3.3 Risk Assessment

All sections of the risk assessment were developed utilizing the best available data in the Lincoln Trail Region. Lincoln Trail staff used GIS resources to assess the physical impact that specific natural hazard events have on the region. When GIS information was not available or applicable, research data and local historic records, such as those obtained from regional emergency management offices, the media, insurance records, and the knowledge of local officials and residents, were used. Research sources include, but are not limited to the following:

- The National Oceanic and Atmospheric Administration (NOAA)
- The Kentucky Energy and Environment Cabinet
- US Geological Survey (USGS)
- National Severe Storms Laboratory
- FEMA
- Kentucky Office of Emergency Management
- Kentucky Geological Survey
- National Center for Environmental Information (NCEI)

Table 3.3.1 - Hazard Maps by Jurisdiction

Jurisdiction			***MAP TYPE***			
	FLOODING	*TORNADO*	*LANDSLIDE*	*KARST*	*EARTHQUAKE*	*RISK*
Breckinridge	Y	Y	Y	Y	Y	Y
Cloverport	Y	Y	Y	Y	NA	Y
Hardinsburg	Y	Y	Y	Y	NA	Y
Irvington	NA	NA	NA	Y	NA	Y
Grayson	Y	Y	Y	Y	Y	Y
Caneyville	Y	Y	Y	NA	NA	Y
Clarkson	Y	Y	NA	Y	NA	Y
Leitchfield	Y	Y	Y	Y	NA	Y
Hardin	Y	Y	Y	Y	Y	Y
Elizabethtown	Y	Y	Y	Y	NA	Y
Radcliff	Y	Y	Y	Y	NA	Y
Sonora	Y	NA	NA	Y	NA	Y
Upton	NA	NA	NA	Y	NA	Y
Vine Grove	Y	Y	Y	Y	NA	Y
West Point	Y	NA	Y	Y	NA	Y
Larue	Y	Y	Y	Y	Y	Y
Hodgenville	Y	Y	Y	Y	NA	Y
Marion	Y	Y	Y	Y	Y	Y
Bradfordsville	Y	Y	Y	NA	NA	Y
Lebanon	Y	Y	Y	Y	NA	Y
Loretto	NA	NA	Y	Y	NA	Y
Raywick	Y	NA	Y	NA	NA	Y
Meade	Y	Y	Y	Y	Y	Y
Brandenburg	Y	Y	Y	Y	NA	Y

Ekron	NA	NA	NA	Y	NA	Y
Muldraugh	NA	NA	NA	Y	NA	Y
Nelson	Y	Y	Y	Y	Y	Y
Bardstown	Y	Y	Y	Y	NA	Y
Bloomfield	Y	NA	Y	NA	NA	Y
Fairfield	NA	NA	NA	NA	NA	Y
New Haven	Y	Y	Y	NA	NA	Y
Washington	Y	Y	Y	Y	Y	Y
Mackville	NA	NA	Y	NA	NA	Y
Springfield	Y	Y	NA	NA	NA	Y
Willisburg	NA	Y	Y	NA	NA	Y

Y = Map Available
NA = Not Applicable

3.3.1 Identifying Hazards

The Lincoln Trail Region encompasses an area of 3,342 square miles and is vulnerable to several natural hazard events. The events outlined in Table 3.3.1.1 have a 100% chance of occurring in any given year within this region and cost the area an average of $223,758 per event. Due to the size of the region, events may be more prevalent in one portion of the area than in others. This phenomenon makes it imperative to include as many research sources as possible, and to look at mitigation strategies appropriate for every jurisdiction within the region. The events listed below were identified using information from local emergency management offices and review of local past disasters in addition to those listed.

Table 3.3.1.1 Lincoln Trail Region Significant Hazard Events

Hazard	How Identified	Reason Identified
Thunderstorm-Wind Total Cost- $74,457,996.00 Number of Events- 2016 60-64 Years	Media Coverage Insurance Records National Center for Environmental Information (NCEI)	Historic Regional Significance (Affects all Jurisdictions)
Floods Total Cost-$132,991,112.0 Number of Events- 510 54 years	Public Input Insurance Records FIRM/DFIRM Maps SHELDUS National Center for Environmental Information (NCEI)	Historic Regional Significance (Affects all Jurisdictions) Presence of Waterways Presence of Flood Prone Area

Hail Total Cost-$130,364,632.0 Number of Events - 630 48-60 years	Media Coverage Insurance Records SHELDUS National Center for Environmental Information (NCEI)	Historic Regional Significance (Affects all Jurisdictions)
Lightning Total Cost-$3,765,207.00 Number of Events- 267 60-61 -years	Media Coverage Insurance Records SHELDUS National Center for Environmental Information (NCEI)	Historic Regional Significance (Affects all Jurisdictions
Snow & Ice Total Cost-$16,342,589.00 Number of Events-372 48-60-years	Community Input Media Coverage National Center for Environmental Information (NCEI)	Historic Regional Significance (Affects all Jurisdictions
Tornado Total Cost-$93,649,450.00 Number of Events-123 61-69 -years	Public Input Insurance Records FEMA Data Wind Zone Maps SHELDUS National Center for Environmental Information (NCEI)	High Wind Risk Area Historic Regional Significance (Affects all Jurisdictions)
Earthquake Total Cost-NA Number of Events- 6 241-years	National Center for Environmental Information (NCEI) Media Coverage	Media Coverage NCEI
Total Number of Events-3924		

Table 3.3.1.2 profiles natural hazards that can affect this region, but which historically, have not posed a significant risk to the area. Most of these hazards do not pose a significant threat to this region but cannot be overlooked. Most have either no reports of past occurrence and/or an adverse impact on local communities.

Table 3.3.1.2 Lincoln Trail Region Hazard Events with Negligible Risk		
Hazard	**How Identified**	**Reason Identified**
Landslides (Road slides)	Local Input Hazard Areas Identified by KY Geological Survey	Topographic Maps Show Significant Potential Regional Impact
Karst/Sinkhole & Subsidence Topography	USGS & KGS Topographic Maps Local Input	Topographic Maps Indicate High Risk of Development
Drought & Heat	KY Mesonet Data Local Input National Center for Environmental Information (NCEI)	Rural Area with Potential for Economic Impact
Wildfires	Public Input National Center for Environmental Information (NCEI)	Area Prone to Grass/Brush Fires
Earthquakes	Historic Data Media Coverage USGS & KGS	Peak Ground Acceleration Maps (PGA Maps)
Dam Safety	KY Energy & Environment Cabinet	No Significant Historic Data
Tsunamis	Historic Data	No Historic Data
Hurricanes	Media Coverage National Center for Environmental Information (NCEI)	Little Historic Data

3.3.2 Profiling Hazard Events

This section provides a profile of each hazard identified in the Lincoln Trail Region. This part of the Lincoln Trail Regional Hazard Mitigation Plan provides the following information based on the best data available:

1. A description of each hazard identified within the planning area and the impact that each hazard has on the area.
2. The historical background of each identified hazard in the planning area and the probability of it occurring again.
3. Maps indicating the locations and areas within the region impacted by Hazard events.

Lincoln Trail staff used GIS resources to assess the physical and economic impact of certain natural disasters on the region. In situations where GIS data was not available, state websites and local records were used to give plan reviewers a more comprehensive understanding of past hazard events. Local records included county emergency management records, media, local officials, community members and the historical knowledge of subcommittee members.

Credible websites accessed and cited throughout the plan include the Kentucky State Climatology Center, the Spatial Hazard Events and Losses Database for the United States (SHELDUS), the National Center for Environmental Information (NCEI), FEMA's Hazard Mapping website, the Kentucky Geological Survey (KGS), the United States Geologic Survey (USGS), and Kentucky MESONET centers. In addition, leaders from regional educational institutions, business, emergency management, and first response agencies were contacted and involved with the planning process per 44 CFR §201.6(b)(2).

In the past, subcommittees reviewed the best available data gathered, several gaps were identified. To project a more accurate and comprehensive record of past hazard events, researching public input and local records played a significant role in augmenting the data. The consensus of subcommittee reviewers is that some local data is not being forwarded to all interested parties. In particular, property damage estimates are not accurately calculated. To bridge this void, local and regional insurance estimates were gathered from providers in the region and incorporated into the plan.

One goal of the Lincoln Trail Regional Mitigation Committee is to capture new data with every update, that will be useful in preparing future proposals and in developing local environmental and economic plans. All information in this regional plan is dated and should be easily discernable from the original data. The plan should guide community development, improve regional resiliency and preparedness, and enhance quality of life throughout the Lincoln Trail Region.

Review: The Lincoln Trail Region has a documented history of several different types of Hazards with various impacts. The impact of these hazards is measured by both the frequency of occurrence and by the cost of the event; both economic and social. This section is focused on the types and frequency of hazards in the Lincoln Trail Region. The costs of events will be addressed in section 3.3.4 and will focus on the potential losses that may be incurred with a future event. The following tables provide an analytical review of documented hazard events in the Lincoln Trail Region. For planning purposes, the historic frequencies will be used in subsequent vulnerability analysis. The tables are presented for each county including incorporated and unincorporated areas and for the region as a whole.

Table 3.3.2.1 - Summary of Hazard Events and Cost by County

BRECKINRIDGE

Hazard	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
Thunderstorm Wind	265	60.5	112	154	222	0.23	438.02%	11.2	7.7	4.44
Floods	60	54.5	20	38	58	0.91	110.09%	2	1.9	1.16
Hail	86	58.5	45	61	73	0.68	147.01%	4.5	3.05	1.46
Lightning	26	60.5	1	1	9	2.33	42.98%	0.1	0.05	0.18
Snow & Ice	48	61.5	22	34	43	1.28	78.05%	2.2	1.7	0.86
Tornado	17	61.5	8	11	14	3.62	27.64%	0.8	0.55	0.28
Earthquake	0	241	0	0	0	0	0.00%	0	0	0

Hazard	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
Thunderstorm Wind	$1,761,803	265	60.5	0.25	4.21	$29,121	$6,648	0.00	0.00	0.07	0.02
Floods	$7,811,684	60	54.5	2.09	0.11	$143,334	$130,195	0.04	0.03	0.00	0.00
Hail	$4,925,750	86	58.5	0.01	0.52	$84,201	$57,276	0.00	0.00	0.01	0.01
Lightning	$489,925	26	60.5	0.04	0.36	$8,098	$18,843	0.00	0.00	0.01	0.01
Snow & Ice	$1,411,082	48	61.5	0.31	1.83	$22,944	$29,398	0.01	0.01	0.03	0.04
Tornado	$5,285,260	17	61.5	1.09	20.00	$85,939	$310,898	0.02	0.06	0.33	1.18
Earthquake	0	0	241	0	0	0	0	0	0	0	0

GRAYSON

Hazard	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
Thunderstorm Wind	224	62.5	69	106	178	0.28	358.40%	6.9	5.3	3.56
Floods	56	54.5	22	36	55	0.97	102.75%	2.2	1.8	1.1
Hail	87	57.5	37	57	75	0.66	151.30%	3.7	2.85	1.5
Lightning	32	60.5	2	2	12	1.89	52.89%	0.2	0.1	0.24
Snow & Ice	51	61.5	24	30	47	1.21	82.93%	2.4	1.5	0.94
Tornado	16	62.5	6	7	5	3.91	25.60%	0.6	0.35	0.1
Earthquake	0	241	0	0	0	0	0.00%	0	0	0

Hazard	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
Thunderstorm Wind	$1,740,288	224	62.5	0.25	6.62	$27,845	$7,769	0.00	0.00	0.11	0.03
Floods	$8,490,065	56	54.5	0.04	0.11	$155,781	$151,608	0.00	0.00	0.00	0.00
Hail	$2,438,935	87	57.5	0.01	0.5	$42,416	$28,034	0.00	0.00	0.01	0.01
Lightning	$423,574	32	60.5	0.04	4.36	$7,001	$13,237	0.00	0.00	0.07	0.14
Snow & Ice	$1,981,398	51	61.5	0.29	3.41	$32,218	$38,851	0.00	0.01	0.06	0.07
Tornado	$56,783,213	16	62.5	3.00	23.09	$908,531	$3,548,951	0.05	0.19	0.37	1.44
Earthquake	0	0	241	0	0	0	0	0	0	0	0

HARDIN

Hazard	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
Thunderstorm Wind	366	64.5	136	205	309	0.18	567.44%	13.6	10.25	6.18
Floods	88	54.5	42	63	86	0.62	161.47%	4.2	3.15	1.72
Hail	113	58.5	51	72	96	0.52	193.16%	5.1	3.6	1.92
Lightning	34	60.5	2	3	13	1.78	56.20%	0.2	0.15	0.26
Snow & Ice	56	61.5	28	34	52	1.10	91.06%	2.8	1.7	1.04
Tornado	26	61.5	10	13	19	2.37	42.28%	1	0.65	0.38
Earthquake	1	241	0	0	1	241	0.00%	0	0	0.02

Hazard	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
Thunderstorm Wind	$65,915,949	366	64.5	4.45	133.17	$1,021,953	$180,098	0.07	0.01	2.06	0.36
Floods	49261888.78	88	54.5	2.17	0.11	$903,888	$559,794	0.04	0.02	0.00	0.00
Hail	$26,768,252	113	58.5	0.01	0.52	$457,577	$236,887	0.00	0.00	0.01	0.00
Lightning	$869,962	34	60.5	1.11	2.36	$14,380	$25,587	0.02	0.03	0.04	0.07
Snow & Ice	$2,792,155	56	61.5	1.29	4.47	$45,401	$49,860	0.02	0.02	0.07	0.08
Tornado	$16,643,723	26	61.5	2.00	73.09	$270,630	$640,143	0.03	0.08	1.19	2.81
Earthquake	0	1	241	No Information Available							

LARUE

Hazard	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
Thunderstorm Wind	217	60.5	60	88	160	0.28	358.68%	6	4.4	3.2
Floods	47	54.5	18	25	45	1.16	86.24%	1.8	1.25	0.9
Hail	66	65.5	27	30	42	0.99	100.76%	2.7	1.5	0.84
Lightning	33	60.5	0	0	8	1.83	54.55%	0	0	0.16
Snow & Ice	46	61.5	20	25	42	1.34	74.80%	2	1.25	0.84
Tornado	12	69.5	5	7	7	5.79	17.27%	0.5	0.35	0.14
Earthquake	1	241	0	0	1	241	0.00%	0	0	0.02

Hazard	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
Thunderstorm Wind	$1,869,787	217	60.5	1.32	11.6	$30,906	$8,617	0.02	0.01	0.19	0.05
Floods	$8,067,971	47	54.5	0.17	0.11	$148,036	$171,659	0.00	0.00	0.00	0.00
Hail	$1,969,355	66	65.5	0.06	0.56	$30,066	$29,839	0.00	0.00	0.01	0.01
Lightning	$61,022	33	60.5	0	0	$1,009	$1,849	0.00	0.00	0.00	0.00
Snow & Ice	$1,050,662	46	61.5	0.29	3.36	$17,084	$22,840	0.00	0.01	0.05	0.07
Tornado	$5,210,111	12	69.5	0.00	19.12	$74,966	$434,176	0.00	0.00	0.28	1.59
Earthquake	0	1	241	No Information Available							

MARION

Hazard	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
Thunderstorm Wind	214	60.5	56	89	156	0.28	353.72%	5.6	4.45	3.12
Floods	58	54.5	23	33	56	0.94	106.42%	2.3	1.65	1.12
Hail	64	60.5	18	24	37	0.95	105.79%	1.8	1.2	0.74
Lightning	36	61.5	1	1	8	1.71	58.54%	0.1	0.05	0.16
Snow & Ice	39	61.5	14	18	35	1.58	63.41%	1.4	0.9	0.7
Tornado	13	61.5	4	6	5	4.73	21.14%	0.4	0.3	0.1
Earthquake	0	241	0	0	0	0	0.00%	0	0	0

Hazard	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
Thunderstorm Wind	$1,547,735	214	60.5	0.24	1.63	$25,582	$7,232	0.00	0.00	0.03	0.01
Floods	$9,800,835	58	54.5	0.31	2.54	$179,832	$168,980	0.01	0.01	0.05	0.04
Hail	$35,497,179	64	60.5	0.06	2.56	$586,730	$554,643	0.00	0.00	0.04	0.04
Lightning	$404,253	36	61.5	0.14	0.39	$6,573	$11,229	0.00	0.00	0.01	0.01
Snow & Ice	$2,681,555	39	61.5	0.29	3.36	$43,603	$68,758	0.00	0.01	0.05	0.09
Tornado	$920,833	13	61.5	0.00	4.15	$14,973	$70,833	0.00	0.00	0.07	0.32
Earthquake	0	0	241	0	0	0	0	0	0	0	0

MEADE

Hazard	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
Thunderstorm Wind	234	61.5	72	110	222	0.26	380.49%	7.2	5.5	4.44
Floods	47	54.5	13	24	45	1.16	86.24%	1.3	1.2	0.9
Hail	74	66.5	26	46	56	0.90	111.28%	2.6	2.3	1.12
Lightning	28	60.5	0	0	11	2.16	46.28%	0	0	0.22
Snow & Ice	49	61.5	24	28	45	1.26	79.67%	2.4	1.4	0.9
Tornado	14	61.5	7	9	10	4.39	22.76%	0.7	0.45	0.2
Earthquake	4	241	0	1	4	60.25	0.02%	0	0.05	0.08

Hazard	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
Thunderstorm Wind	$1,959,733	234	61.5	3.45	46.26	$31,866	$8,375	0.06	0.01	0.75	0.20
Floods	$7,284,005	47	54.5	1.14	0.11	$133,651	$154,979	0.02	0.02	0.00	0.00
Hail	$25,032,572	74	66.5	0.01	2.52	$376,430	$338,278	0.00	0.00	0.04	0.03
Lightning	$129,715	28	60.5	0	0	$2,144	$4,633	0.00	0.00	0.00	0.00
Snow & Ice	$1,420,840	49	61.5	0.29	1.81	$23,103	$28,997	0.00	0.01	0.03	0.04
Tornado	$6,342,324	14	61.5	31.00	268.07	$103,127	$453,023	0.50	2.21	4.36	19.15
Earthquake		4	241	No Information Available							

NELSON

Hazard	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
Thunderstorm Wind	296	60.5	91	97	216	0.20	489.26%	9.1	4.85	4.32
Floods	104	54.5	45	78	102	0.52	190.83%	4.5	3.9	2.04
Hail	85	60.5	36	53	61	0.71	140.50%	3.6	2.65	1.22
Lightning	42	61.5	2	6	16	1.46	68.29%	0.2	0.3	0.32
Snow & Ice	50	61.5	22	27	46	1.23	81.30%	2.2	1.35	0.92
Tornado	14	61.5	3	4	9	4.39	22.76%	0.3	0.2	0.18
Earthquake	0	241	0	0	0	0	0.00%	0	0	0

Hazard	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
Thunderstorm Wind	$1,794,130	294	60.5	0.3	12.58	$29,655	$6,102	0.00	0.00	0.21	0.04
Floods	35033005.07	104	54.5	3.17	2.11	$642,807	$336,856	0.06	0.03	0.04	0.02
Hail	22857556	85	60.5	0.06	1.56	$377,811	$268,912	0.00	0.00	0.03	0.02
Lightning	$932,717	42	61.5	2.12	2.34	$15,166	$22,208	0.03	0.05	0.04	0.06
Snow & Ice	$2,307,155	50	61.5	1.29	3.47	$37,515	$46,143	0.02	0.03	0.06	0.07
Tornado	$2,233,978	14	61.5	1.00	28.15	$36,325	$159,570	0.02	0.07	0.46	2.01
Earthquake	0	0	241	0	0	0	0	0	0	0	0

WASHINGTON

Hazard	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
Thunderstorm Wind	200	60.5	50	77	142	0.30	330.58%	5	3.85	2.84
Floods	50	54.5	15	23	48	1.09	91.74%	1.5	1.15	0.96
Hail	55	60.5	16	22	30	1.10	90.91%	1.6	1.1	0.6
Lightning	36	61.5	0	0	9	1.71	58.54%	0	0	0.18
Snow & Ice	49	61.5	17	21	41	1.26	79.67%	1.7	1.05	0.82
Tornado	11	61.5	5	7	4	5.59	17.89%	0.5	0.35	0.08
Earthquake	0	241	0	0	0	0	0.00%	0	0	0

Hazard	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
Thunderstorm Wind	$1,668,572	200	60.5	0.22	3.58	$27,580	$8,343	0.00	0.00	0.06	0.02
Floods	$9,124,658	50	54.5	1.17	1.11	$167,425	$182,493	0.02	0.02	0.02	0.02
Hail	$11,037,640	55	60.5	0.06	3.56	$182,440	$200,684	0.00	0.00	0.06	0.06
Lightning	$223,179	36	61.5	0.12	0.34	$3,629	$6,199	0.00	0.00	0.01	0.01
Snow & Ice	$2,697,743	49	61.5	0.37	3.48	$43,866	$55,056	0.01	0.01	0.06	0.07
Tornado	$1,840,007	11	61.5	0.00	5.15	$29,919	$167,273	0.00	0.00	0.08	0.47
Earthquake	0	0	241	0	0	0	0	0	0	0	0

LINCOLN TRAIL REGION

Hazard	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
Thunderstorm Wind	2016	64.5	646	926	1605	0.03	113.08%	64.6	46.3	32.1
Floods	510	54.5	198	320	495	0.11	31.14%	19.8	16	9.9
Hail	630	65.5	256	365	470	0.10	38.30%	25.6	18.25	9.4
Lightning	267	61.5	8	13	86	0.23	37.75%	0.8	0.65	1.72
Snow & Ice	388	61.5	171	217	351	0.158505	78.86%	17.1	10.85	7.02
Tornado	123	63	48	64	73	0.51	6.46%	4.8	3.2	1.46
Earthquake	6	241	0	1	6	40.3	0.02%	0	0.05	0.12

Hazard	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
Thunderstorm Wind	$78,257,999	2014	64.5	10.48	219.65	$1,213,302	$38,857	0.16	0.01	3.41	0.11
Floods	$134,874,112	510	54.5	10.26	6.31	$2,474,754	$264,459	0.19	0.02	0.12	0.01
Hail	$130,527,238	630	66.5	0.28	12.3	$1,962,816	$207,186	0.00	0.00	0.18	0.02
Lightning	$4,265,847	276	60.5	5.57	13.15	$70,510	$15,456	0.09	0.02	0.22	0.05
Snow & Ice	$16,342,589	388	61.5	4.42	25.19	$265,733	$42,120	0.07	0.01	0.41	0.06
Tornado	$95,259,449	123	63	38.09	440.82	$1,521,109	$774,467	0.61	0.31	7.04	3.58
Earthquake		6	241	No Information Available							

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically, that would average two events a year. Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 20 years (NCDC & NEIC weather records). 3) It is important to include all significant recorded hazard events that will include periodic updates to this table.

The values in the preceding tables should be considered low. More events have occurred than are documented by the sources used in these tables.

1. Compilation of SHELDUS, NCDC & NEIC, SHELDUS Data Base, Hazard Research Lab, University of South Carolina, 2009. Dates 1960-2009. National Climate Data Center (NCDC), NOAA & National Weather Service, various ranges 1950-2009. National Environmental Information Center (NEIC) July 1, 2009 - June 30, 2015.

2. USGS & National Earthquake Information Center (NEIC) Databases, "USGS/NEIC 1973-Sept. 9, 2015" & "Eastern, Central and Mountain States of U.S., 1534 - 1986".

3. Includes cumulative reports of claims filed from various insurance providers.

4. Consolidated based on review of repeated events in individual counties.

3.3.2.1 Flooding

I. Background

Definition: **“**An overflow of water onto lands that are used or usable by man and not normally covered by water. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, lake, or ocean.” (Water Science Glossary of Terms; http://ga.water.usgs.gov/edu/dictionary.html)

A **Flood,** as defined by the National Flood Insurance Program (NFIP) is: “A general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties (at least one of which is your property) from:

- Overflow of inland or tidal waters,
- Unusual and rapid accumulation or runoff of surface waters from any source, or
- A mudflow

Or it can be a collapse or subsidence of land along the shore of a lake or similar body of water because of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels that result in a flood.”

Description
A flood is a natural event around rivers and streams. Excessive water from snowmelt, rainfall, or a storm surge accumulates and overflows onto the banks and adjacent floodplains. **Floodplains** are lowlands, adjacent to rivers, lakes, and oceans that are subject to recurring floods. Over nine million U.S. households are in floodplains.

Flooding is caused in a variety of ways. Winter or spring rains, coupled with melting snows, can fill river basins too quickly. Torrential rains from decaying hurricanes or other tropical systems can also produce river flooding.

During the 20th century, flooding was the leading cause of property damage and loss of life of all natural disasters in the United States. Most U.S. communities have experienced some kind of flooding due to spring rains, heavy thunderstorms, or winter snow thaws. Floods can be either slow or fast rising, but generally develop over a period of days. Hundreds of floods occur each year, making it one of the most common hazards in all U.S. states.

In most years, 75% of all Federal disaster declarations involve flooding either in part or exclusively. Flooding claims an average of 140 lives per year and is responsible for more annual property damage than any other type of weather hazard according to the National Severe Storms Laboratory.

Factors that determine flooding severity and/or exacerbate the effects of floods:

- Rainfall Intensity and Duration
- Large amounts of rain over a short time can result in Flash Flooding
- Small amounts of rain can cause flooding where soil is saturated
- Small amounts of rain can cause flooding if concentrated in an area of impermeable surfaces

- Topography and Ground Cover
- Water runoff is greater in areas of steep slopes and little vegetation
- Development without adequate elevation or Flood Proofing
- Storm Sewer or Sinkhole backup
- Debris or Obstructions

The frequency of flooding depends on the climate, soil, and channel slope. In regions without prolonged periods of below-freezing temperatures, floods usually occur in the season with the highest precipitation.

Types of Flooding:
While floods can be the result of numerous naturally occurring and manmade factors, all floods can be defined as the accumulation of too much water, in too little time, within a specific area. Types of floods include regional, river or riverine, flashfloods, urban, ice-jam, storm surge, dam or levee failure, and debris, landslide, and mudflow.

Regional Flooding
Seasonal, regional flooding can occur when winter or spring rains, coupled with melting snow, fill river basins with too much water too quickly. Frozen ground further reduces water infiltration into the soil and causes runoff. Extended wet periods, at any time during the year, can result in saturated soils and exacerbates runoff into streams and rivers until their water containment capabilities are exceeded.

River or Riverine Floods
River/riverine flooding occurs when a high volume of water from a river or similar body of water occurs over a period too long to be considered a flash flood.


The spillway at Rough River Lake April 27 2011 Falls of Rough, Ky. - Heavy rains in the area caused Rough River Lake to reach a record pool causing water to run into the spillway for the first time since the dam became operational in 1961. *Image: US Army Corps of Engineers photo by Mike Lush*

Flash Floods
Flash floods are the result of quickly rising waters that occur as the result of heavy rains over the period of a few hours or less. Flash flooding can occur within several seconds to several hours, and with little warning. Flash floods are deadly because they produce rapid increases in water volume that often has swift velocities.

Several factors can contribute to flash flooding including rainfall intensity, rainfall duration, surface conditions, topography, and the slope of the receiving basin. Urban areas are more susceptible to flash flooding since a great percentage of the surface area is composed of impervious surfaces such as roads, roofs and parking lots causing rapid runoff of water. They can also be caused by ice jams on rivers in conjunction with a winter or spring thaw, or even a dam break. Flash flooding is characterized by the rapid and constant influx of water that caused a treacherous overflow with volume and velocity sufficient to sweep vehicles away, roll boulders onto roadways, uproot trees, level buildings, and sweep bridges off their piers.

Urban Flooding
As land is developed from fields and woodlands into roads, parking lots and built environments, it loses its ability to absorb rainfall. Urbanization of a watershed changes the hydrologic systems of a basin. Heavy rainfall collects and flows faster on impervious surfaces such as asphalt and concrete. Water falls from the clouds and moves along the surface and into streams at a much faster rate in urban areas. Adding a built environment into hydrologic systems can result in floodwaters rising very quickly and moving extremely swiftly. During periods of urban flooding, streets can become rapidly moving rivers and basements can fill with water. Often, storm drains become clogged with debris causing additional, localized flooding.

Most People are Unaware that:

- Over half of deaths due to flooding occur in vehicles. Most happen when drivers try to navigate through floodwaters. The next highest is due to walking into or near flood waters. (NWS)
- Just 6 inches of rapidly moving floodwater can knock a person down. (NWS)
- It only takes 2 feet of water to float a large vehicle. (NWS)
- One-third of all flooded roads and bridges are so damaged by water, that any vehicle trying to cross stands only a 50% chance of making it to the other side.
- 95% of people killed by a flash flood try to outrun rapidly moving water rather than seeking higher grounds.

Ice-Jam Floods
Ice-jam floods can occur when rivers become totally or partially frozen. A rise in stream stage will break up a totally frozen river and create ice flows that can pile up on channel obstructions such as shallow riffles, log jams, or bridge piers. The jammed ice creates a dam across the channel that water and ice cannot breach. The mixture can then rise rapidly and overflow the channel banks. Flooding then moves downstream when the ice dam fails, and the water stored behind the dam is released. At this juncture, the flood takes on the characteristics of a flash flood, with the added danger of ice flows gaining velocity. Such flooding can seriously damage structures in its path.

Storm-Surge Floods
Storm-surge flooding occurs when water is pushed up onto otherwise dry land by onshore winds. Friction between the water and the moving air creates drag that, depending on the distance of the water (fetch) and the velocity of the wind, can pile water up to depths greater than twenty feet. Intense, low-pressure systems and hurricanes can create storm-surge flooding. Storm surge is

unquestionably the most dangerous part of a hurricane when pounding waves create very hazardous flood currents.

Dam and Levee Failure floods
Dam failures are potentially the worst flood events. Dam failure is usually the result of neglect, poor design, or structure damage caused by a major event such as an earthquake. When a dam fails, an immense volume of water is sent speeding downstream, destroying everything in its path. Dams and levees are designed and built for flood protection and are usually engineered to withstand a flood with a calculated risk of occurrence. For example, a dam or levee may be designed to contain a flood at one location on a stream that has a certain probability of occurring in any given year. If a larger flood occurs, that structure will be overtopped. If a dam or levee is overtopped, it could result in the structure being washed out and the water behind it becomes a flash flood. A failed dam or levee can create a flood that is catastrophic to life and property due to the tremendous energy of the water that is released.

Debris and Landslide Floods
Debris and landslide flooding occurs when the accumulation of debris, mud, rocks, and logs in a channel form a temporary dam. Flooding occurs upstream as water becomes trapped behind the temporary dam and quickly becomes a flash flood as water breaches the dam and rapidly washes away. Landslides can also create large waves on lakes or embayments that can be deadly.

Most loss of life occurs when people are swept away by flood currents, while most property damage results from inundation by sediment-laden water. Floodwaters have the potential to be an extremely destructive force. Lateral forces can demolish buildings while erosion can undermine bridge foundations and footings that can lead to collapse of structures.

Flood Facts
- Omitting heat related fatalities, more deaths occur due to flooding than any other hazard and most flood related deaths are due to flash floods. The national, 30-year average for flood related deaths in the U.S. is 88 according to the National Weather Service (NWS).
- Fifty percent of all flash-flood fatalities are vehicle related.
- Most homeowner insurance policies do not cover floodwater damage – Just one inch of water in an average sized home can cause more than $25,000 in damage.
- Estimated property damage in the U.S. in 2019 was $3.75 billion according to the National Weather Service.

Common Terms:

100-Year Flood Plain: An area with a 1% chance of flooding in any given year. This is also known as the Base Flood level.

