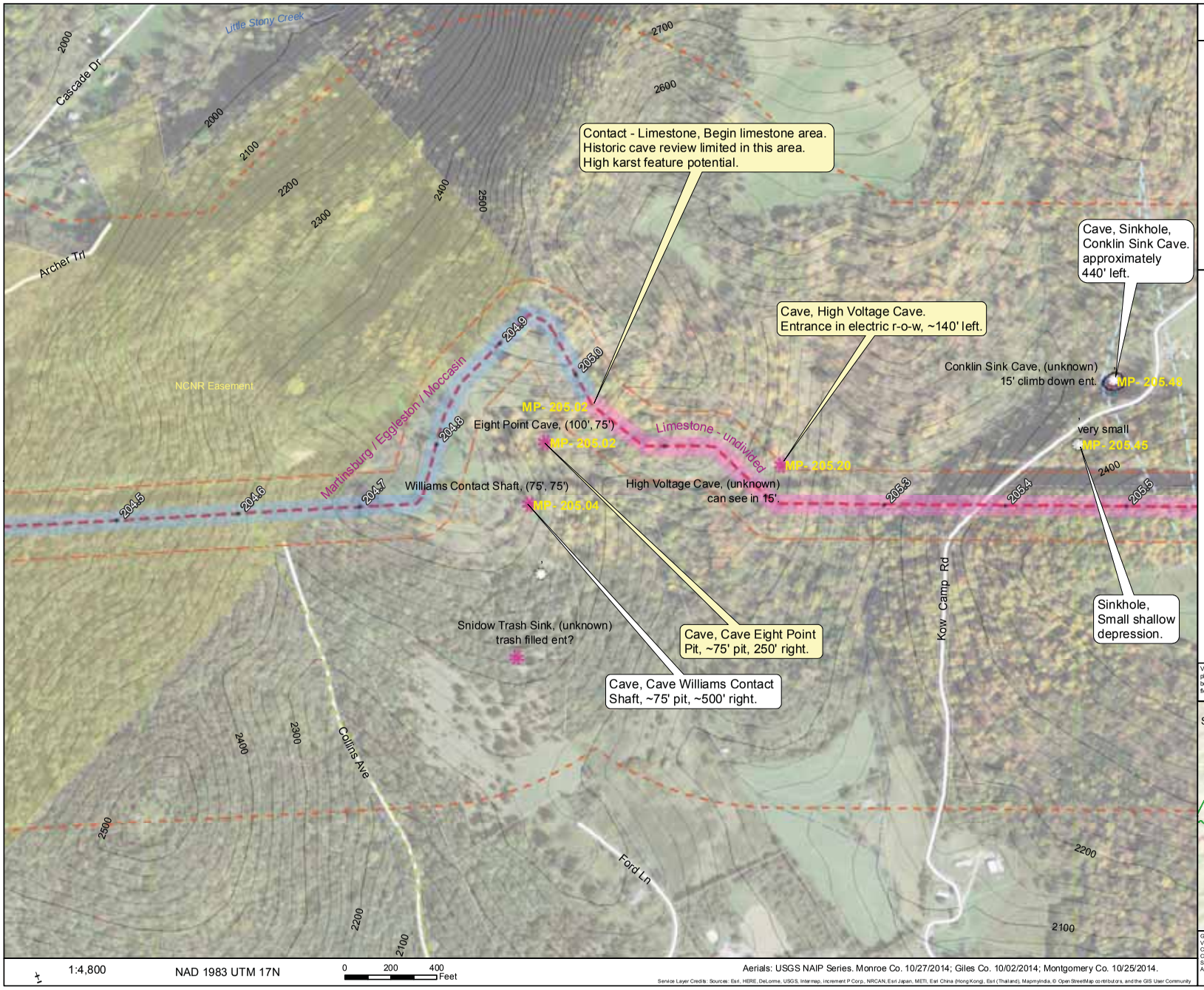

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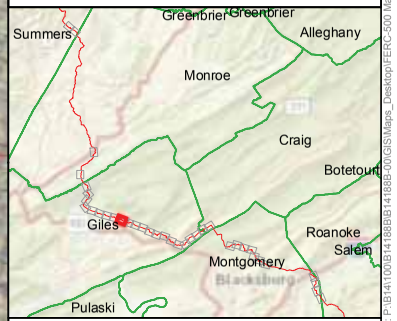

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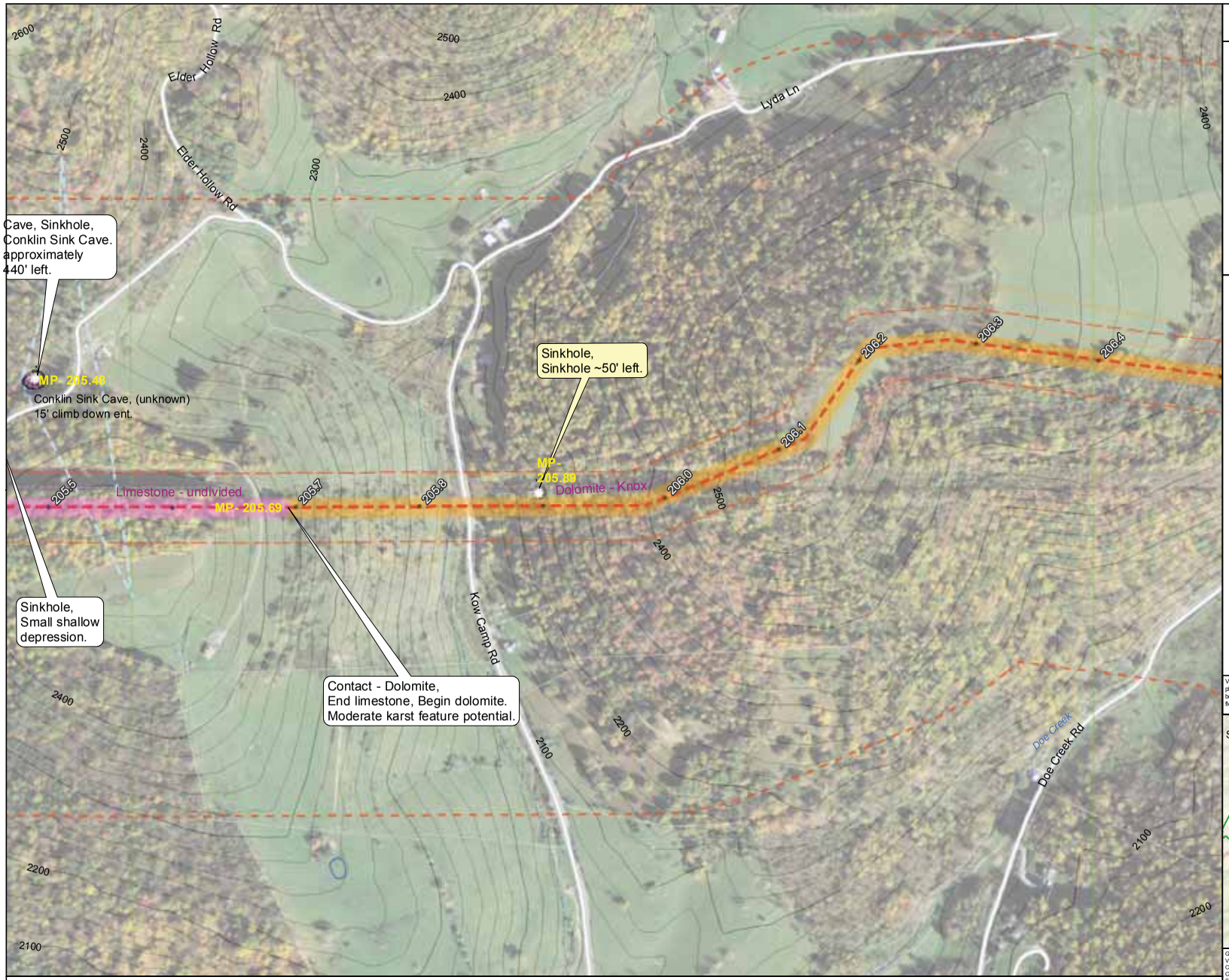

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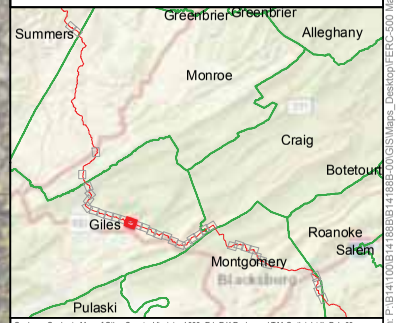

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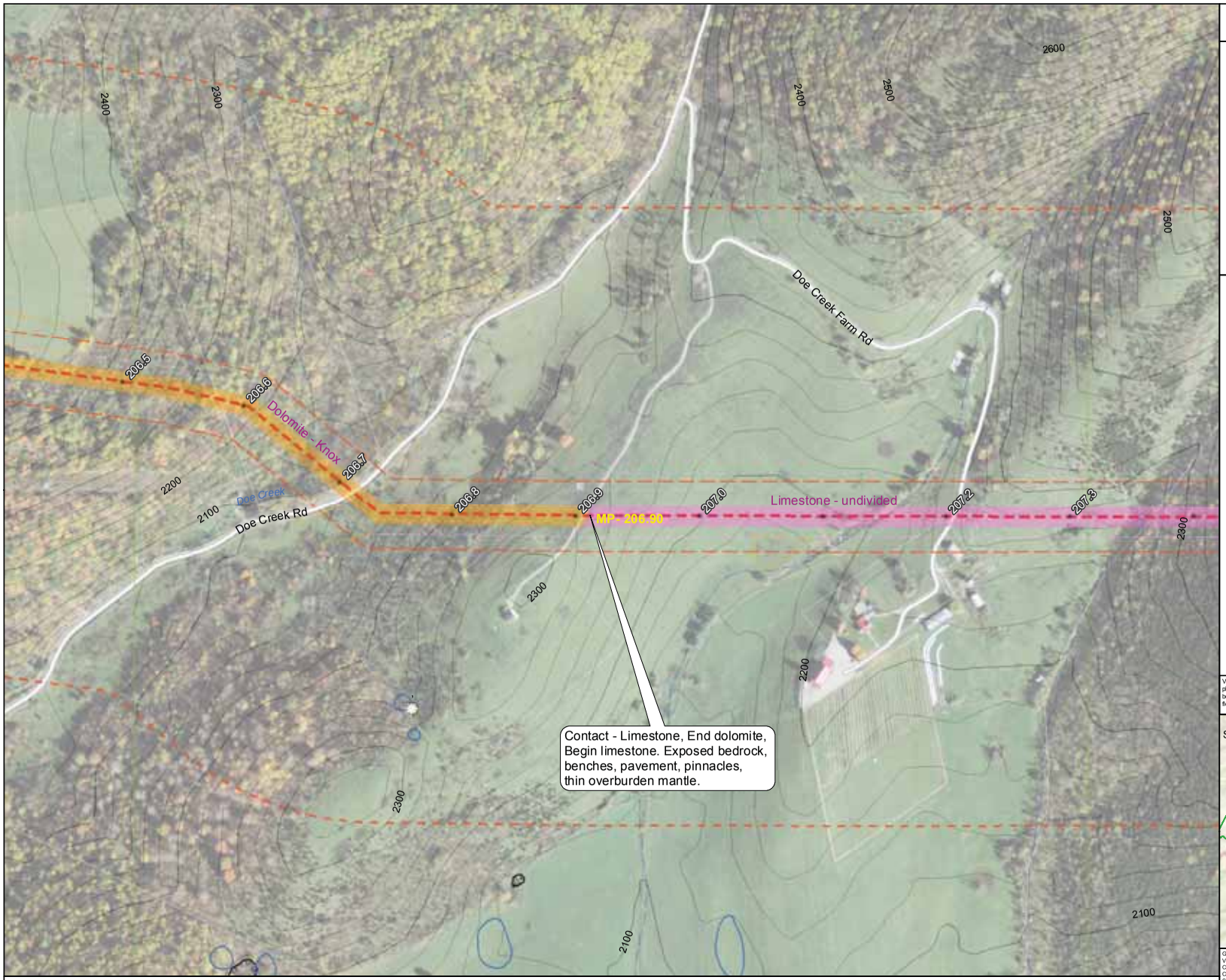

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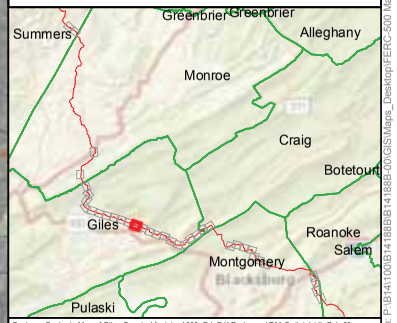

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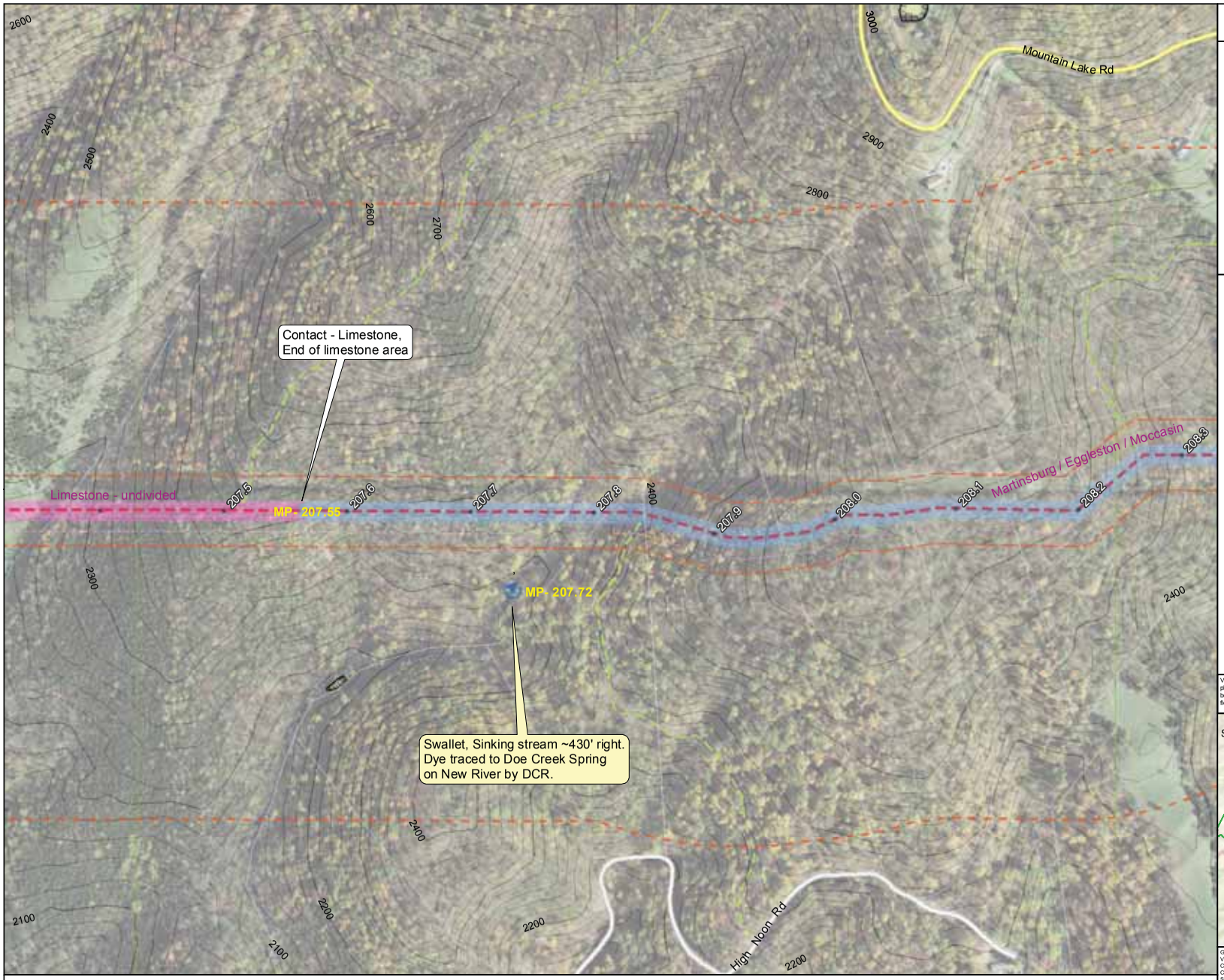

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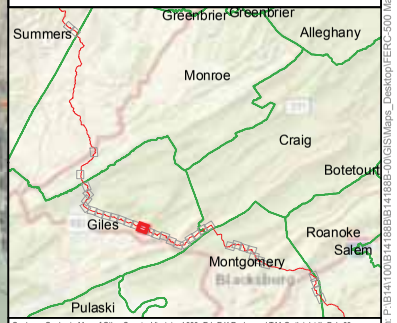

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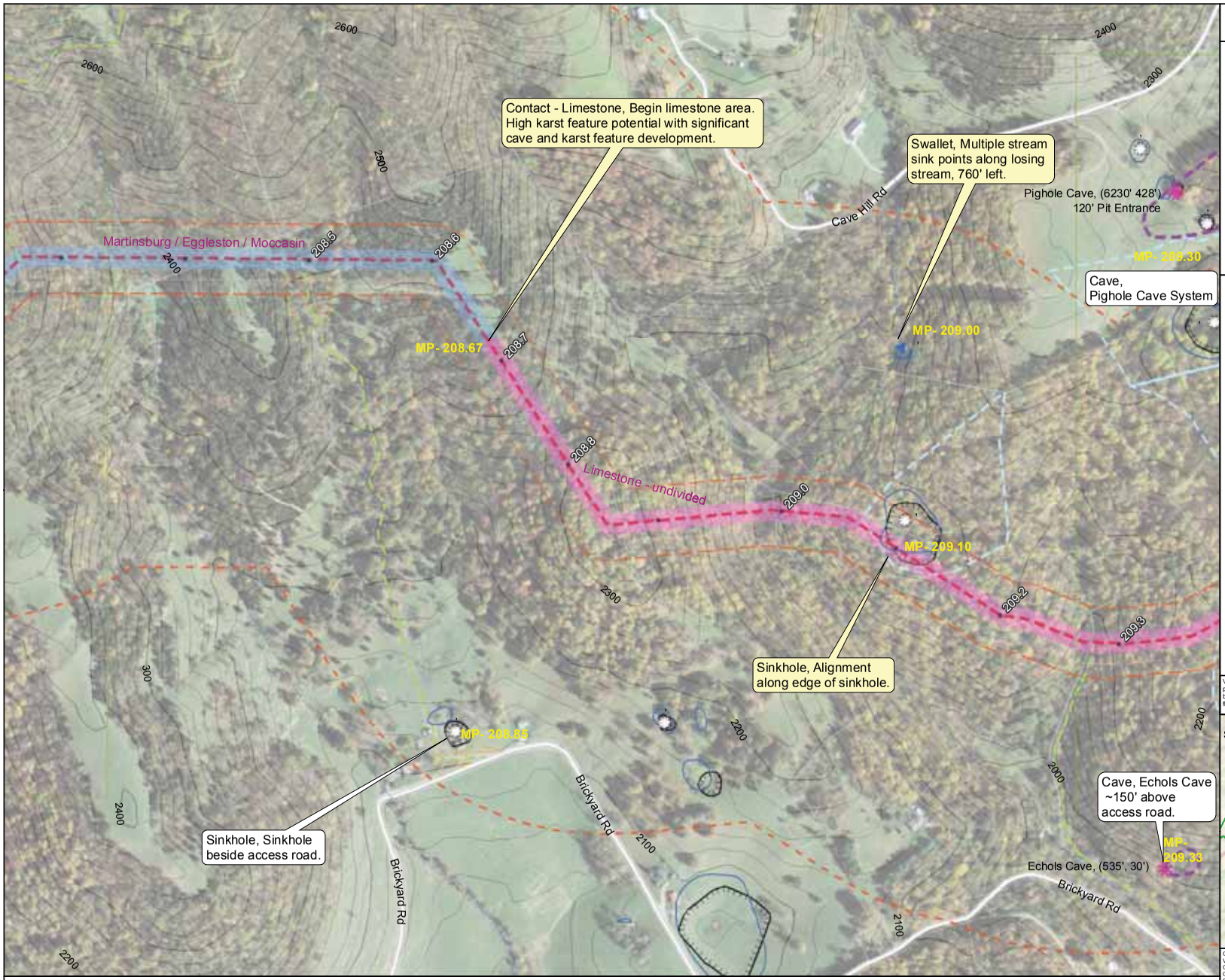

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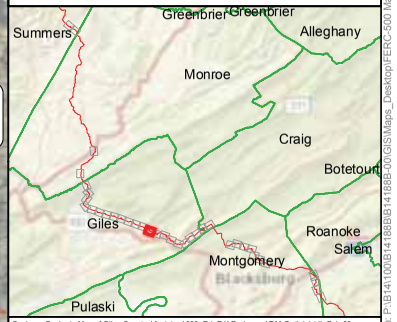

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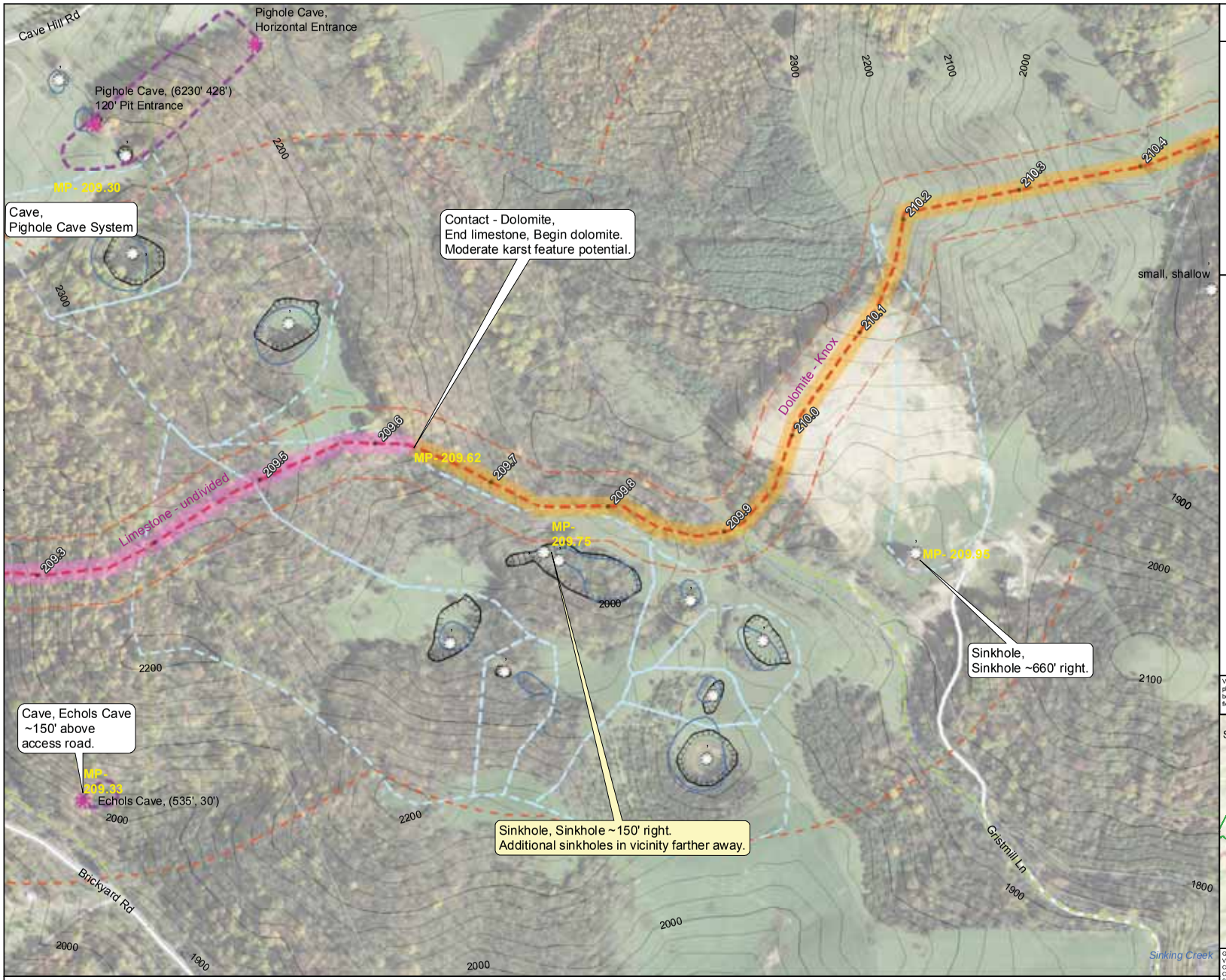