500-Year Flood Plain: An area with a 0.2% chance of flooding in any given year.

Base Flood: A flood that has a 1% chance of being equaled or exceeded in any given year. In this respect, it is also the regulatory standard for the "100-yeard flood." The base flood is the national standard used by the National Flood Insurance Program (NFIP) and all federal agencies for the purpose of requiring the purchase of flood insurance and the regulation of new development. Base Flood Elevations (BFEs) are usually shown on Flood Insurance Rate Maps (FIRMs)(DFIRMs).

Floodplain: A floodplain is an area of land adjacent to a river, stream, lake, estuary, or other body of water that is subject to flooding. This area of land, if left undisturbed, serves the purpose of storing excess floodwater. A floodplain has two sections, the floodway, and the flood fringe.

Floodway: The NFIP defines floodway as "the channel of a river or other watercourse and adjacent land areas that must be reserved, in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot." The floodway carries the majority of floodwater downstream and is usually the area where water velocity and force are the greatest. NFIP regulations require the floodway be kept open and free from any development or construction that would obstruct or divert floodwaters onto other properties. Floodways are not mapped for all rivers and streams but are generally mapped in developed areas.

Flood Fringe: The flood fringe is the area of a floodplain outside of the floodway. The land area outside of a floodway is subject to inundation by regular flooding.

Annual Flooding: Annual flooding occurs far more frequently than indicated by the term "100-year flood." Over time, a structure located within a 100-year floodplain is at a much greater risk than indicated by the time frame of 100-year.

History of Flooding in Kentucky

As of June 2021, Kentucky has declared 72 major disasters since 1953 according to FEMA's website. Of Kentucky's 72 major disaster declarations, most were due to flooding or included flooding. Flooding in Kentucky occurs almost every year, and it is not unusual for several flooding events to occur in any given year.

An Overview of Kentucky Water and Water Events
13 = Number of Major Basins in Kentucky Approximately 49 = Average Rainfall Maximum Rainfall occurs in Winter and Spring Minimum Rainfall occurs in Late Summer and Fall More than 90,000 = Miles of Rivers and Streams in the Commonwealth 637,000 = Acres of Wetlands 45 = Number of major lakes, including reservoirs, with 29 dams 50 feet tall or higher.

Significant Kentucky floods, resulting in declarations, occurred in 1973, 1975, 1977, 1978, 1982, 1984, three in 1989, 1991, 1997, 1998, 2000, 2001, 2002, 2003, 2004, 2007, 2008, 2009, 2010, 2011, 2012, 2014, 2015, 2016, 2018, 2019, 2020, 2021. The flooding in 1997 involved disaster declarations in 101, Kentucky Counties. The two types of flooding most common in Kentucky are *flash floods* and *river basin* or riverine floods.

Flash Flooding: Resulting from excessive rainfall in a short amount of time, flash flooding occurs in the entire state, but is more common in Eastern Kentucky due to the region's mountainous terrain, narrow gorges, and numerous streams and riverbeds. Flash floods can occur at any time of the year but are more prevalent during the spring and summer months.

River Basin Flooding: River basin flooding is common along Kentucky's major streams such as the Kentucky, Green, Licking, Ohio and Mississippi Rivers. It is most likely to occur during late winter and early spring and seriously affects the major Kentucky cities of Frankfort, Louisville, Owensboro, and Paducah. Every two to three years, serious flooding occurs along one or more of Kentucky's major streams and it is not uncommon for flooding to occur several years in succession.

Aerial photo of Rough River Lake 29 April 2011. On April 30 Rough River Lake pool is recoreded at 524.7ft, a new record. *Image: US Army Corps of Engineers*

II. Profile

The Lincoln Trail Area Development District is bordered on the north in part by the Ohio River. Numerous rivers and streams crisscross the region including Rough River, Nolin River, Beech Fork, Rolling Fork, Chaplin River, Salt River, Clover Creek, Sinking Creek and Otter Creek. These waterways and their tributaries drain an immediate area of 4,600 square miles. Since the Lincoln Trail Region consists of only 3,342 square miles, the potential for flooding is obvious.

Historically, flooding has occurred on all these waterways. Ohio River flooding in the towns of West Point, Brandenburg, and Cloverport has resulted in tremendous property damage and loss of life. Localized flooding resulting in property damage and loss of life has also occurred on most other major streams within the region and has affected the communities of Fredericktown, Bradfordsville and New Haven.


Bradfordsville: South Rolling Fork flooding KY 49, March 2015. *Photo Courtesy: David Edelen.*

Several flood controls projects have been completed within the region, over the years. Most have been construction projects initiated by the U.S. Corps of Engineers and USDA on the Ohio, Rough and Nolin River systems and their tributaries. Local projects have also been completed to deal with storm water runoff and bank erosion issues.

Based on FEMA DFIRM data from 2007 – 2012, 6.23 square miles of land or 0.2% of the Lincoln Trail Region lies in a 500-year floodplain and 256.68 square miles of land or 7.6% of the area lies within a 100-year floodplain. Since approval of the original plan in 2005 all of the eight Lincoln Trail counties have gone through the map modernization program of the floodplains.

DFIRM versions

Breckinridge (8/4/2008)	Grayson (9/19/2012)	Hardin (8/16/2007)
LaRue (1/16/2009)	Marion (1/6/2010)	Meade (7/18/2011)
Nelson (5/24/2011)	Washington (2/17/2010)	

Overview of the Kentucky Floodplain Management Program

Number of Kentucky communities that Participate in the National Flood Insurance Program	116 out of 120 counties 245 cities out of 422
Number of Lincoln Trail communities that Participate in the National Flood Insurance Program	8 out of 8 counties 20 out of 27 cities
Presidential flood declarations between 2005 And April of 2021	22
Presidential flood declaration between 1970 and 2021	34

Source: FEMA.gov and the Kentucky Office of Emergency Management

Table 3.3.2.1.1 lists historical flood claims and their associated cost in each jurisdiction in the Lincoln Trail area because of flooding events. It should be noted that the claims reported to the National Flood Insurance Program (NFIP) may not be the only assistance available to property owners. Flood assistance is also available from FEMA and other state or federal agencies because of a disaster declaration.

Table 3.3.2.1.1

Jurisdiction	Flood Claims	Total Payments
Breckinridge County	3	$131,776
City of Cloverport	17	$133,279
City of Hardinsburg	2	$30,036
City of Irvington	4	$27,373
Grayson County	1	$0
City of Caneyville		$0
Hardin County	92	$1,730,681
City of Elizabethtown	62	$370,001
City of Radcliff	17	$334,542
City of Vine Grove	5	$28,105
City of West Point	207	$3,401,326
LaRue County	21	$201,813
Marion County	6	$100,125
City of Bradfordsville	1	$32,000
City of Lebanon	3	$14,157
Meade County	6	$34,561
City of Brandenburg	4	$169,035

Nelson County	56	$1,427,188
City of Bardstown	7	$90,663
City of Bloomfield	3	$1,883
City of New Haven	26	$705,102
Washington County	20	$467,554
City of Springfield	8	$140,790
City of Williamsburg	1	$53,994
Policy and Loss Data by Geography (HUDEX)		

The National Flood Insurance Program (NFIP) defines a repetitive loss (RL) as any insurable building for which two or more claims of $1,000.00 were paid by the NFIP within any rolling ten-year period, since 1978. A RL property may or may not be currently insured by NFIP. Currently, there are over 122,000 RL properties nationwide. The National Flood Insurance Reform Act of 2004 recognized repetitive loss as a significant problem. The Act also defined severe repetitive loss (SRL) as "a single family property consisting of 1 to 4 residences that is covered under flood insurance by the NFIP and has incurred flood related damage for which 4 or more separate claims payments have been paid under flood insurance coverage, with the amount of each claim payment exceeding $5,000.00 and with the cumulative amount of such claims payments exceeding $20,000.00; or for which at least 2 separate claims payments have been made with the cumulative amount of such claims exceeding the reported value of the property." Currently, there are approximately 6,000 properties nationwide, meeting the definition of SRL.

Table 3.3.2.1.2	
Flood or Flash Flood Related Disaster Declarations in the Lincoln Trail Region	
Declaration Date and Number	**LTADD Counties included in the Declaration**
3-3-15 #4218	Larue and Washington Counties (Public Assistance)
2-21-18 #4361	Hardin and Washington Counties (Public Assistance)
2-6-19 #4428	Marion and Washington Counties (Public Assistance)
2-8-21 #4592	Marion and Nelson Counties (Public Assistance)
2-27-21 #4595	Marion County (Public Assistance)
Source: https://www.fema.gov/disaster/declarations	

In 1973 Congress made the purchase of Flood Insurance mandatory for many properties. Lending institutions could not increase, extend, or renew funds secured by real estate located in a flood hazard area, unless the property was covered under the NFIP.

Participation: The Lincoln Trail currently has all 8 counties and 20 of 27 cities with NFIP policies. The region has seen steady gains in policies. In 2005 only 7 counties and 16 cities had policies. In

2010 all 8 counties and 17 cities had policies and in 2015 all 8 counties and 18 cities had policies. Through conversations with local insurance providers and floodplain managers it was determined the increase is a result of new flood mapping in some areas and increased emphasis on the National Flood Insurance Program.

Non-participation: Jurisdictions not actively participating in the NFIP have deemed it unnecessary to do so, due to the absence of identified flood prone areas within their boundaries. These include: Sonora, which only has an edge of their corporate boundary in a mapped flood plain, no structures within the floodplain and no history of loss.

- Upton, which has no flood plains in mapped section. LaRue County section has not been mapped. It has no streams and no history of loss.
- Loretto, which sits on a ridge and has no flood plain, and no history of loss.
- Ekron, Has no flood plain, no streams and no history of loss.
- Muldraugh, which sits on a ridge and has no steams, no flood plain, and no history of loss.
- Mackville, which sits on a ridge, has no flood plain, and no history of loss.
- Willisburg, which sits on a ridge, has no flood plain, and no history of loss.

The above information is illustrated in the Table 3.3.2.1.3 along with the subsequent maps included in this plan.

Table 3.3.2.1.3 - NFIP and Mapping Summary

Jurisdiction	Affected by 100/500 Year Floodplain	Flood area mapped by FEMA	Map Status Date	NFIP Participant	Total # of Active Policies as of 2004	Total # of Active Policies as of 2009	Total # of Active policies as of 6/30/2015	Total # of Active Policies as of 5/31/2021	Total Written Premium in Force 5/31/2021
Breckinridge Co.	**Yes**	**Yes**	**8/4/08**	**Yes**	**8**	**19**	**30**	**9**	**$8,971**
Cloverport	Yes	Yes		Yes	13	19	12	8	$15,796
Hardinsburg	Yes	Yes		Yes	0	0	1	1	$321
Irvington	No	Yes		Yes	3	1	1	0	
Grayson Co.	**Yes**	**Yes**	**9/19/12**	**Yes**	**2**	**14**	**15**	**19**	**$11,242**
Caneyville	Yes	Yes		Yes	1	1	3	1	$4,118
Clarkson	Yes	Yes		No	0	0	0	0	
Leitchfield	Yes	Yes		Yes	1	0	0	0	
Hardin Co.	**Yes**	**Yes**	**8/16/07**	**Yes**	**46**	**97**	**154**	**90**	**$66,776**
Elizabethtown	Yes	Yes		Yes	30	113	161	122	$142,212
Radcliff	Yes	Yes		Yes	21	29	30	13	$5,502
Sonora	Yes	Yes		No	0	0	0	0	
Upton	No	Partial		No	0	0	0	0	
Vine Grove	Yes	Yes		Yes	7	16	29	26	$24,092
West Point	Yes	Yes		Yes	176	159	145	104	$125,983
LaRue Co.	**Yes**	**Yes**	**1/16/10**	**Yes**	**12**	**13**	**13**	**14**	**$16,934**
Hodgenville	Yes	Yes		Yes	2	9	4	4	$5,350
Marion Co.	**Yes**	**Yes**	**1/6/10**	**Yes**	**6**	**10**	**19**	**25**	**$19,186**
Bradfordsville	Yes	Yes		Yes	1	2	4	4	$4,144
Lebanon	Yes	Yes		Yes	2	2	6	9	$5,365
Loretto	No	Yes		No	0	0	0	0	
Raywick	Yes	Yes		Yes	0	0	0	0	
Meade Co.	**Yes**	**Yes**	**7/18/11**	**Yes**	**8**	**12**	**20**	**21**	**$11,340**
Brandenburg	Yes	Yes		Yes	1	2	3	2	$699
Ekron	No	Yes		No	7	0	0	0	
Muldraugh	No	Yes		No	0	0	0	0	
Nelson Co.	**Yes**	**Yes**	**5/24/11**	**Yes**	**47**	**38**	**31**	**25**	**$27,123**
Bardstown	Yes	Yes		Yes	6	5	5	6	$5,747
Bloomfield	Yes	Yes		Yes	7	12	21	15	$26,783
Fairfield	No	Yes		Yes	0	0	0	0	
New Haven	Yes	Yes		Yes	21	19	25	18	
Washington Co.	**Yes**	**Yes**	**2/17/10**	**Yes**	**10**	**9**	**15**	**14**	**$11,349**
Mackville	No	Yes		No	0	0	0	0	
Springfield	Yes	Yes		Yes	7	4	9	5	$37,462
Willisburg	No	Yes		No	0	0	0	0	

Original Source: http://www.fema.gov/nfip/10110309.html
Source of 2009 Update: http://bsa.nfipstat.com/reports/1040.html & http://bsa.nfipstat.com/reports/1011.html
Source of 2015 Update: http://bsa.nfipstat.fema.gov/reports/reports.html
Source of 2021 Update: https://nfipservices.floodsmart.gov/reports-flood-insurance-data

Table 3.3.2.1.4 - Claims Summary

Jurisdction	Total # Claims 1978-2004	Total # Claims 2004-2009	Total # Claims 2010-2015	Total # Claims Since 2015	Total Claim	Total Payments	Payments Prior to 2016	Change Since 2015
Breckinridge Co.	**0**	**0**	**4**	**0**	**4**	**$131,776**	**$131,776**	**$0**
Cloverport	11	2	5	2	20	$133,279	$87,994	$45,285
Hardinsburg	0	0	0	2	2	$30,036	$0	$30,036
Irvington	2	2	0	0	4	$27,373	$27,373	$0
Grayson Co.	**0**	**0**	**2**	**0**	**2**	**$0**	**$0**	**$0**
Caneyville	1	0	0	1	2	$0	$0	$0
Clarkson	0	0	0	0	0	$0	$0	$0
Leitchfield	0	0	0	0	0	$0	$0	$0
Hardin Co.	**44**	**23**	**39**	**6**	**112**	**$1,730,681**	**$1,662,464**	**$68,217**
Elizabethtown	18	27	22	12	79	$370,001	$305,618	$64,383
Radcliff	3	7	10	1	21	$334,542	$309,225	$25,317
Sonora	0	0	0	0	0	$0	$0	$0
Upton	0	0	0	0	0	$0	$0	$0
Vine Grove	0	2	0	3	5	$28,105	$23,071	$5,034
West Point	145	2	39	36	222	$3,401,326	$2,302,270	$1,099,056
LaRue Co.	**17**	**0**	**5**	**0**	**22**	**$203,045**	**$203,045**	**$0**
Hodgenville	0	0	0	0	0	$0	$0	$0
Marion Co.	**3**	**0**	**5**	**0**	**8**	**$100,125**	**$100,125**	**$0**
Bradfordsville	0	0	1	0	1	$32,000	$32,000	$0
Lebanon	5	0	0	0	5	$14,157	$14,157	$0
Loretto	0	0	0	0	0	$0	$0	$0
Raywick	0	0	0	0	0	$0	$0	$0
Meade Co.	**0**	**3**	**3**	**2**	**8**	**$34,561**	**$30,702**	**$3,859**
Brandenburg	3	0	0	1	4	$169,035	$161,330	$7,705
Ekron	0	0	0	0	0	$0	$0	$0
Muldraugh	0	0	0	0	0	$0	$0	$0
Nelson Co.	**39**	**0**	**20**	**3**	**62**	**$1,427,188**	**$1,350,576**	**$76,612**
Bardstown	4	0	3	0	7	$90,663	$90,663	$0
Bloomfield	2	0	0	1	3	$1,883	$1,883	$0
Fairfield	0	0	0	0	0	$0	$0	$0
New Haven	15	0	11	3	29	$705,102	$472,457	$232,645
Washington Co.	**3**	**1**	**8**	**9**	**21**	**$467,554**	**$396,666**	**$70,888**
Mackville	0	0	0	0	0	$0	$0	$0
Springfield	2	0	4	0	6	$172,515	$172,515	$0
Willisburg	0	0	0	1	1	$53,994	$0	$53,994

Original Source: http://www.fema.gov/nfip/10110309.html
Source of 2009 Update: http://bsa.nfipstat.com/reports/1040.html & http://bsa.nfipstat.com/reports/1011.html
Source of 2015 Update: http://bsa.nfipstat.fema.gov/reports/reports.html
Source of 2020 Update: Policy and Loss Data by Geography (HUDEX)

III. Analysis

To identify flooding as a threat to the Lincoln Trail Region, the types of floods and their causes were analyzed; areas of vulnerability were determined; historical data was researched; and maps were created to identify the vulnerable areas. The Sources for this information include FEMA, the National Center for Environmental Information (NCEI), the Kentucky Climatic Data Center, the National Weather Service (NWS), the National Flood Insurance Program, and the Atlas of Kentucky.

One date that will stand out in the history of the Lincoln Trail Region, is March 1997. Ninety-two counties in Kentucky and 14 counties in southern Indiana were declared disaster areas. Tens of thousands of people were evacuated from their homes, with total damage across the region estimated at $400,000,000. In the small city of West Point in Hardin County, it was estimated that 85% of the city was under water leaving residents devastated and property destroyed.

The following tables outline the history of flooding events that have been recorded in each county/jurisdiction within the Lincoln Trail region since 1967. The impact, of these flooding events, is documented by the number of lives lost, individual injuries reported, and the estimated cost of property and crop damage. This information was reported to the Spatial Hazard Events and Losses Databases for the United States (SHELDUS) and later the National Climate Data Center (NCDC) and was subsequently rolled into the National Centers for Environmental Information (NCEI) database. For the original, plan data was only available through 2003. The 2010 update provided data thru 30 June 2009. The 2015 update included events for the period 1 July 2009 through 30 June 2015. This update includes events from 1 July 2015 to May of 2021. The summary tables, 3.3.2.1.5 & 3.3.2.1.6 show data for the entire period covered by the various sources. Note that there are many variations in recording the locations of the events over time. In the past this was typically done at a county level. More recently, nearest place names have been used. Because of this, the records in the summation tables that pertain to individual incorporated areas should not be considered all encompassing.

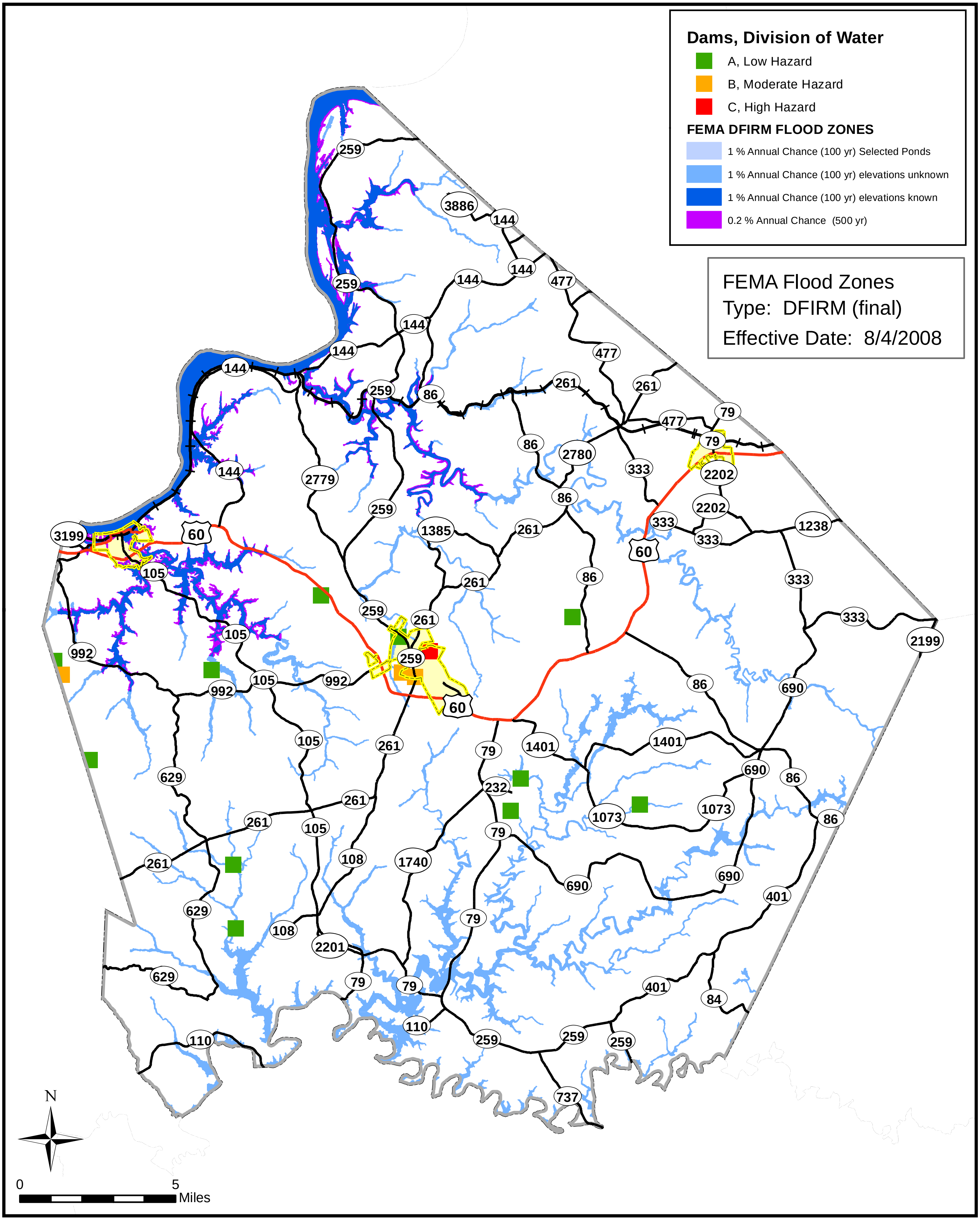
Table 3.3.2.1.5 - County Specific Data – Flooding, ***Source: NCEI***

BRECKINRIDGE
60 Flood/Flash Flood event(s) were recorded between 1967 and 5/15/2021 by SHELDUS and the NCDC.

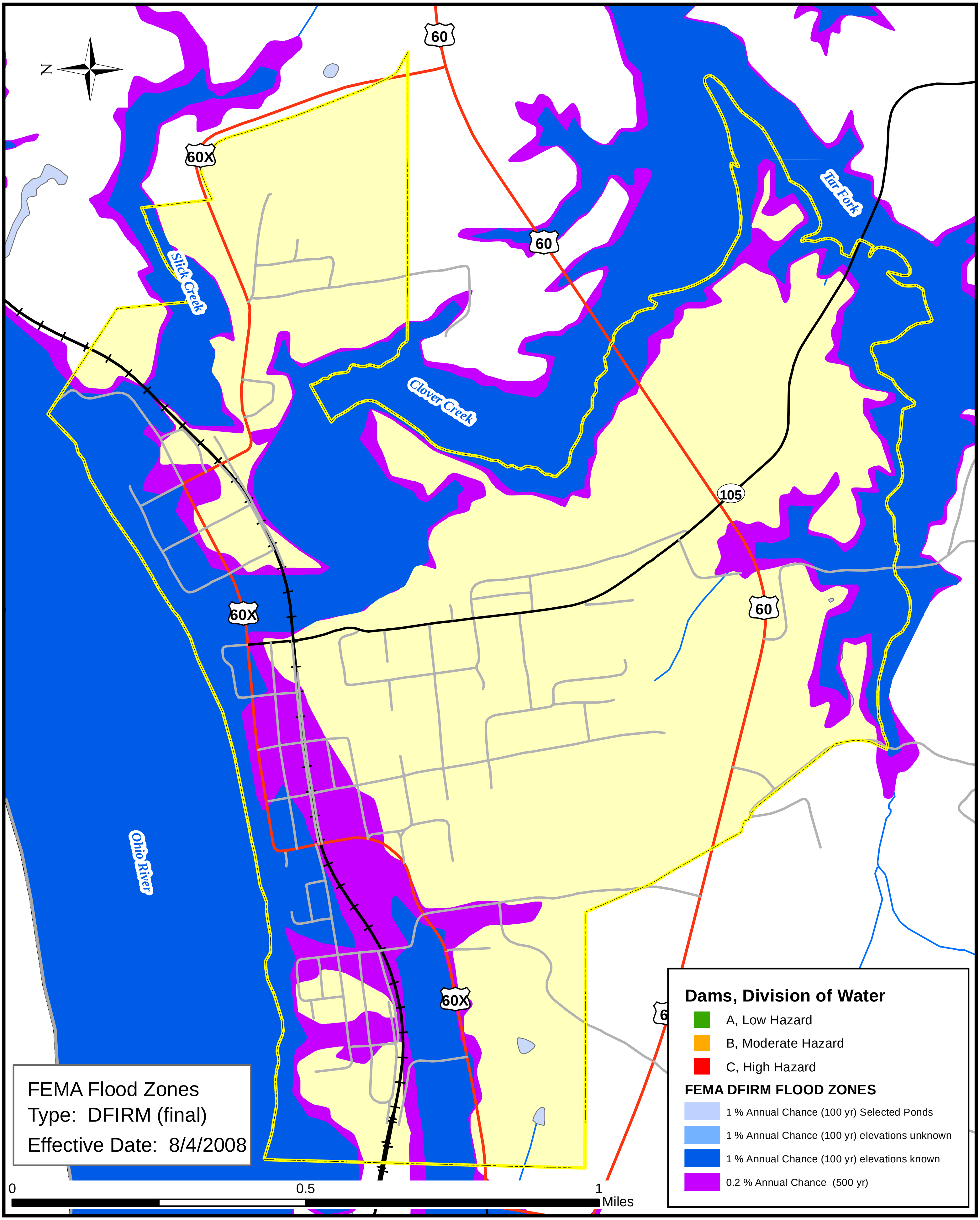
There have been 7 Flood/Flash Flood events recorded from 7/1/2015 through 5/15/2021 in NCEI.

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE ($)	CROP DAMAGE ($)
HARDINSBURG ARPT	7/3/15	0	0	0	0
BRECKINRIDGE CO.	2/23/18	0	0	0	0
BRECKINRIDGE CO.	2/23/18	0	0	0	0
CLOVERPORT	2/23/18	0	0	0	0
HARDINSBURG ARPT	2/25/18	0	0	0	0
BRECKINRIDGE CO.	11/1/18	0	0	0	0
BRECKINRIDGE CO.	11/30/19	0	0	10000	0

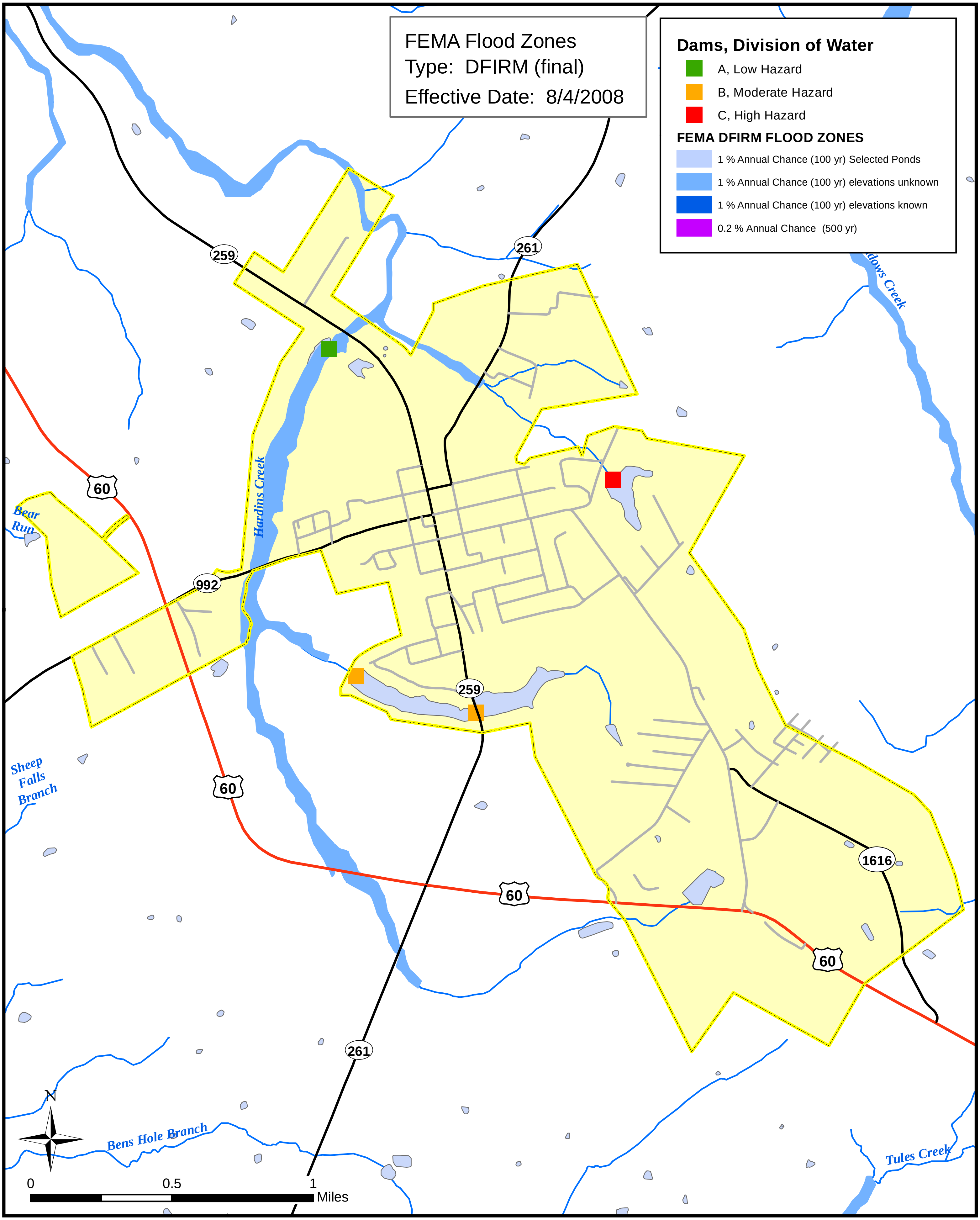
35a


Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 8/4/2008
N
0
5
Miles

35b


N
60
60X
60
Slick Creek
Clover Creek
Tar Fork
105
60
60X
Ohio River
60X
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 8/4/2008
0
0.5
1
Miles
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)

35c


FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 8/4/2008
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
259
261
60
992
1616
Hardins Creek
Bear Run
Sheep Falls Branch
Bens Hole Branch
Tules Creek
N
0
0.5
1
Miles

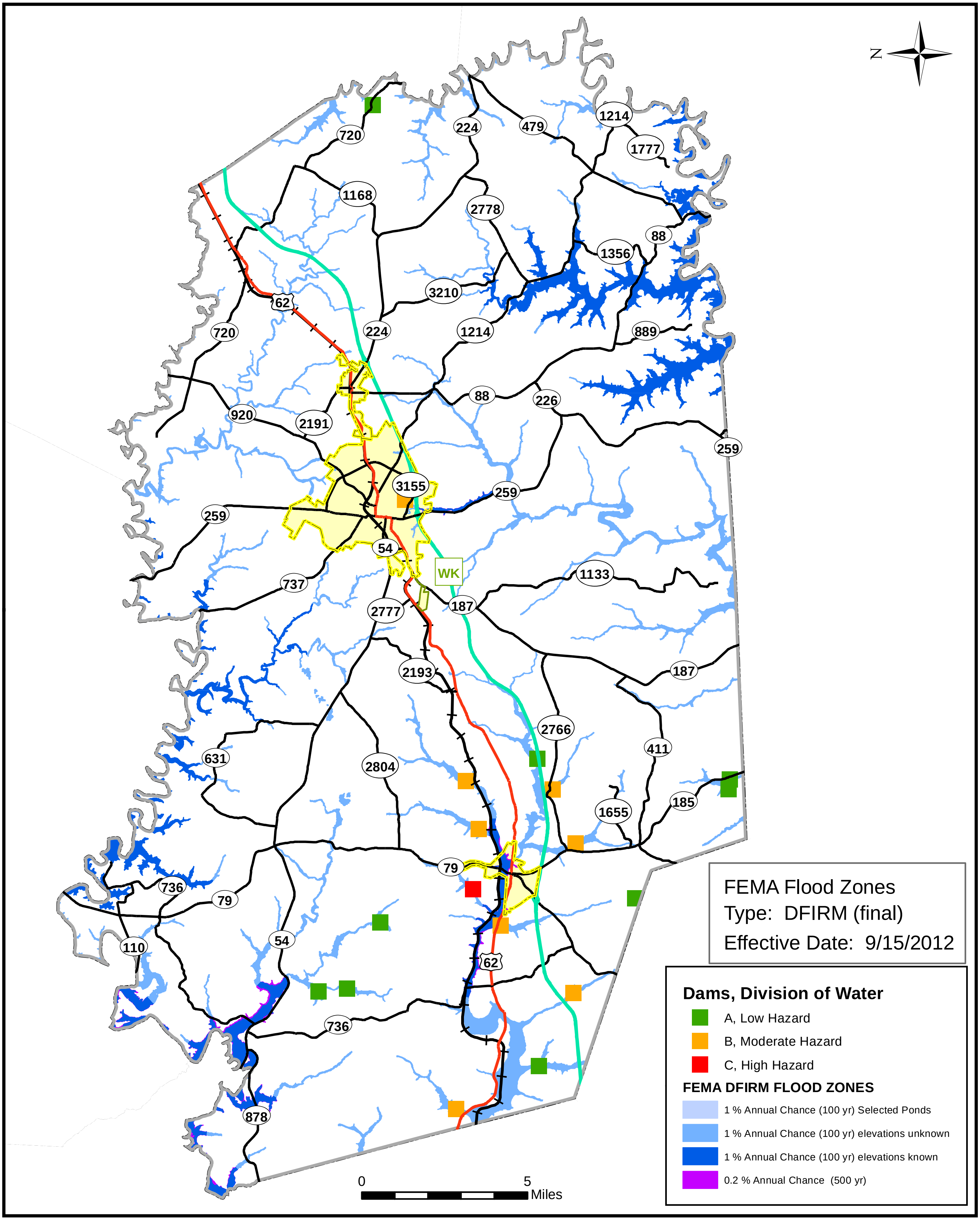
GRAYSON
56 Flood/Flash Flood event(s) were recorded between 1967 and 5/15/2021 by SHELDUS and the NCDC.