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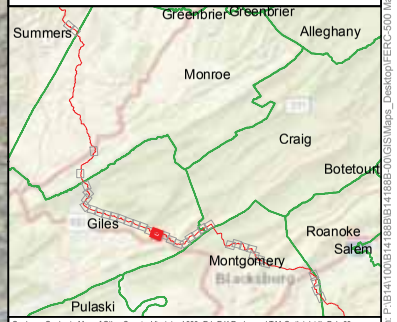

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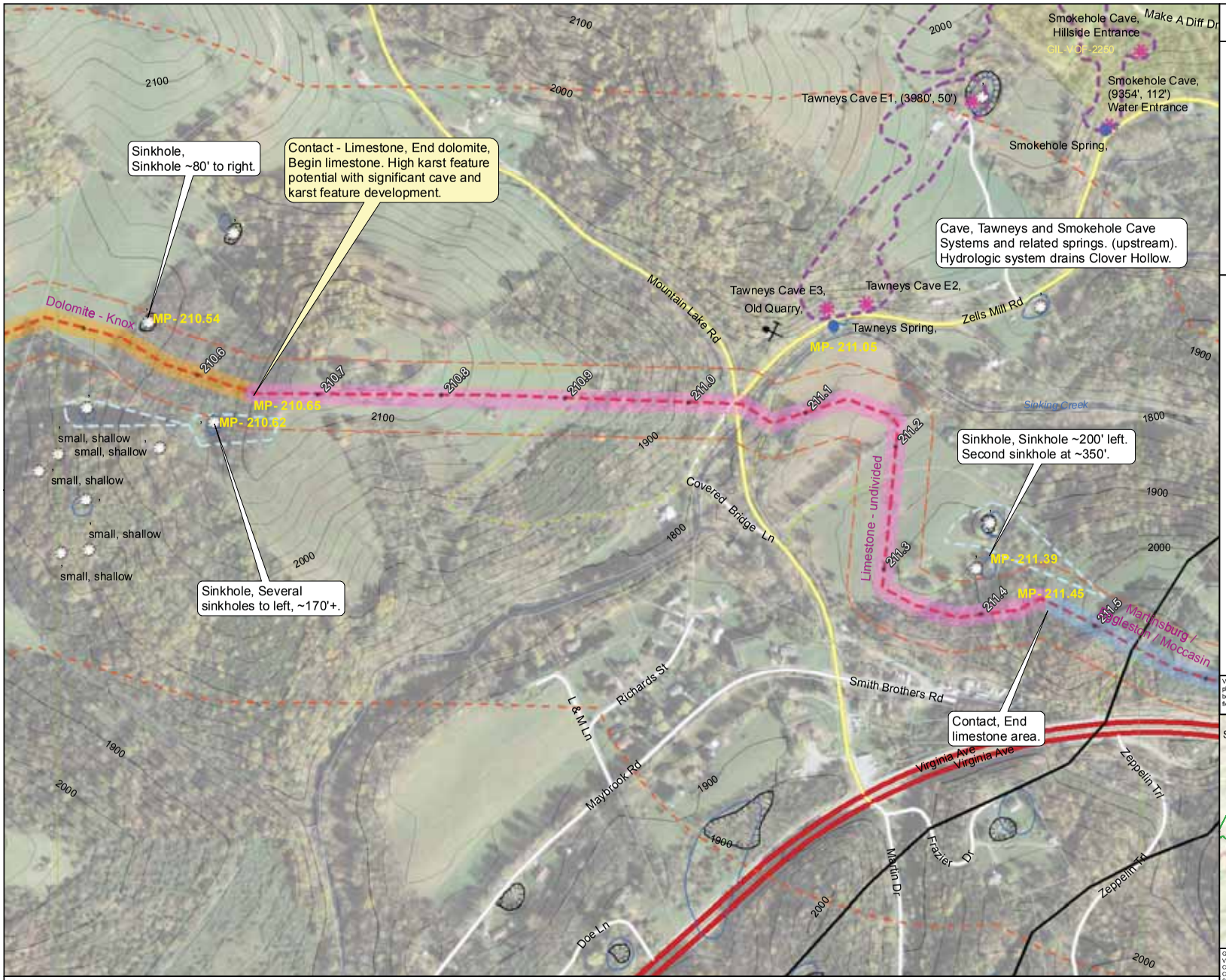

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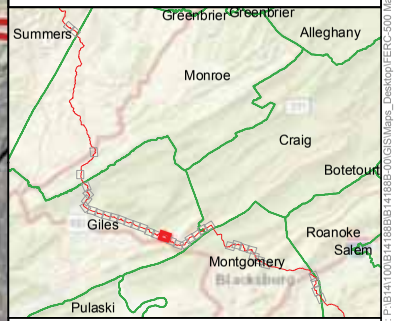

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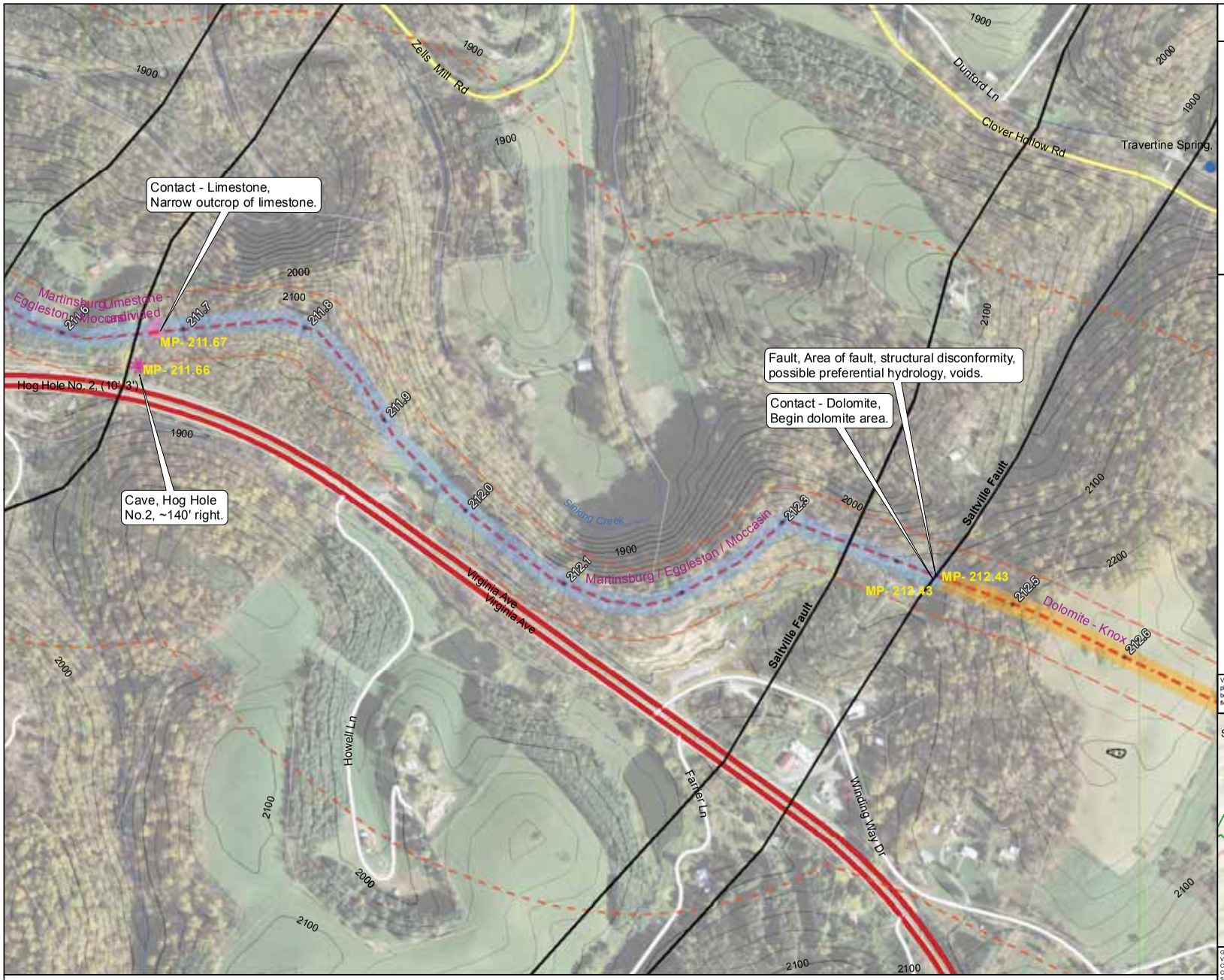

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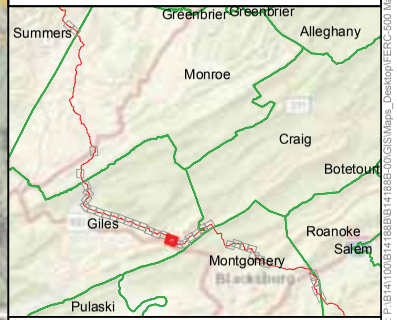