There have been 10 Flood/Flash Flood events recorded from 7/1/2015 through 5/15/2021 in NCEI.

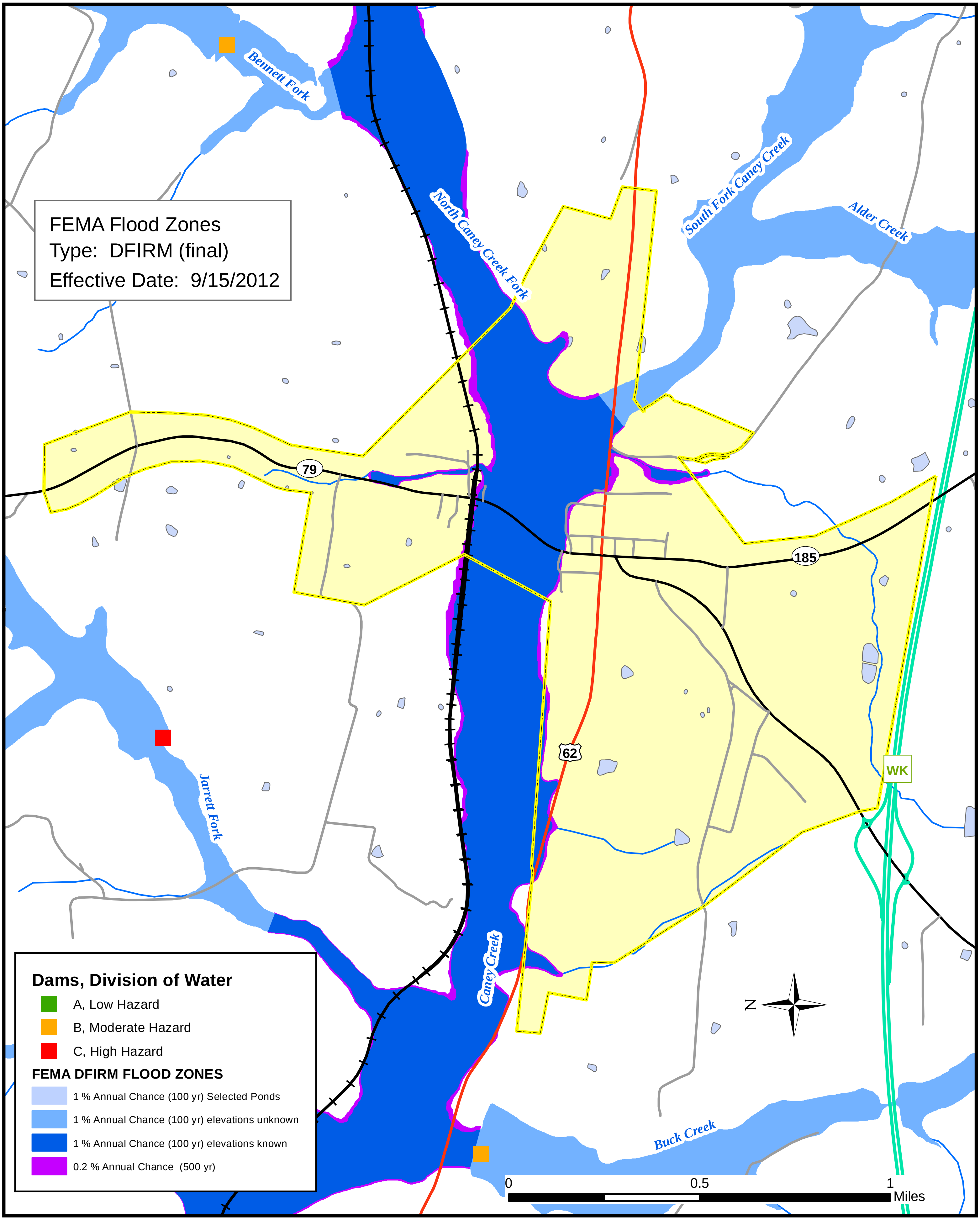
LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE ($)	CROP DAMAGE ($)
CLARKSON	4/27/16	0	0	0	0
CANEYVILLE	2/22/18	0	0	250000	0
GRAYSON CO.	2/23/19	0	0	0	0
GRAYSON CO.	11/30/19	0	0	10000	0
CLARKSON	3/28/20	0	0	0	0
GRAYSON CO.	6/28/20	0	0	0	0
GRAYSON CO.	6/28/20	0	0	30000	0
GRAYSON CO.	6/28/20	0	0	15000	0
GRAYSON CO.	6/28/20	0	0	0	0
CLARKSON	7/5/20	0	0	0	0


Road Washout in Grayson County, May 8, 2009, and a flooded cornfield, Grayson County June 2009. *LTADD Archives.*

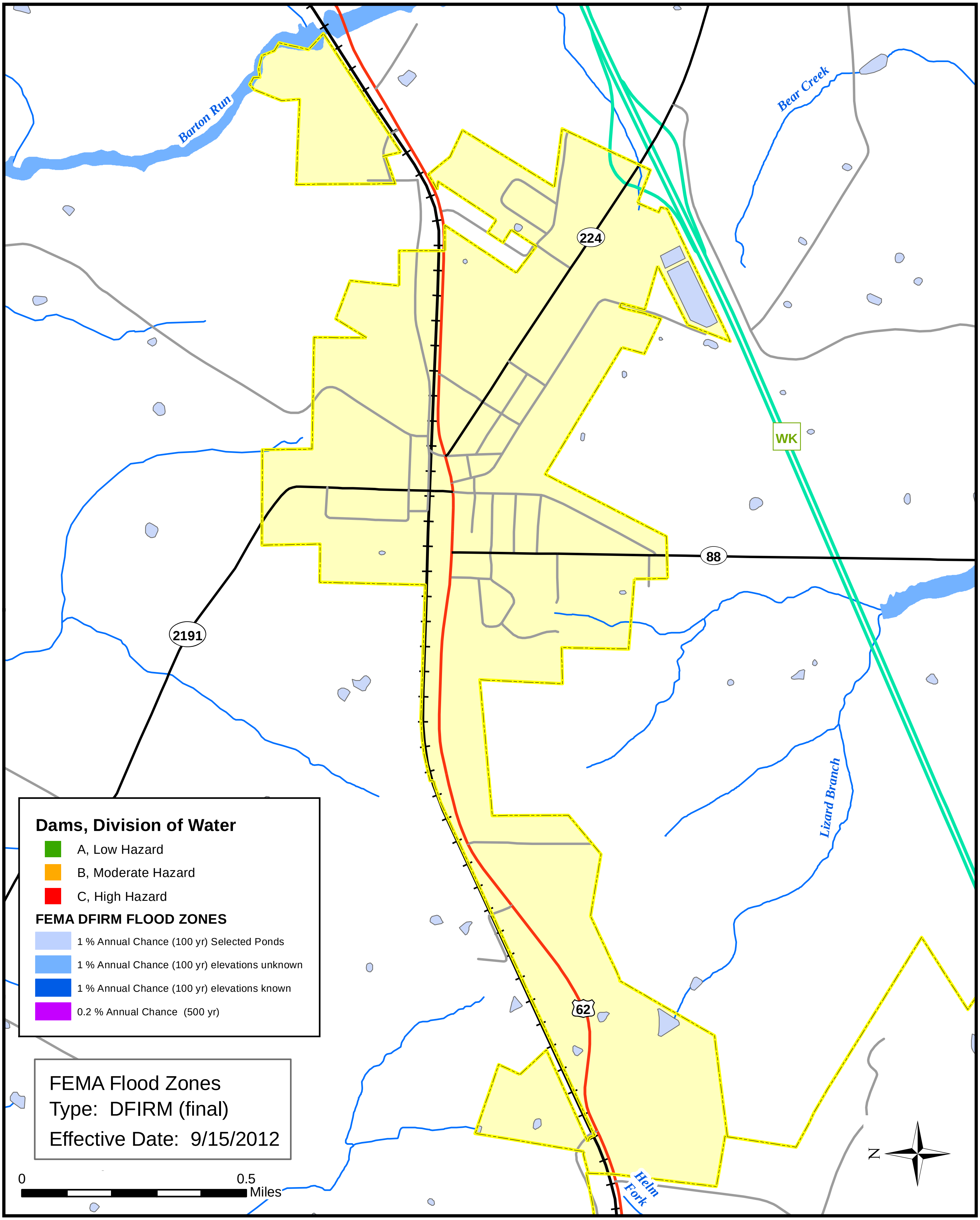
36a


FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 9/15/2012
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
0
5
Miles
N
WK
720
224
479
1214
1777
1168
2778
88
1356
3210
62
720
224
1214
889
88
226
920
2191
259
3155
259
259
54
1133
737
2777
187
2193
187
2766
411
631
2804
185
1655
79
736
79
110
54
62
736
878

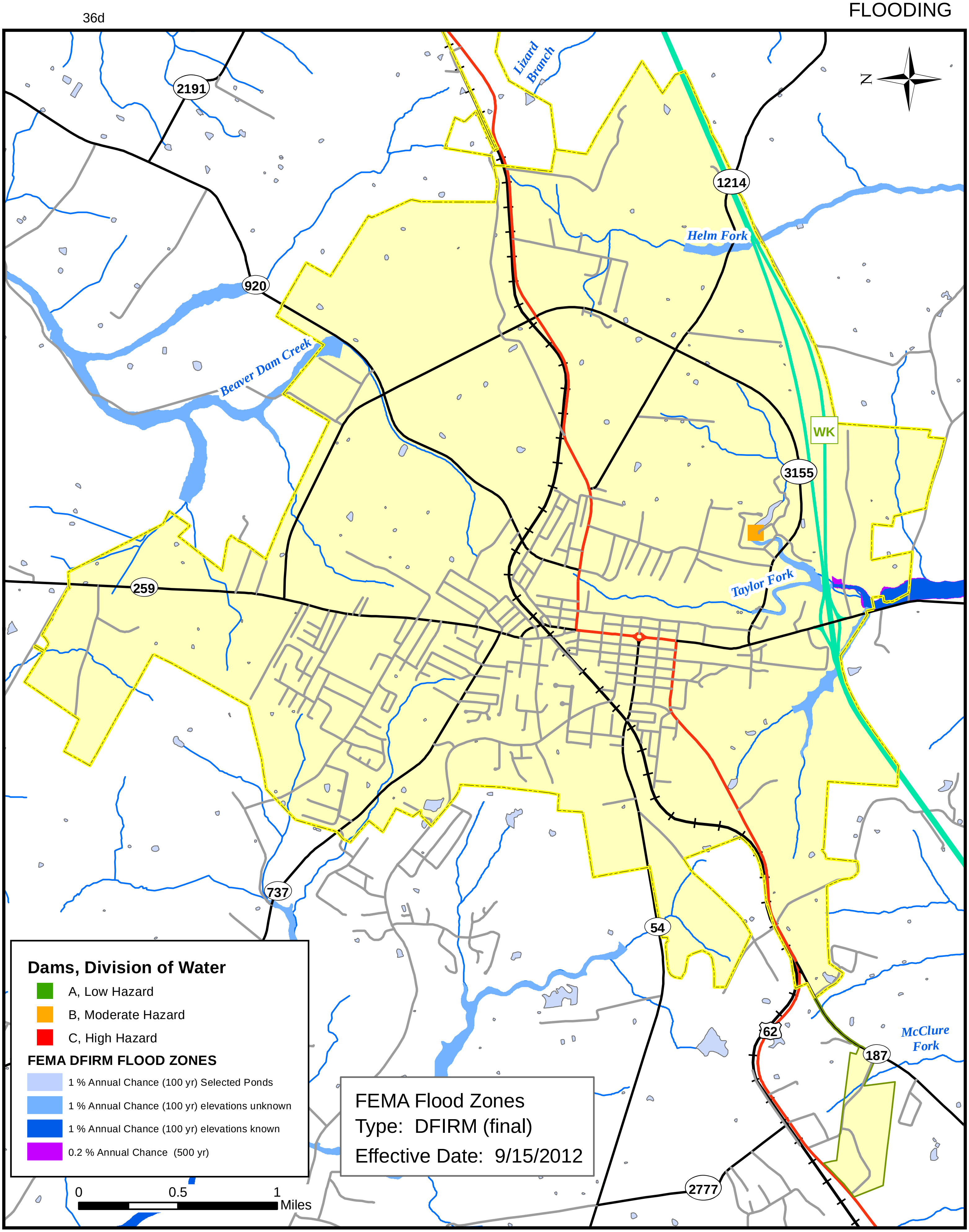
CANEYVILLE
FLOODING



36c


Barton Run
Bear Creek
224
WK
2191
88
Lizard Branch
62
Helm Fork
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 9/15/2012
0
0.5
Miles
N

LEITCHFIELD
FLOODING



HARDIN

88 Flood/Flash Flood event(s) were recorded between 1967 and 5/15/2021 by SHELDUS and the NCDC.

There have been 19 Flood/Flash Flood events recorded from 7/1/2015 through 5/15/2021 in NCEI.

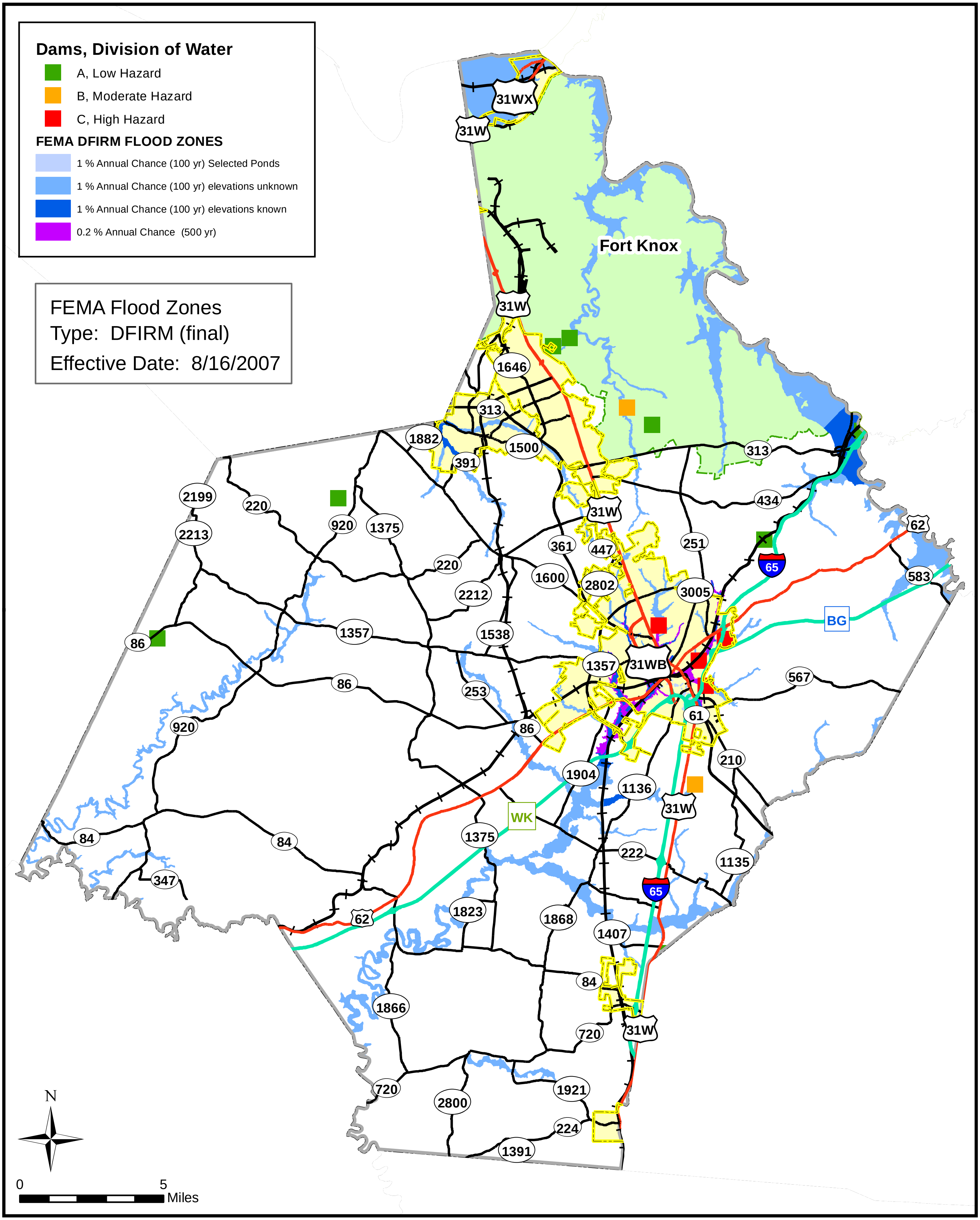
LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE ($)	CROP DAMAGE ($)
ELIZABETH TOWN	5/10/16	0	0	0	0
ELIZABETH TOWN ARPT	7/22/16	0	0	0	0
HARDIN CO.	6/23/17	0	0	0	0
HARDIN CO.	6/23/17	0	0	0	0
HARDIN CO.	6/23/17	0	0	0	0
HARDIN CO.	6/23/17	0	0	0	0
WEST POINT	2/22/18	0	0	1250000	0
HARDIN CO.	2/24/18	0	0	0	0
HARDIN CO.	2/25/18	0	0	0	0
ELIZABETH TOWN	6/25/18	0	0	0	0
HARDIN CO.	6/25/18	0	0	0	0
HARDIN CO.	6/26/18	0	0	0	0
VINE GROVE	11/30/19	0	0	0	0
ELIZABETH TOWN ARPT	11/30/19	0	0	0	0
HARDIN CO.	11/30/19	0	0	0	0
HARDIN CO.	11/30/19	0	0	15000	0
HARDIN CO.	3/12/20	0	0	3000	0
ELIZABETH TOWN ARPT	7/20/20	0	0	100000	0
HARDIN CO.	8/14/20	0	0	0	0

Flood damage in Vine Grove parks, Spring 2008. *Photos courtesy of City of Vine Grove.*

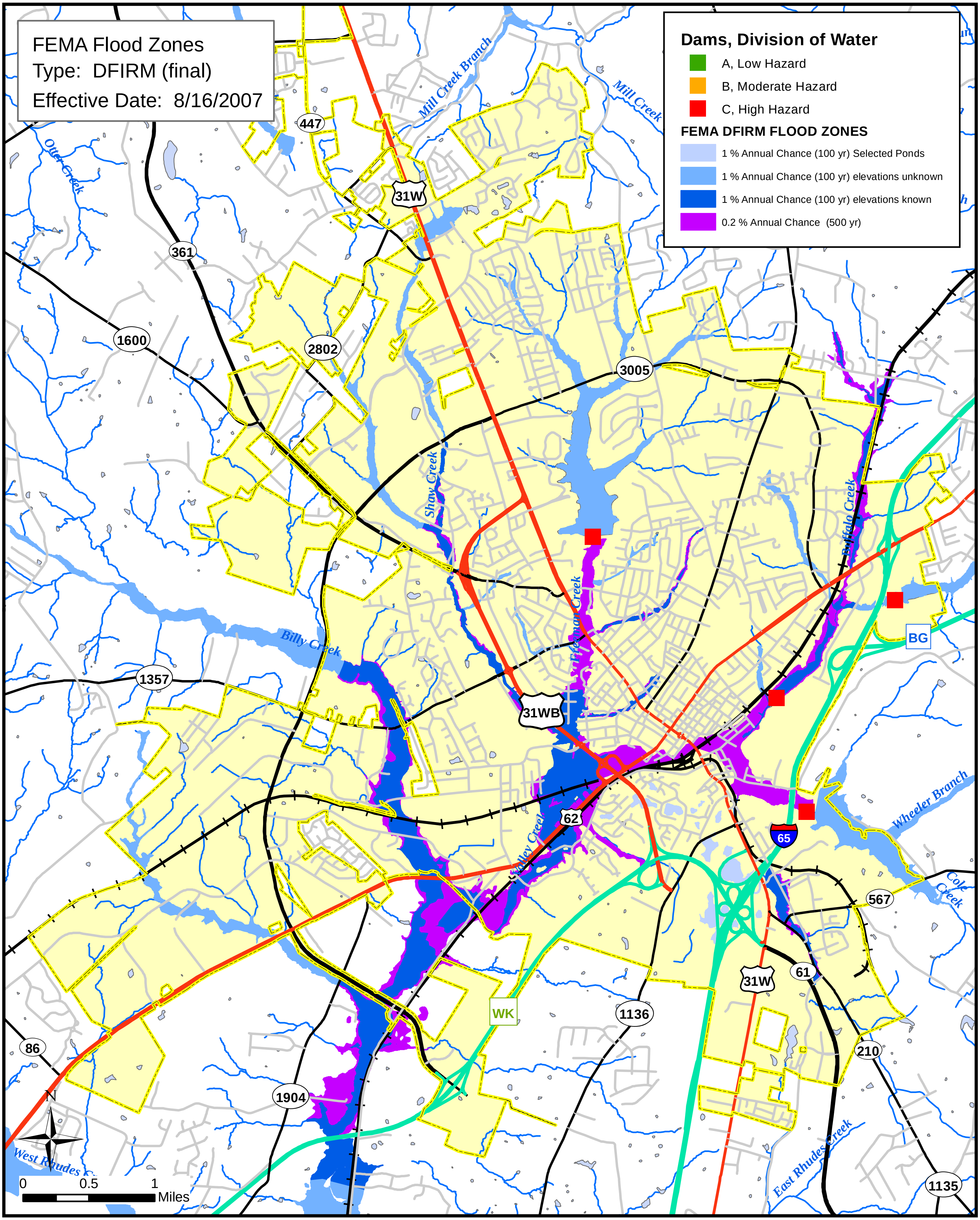
2011 Flooding in Vine Grove - Zoom of previous photo. *Photo courtesy of the City of Vine Grove*

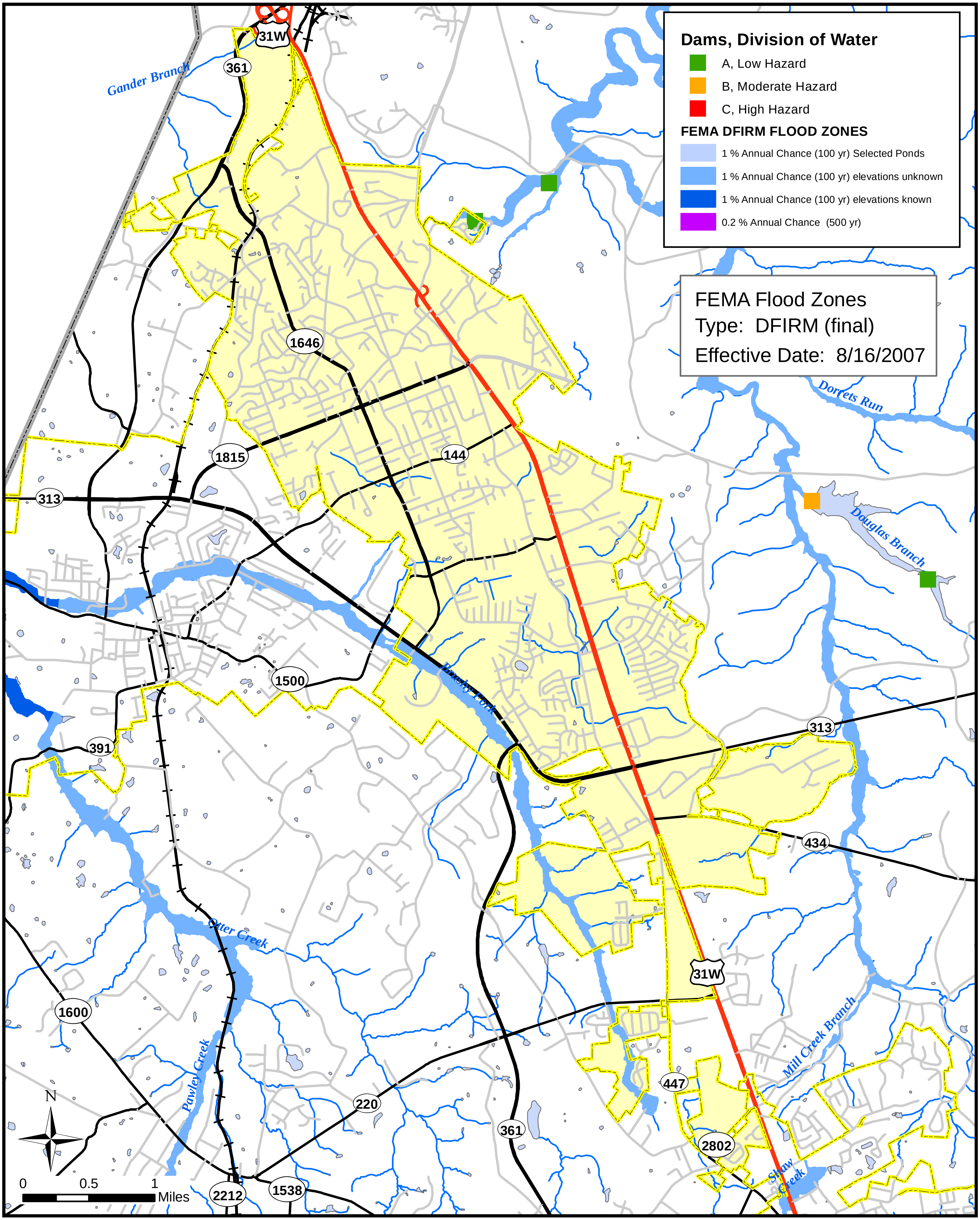
Flooded homes in West Point in March 2021. *Source: The News Enterprise*

38a

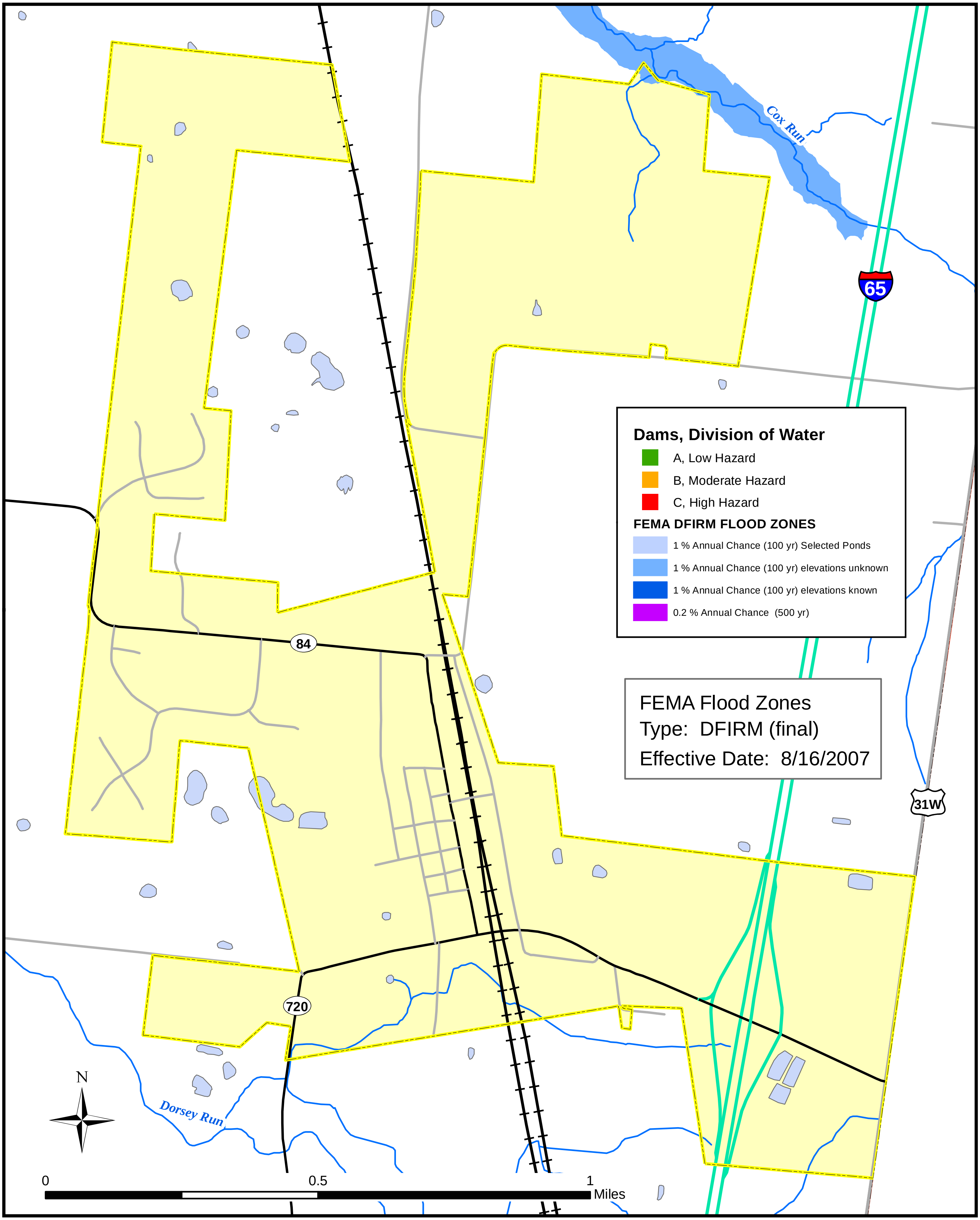

Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 8/16/2007
Fort Knox
N
0
5
Miles