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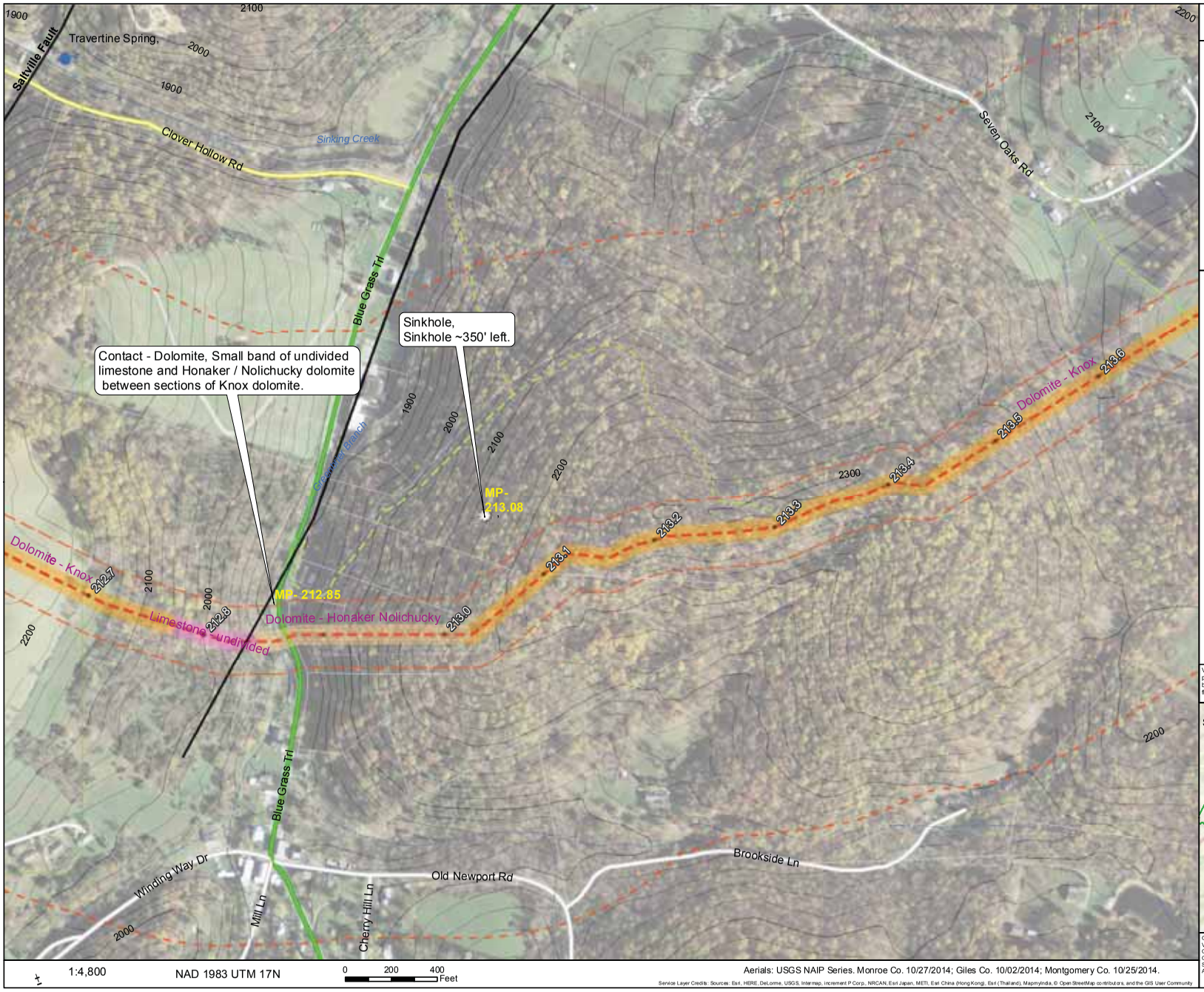

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Legend

- Cave (Length, Depth)
- Spring
- Swallet
- Sinkhole
- Quarry / Mine
- Known Cave Extent
- Sinkholes VGIN-5ft
- Sinkholes VaDMME
- Select Sinkhole Watersheds
- Fault
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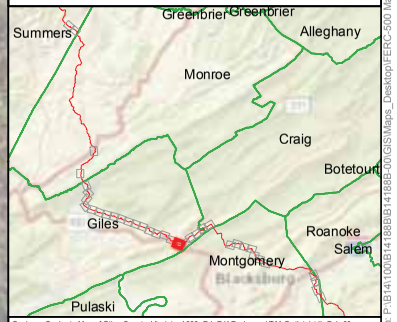

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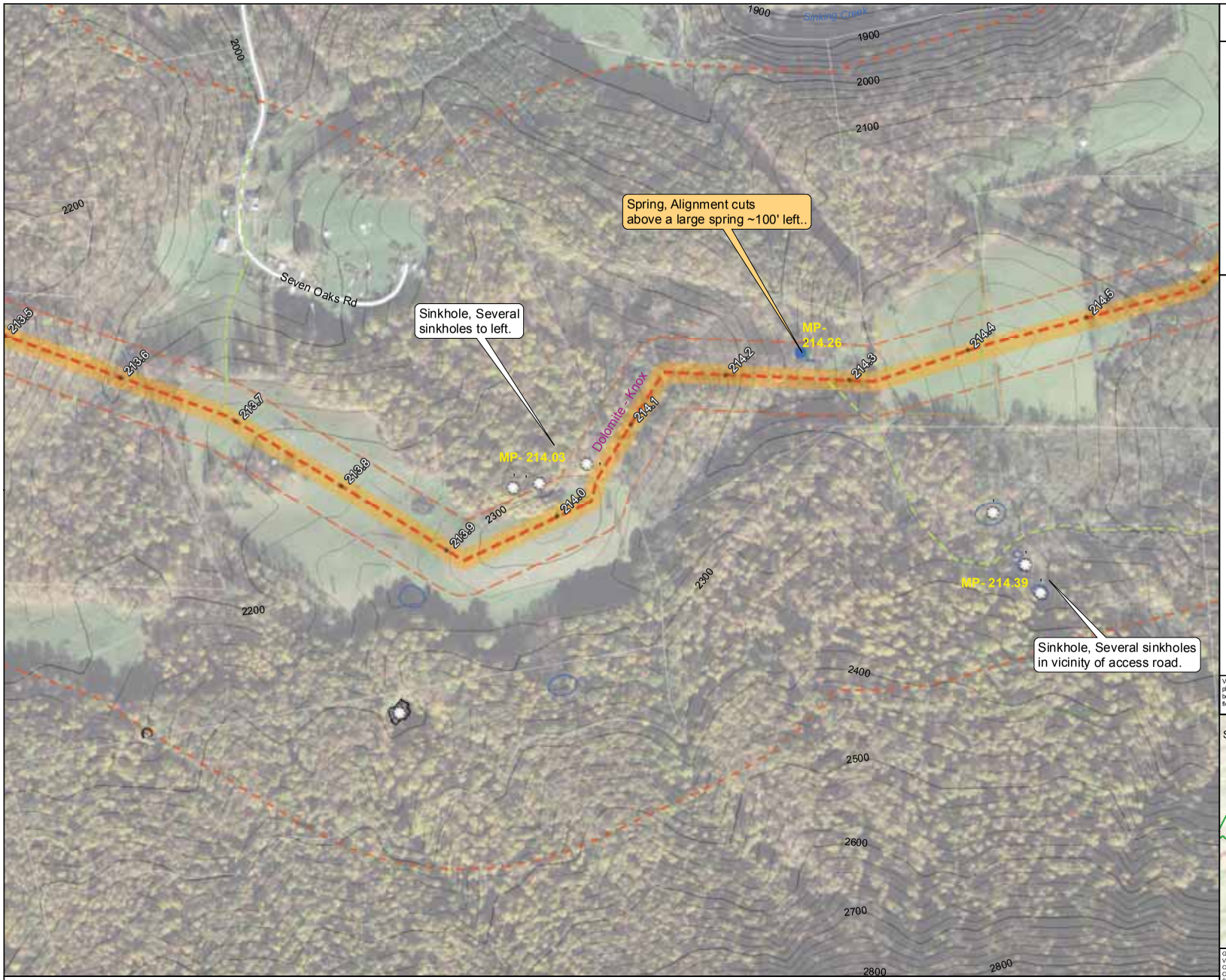

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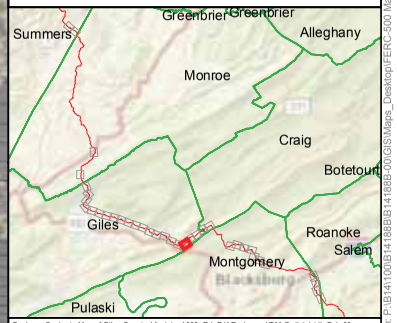

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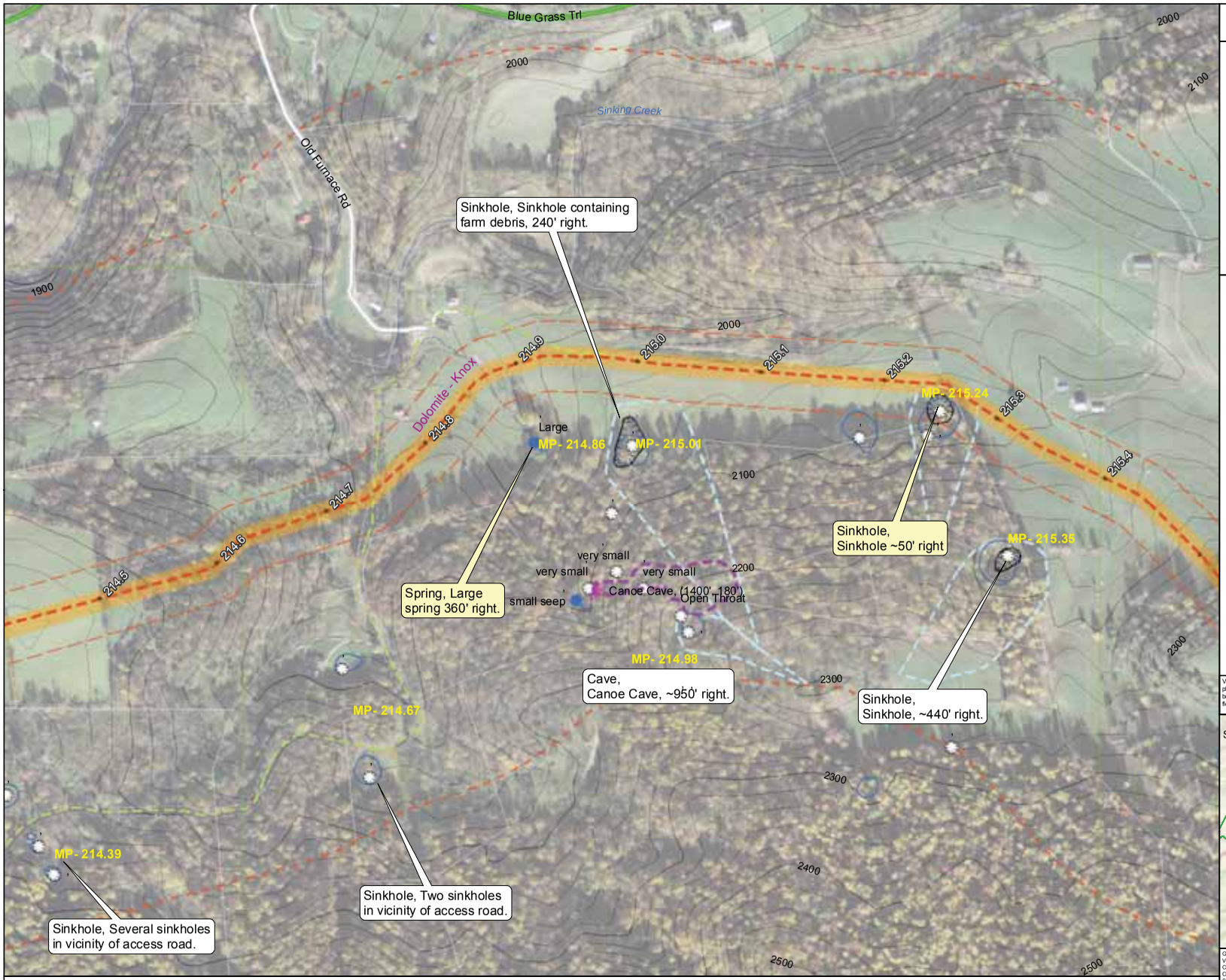

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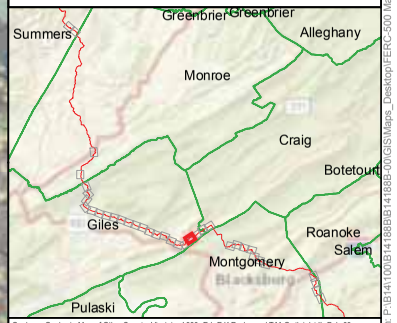

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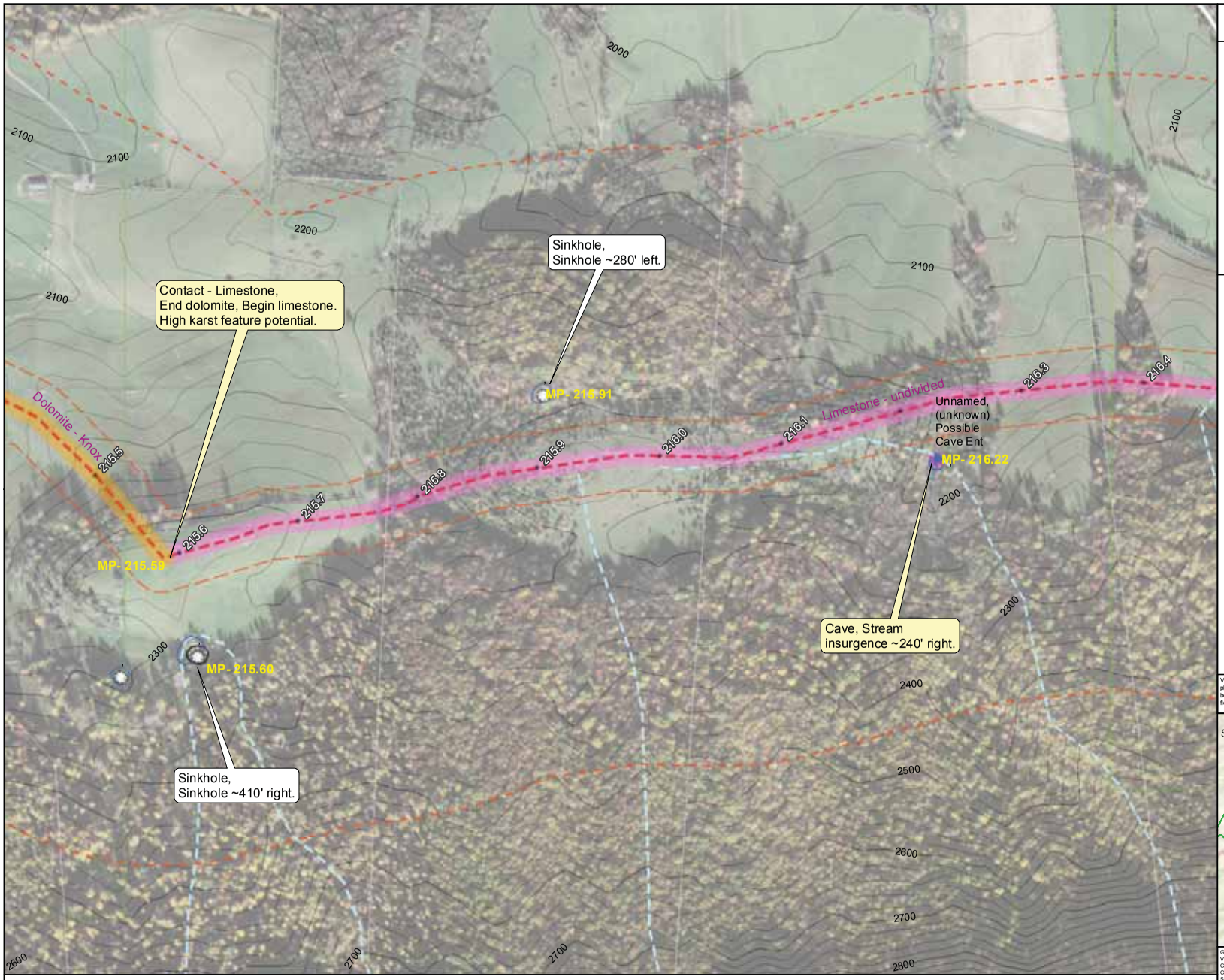

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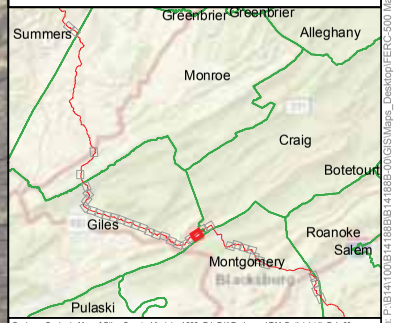

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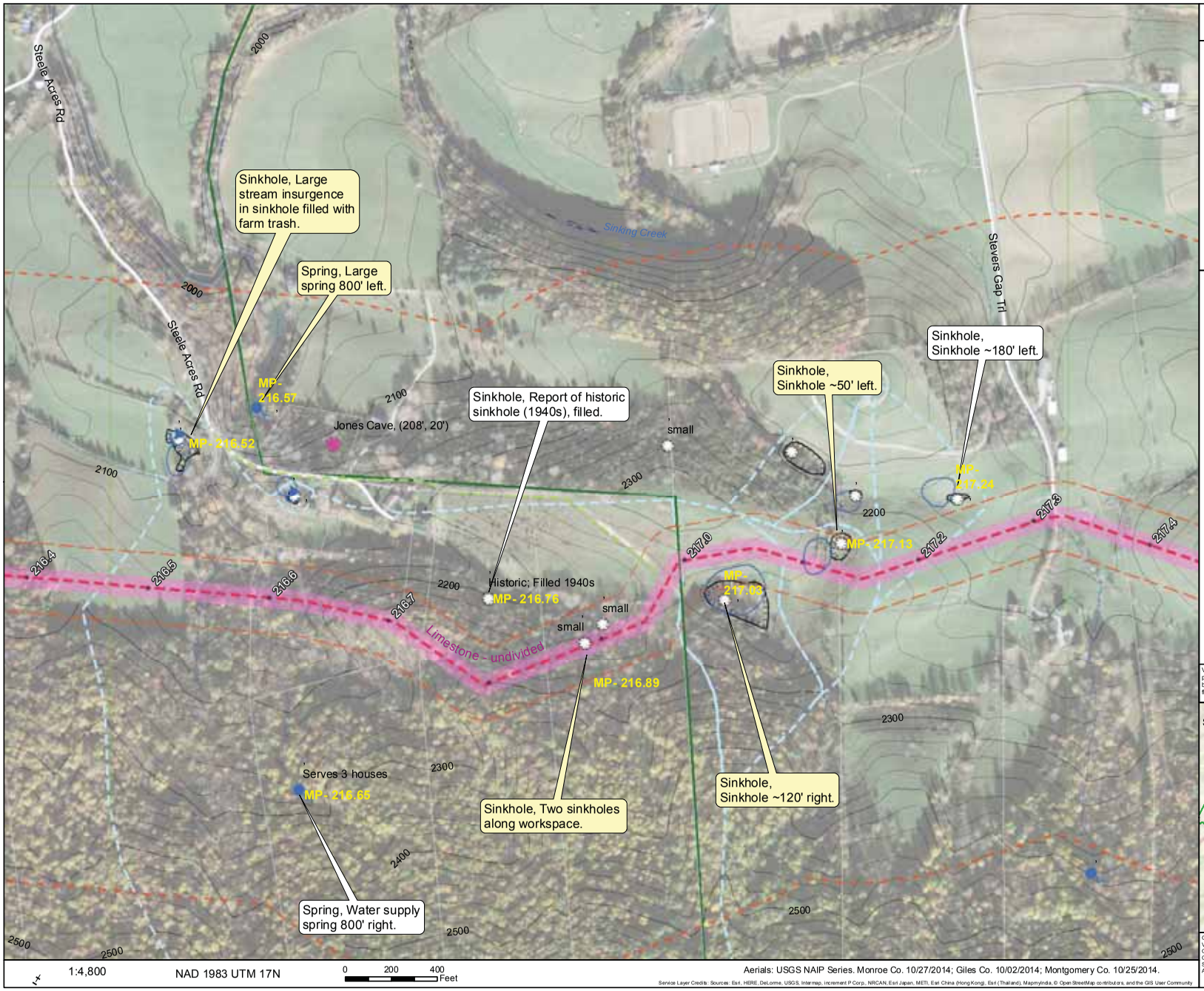

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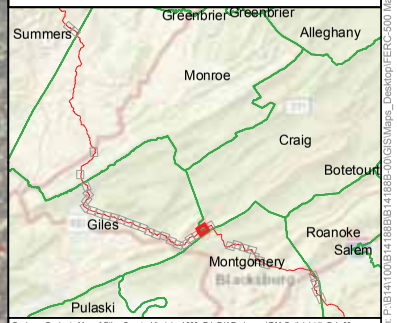

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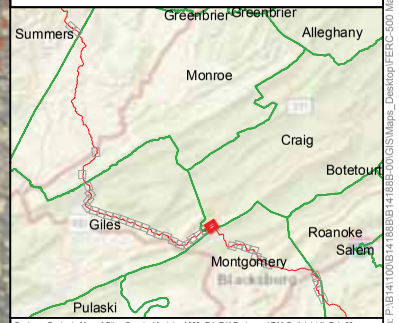

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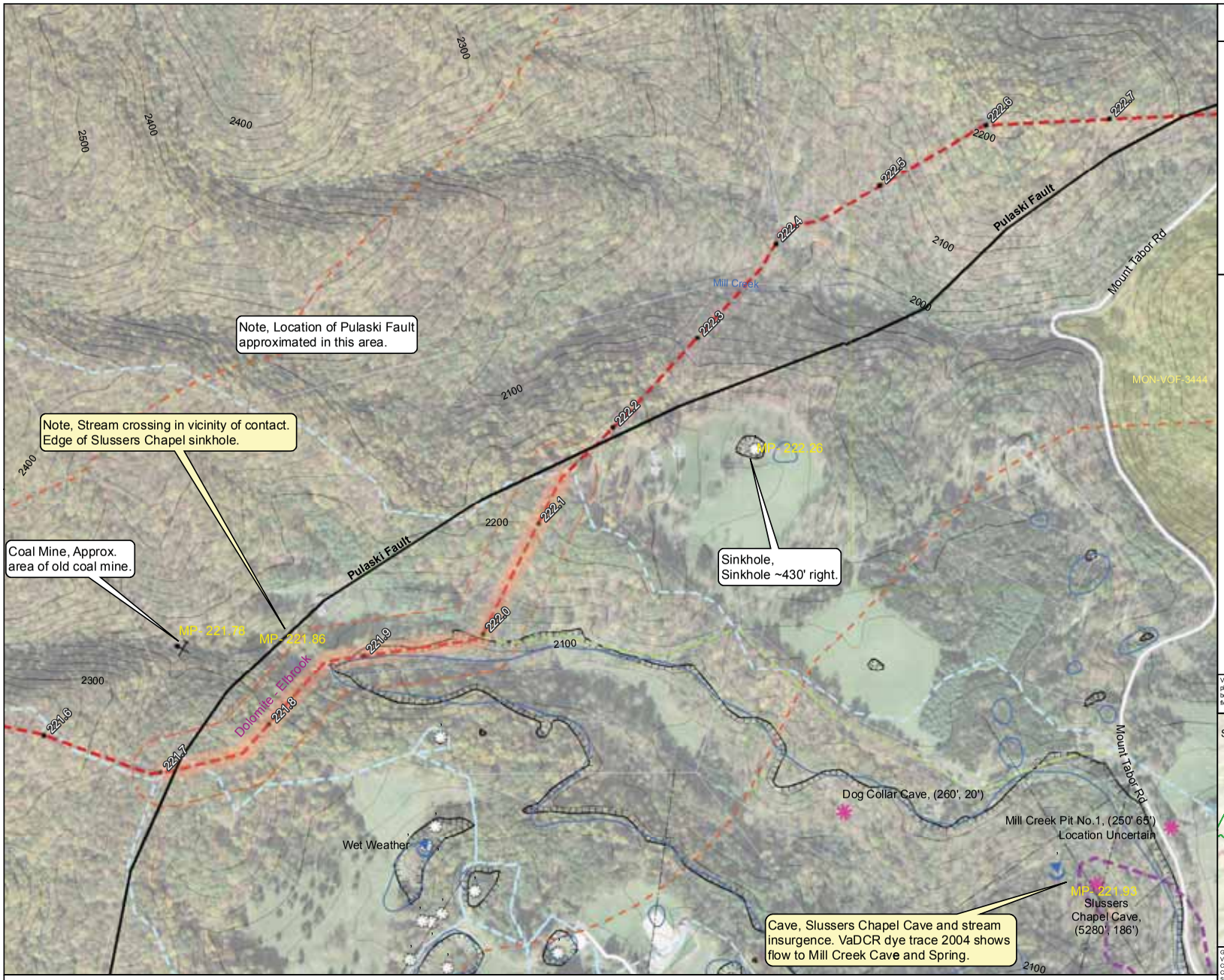