38b

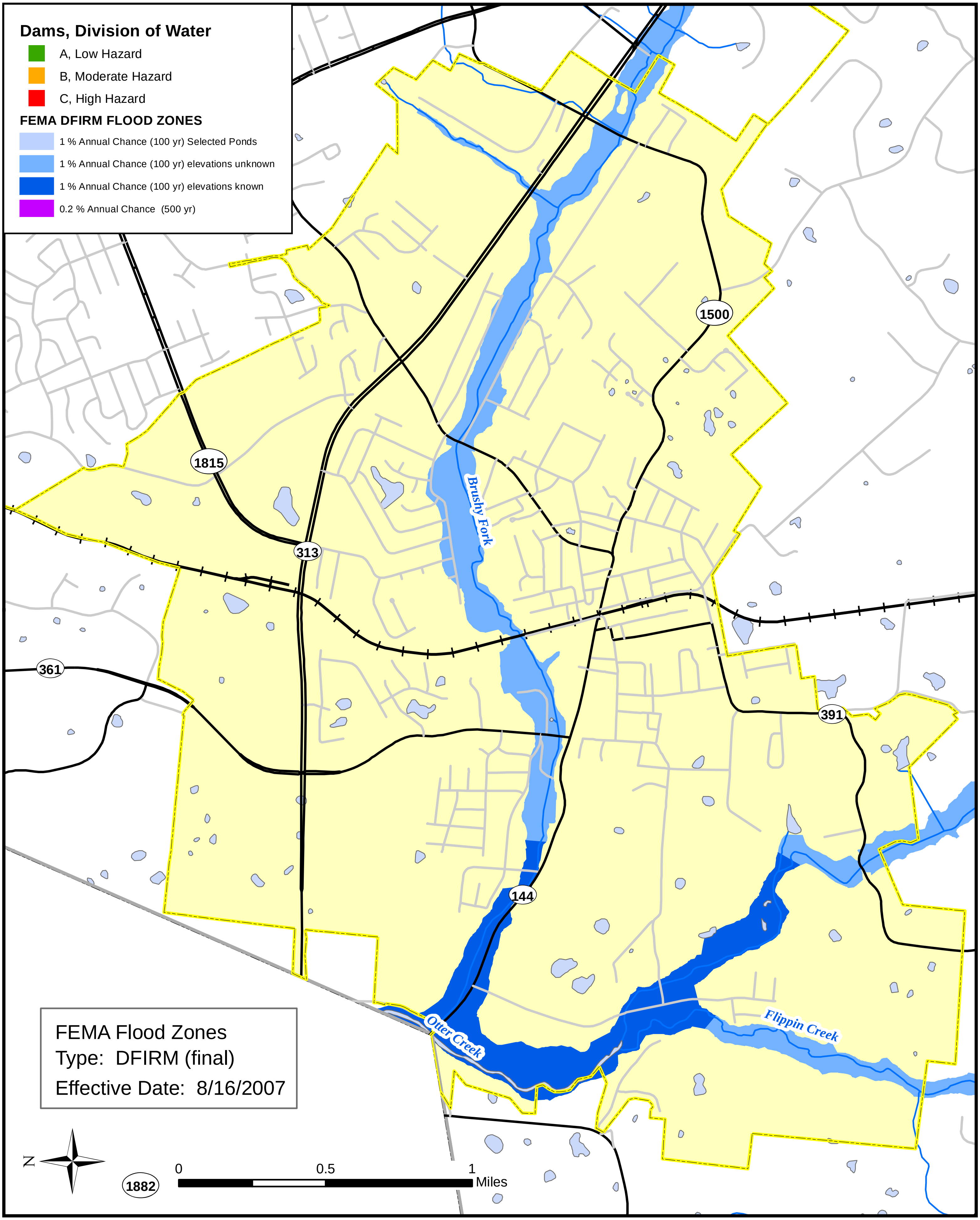

FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 8/16/2007
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
Mill Creek Branch
Mill Creek
Otter Creek
Shaw Creek
Billy Creek
Freeman Creek
Buffalo Creek
Valley Creek
Wheeler Branch
Cole Creek
West Rhudes Creek
East Rhudes Creek
447
31W
361
1600
2802
3005
1357
31WB
62
65
567
61
1136
86
1904
210
1135
BG
WK
N
0
0.5
1
Miles

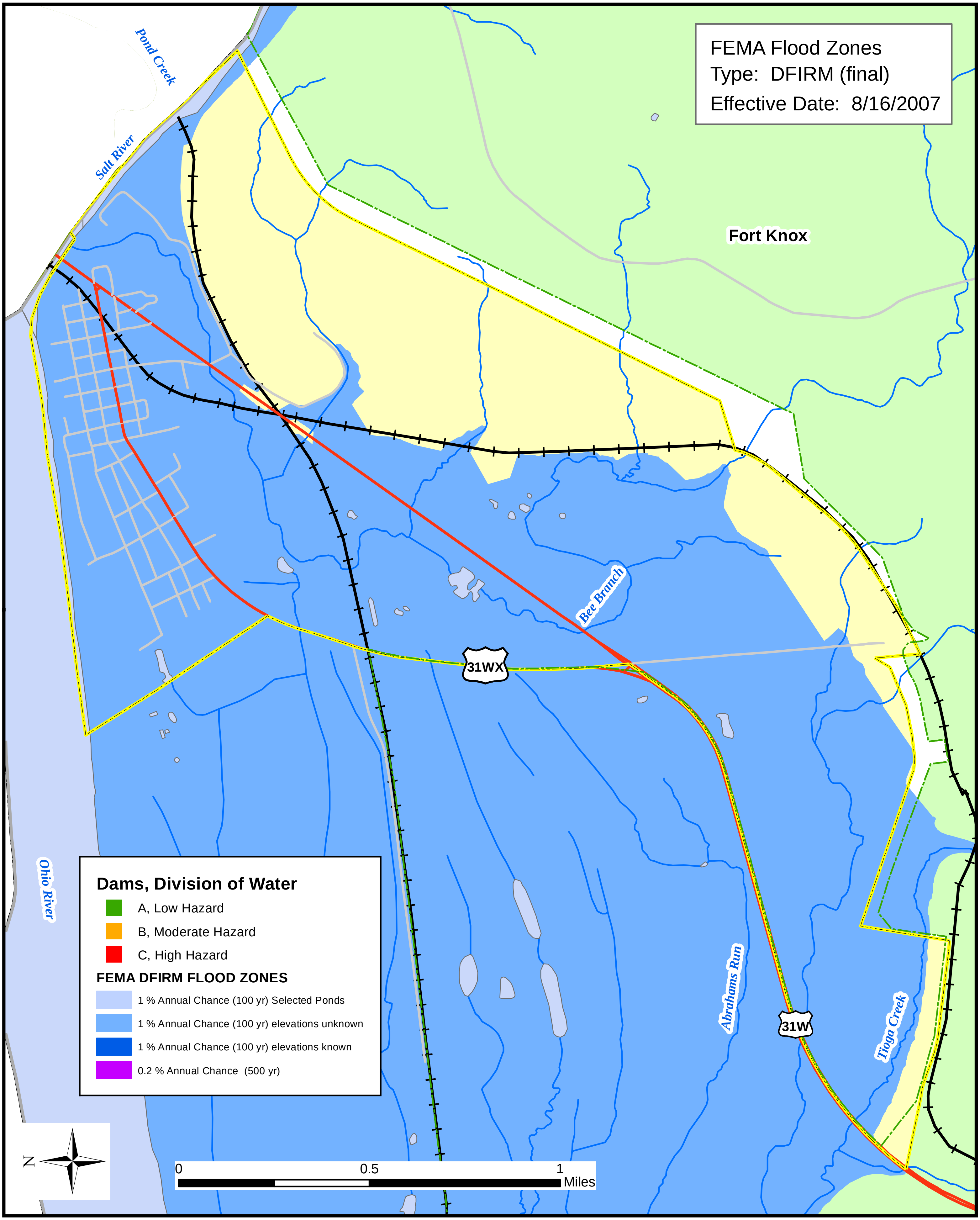

Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 8/16/2007
Gander Branch
Dorrets Run
Douglas Branch
Brushy Fork
Otter Creek
Pawley Creek
Mill Creek Branch
Shaw Creek
31W
361
1646
1815
144
313
1500
391
434
1600
220
447
2802
2212
1538
N
0
0.5
1
Miles

38d


Cox Run
65
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 8/16/2007
84
31W
720
N
Dorsey Run
0
0.5
1
Miles

VINE GROVE
FLOODING




FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 8/16/2007
Pond Creek
Salt River
Fort Knox
Bee Branch
31WX
Ohio River
Abrahams Run
31W
Tioga Creek
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
N
0
0.5
1
Miles

LARUE

47 Flood/Flash Flood event(s) were recorded between 1967 and 5/15/2021 by SHELDUS and the NCDC.

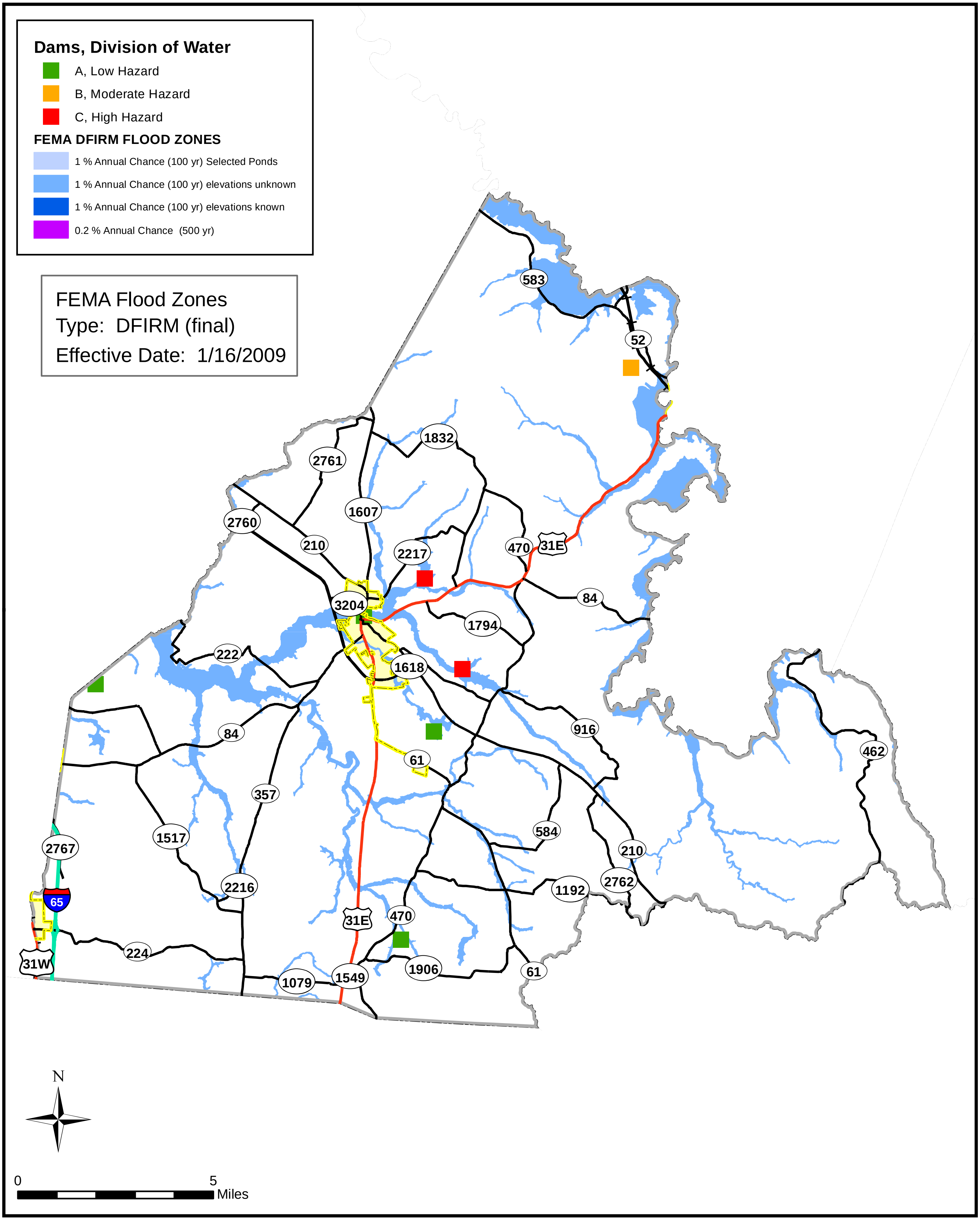
There have been 10 Flood/Flash Flood events recorded from 7/1/2015 through 5/15/2021 in NCEI.

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE ($)	CROP DAMAGE ($)
HODGENVILLE	7/3/15	0	0	0	0
HODGENVILLE	7/3/15	0	0	0	0
LARUE CO.	8/5/15	0	0	0	0
LARUE CO.	2/23/19	0	0	0	0
LARUE CO.	2/24/19	0	0	0	0
LARUE CO.	7/5/20	0	0	0	0
LARUE CO.	7/17/20	0	0	0	0
LARUE CO.	7/17/20	0	0	0	0
LARUE CO.	7/17/20	0	0	0	0
LARUE CO.	7/17/20	0	0	0	0

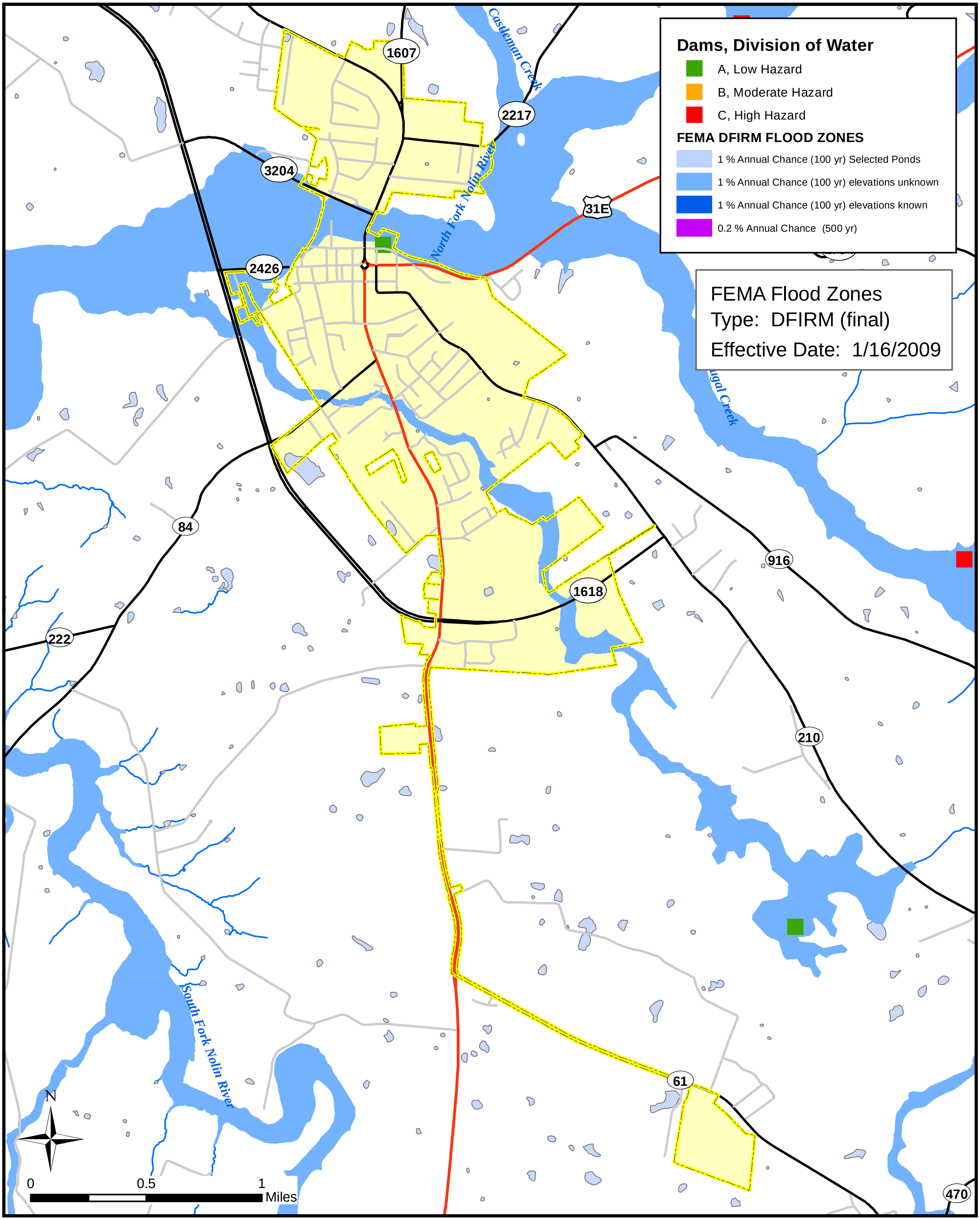
Flooding in Hodgenville. *Photo courtesy of City of Hodgenville.*


Flooded Park in Hodgenville in 2018. *Source: Herald News*

40a


Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 1/16/2009
583
52
1832
2761
1607
2760
210
2217
470
31E
84
3204
1794
222
1618
916
84
61
462
357
584
1517
2767
210
2216
2762
1192
65
31E
470
224
31W
1906
61
1079
1549
N
0
5
Miles

40b


Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 1/16/2009
Castleman Creek
North Fork Nolin River
South Fork Nolin River
1607
2217
3204
31E
2426
84
222
916
1618
210
61
470
N
0
0.5
1
Miles

MARION
58 Flood/Flash Flood event(s) were recorded between 1967 and 5/15/2021 by SHELDUS and the NCDC.

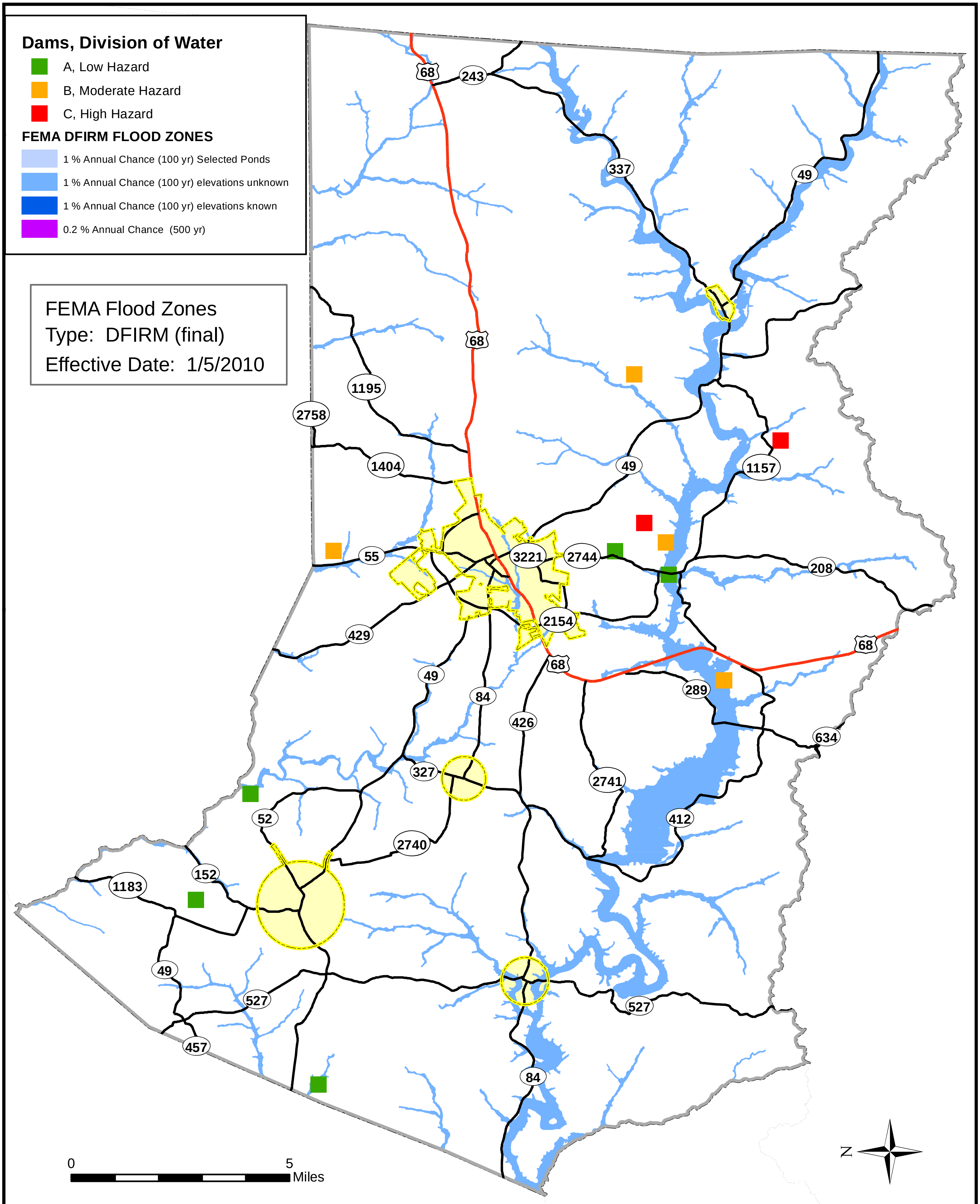
There have been 14 Flood/Flash Flood events recorded from 7/1/2015 through 5/15/2021 in NCEI.

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE ($)	CROP DAMAGE ($)
MARION CO.	7/19/15	0	0	0	0
BRADFORDSVILLE	12/25/15	0	0	0	0
MARION CO.	5/31/18	0	0	0	0
LEBANON	5/31/18	0	0	0	0
LEBANON	5/31/18	0	0	0	0
LEBANON	5/31/18	0	0	0	0
MARION CO.	6/26/18	0	0	0	0
MARION CO.	6/26/18	0	0	0	0
MARION CO.	6/26/18	0	0	0	0
MARION CO.	11/30/19	0	0	0	0
BRADFORDSVILLE	6/29/20	0	0	0	0
BRADFORDSVILLE	6/29/20	0	0	0	0
MARION CO.	6/29/20	0	0	50000	0
MARION CO.	6/29/20	0	0	10000	0

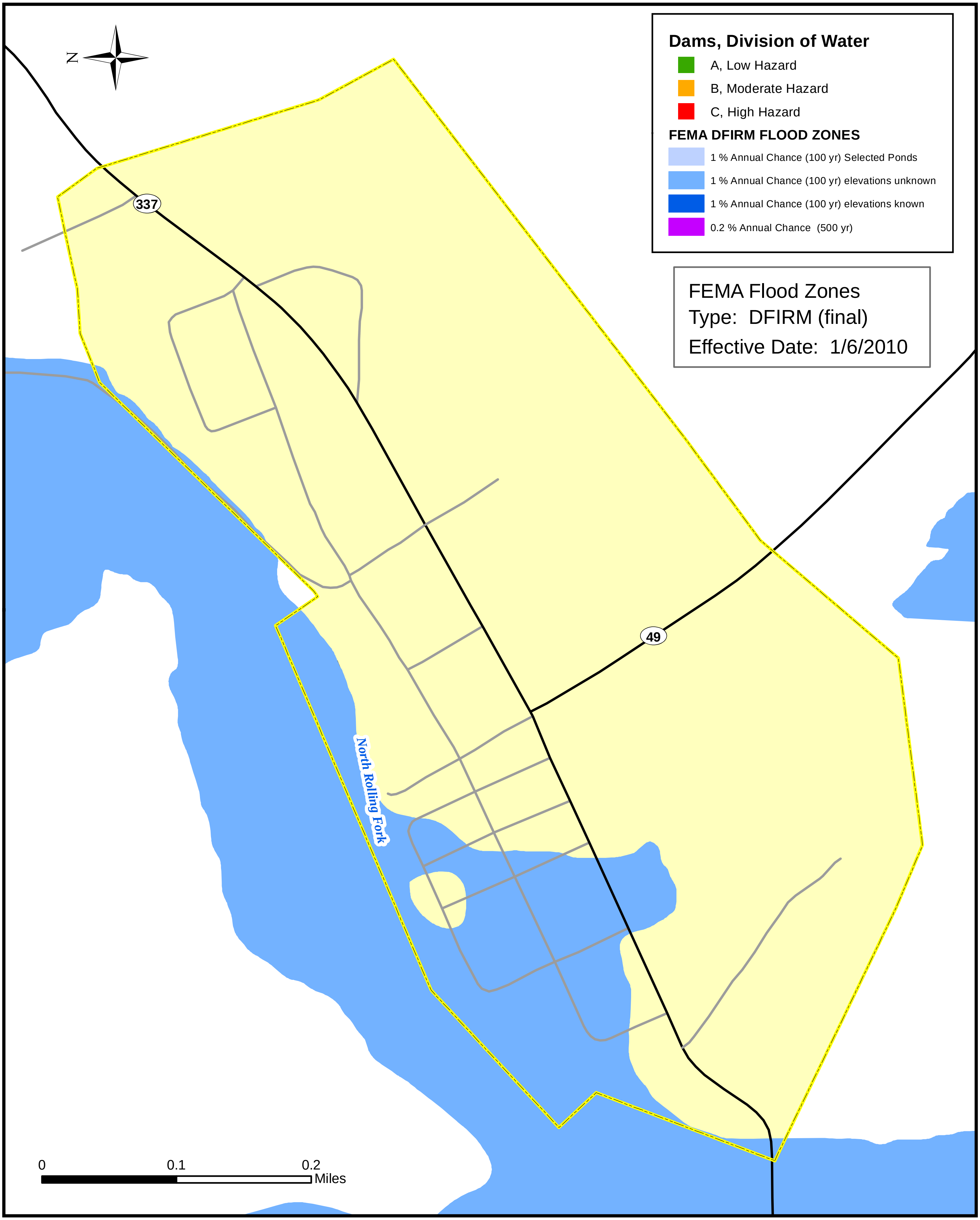
Bradfordsville, North Rolling Fork Flooding, March 2015, *Photo: David Edelen.*


Drone photograph of flooded fields in Marion County in March 2021. *Source: The Lebanon Enterprise.*

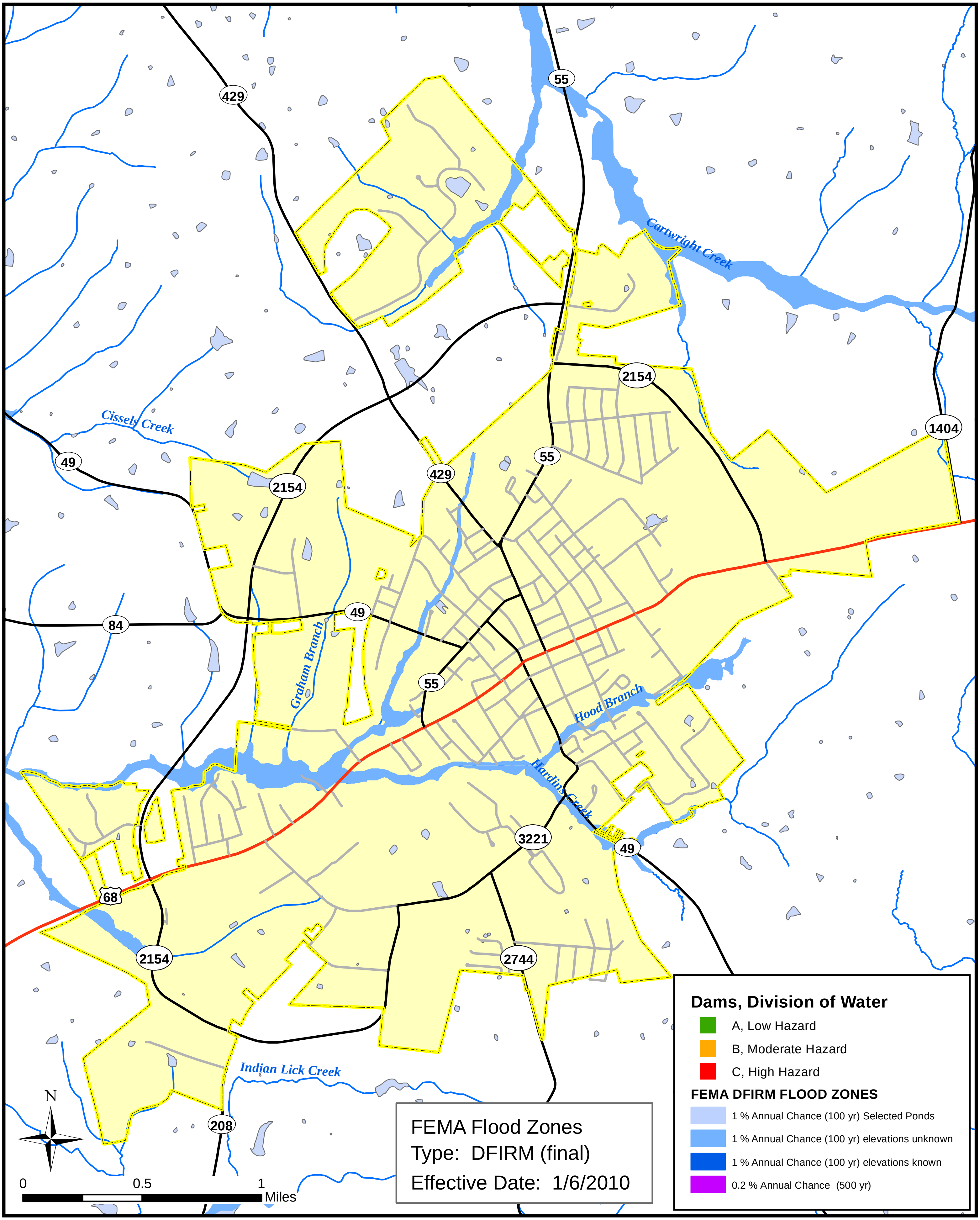
MARION COUNTY FLOODING

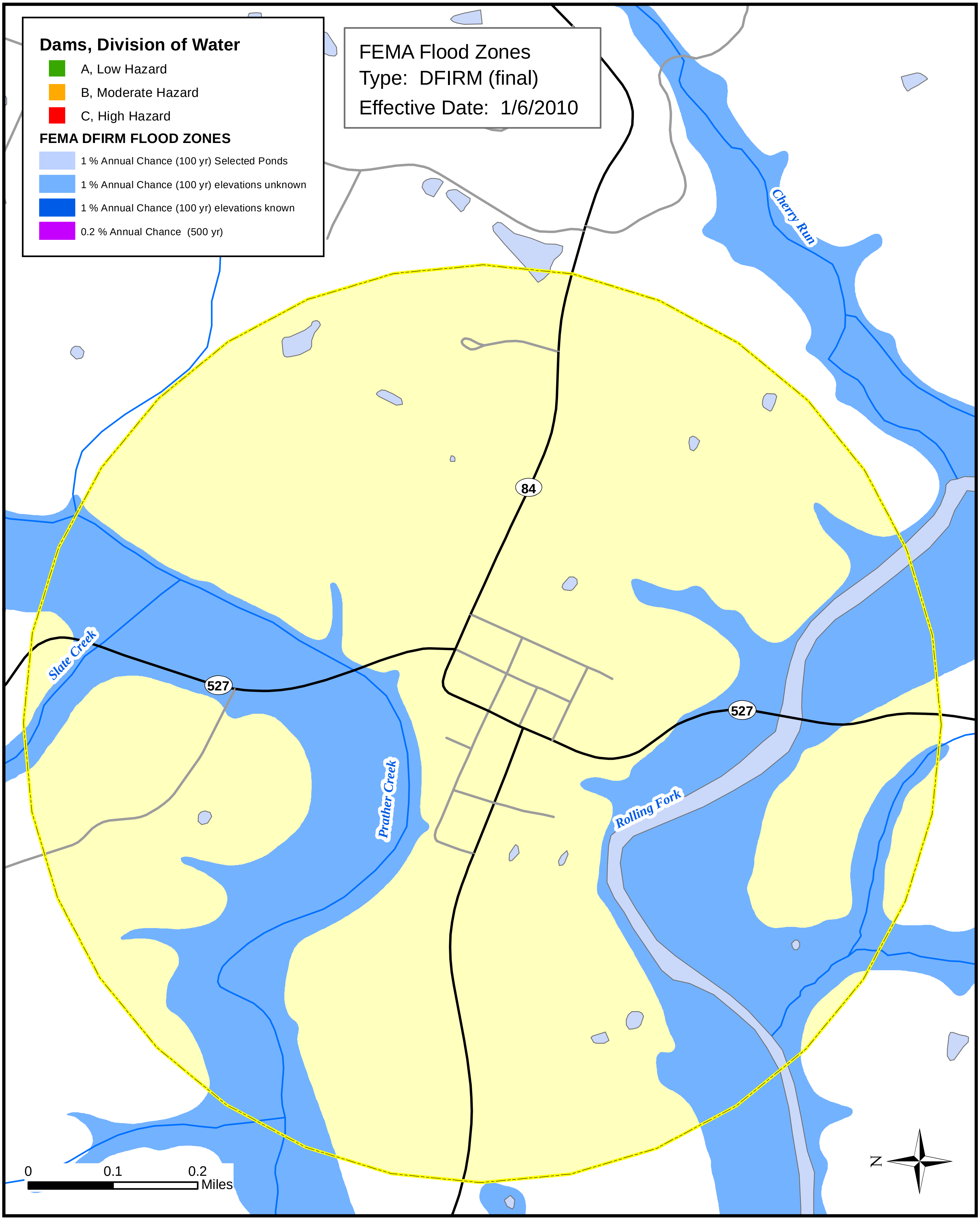


42b


N
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 1/6/2010
337
49
North Rolling Fork
0
0.1
0.2
Miles