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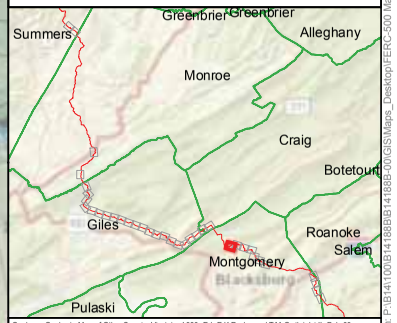

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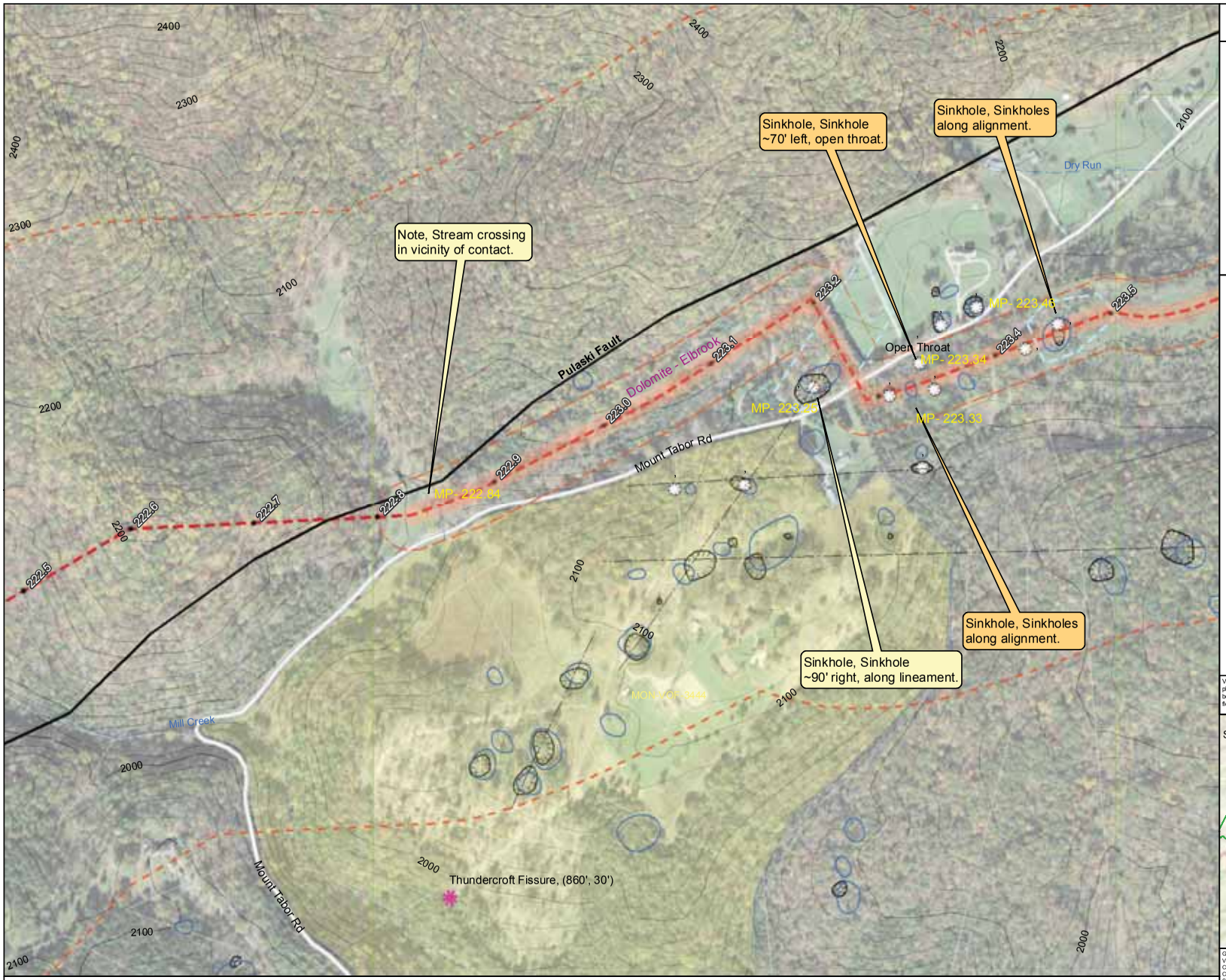

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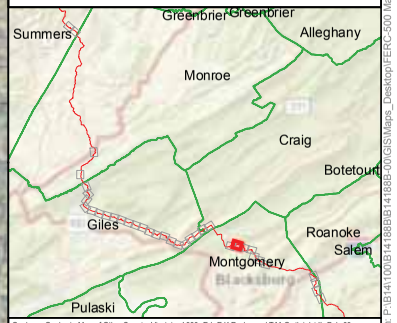

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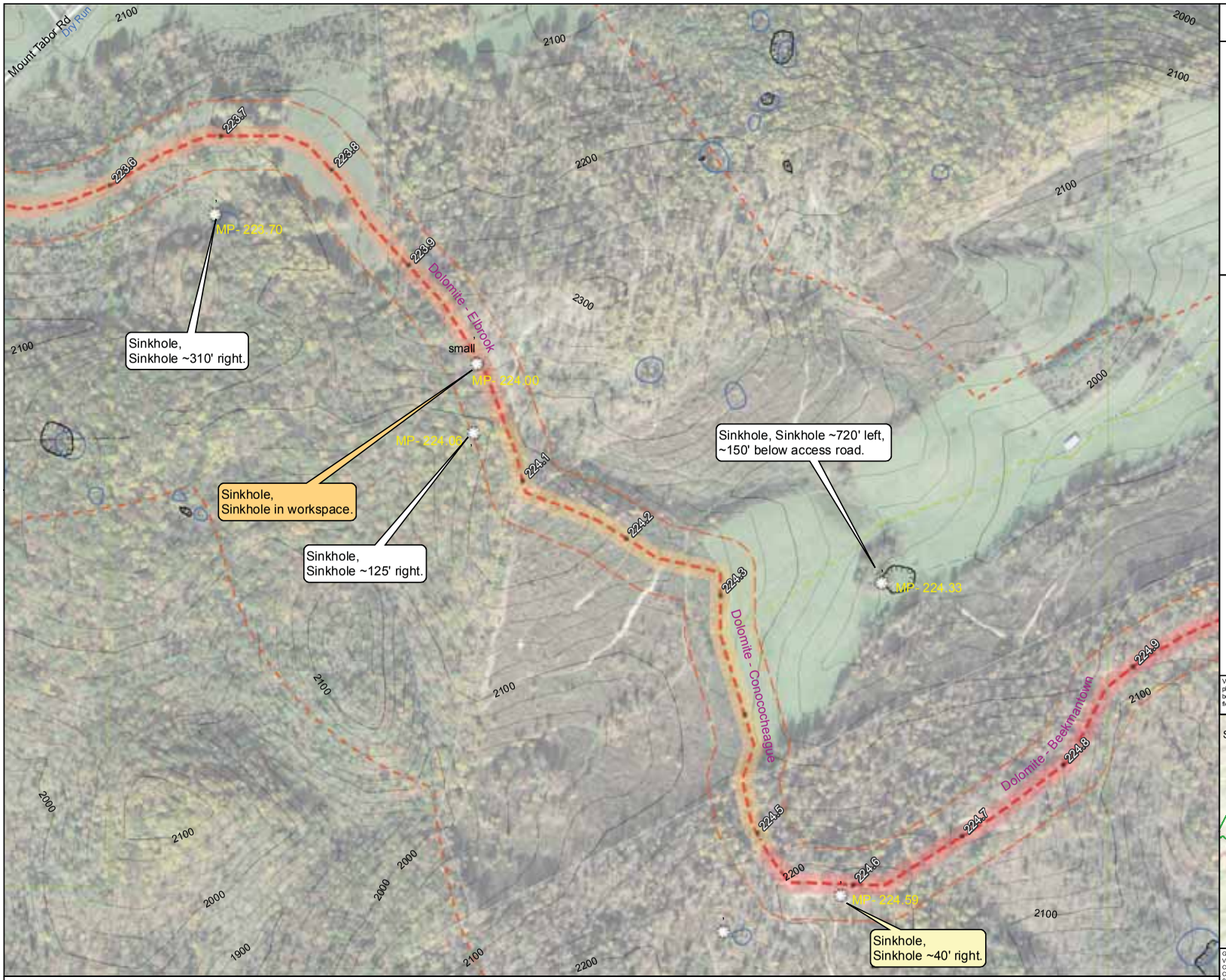

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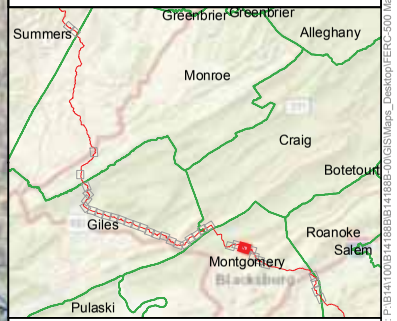

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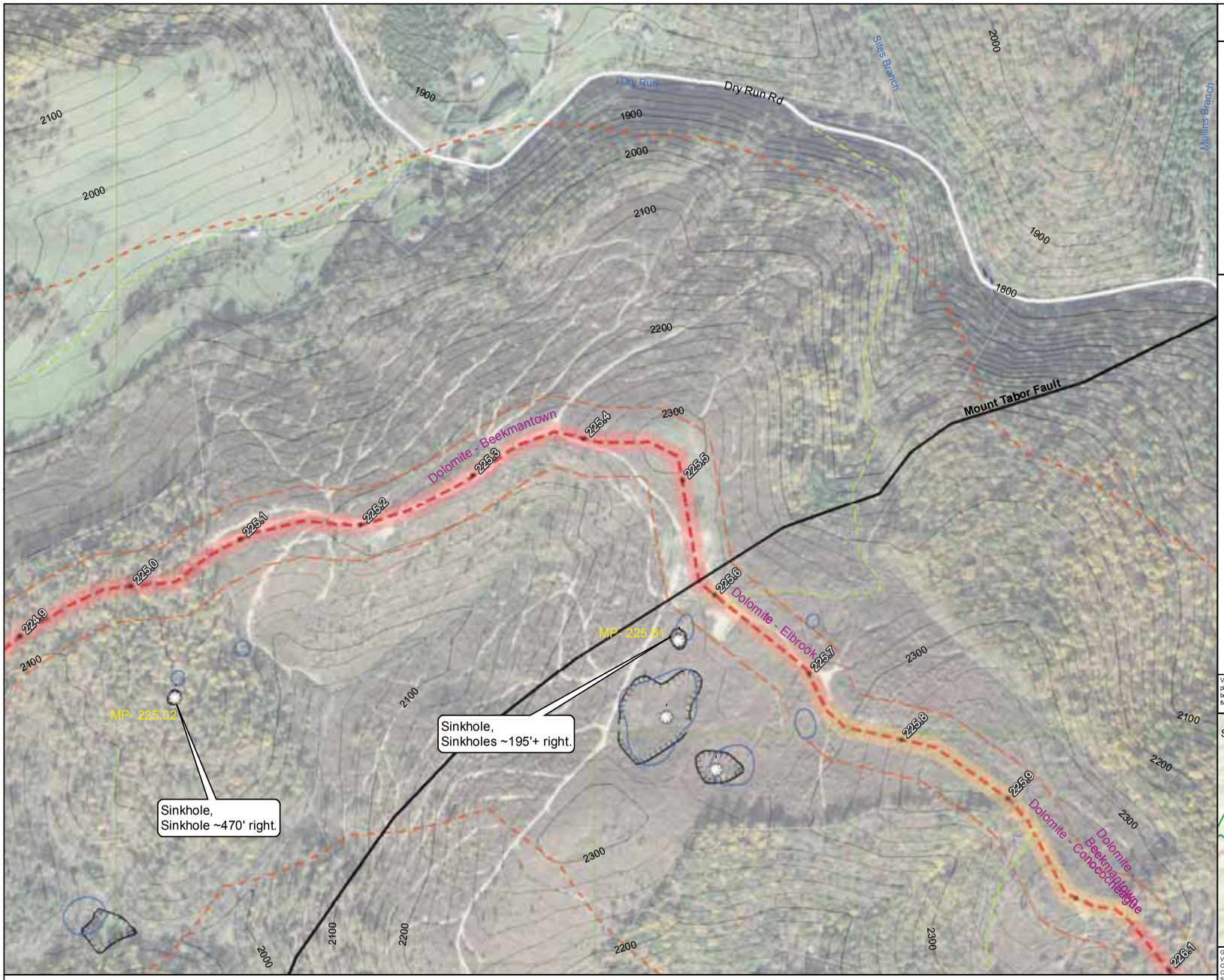

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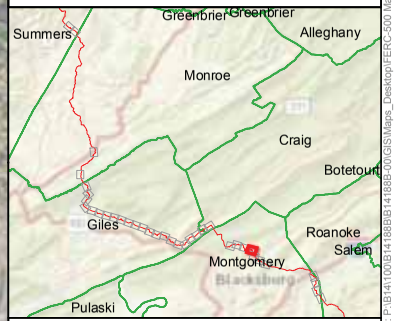

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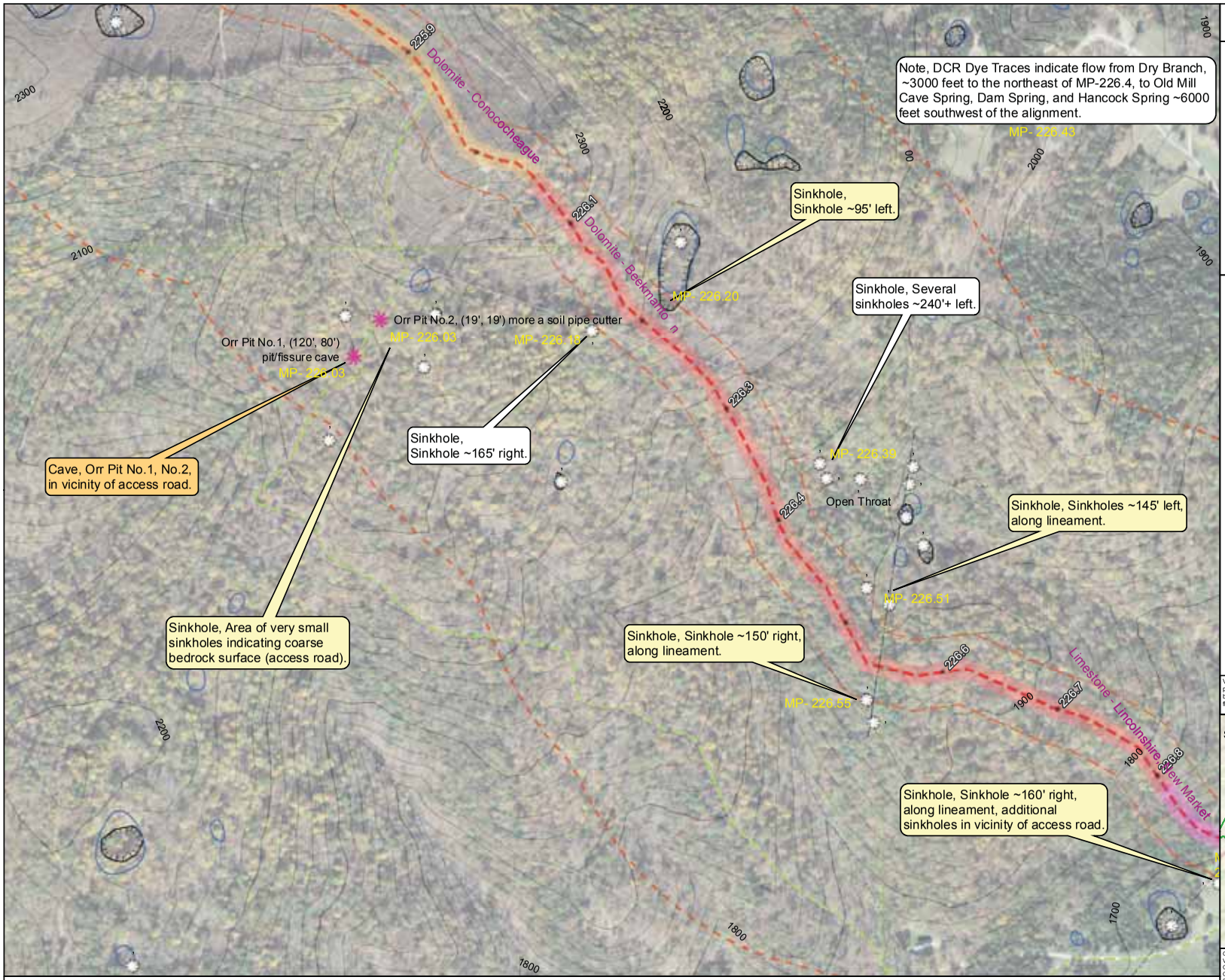

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Legend

- Cave (Length, Depth)
- Spring
- Swallet
- Sinkhole
- Quarry / Mine
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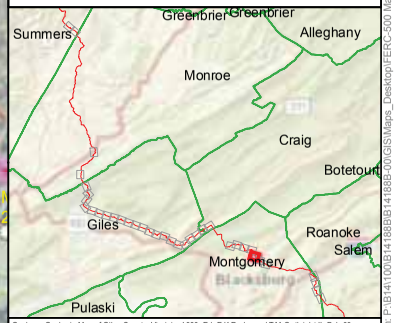

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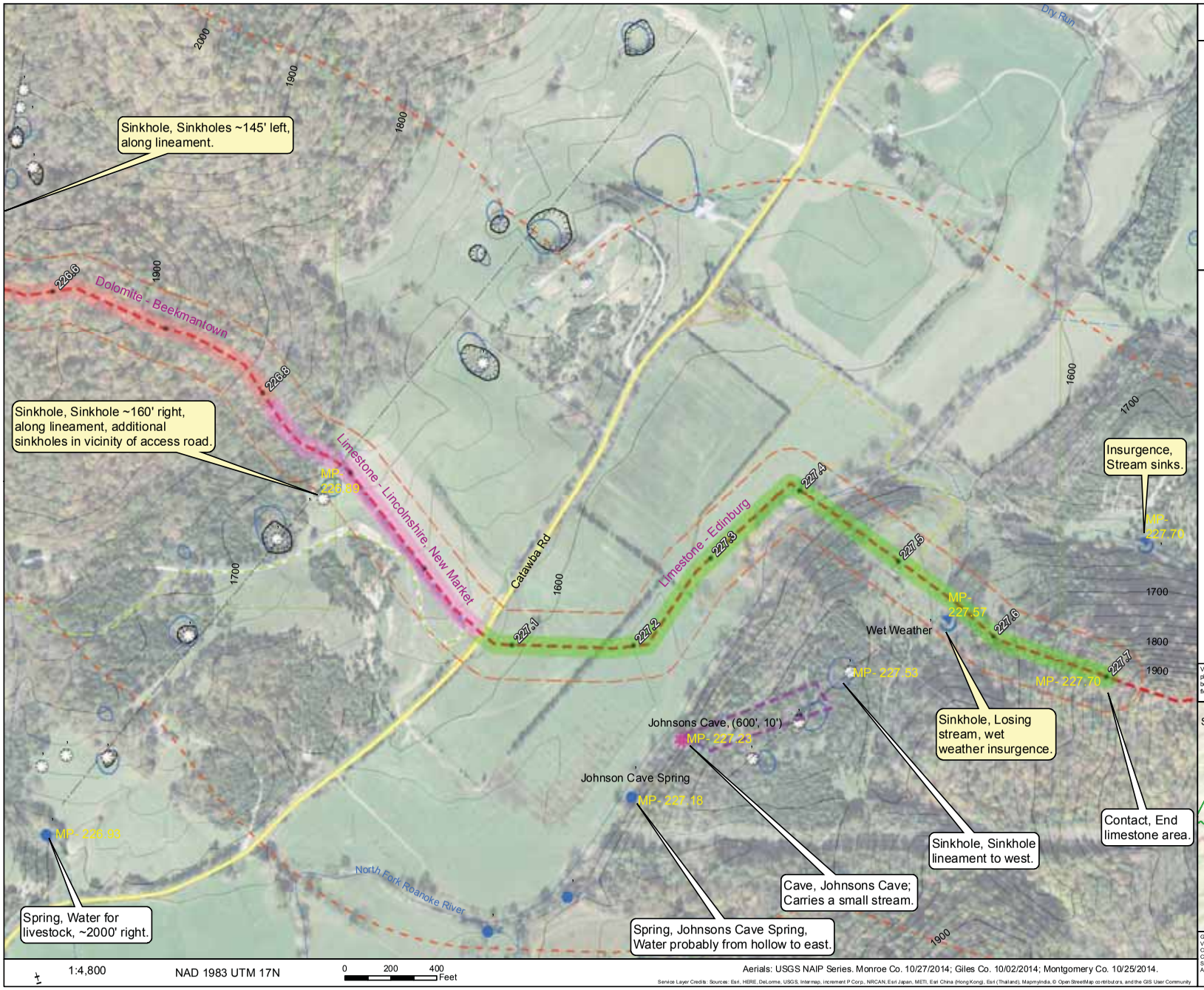

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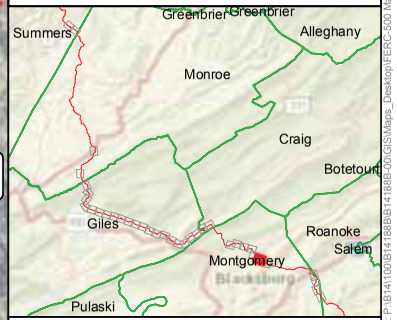