42c


429
55
Cartwright Creek
2154
1404
Cissels Creek
49
2154
429
55
84
49
Graham Branch
55
Hood Branch
Hardins Creek
3221
49
68
2154
2744
Indian Lick Creek
208
N
0
0.5
1
Miles
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 1/6/2010
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)

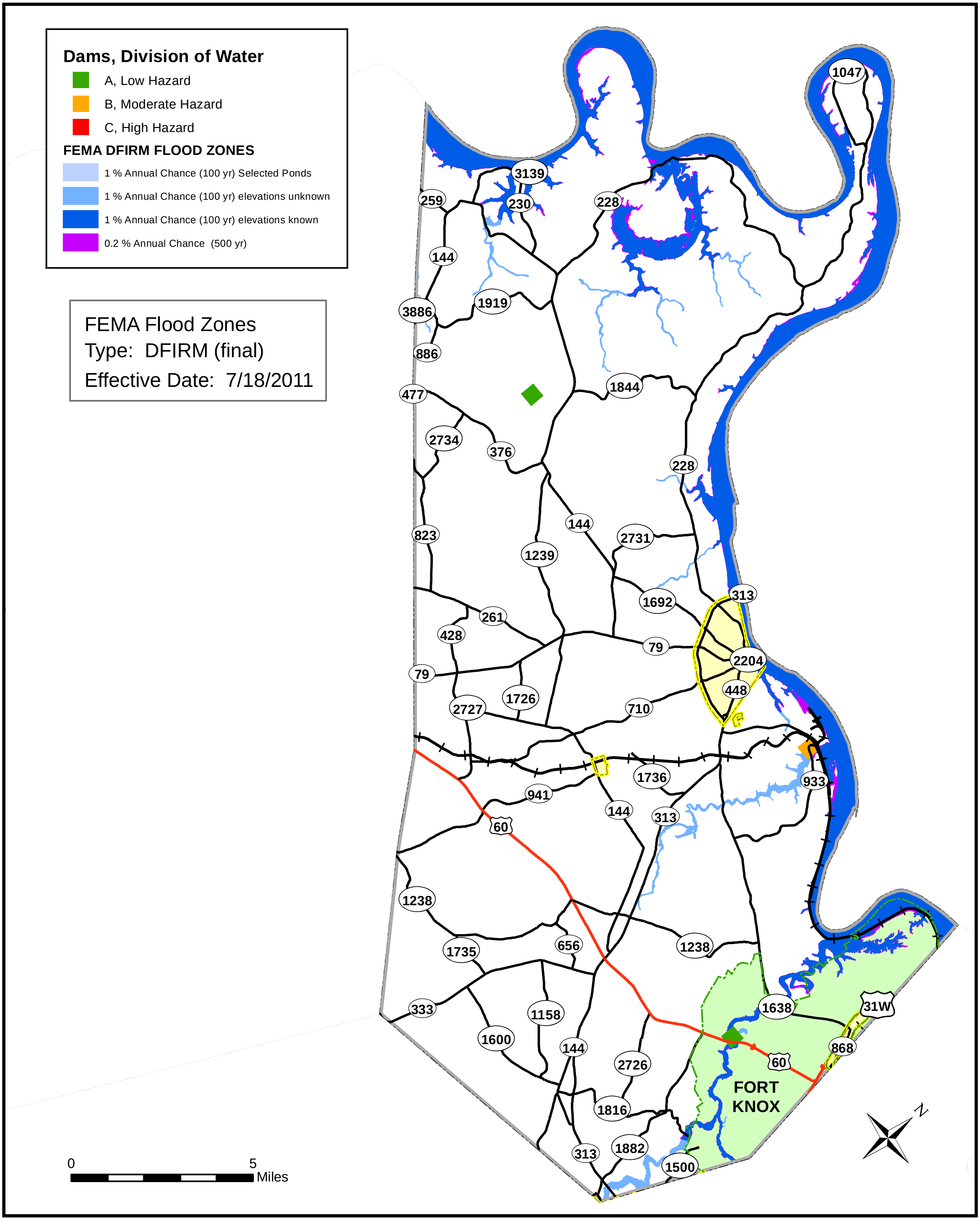

Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 1/6/2010
Cherry Run
84
Slate Creek
527
527
Prather Creek
Rolling Fork
0
0.1
0.2
Miles
N

MEADE

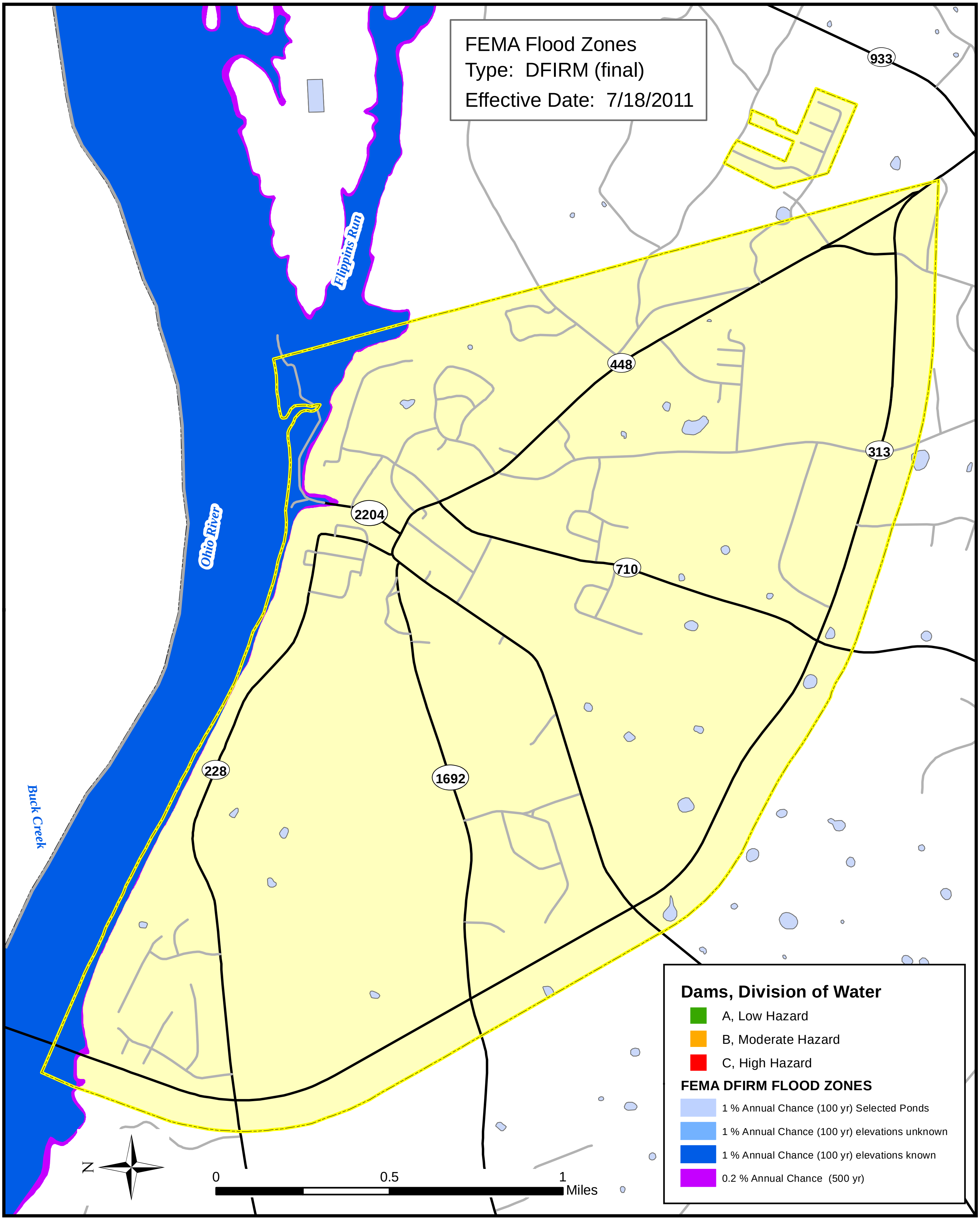
47 Flood/Flash Flood event(s) were recorded between 1967 and 5/15/2021 by SHELDUS and the NCDC.

There have been 5 Flood/Flash Flood events recorded from 7/1/2015 through 5/15/2021 in NCEI.

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE ($)	CROP DAMAGE ($)
MULDRAUGH	2/23/18	0	0	0	0
MEADE CO.	2/23/18	0	0	0	0
MEADE CO.	2/25/18	0	0	0	0
MEADE CO.	2/20/19	0	0	0	0
MEADE CO.	11/30/19	0	0	0	0


Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 7/18/2011
FORT
KNOX
0
5
Miles
N

43b


FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 7/18/2011
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
Flippins Run
Ohio River
Buck Creek
933
448
313
2204
710
228
1692
N
0
0.5
1
Miles

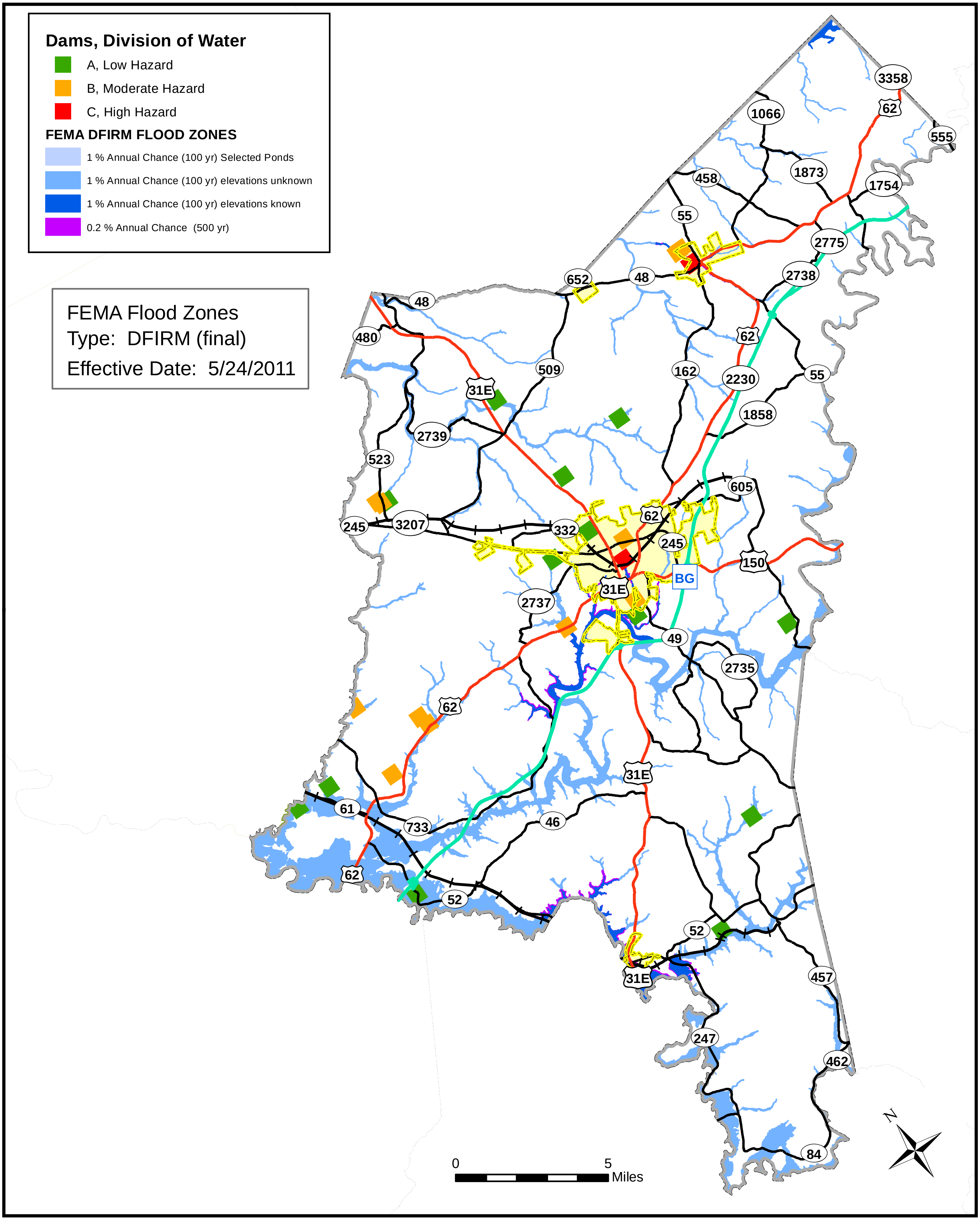
NELSON

104 Flood/Flash Flood event(s) were recorded between 1967 and 5/15/2021 by SHELDUS and the NCDC.

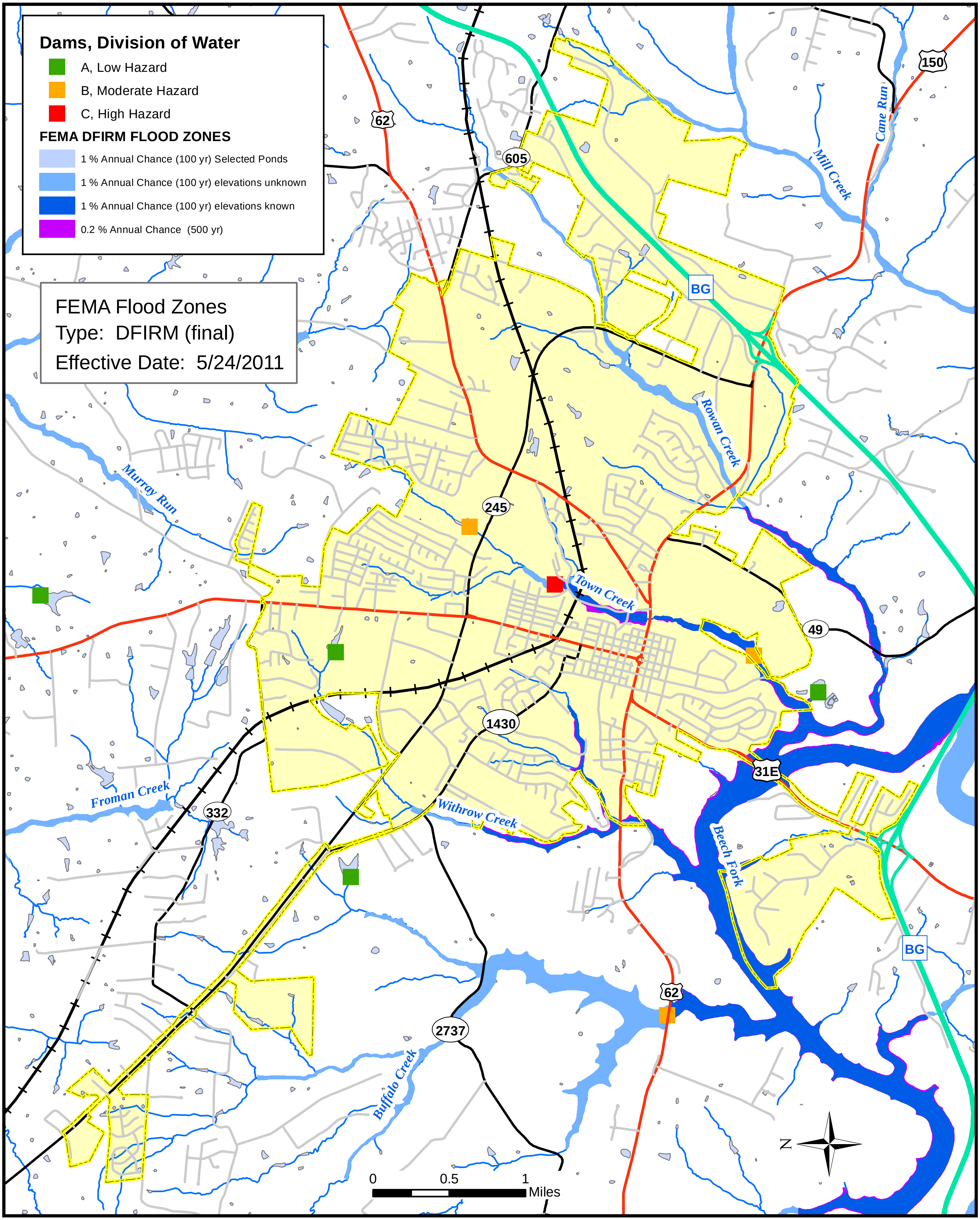
There have been 11 Flood/Flash Flood events recorded from 7/1/2015 through 5/15/2021 in NCEI.

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE ($)	CROP DAMAGE ($)
BLOOMFIELD	7/14/15	0	0	0	0
NELSON CO.	7/14/15	0	0	0	0
NELSON CO.	12/24/15	0	0	0	0
NELSON CO.	2/3/16	0	0	0	0
BLOOMFIELD	6/18/17	0	0	0	0
NELSON CO.	6/23/17	0	0	0	0
NELSON CO.	6/23/17	0	0	0	0
NELSON CO.	2/22/18	0	0	0	0
NELSON CO.	2/25/18	0	0	0	0
BARDSTOWN	6/29/20	0	0	0	0
NELSON CO.	6/29/20	0	0	0	0

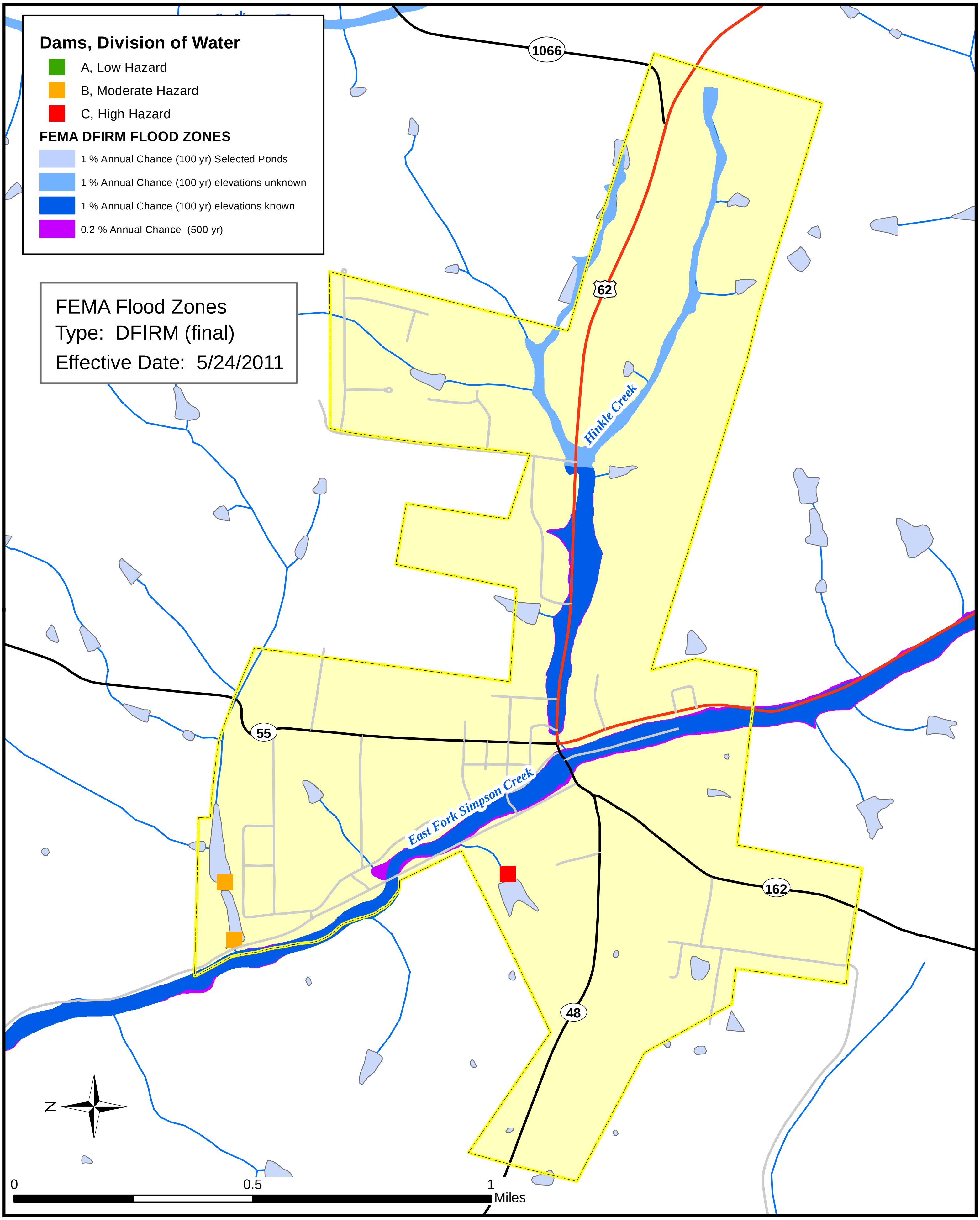
New Haven flood in March 2021. *Source Wave 3 News*


Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 5/24/2011
3358
62
1066
555
458
1873
1754
55
2775
652
48
2738
480
62
509
162
2230
55
31E
1858
2739
523
605
62
245
3207
332
245
150
BG
31E
2737
49
2735
62
31E
61
46
733
62
52
52
31E
457
247
462
84
0
5
Miles
N

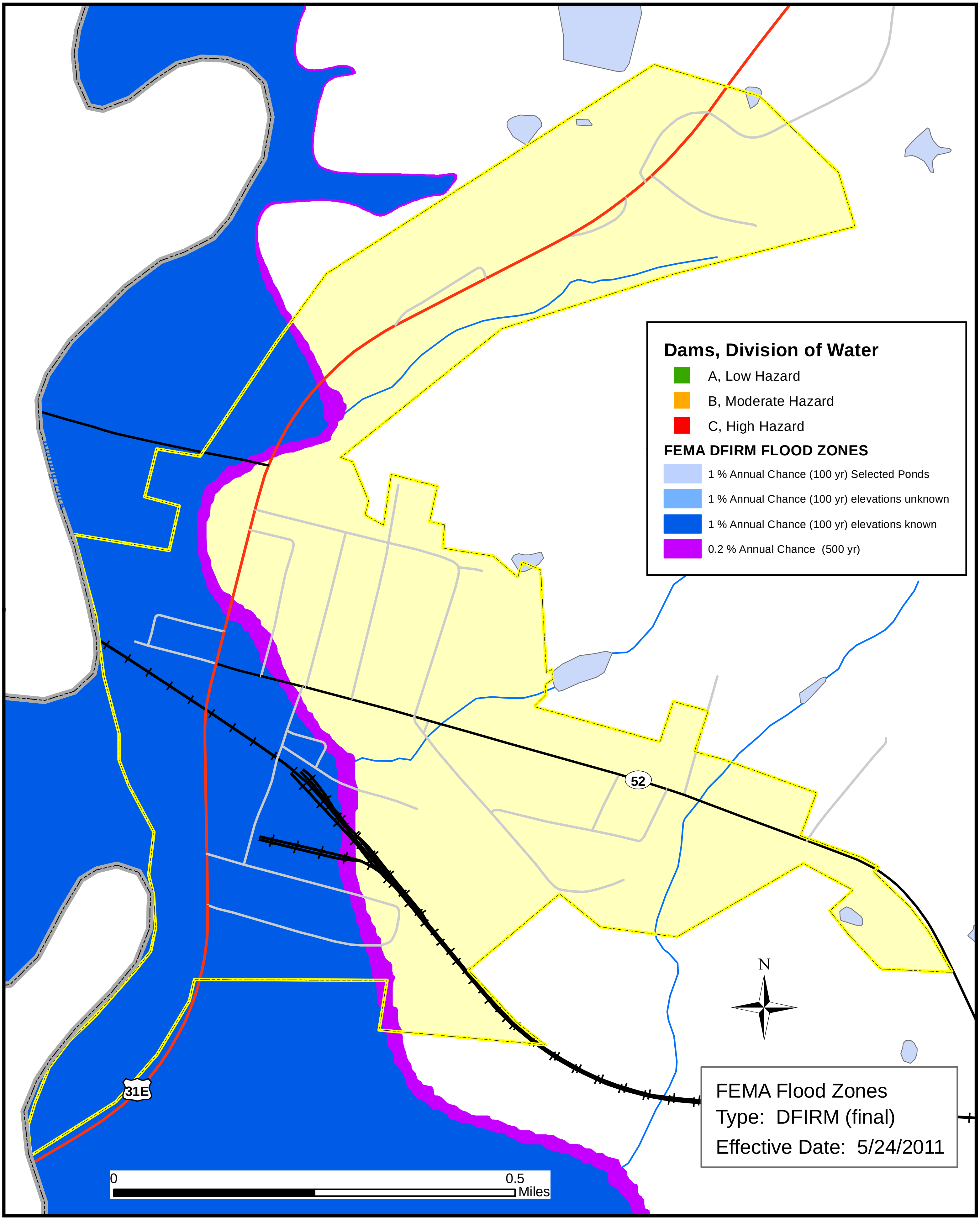
44b


Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 5/24/2011
Murray Run
Froman Creek
Withrow Creek
Town Creek
Rowan Creek
Mill Creek
Cane Run
Beech Fork
Buffalo Creek
62
605
245
1430
332
2737
49
31E
150
BG
0
0.5
1
Miles
N

44c


Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 5/24/2011
1066
62
Hinkle Creek
55
East Fork Simpson Creek
162
48
N
0
0.5
1
Miles

NEW HAVEN FLOODING



WASHINGTON

50 Flood/Flash Flood event(s) were recorded between 1967 and 5/15/2021 by SHELDUS and the NCDC.

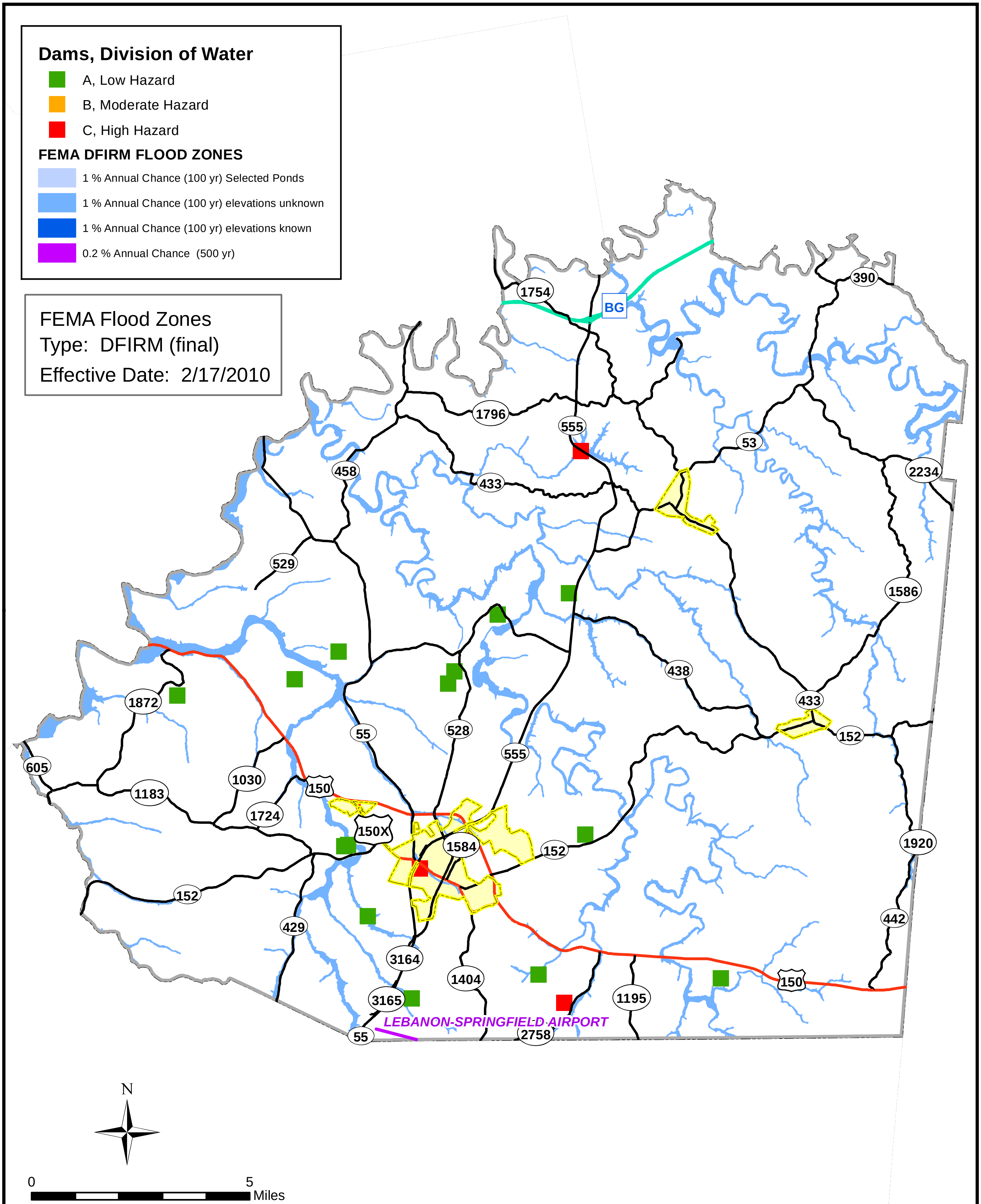
There have been 11 Flood/Flash Flood events recorded from 7/1/2015 through 5/15/2021 in NCEI.

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE ($)	CROP DAMAGE ($)
WASHINGTON CO.	2/22/18	0	0	0	0
WASHINGTON CO.	5/31/18	0	0	0	0
WASHINGTON CO.	6/26/18	0	0	0	0
WASHINGTON CO.	11/30/19	0	0	0	0
SPRINGFIELD	6/29/20	0	0	0	0
WILLISBURG	6/29/20	0	0	0	0
WASHINGTON CO.	6/29/20	0	0	60000	0
WASHINGTON CO.	6/29/20	0	0	0	0
WILLISBURG	6/29/20	0	0	0	0
WILLISBURG	6/29/20	1	1	30000	0
WILLISBURG	6/29/20	0	0	50000	0

Barn under water, Washington Co. April 2008. *LTADD Archives*.

County road under water near Frederickstown, Washington Co. April 2008. *LTADD Archives*.

46a


Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)
FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 2/17/2010
1754
BG
390
1796
555
53
2234
458
433
529
1586
438
433
1872
55
528
152
555
605
1030
150
1183
1724
150X
1584
152
1920
152
429
442
3164
1404
3165
1195
150
LEBANON-SPRINGFIELD AIRPORT
55
2758
N
0
5
Miles

46b

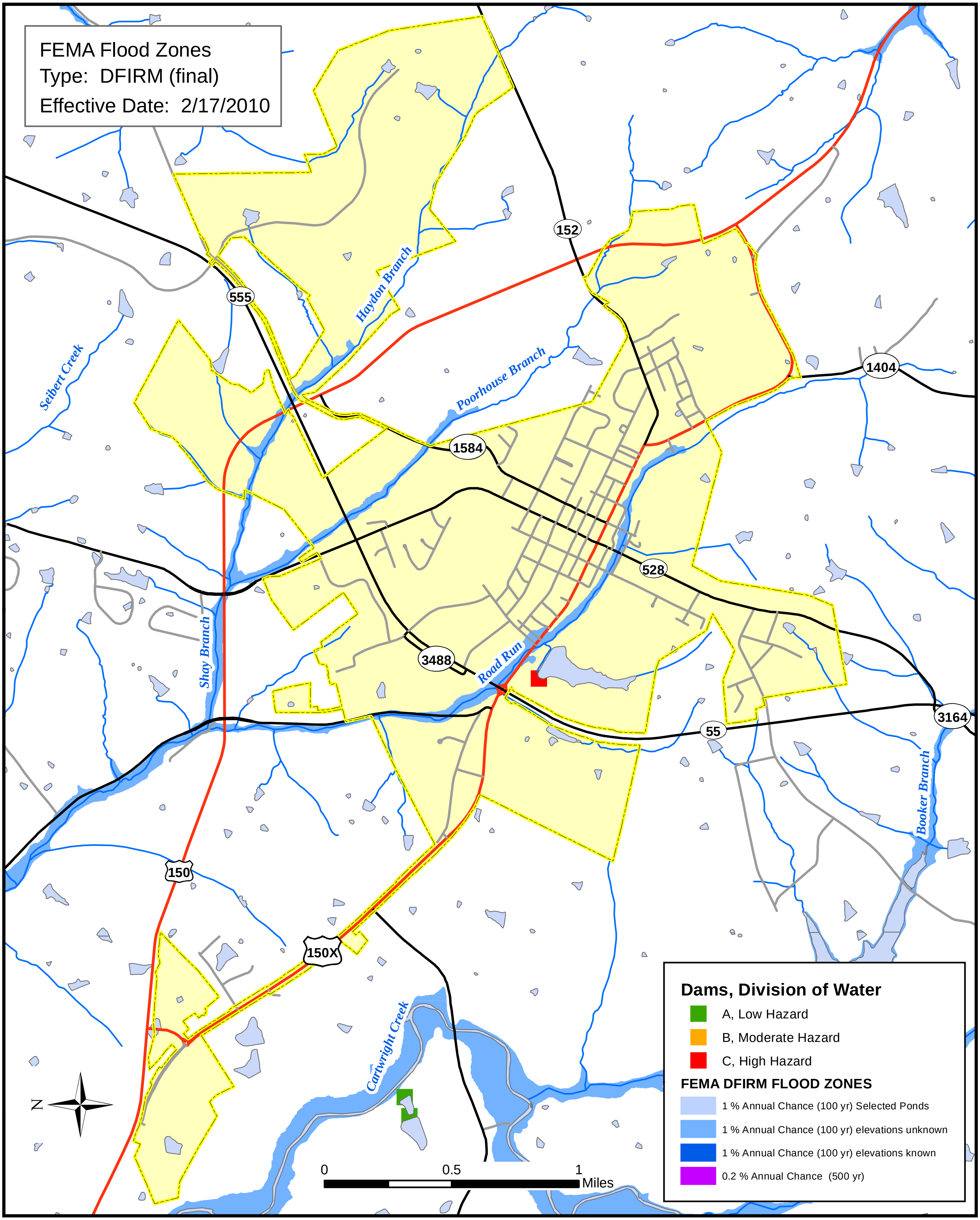

FEMA Flood Zones
Type: DFIRM (final)
Effective Date: 2/17/2010
Haydon Branch
Seibert Creek
Poorhouse Branch
Shay Branch
Road Run
Booker Branch
Cartwright Creek
152
555
1404
1584
528
3488
55
3164
150
150X
N
0
0.5
1
Miles
Dams, Division of Water
A, Low Hazard
B, Moderate Hazard
C, High Hazard
FEMA DFIRM FLOOD ZONES
1 % Annual Chance (100 yr) Selected Ponds
1 % Annual Chance (100 yr) elevations unknown
1 % Annual Chance (100 yr) elevations known
0.2 % Annual Chance (500 yr)

Table 3.3.2.1.6 - Summary of Flooding Data, Costs

FLOODS	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDGE	$7,811,684	60	54.5	2.09	0.11	$143,334	$130,195	0.04	0.03	0.00	0.00
Cloverport	$0	2	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Hardinsburg	$0	3	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Irvington	$10,000	4	54.5	1	0	$183	$2,500	0.02	0.25	0.00	0.00
GRAYSON	$8,490,065	56	54.5	0.04	0.11	$155,781	$151,608	0.00	0.00	0.00	0.00
Caneyville	$250,000	2	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Clarkson	$0	4	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Leitchfield	$0	5	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
HARDIN	$49,261,889	88	54.5	2.17	0.11	$903,888	$559,794	0.04	0.02	0.00	0.00
Elizabethtown	$5,230,000	16	54.5	0	0	$95,963	$326,875	0.00	0.00	0.00	0.00
Radcliff	$0	1	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Sonora	$0	1	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Upton	$0	0	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Vine Grove	$250,000	4	54.5	0	0	$4,587	$62,500	0.00	0.00	0.00	0.00
West Point	$1,250,000	1	54.5	0	0	$22,936	$0	0.00	0.00	0.00	0.00
LARUE	$8,067,971	47	54.5	0.17	0.11	$148,036	$171,659	0.00	0.00	0.00	0.00
Hodgenville	$0	4	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
MARION	$9,800,835	58	54.5	0.31	2.54	$179,832	$168,980	0.01	0.01	0.05	0.04
Bradfordsville	$0	3	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Lebanon	$75,000	9	54.5	0	0	$1,376	$8,333	0.00	0.00	0.00	0.00
Loretto	$0	1	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Raywick	$2,000	1	54.5	0	0	$37	$0	0.00	0.00	0.00	0.00
MEADE	$7,284,005	47	54.5	1.14	0.11	$133,651	$154,979	0.02	0.02	0.00	0.00
Brandenburg	$0	5	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Ekron	$0	0	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Muldraugh	$0	1	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
NELSON	$35,033,005	104	54.5	3.17	2.11	$642,807	$336,856	0.06	0.03	0.04	0.02
Bardstown	$2,000	5	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Bloomfield	$0	2	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Fairfield	$0	0	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
New Haven	$0	2	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
WASHINGTON	$9,124,658	50	54.5	1.17	1.11	$167,425	$182,493	0.02	0.02	0.02	0.02
Mackville	$0	0	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Springfield	$75,000	4	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Willisburg	$80,000	4	54.5	1	1	$0	$0	0.02	0.00	0.02	0.00
LTADD	$134,874,112	510	54.5	10.26	6.31	$2,474,754	$264,459	0.19	0.02	0.12	0.01

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2021.

Table 3.3.2.1.6 - Summary of Flooding Data, Events

FLOODS	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	60	54.5	20	38	58	0.91	110.09%	2	1.9	1.16
Cloverport	2	54.5	2	2	2	27.25	3.67%	0.2	0.1	0.04
Hardinsburg	3	54.5	2	3	3	18.17	5.50%	0.2	0.15	0.06
Irvington	4	54.5	2	3	4	13.63	7.34%	0.2	0.15	0.08
GRAYSON	56	54.5	22	36	55	0.97	102.75%	2.2	1.8	1.1
Caneyville	2	54.5	2	2	2	27.25	3.67%	0.2	0.1	0.04
Clarkson	4	54.5	4	4	4	13.63	7.34%	0.4	0.2	0.08
Leitchfield	5	54.5	2	5	5	10.90	9.17%	0.2	0.25	0.1
HARDIN	88	54.5	42	63	86	0.62	161.47%	4.2	3.15	1.72
Elizabethtown	16	54.5	10	14	15	3.41	29.36%	1	0.7	0.3
Radcliff	1	54.5	0	1	1	54.50	1.83%	0	0.05	0.02
Sonora	1	54.5	1	1	1	54.50	1.83%	0.1	0.05	0.02
Upton	0	54.5	0	0	0	0.00	0.00%	0	0	0
Vine Grove	4	54.5	3	4	4	13.63	7.34%	0.3	0.2	0.08
West Point	1	54.5	1	1	1	54.50	1.83%	0.1	0.05	0.02
LARUE	47	54.5	18	25	45	1.16	86.24%	1.8	1.25	0.9
Hodgenville	4	54.5	4	4	4	13.63	7.34%	0.4	0.2	0.08
MARION	58	54.5	23	33	56	0.94	106.42%	2.3	1.65	1.12
Bradfordsville	3	54.5	3	3	3	18.17	5.50%	0.3	0.15	0.06
Lebanon	9	54.5	7	9	9	6.06	16.51%	0.7	0.45	0.18
Loretto	1	54.5	0	1	1	54.50	1.83%	0	0.05	0.02
Raywick	1	54.5	1	1	1	54.50	1.83%	0.1	0.05	0.02
MEADE	47	54.5	13	24	45	1.16	86.24%	1.3	1.2	0.9
Brandenburg	5	54.5	2	4	5	10.90	9.17%	0.2	0.2	0.1
Ekron	0	54.5	0	0	0	0.00	0.00%	0	0	0
Muldraugh	1	54.5	1	1	1	54.50	1.83%	0.1	0.05	0.02
NELSON	104	54.5	45	78	102	0.52	190.83%	4.5	3.9	2.04
Bardstown	5	54.5	2	4	5	10.90	9.17%	0.2	0.2	0.1
Bloomfield	2	54.5	2	2	2	27.25	3.67%	0.2	0.1	0.04
Fairfield	0	54.5	0	0	0	0.00	0.00%	0	0	0
New Haven	2	54.5	1	2	2	27.25	3.67%	0.1	0.1	0.04
WASHINGTON	50	54.5	15	23	48	1.09	91.74%	1.5	1.15	0.96
Mackville	0	54.5	0	0	0	0.00	0.00%	0	0	0
Springfield	4	54.5	3	4	4	13.63	7.34%	0.3	0.2	0.08
Willisburg	4	54.5	4	4	4	13.63	7.34%	0.4	0.2	0.08
LTADD	510	54.5	198	320	495	0.11	935.78%	19.8	16	9.9

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2021.

Extent

The extent of flooding in the Lincoln Trail eight-county region is difficult to document. However, on April 30, 2011, the pool at Rough River Lake in Grayson County was recorded at a depth of 524.7 feet, a new record. Grayson County received FEMA assistance in funding two bridge elevation projects under DR-1818-0027 and DR-1818-0153 on Lake Shore Road and on Bloomington Church Road. Widespread flooding in these areas would reach a depth of up to 24 inches and closed these roads for days. Another bridge elevation project was funded in the City of Leitchfield in Grayson County, under DR-1818-0063. Floodwaters reaching depths of twelve to twenty-four inches closed a road there.

In April of 2011, Ohio River flooding affected the City of West Point in Hardin County. On 4/26/2011, the river crested at 61.8 feet, about 6.8 feet above flood stage.

The Rolling Fork River meanders through Hardin County and becomes the boundary between Hardin and Nelson County. The flood stage of the Rolling Fork is thirty-five feet, moderate flooding occurs at forty-two feet with major flooding occurring at forty-five feet. The Rolling Fork often floods rural areas of Hardin County as well as the Boston and New Haven regions of Nelson County. The Chart below documents crest stage levels of the Rolling Fork.

Table 3.3.2.1.7 - Recent Crests of the Rolling Fork River (Flood Stage = 35')	
Date	Depth in Feet
3/3/21	46.24 Feet
7/1/20	38.15 Feet
2/14/20	36.63 Feet
12/19/19	39.19 Feet
12/3/19	36.30 Feet
2/26/19	40.61 Feet
2/22/19	37.32 Feet
2/14/19	40.70 Feet
11/8/18	35.83 Feet
3/26/18	36.63 Feet
Source: NOAA - Advanced Hydrologic Prediction Service	

3.3.2.2 Tornados

I. Background

According to the National Severe Storms Laboratory (NSSL) of the National Oceanic and Atmospheric Administration (NOAA) a tornado is "a narrow, violently rotating column of air that extends from the base of a thunderstorm to the ground. Because wind is invisible, it is hard to see a tornado unless it forms a condensation funnel made up of water droplets, dust, and debris. Tornados are the most violent of all atmospheric storms."

Attributes: About 1,000 tornados hit the United States annually. Historical data pertaining to tornados only date back to 1950 and methodology for spotting and reporting tornados has greatly evolved over the last few decades.

Tornado season in the U.S. usually refers to the time of year when tornados are most likely to occur. For the southern plains, it occurs during May and into early June. On the Gulf Coast, it is earlier in the spring. In the northern plains and upper Midwest, tornado season is in June or July. However, a tornado can occur at any time during the year and can happen at any time of day or night. Most tornados occur between 4 and 9 p.m.

The most destructive and deadly tornados are spawned from supercells with a well-defined radar circulation called a mesocyclone. Supercells can also produce damaging hail, severe non-tornadic winds, frequent lightning, and flash floods.

Analysis of damage caused by the storm, is a common and practical method for determining the strength of a tornado. From the extent of damage, an estimated wind speed can be determined. The "Enhanced Fujita Scale" was implemented by the National Weather Service in 2007 to rate tornados in a consistent and accurate manner. The EF-Scale accounts for more variables than the original Fujita Scale (F-Scale) when determining wind speed rating to a tornado by incorporating 28 damage indicators such as building type, structures, and trees. For each damage indicator, there are 8 degrees of damage ranging from the beginning of visible damage to complete destruction of the damage indicator. The original F-scale did not take degrees of damage into account. The historic F-Scale database will not change. A tornado rated F5 years ago is still an F5, but wind speed may have been slightly less than previously estimated.

A comparison between the Fujita Scale and the Enhanced Fujita Scale is shown below. The Enhanced Fujita Scale is a set of wind estimates (not measurements) based on damage evaluations. According to the National Oceanic and Atmospheric Administration the Enhance Fujita Scale "uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to 28 indicators." These 28 indicators are based on the structure type, ranging from manufactured housing to institutional buildings, and from trees to light poles. It is important to note that a 3 second gust is not the same speed of wind observed in standard surface wind. Measurements are taken by weather stations located in open exposures and using a directly measured, "one minute mile" speed.

Table 3.3.2.2.1 - Fujita/Enhanced Fujita Scale						
FUJITA SCALE			**DERIVED EF SCALE**		**OPERATIONAL EF SCALE**	
F Number	**Fastest ¼ mile (mph)**	**3 Second Gust (mph)**	**EF Number**	**3 Second Gust (mph)**	**EF Number**	**3 Second Gust (mph)**
0	40-72	45-78	0	65-85	0	65-85
1	73-112	79-117	1	86-109	1	86-110
2	113-157	118-161	2	110-137	2	111-135
3	158-207	162-209	3	138-167	3	136-165
4	208-260	210-261	4	168-199	4	166-200
5	261-318	262-317	5	200-234	5	Over 200
Source: NOAA						

Tornado - February 29, 2012, Near LaRue County High School in Hodgenville
Photo Tara Wooden

Tornado Facts and Effects

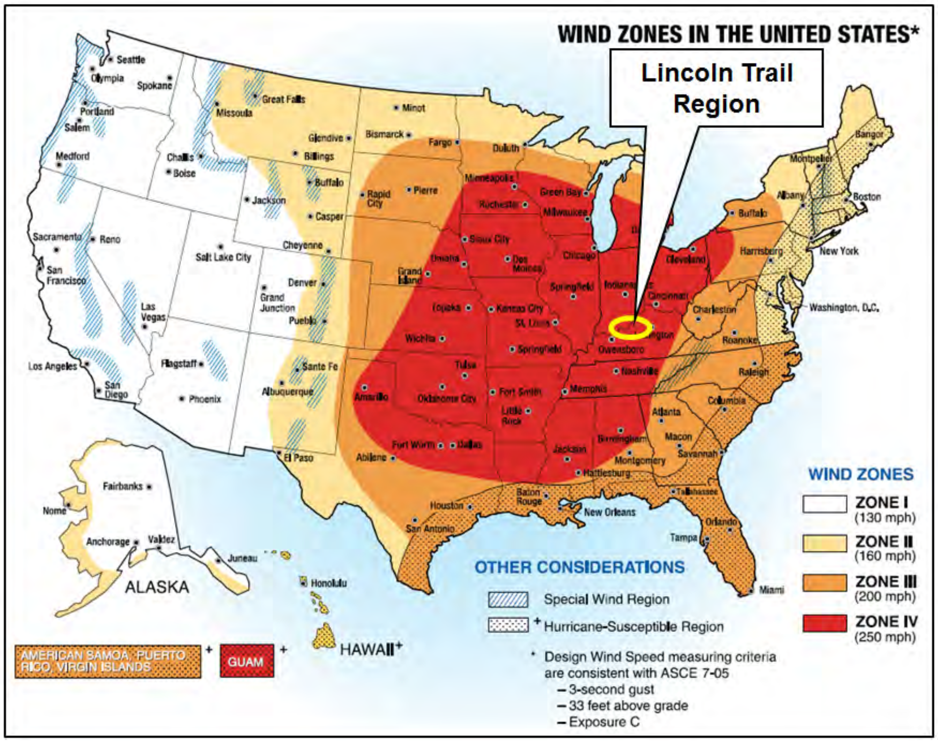
- Tornadoes can last from several seconds to more than an hour.
- A tornado is considered "significant" if it is rated EF2 or greater on the Enhanced Scale or at least F2 on the old F-Scale.
- Hurricanes and tropical storms can spawn tornados.

- Tornados are forecast when the development of temperature and wind flow patterns in the atmosphere can cause enough moisture, instability, life, and wind shear for the formation of tornadic thunderstorms. These are the four main factors for the formation of tornados.
- Tornado damage occurs as the result of exposure to extreme winds or the impact of flying debris. Another hazard exists when hazardous materials are released by tornados such as natural gas, medical waste, gasoline, and other dangerous chemicals or sewage. Winds can topple trees and power lines resulting in long-term power outages.
- Wind associated with tornados can loft debris several miles into the air and carry it for long distances. Small items and paper can be carried over 100 miles away.
- Tornados vary in size with the widest ground width measured at about 4.3 miles. Wind speed also varies. The greatest ground-level speeds have never been measured, but on May 3, 1999, 302 mph winds were recorded near Bridge Creek, OK.
- April is the month with the greatest number of tornado outbreaks. In April 2011, the NOAA Storm Prediction Center data shows 817 tornados occurred.
- The tornados with the greatest death toll occurred on March 18, 1925, when 695 people were killed when tornados raced across Missouri, Illinois and Indiana producing F5 damage. On April 3, 1974, the main day of a two-day "Super Outbreak," tornados killed 310 people. During that outbreak, seven F5 tornados occurred in one day. The Dixie outbreak of April 27, 2011, killed about 316 people.
- Approximately 1,000 tornados occur in the United States each year. On average, 60 people are killed annually because of tornados, most from flying or falling debris. Since records have been kept, the greatest number of deaths from tornados occurred in 2011 when 550 people died in 15 states.
- Funnel clouds have rotation, but do not touch the ground. Only a true tornado has ground contact.
- The size or shape of a tornado does not have anything to do with its strength.

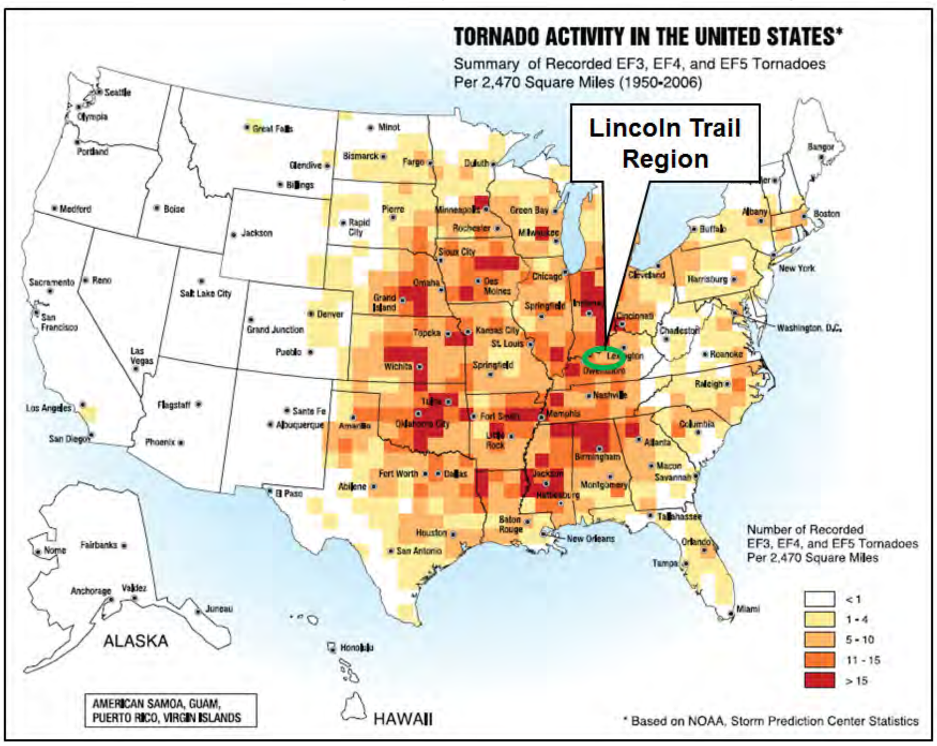
II. Profile

Kentucky is located in Wind Zone IV, the most severe wind zone in the United States. The states most vulnerable to tornado activity are located within this wind zone.

The risk associated with tornados in Kentucky is illustrated in Chart 3.3.2.2.1. Of the 1214 tornados reported throughout the State between 1950 and 2021, each of the counties within the Lincoln Trail Region experienced at least 11.



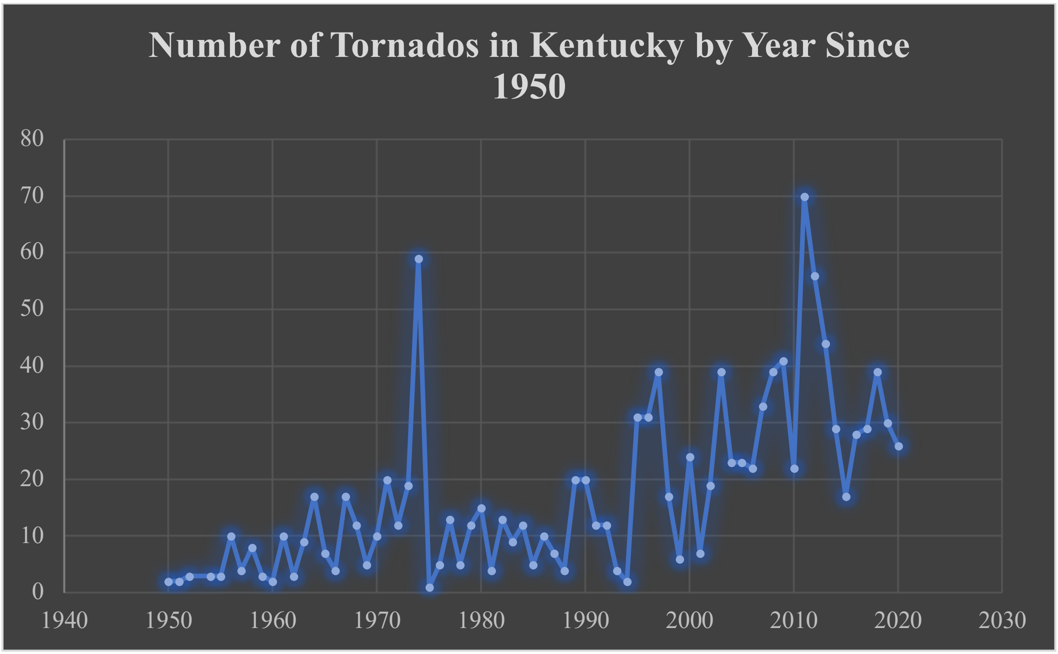
Source: FEMA, *Taking Shelter from the Storm*, 3rd Edition, Fig 1-4.



Source: FEMA, *Taking Shelter from the Storm*, 3rd Edition, Fig 1-2.

Kentucky averaged over 30 tornados annually from 2016-2020. Of the 149 people killed in Kentucky due to tornados, 38 were killed in the Lincoln Trail Region. Tornado data has only been collected since 1950 and the history of tornado events in the Lincoln Trail Region dates from 1950 through 2021. Clearly, the Lincoln Trail Region is at risk for tornado activity.

Chart 3.3.2.2.1



Source: https://data.courier-journal.com/tornado-archive/

Table 3.3.2.2.2 – Tornado Activity

Tornado Activity in Kentucky and the 8-County Lincoln Trail Region Between 1950 and 2021							
Jurisdiction	Dates Yr.,Month,Day	Tornados	Fatalities	Injuries	Highest Injuries	Longest Path	Widest Path
Kentucky	1950/11/20 – 2021/5/14	1214	149 People	3,066 People	350 People	84.99 Miles	3,000 Yards
Breckinridge Co.	1960/06/28 – 2016/0/10	17	1 People	20 People	13 People	32.3 Miles	440 Yards
Grayson Co.	1959/01/21 – 2018/04/3	16	3 People	26 People	16 People	58 Miles	880 Yards
Hardin Co.	1960/06/28 – 2018/31/10	26	2 People	73 People	57 People	37.9 Miles	440 Yards
LaRue Co.	1952/03/22 – 2017/06/23	12	0 People	19 People	18 People	6.65 Miles	1200 Yards
Marion Co.	1960/06/26 – 2018/11/05	13	0 People	4 People	2 People	6.65 Miles	1200 Yards
Meade Co.	1960/06/28 – 2017/11/18	14	31 People	268 People	257 People	32.3 Miles	440 Yards
Nelson Co.	1960/06/28 – 2020/04/06	14	1 People	28 People	24 People	37.9 Miles	1500 Yards
Washington Co.	1960/06/28 – 2020/04/06	11	0 People	5 People	4 People	46.6 Miles	800 Yards
Source: Storm Prediction Center, Historical Tornado Data File (NOAA)							

III. Analysis

To analyze tornados as a hazard threat to the Lincoln Trail Region historical data was researched. The sources of this information include the National Weather Service, National Climatic Data Center, Kentucky Climatic Data Center, ESRI, FEMA, Kentucky Emergency Management Area III, and LTADD GIS.

The following map and tables illustrate a number of the documented tornadic events that have occurred in the Lincoln Trail Region. Note that the general paths are consistent with tornados in this region of the United States. They do affect a widespread region and are not affected in general by geography.

The level of impact is evidenced through the number of lives lost or individual injuries reported, as well as the estimated property and crop damage based on information reported to the National Climate Data Center. This information was subsequently rolled into the data from the National Centers for Environmental Information (NCEI). Data for the original plan was only available through 2003. The 2010 update provided data thru 30 June 2009. The 2015 update provided data from 1 July 2009 through 30 June 2015. This update shows only individual events for the period 1 July 2015 through 14 May 2021. The summary tables show data for the entire periods covered by the various sources. Note that there are many variations in recording the locations of the events over time. In the past, this was typically done at a county level. More recently, nearest place names have been used. Because of this, the records in the summation tables regarding the individual incorporated areas should not be considered all encompassing.