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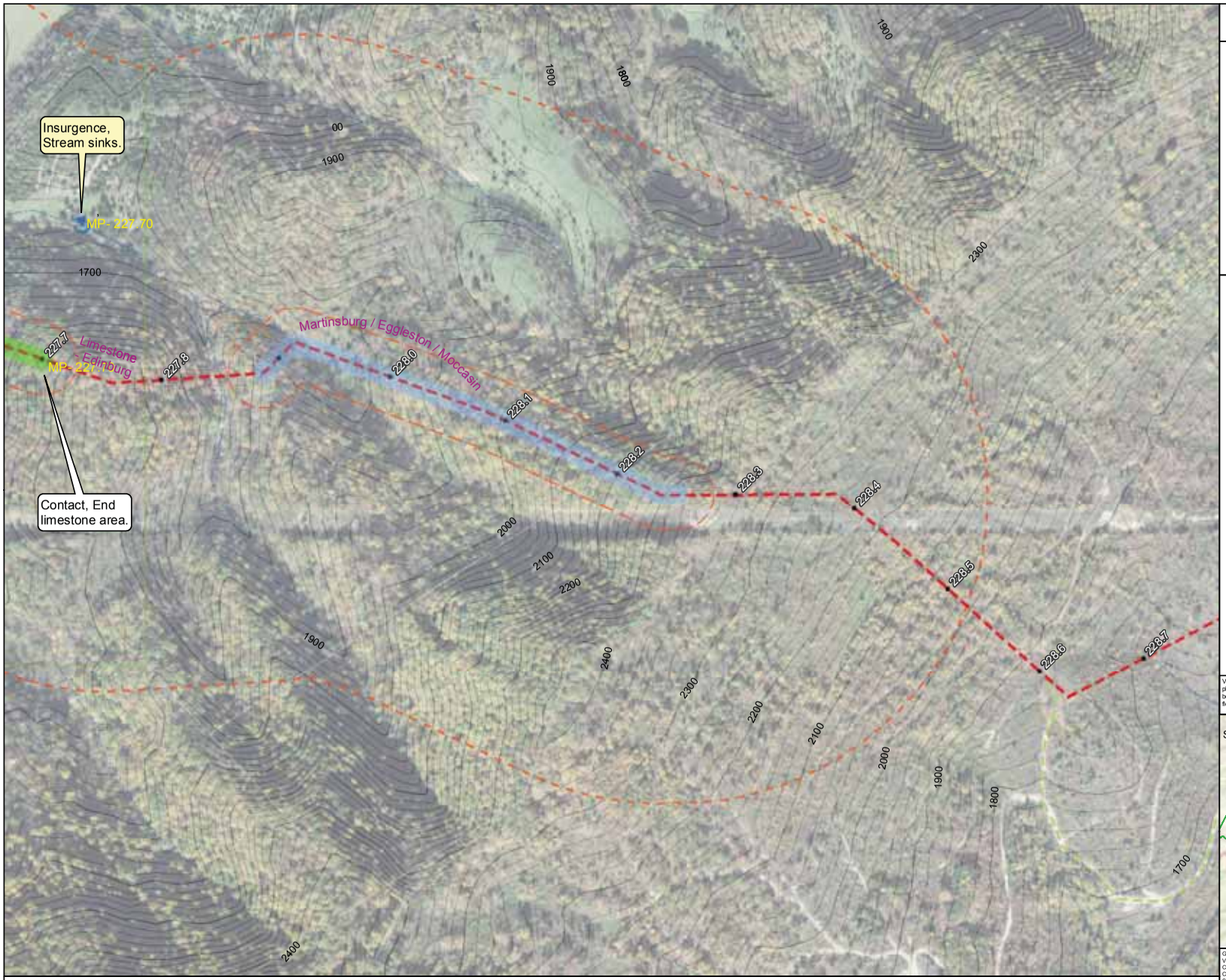

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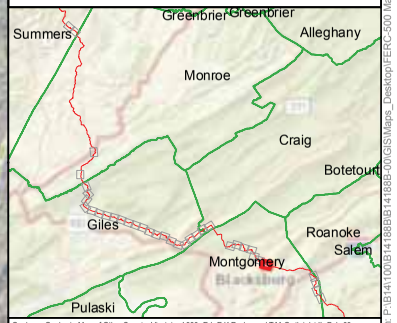

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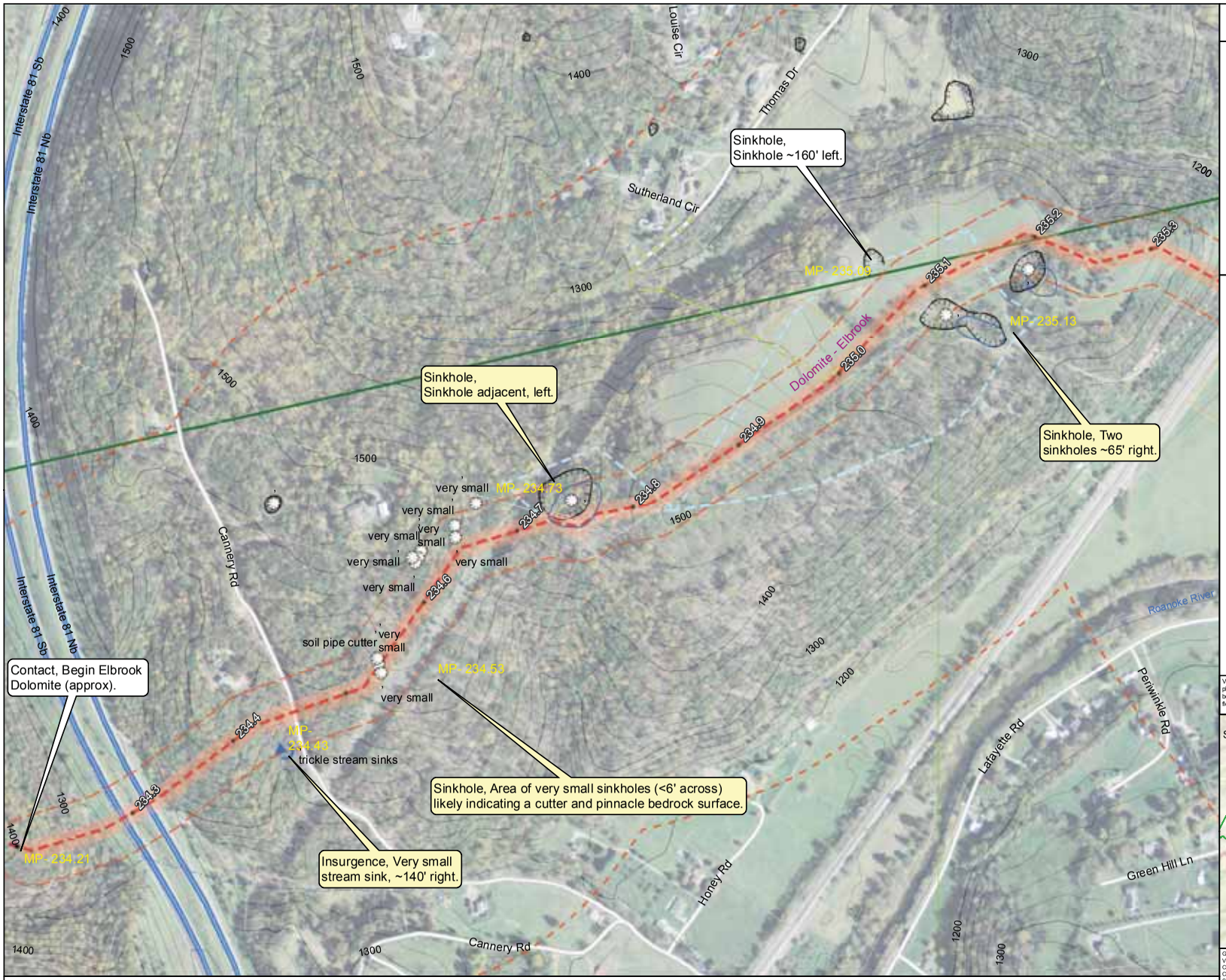

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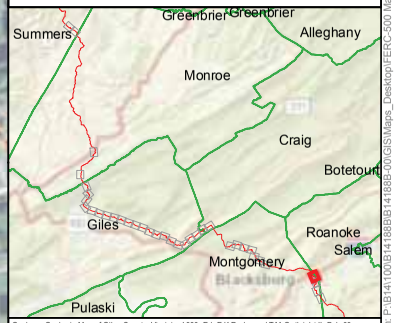

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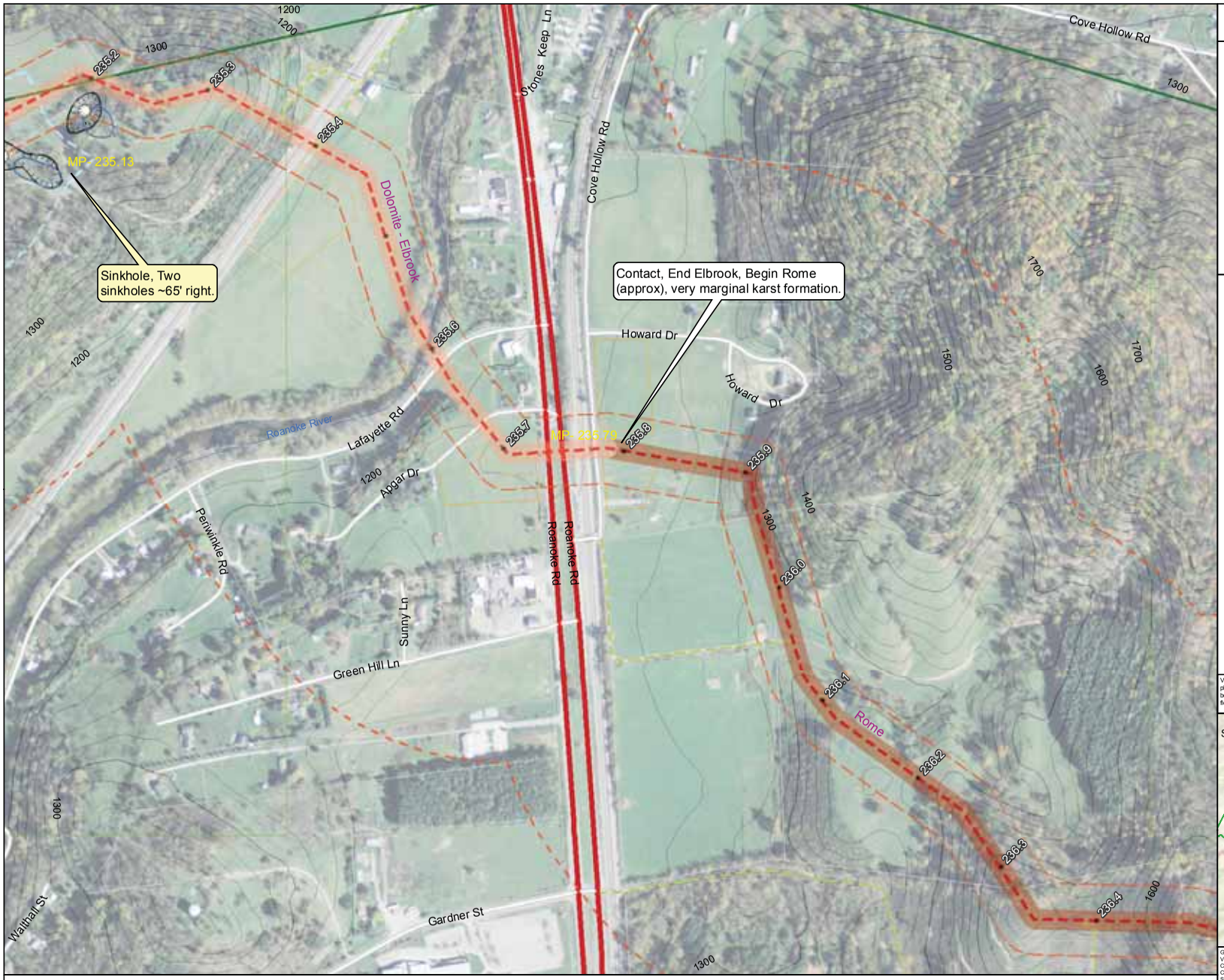

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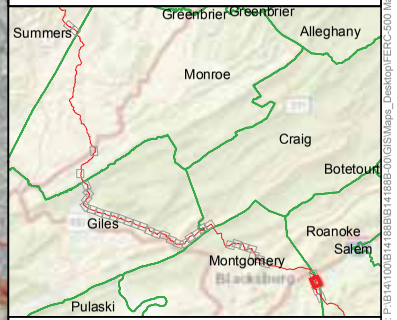

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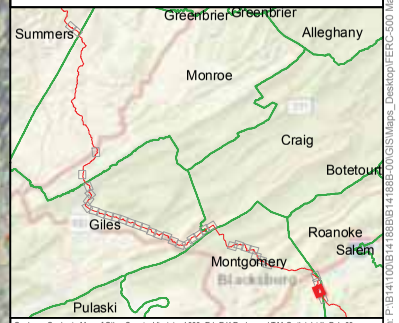

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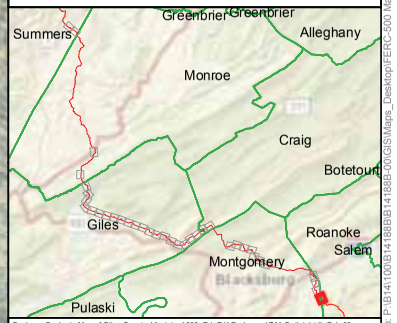

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