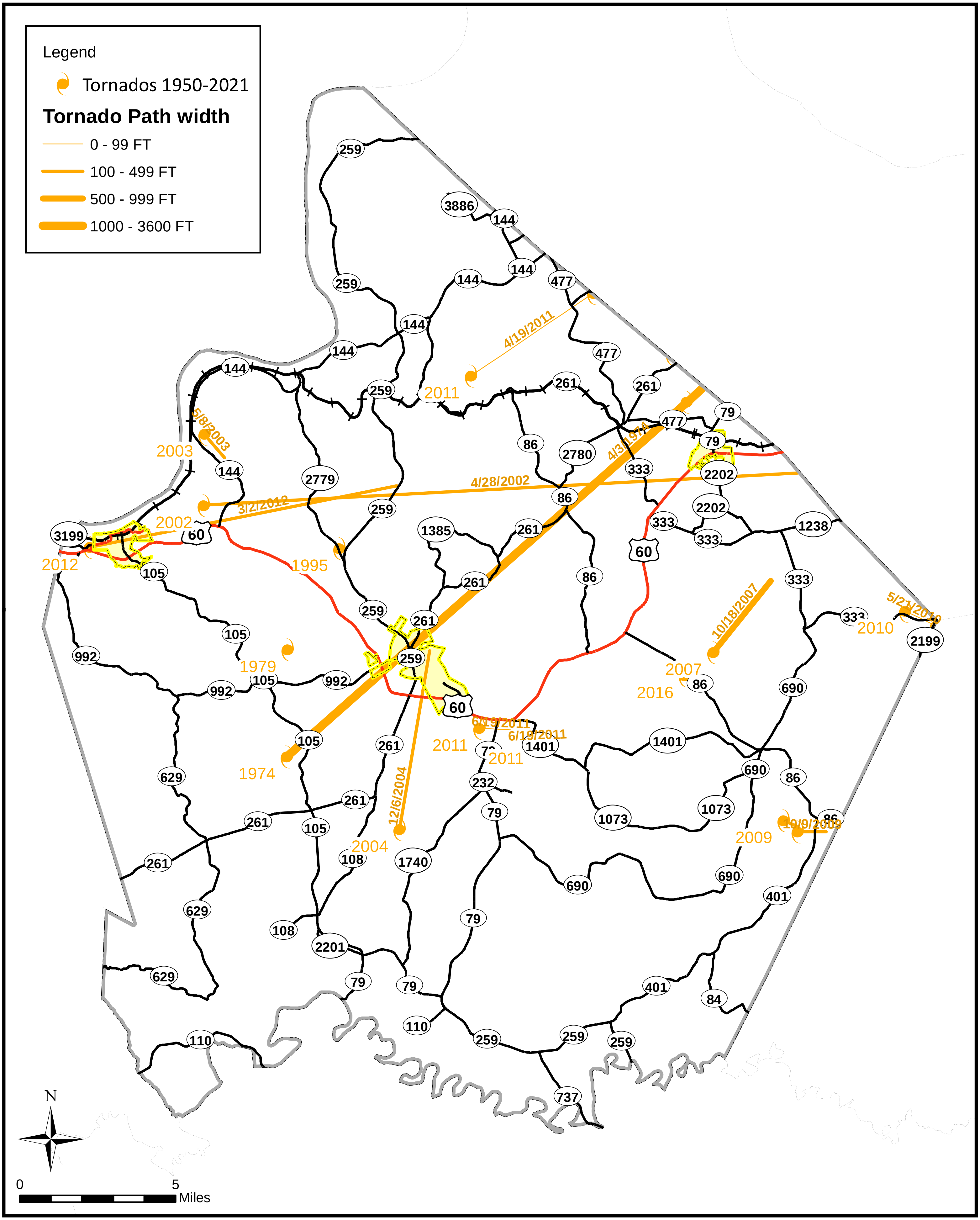
Throughout the following tables, April 3, 1974, will stand out and is probably the most significant day to remember in our region, if not the state, as it pertains to natural hazards and the devastating effects, they can have on us all. In what is labeled the worst tornado outbreak in U.S. history, 148 twisters touched down in 13 states, killing 330 people and injuring 5,484. Between the hours of 3:40pm and midnight 26 of those tornados touched down in Kentucky and affected 39 of our 120 counties, killing 77 people and injuring 1,377. Closer to home, within the Lincoln Trail Region a total of 36 of our residents were killed and 353 were injured. The tornado causing the most destruction hit Meade County and had an intensity rating of F5 on the Fujita scale and a path 550 yards wide.

Table 3.3.2.2.3 - County Specific Data – Tornados, *Source: NCEI*

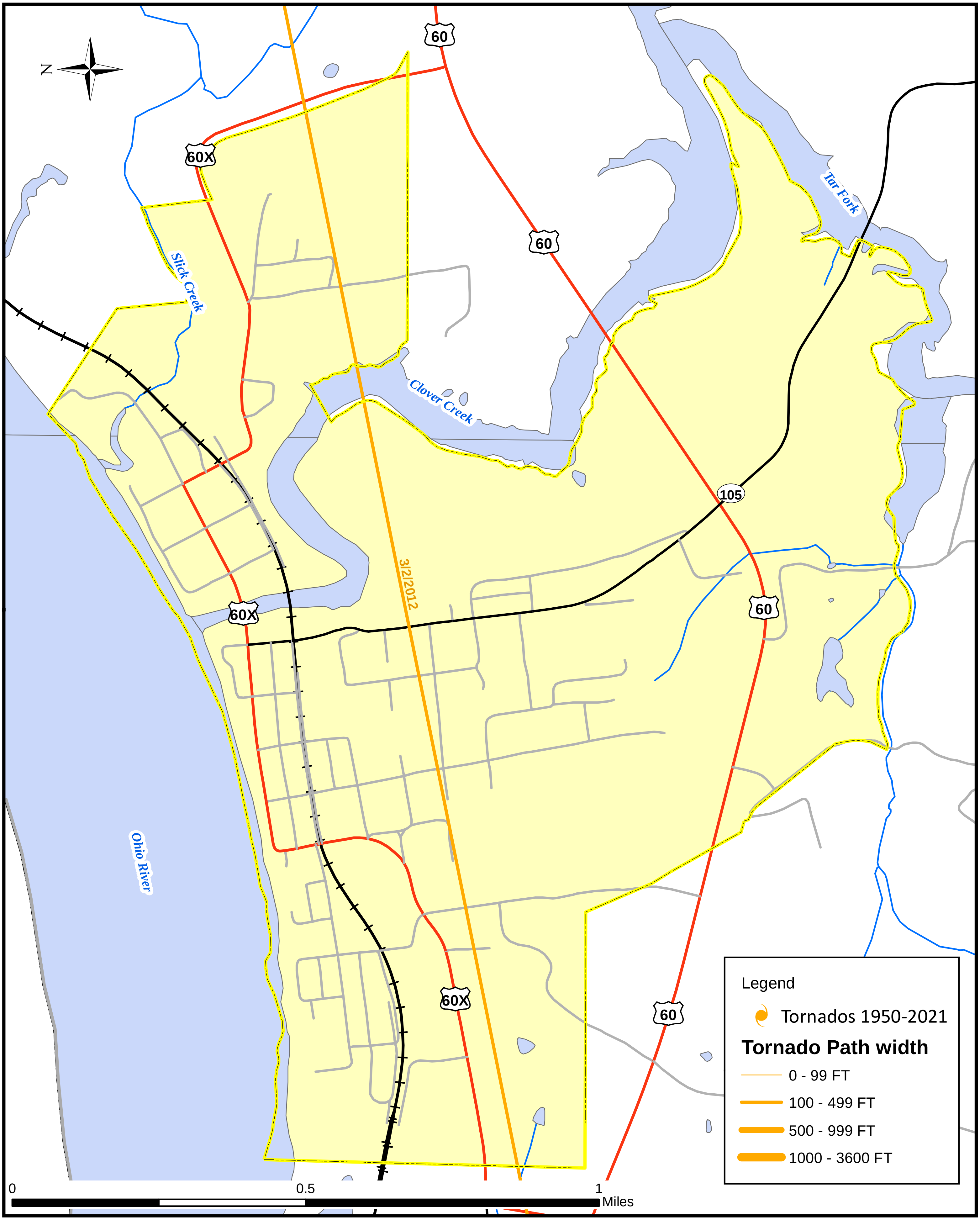
BRECKINRIDGE

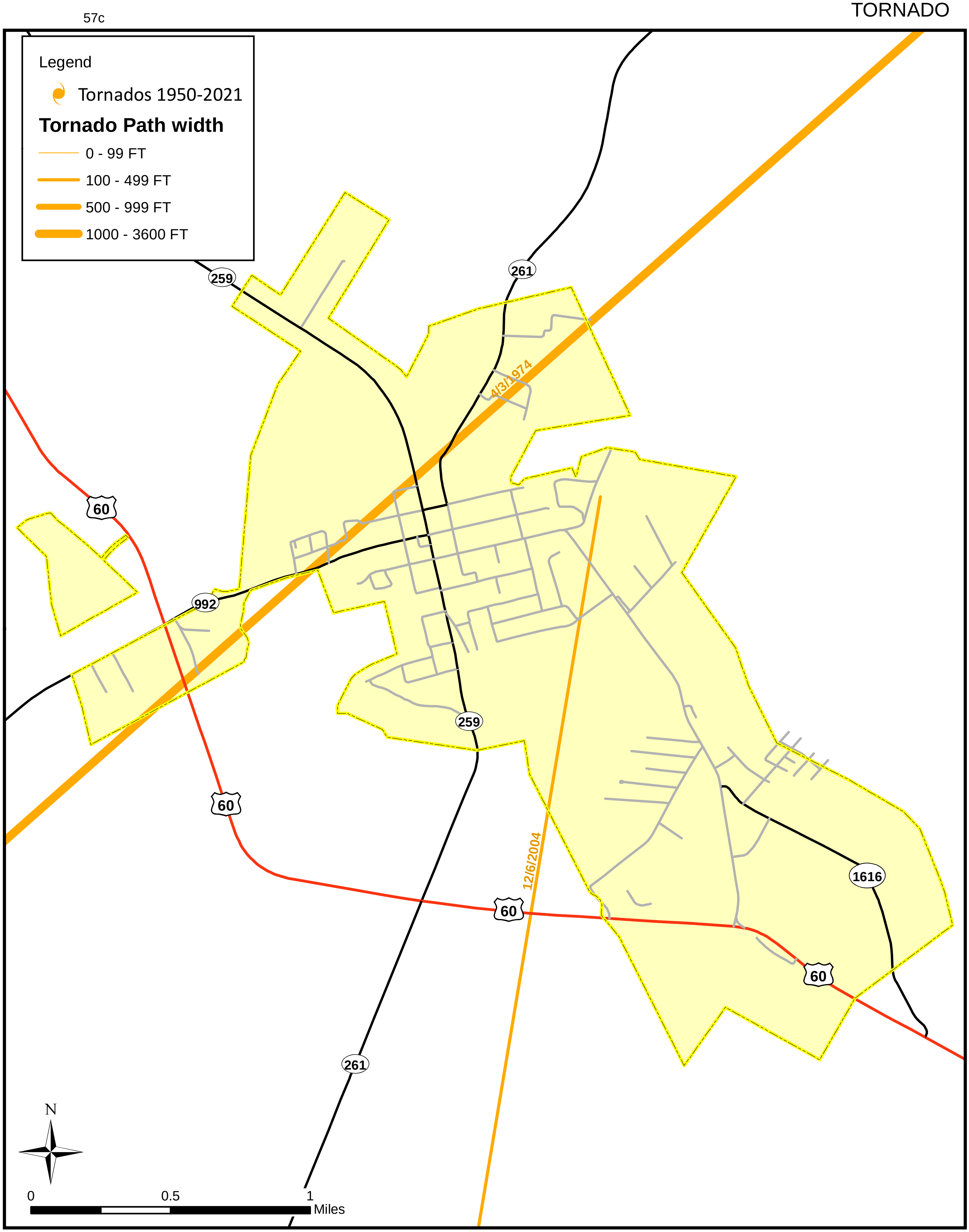
LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
GRAYSVILLE	5/10/16	0	0	100000	0	EF1

57a


Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
N
0
5
Miles
4/19/2011
2011
5/8/2003
2003
4/3/1974
4/28/2002
3/2/2012
2002
2012
1995
1979
1974
12/6/2004
2004
6/19/2011
2011
10/18/2007
2007
2016
5/21/2010
2010
10/9/2009
2009

CLOVERPORT
TORNADO



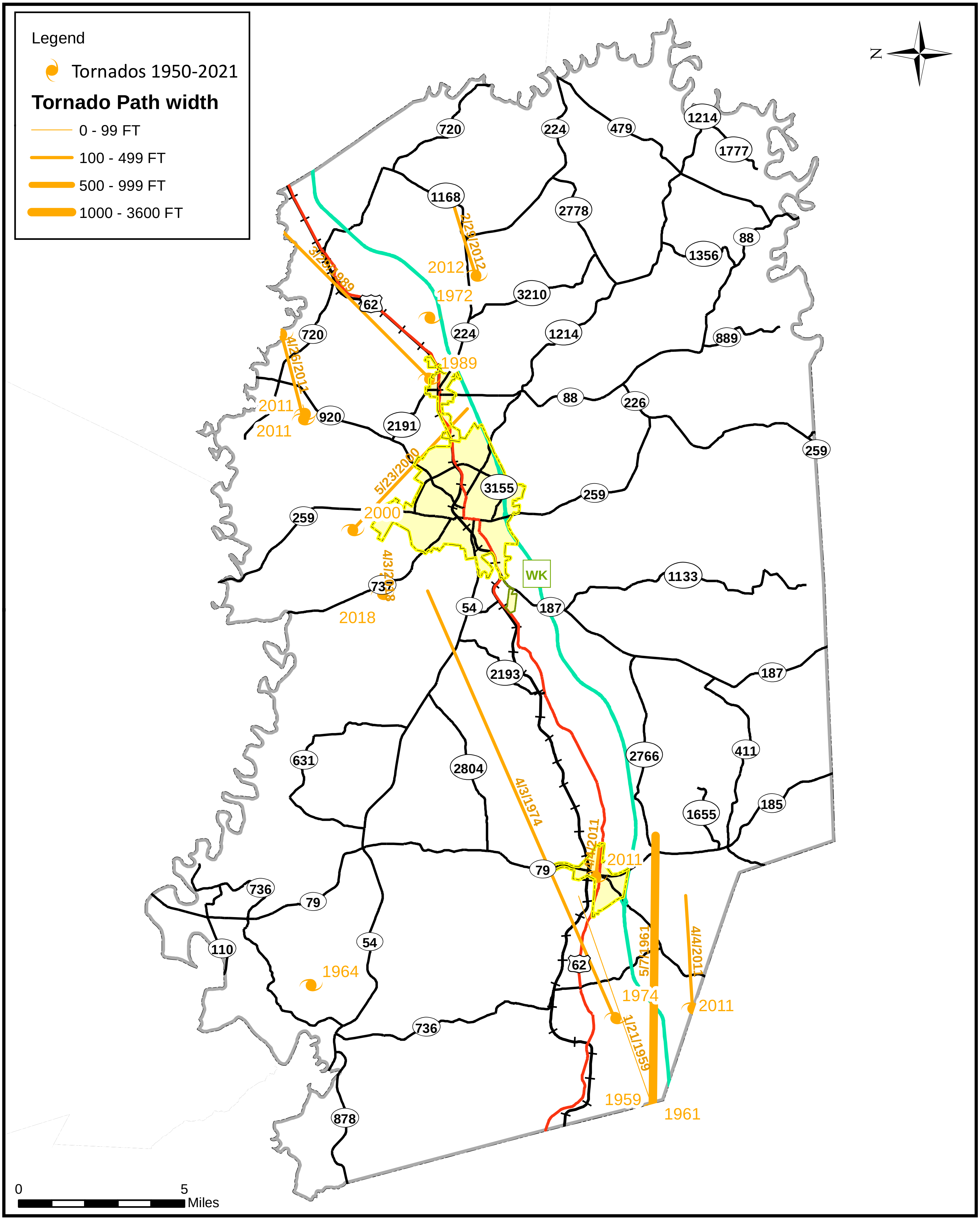

57c
Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
259
261
4/3/1974
60
992
12/6/2004
1616
N
0
0.5
1
Miles

GRAYSON

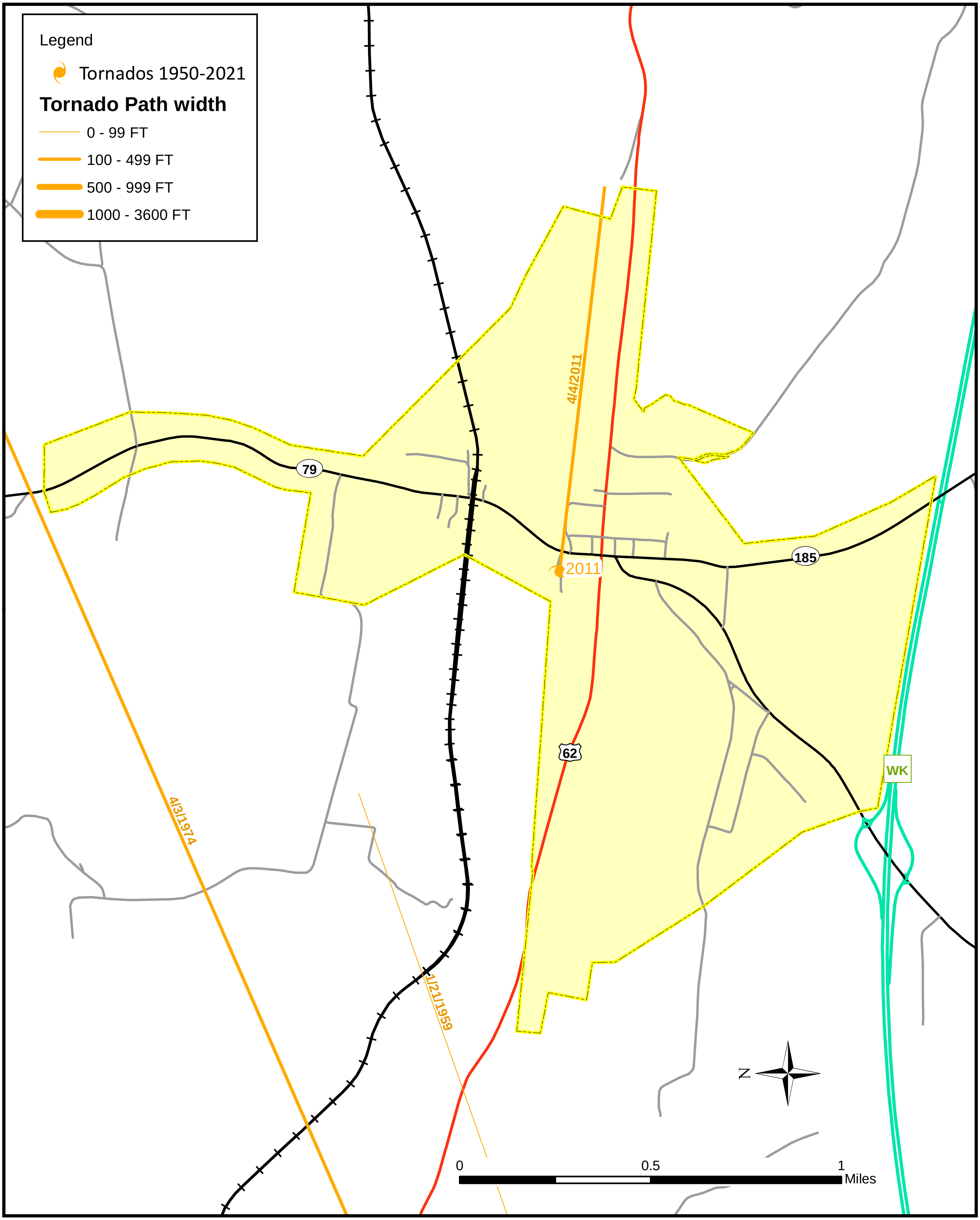
LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
LILAC	4/3/18	0	0	300000	0	EF1

Cleanup in Grayson County after a residential garage was destroyed by a tornado in March 2021. *Source: National Weather Service Louisville*

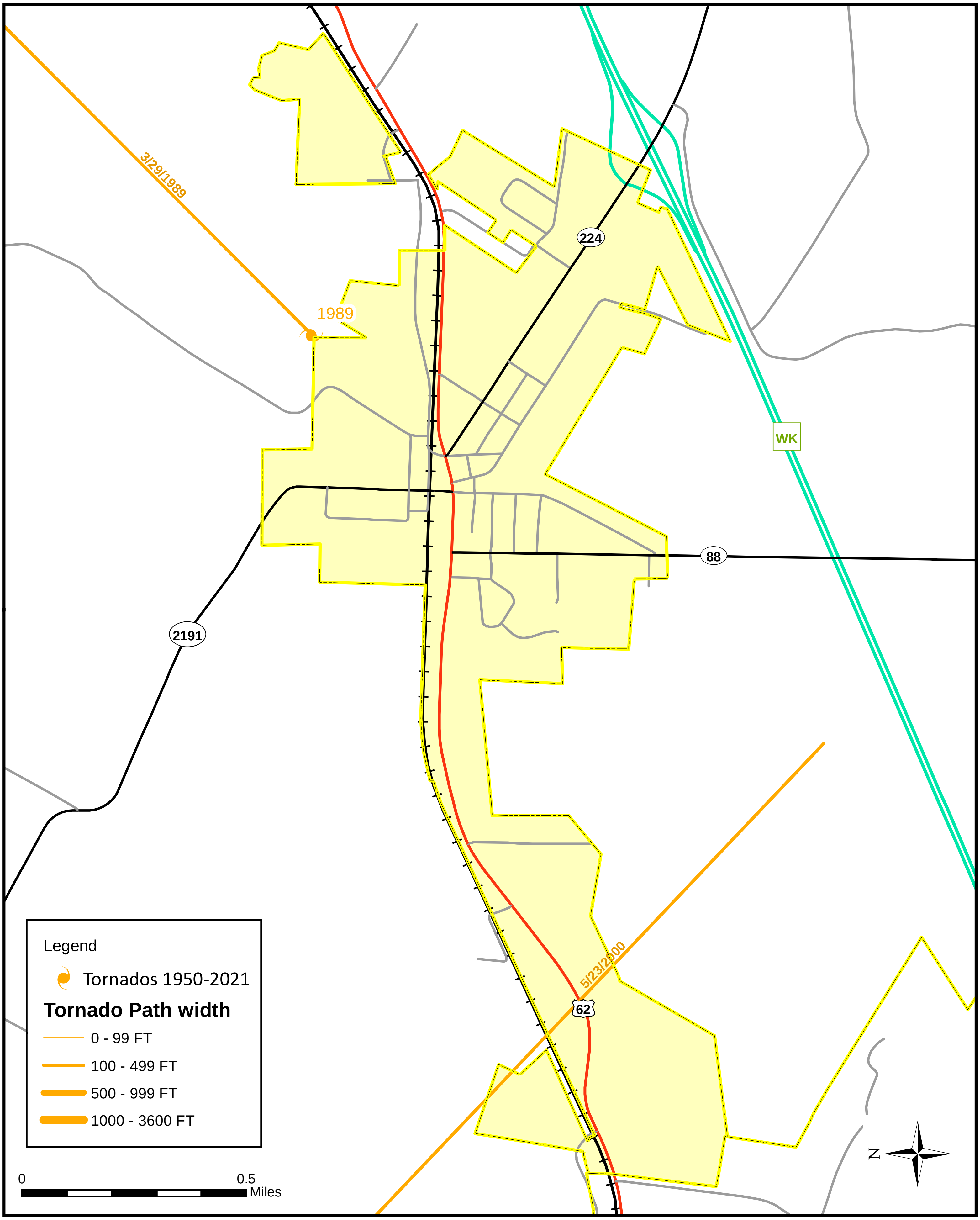
58a

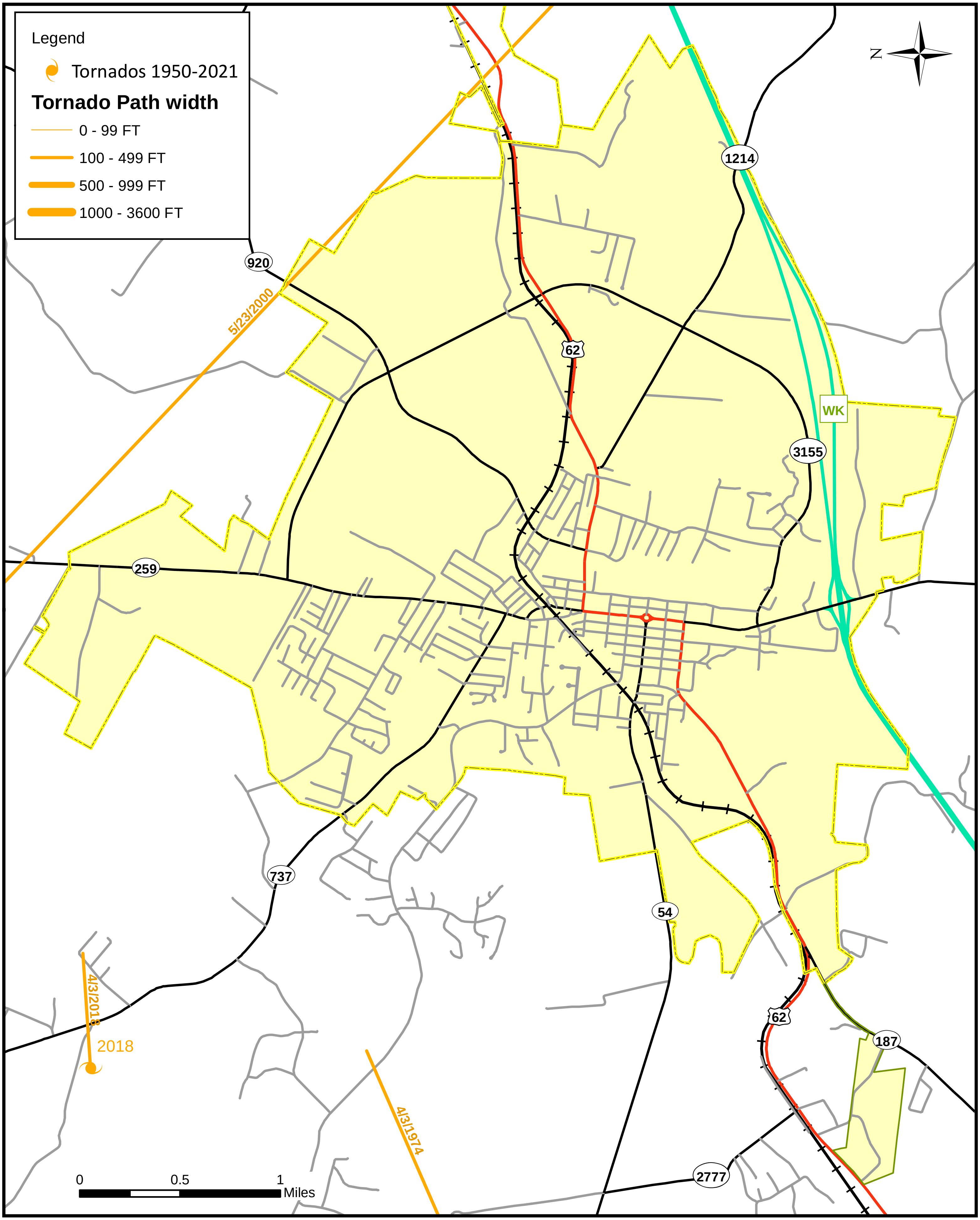

Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
N
0
5
Miles
WK
720
224
479
1214
1777
1168
2778
88
1356
2/29/2012
2012
3/29/1989
1972
3210
62
720
224
1214
889
1989
4/26/2011
2011
2011
920
2191
88
226
259
5/23/2000
3155
259
259
2000
4/3/2018
737
2018
1133
54
187
2193
187
631
2804
4/3/1974
2766
411
1655
185
4/4/2011
2011
79
736
79
110
54
5/7/1961
4/4/2011
1964
62
1974
2011
1/21/1959
736
1959
1961
878

58b


Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
79
185
62
WK
2011
4/4/2011
4/3/1974
1/21/1959
N
0
0.5
1
Miles

CLARKSON
TORNADO



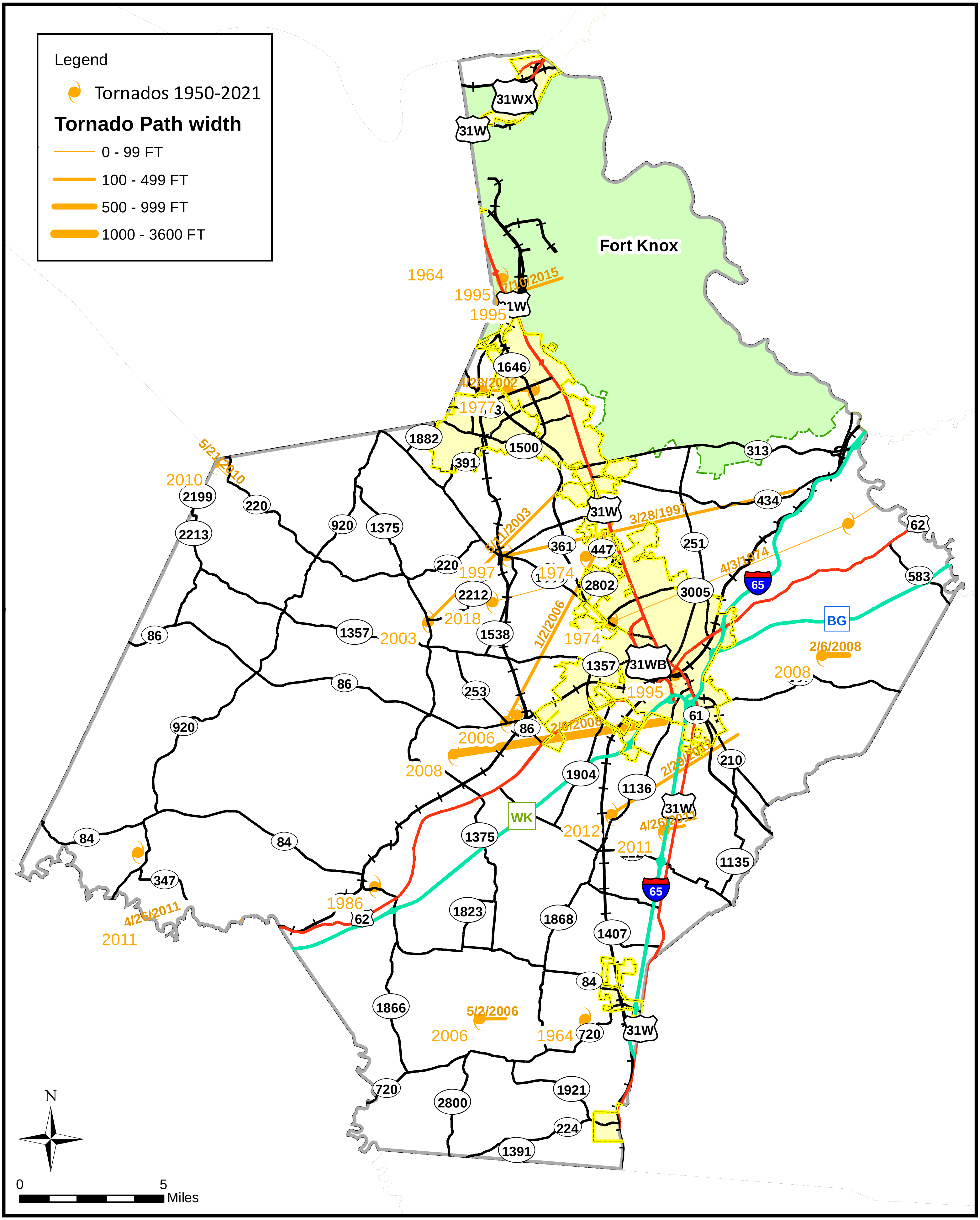

Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
N
5/23/2000
4/3/2018
2018
4/3/1974
920
62
1214
WK
3155
259
737
54
62
187
2777
0
0.5
1
Miles

HARDIN

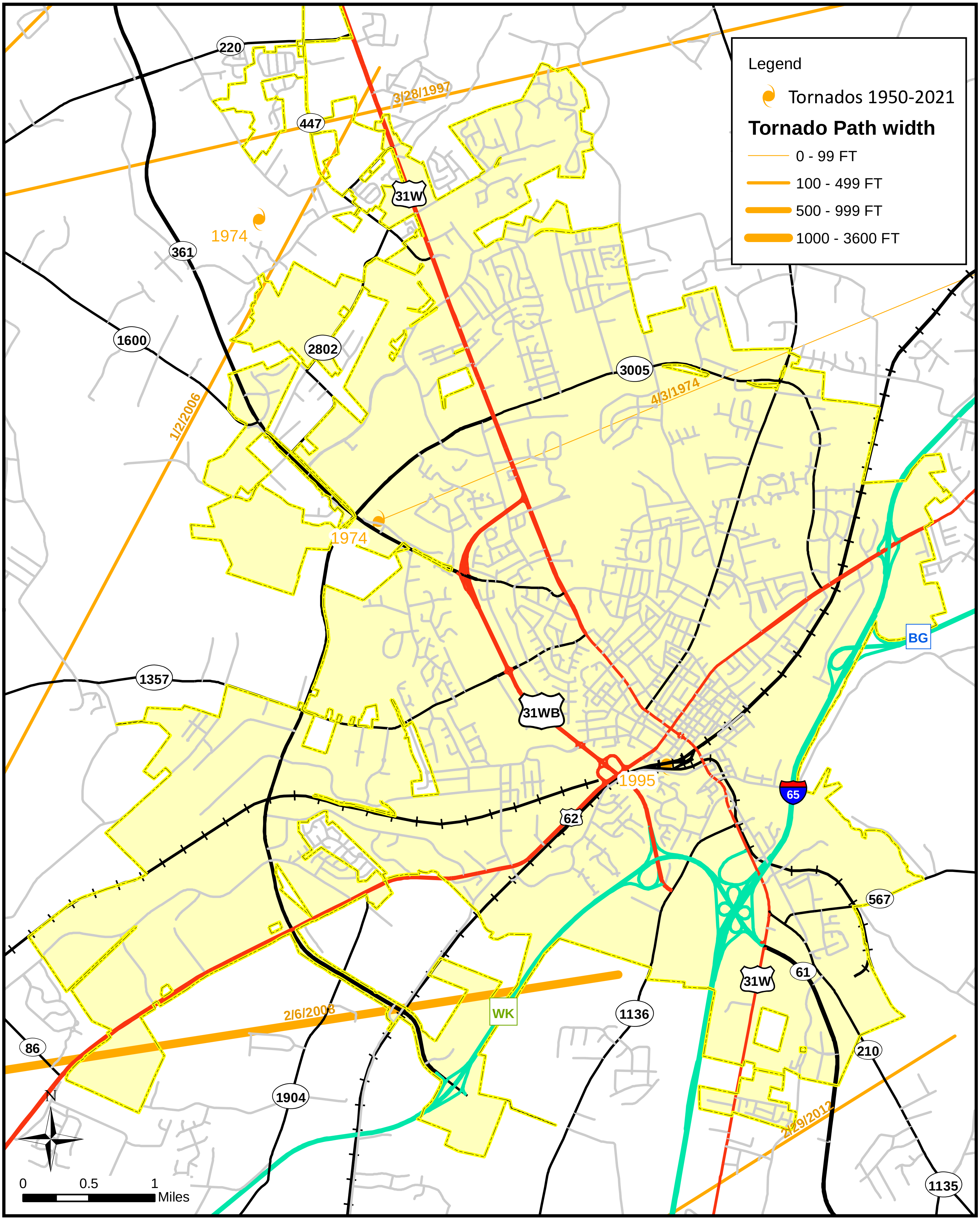
LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
PRICHARD PLACE	7/10/15	0	0	25000	0	EF0
KRAFT	10/31/18	0	0	500000	0	EF1

Building debris from an October 2018 tornado in Hardin County. *Source: The News Enterprise*

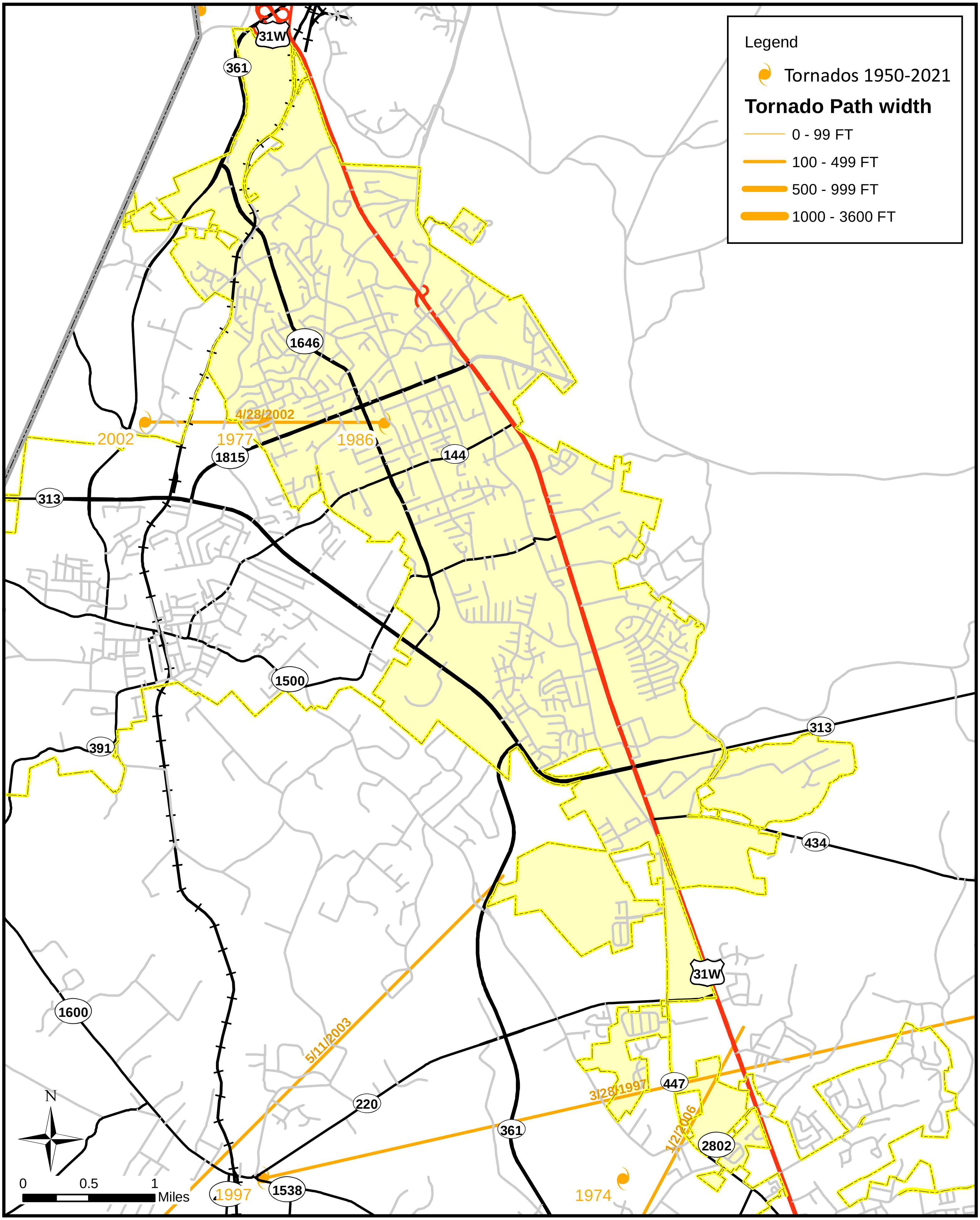
59a


Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
Fort Knox
31WX
31W
1964
7/10/2015
1995
1995
1646
4/28/2002
1977
1882
1500
391
313
5/21/2010
2010
2199
220
2213
920
1375
434
31W
3/28/1997
62
5/1/2003
361
447
251
4/3/1974
220
1997
1974
2802
3005
583
65
2212
2018
BG
86
1357
2003
1538
1/2/2006
1974
2/6/2008
1357
31WB
2008
86
253
1995
920
61
86
2/6/2008
2006
210
2008
1904
1136
31W
WK
4/26/2011
84
1375
2012
84
2011
1135
347
65
1986
4/26/2011
62
1823
1868
2011
1407
84
1866
5/2/2006
2006
1964
720
31W
720
1921
2800
224
1391
N
0
5
Miles

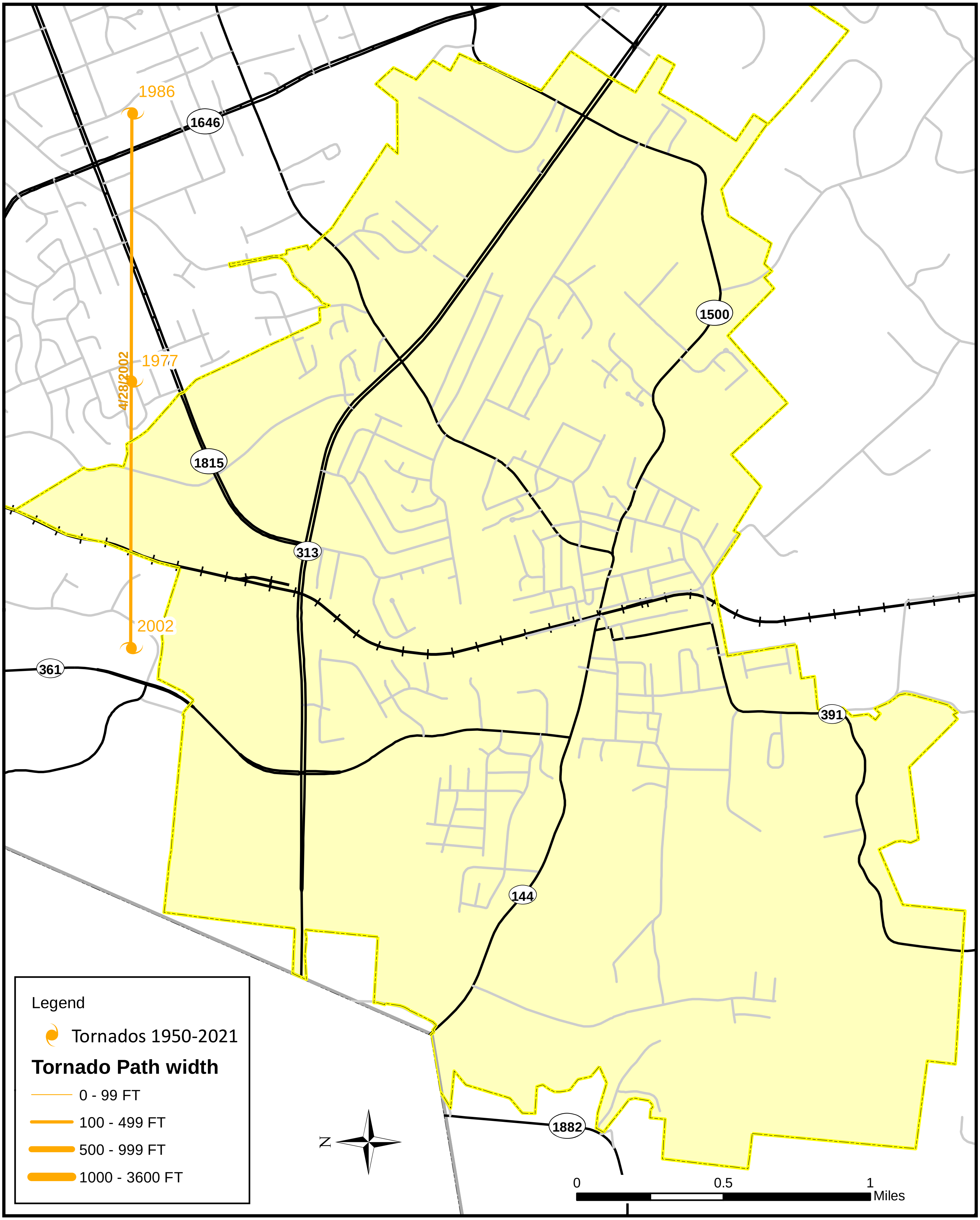
59b


Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
3/28/1997
1974
1974
1995
4/3/1974
1/2/2006
2/6/2008
2/29/2012
220
447
31W
361
1600
2802
3005
1357
31WB
62
65
BG
567
61
31W
1136
WK
210
86
1904
1135
N
0
0.5
1
Miles

RADCLIFF
TORNADO



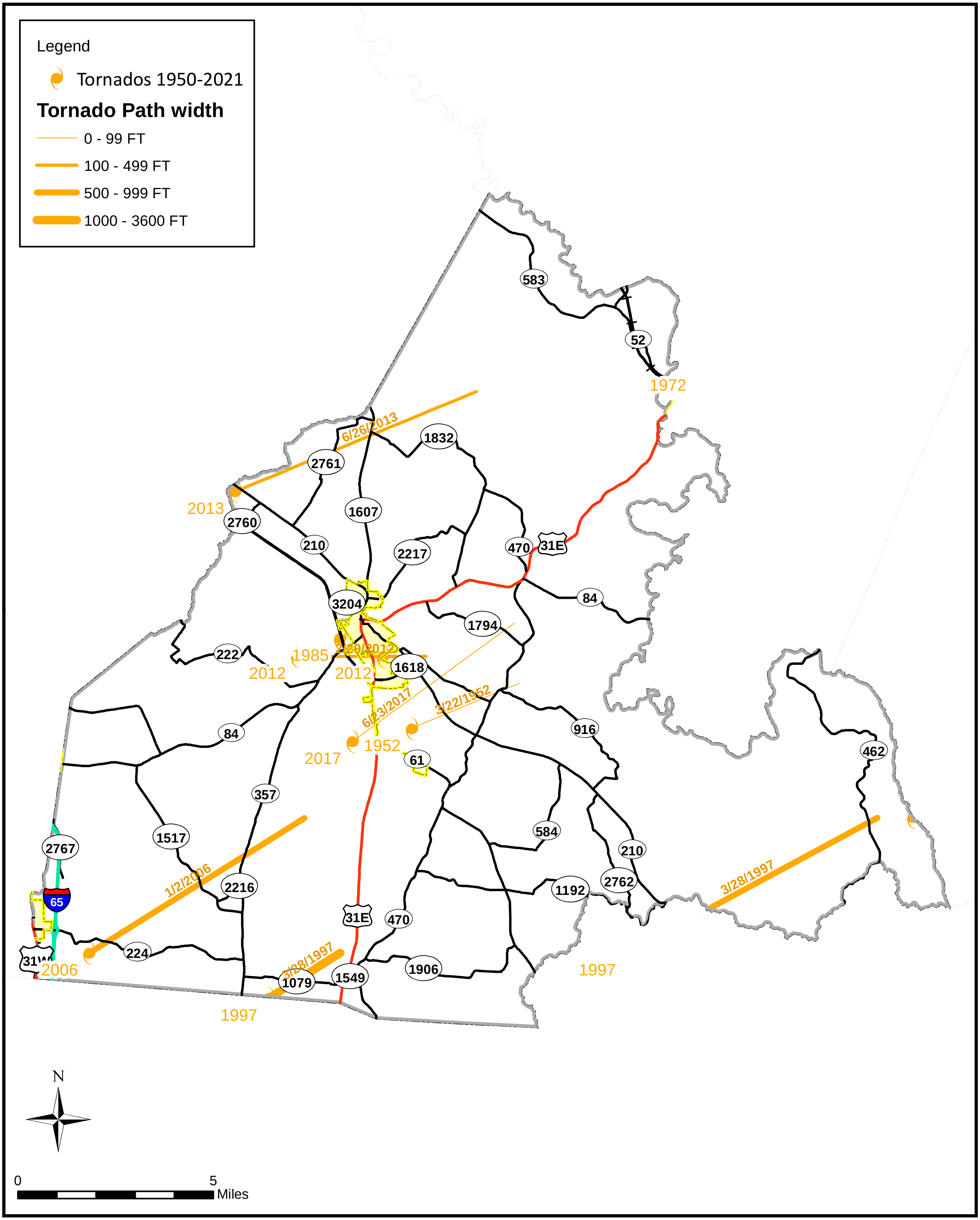
VINE GROVE
TORNADO

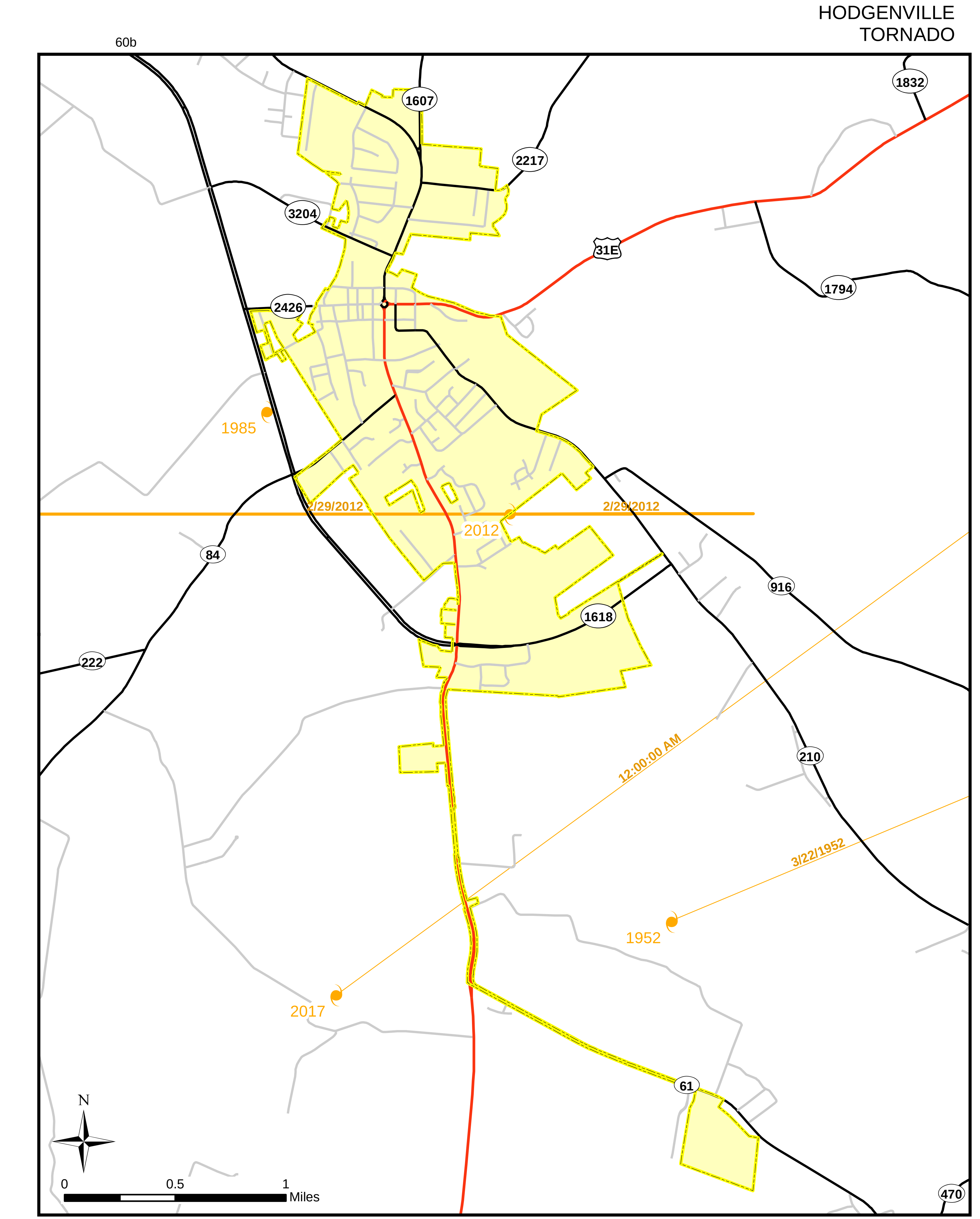


LARUE

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
MATHERS MILL	6/23/17	0	0	100000	0	EF1


Property damage in LaRue County from March 2021 tornado. *Source: Wave 3 News*


Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
583
52
1972
6/26/2013
1832
2761
2013
1607
2760
210
2217
470
31E
84
3204
1794
222
1985
2/29/2012
2012
2012
1618
3/22/1952
6/23/2017
916
84
1952
2017
61
462
357
584
1517
2767
210
1/2/2006
2216
1192
2762
3/28/1997
65
31E
470
224
31W
2006
3/28/1997
1079
1549
1906
1997
1997
N
0
5
Miles



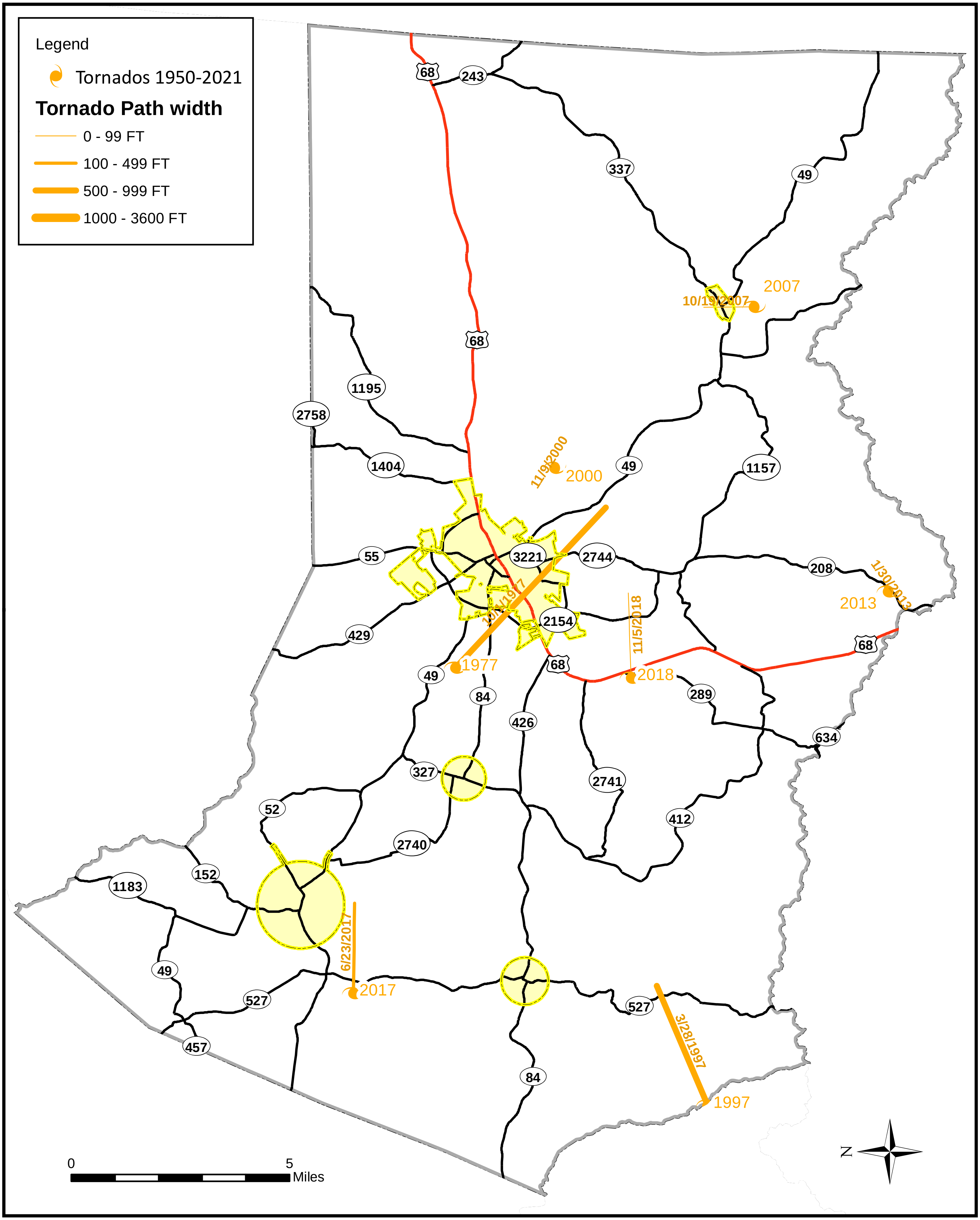
HODGENVILLE
TORNADO
60b
1607
1832
2217
3204
31E
1794
2426
1985
2/29/2012
2/29/2012
2012
84
916
1618
222
12:00:00 AM
210
3/22/1952
1952
2017
61
470
N
0
0.5
1
Miles

MARION

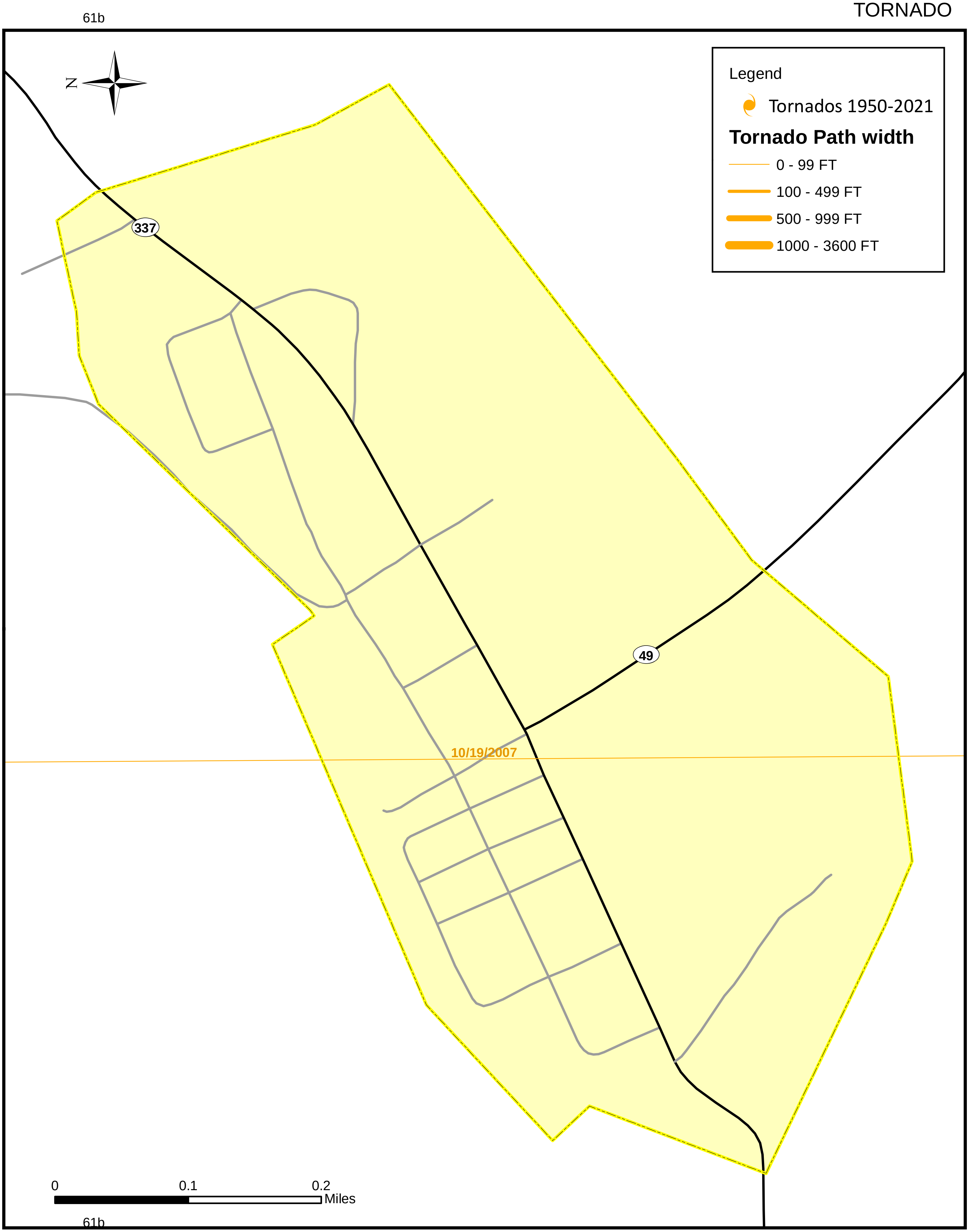
LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
ST FRANCIS	6/23/17	0	0	150000	0	EF1
BELLTOWN	11/5/18	0	0	35000	0	EF0


Structure damage at the Lebanon-Springfield Airport due to strong winds and damage to trees at a residential property due to a June 2017 tornado. *Source: The Lebanon Enterprise*

61a


Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
68
243
337
49
2007
10/19/2007
68
1195
2758
1404
11/9/2000
2000
49
1157
55
3221
2744
208
1/30/2013
2013
10/1/1977
2154
11/5/2018
429
68
1977
49
68
2018
84
289
426
634
327
2741
52
412
2740
152
1183
6/23/2017
49
2017
527
527
3/28/1997
457
84
1997
0
5
Miles
N

BRADFORDSVILLE
TORNADO



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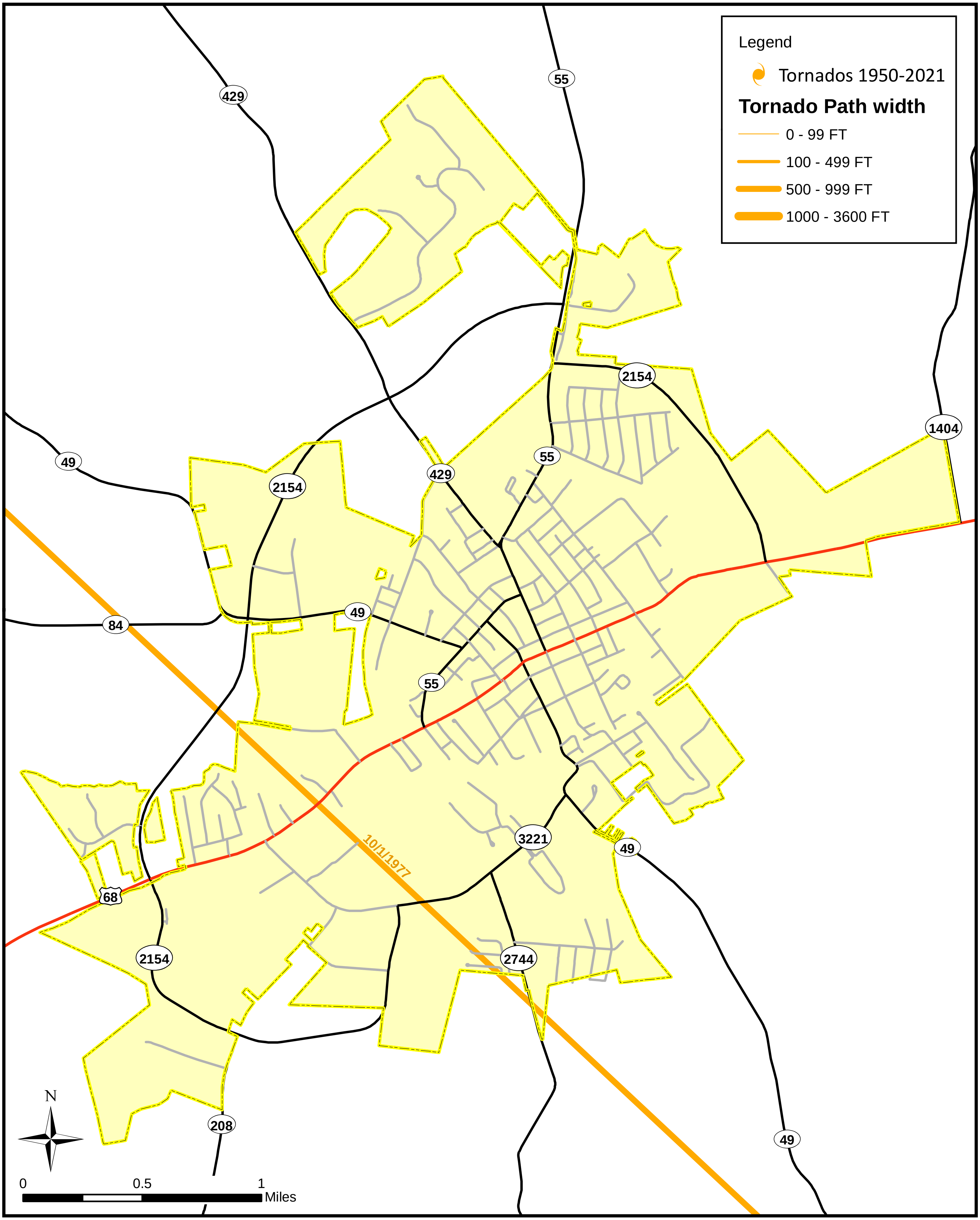
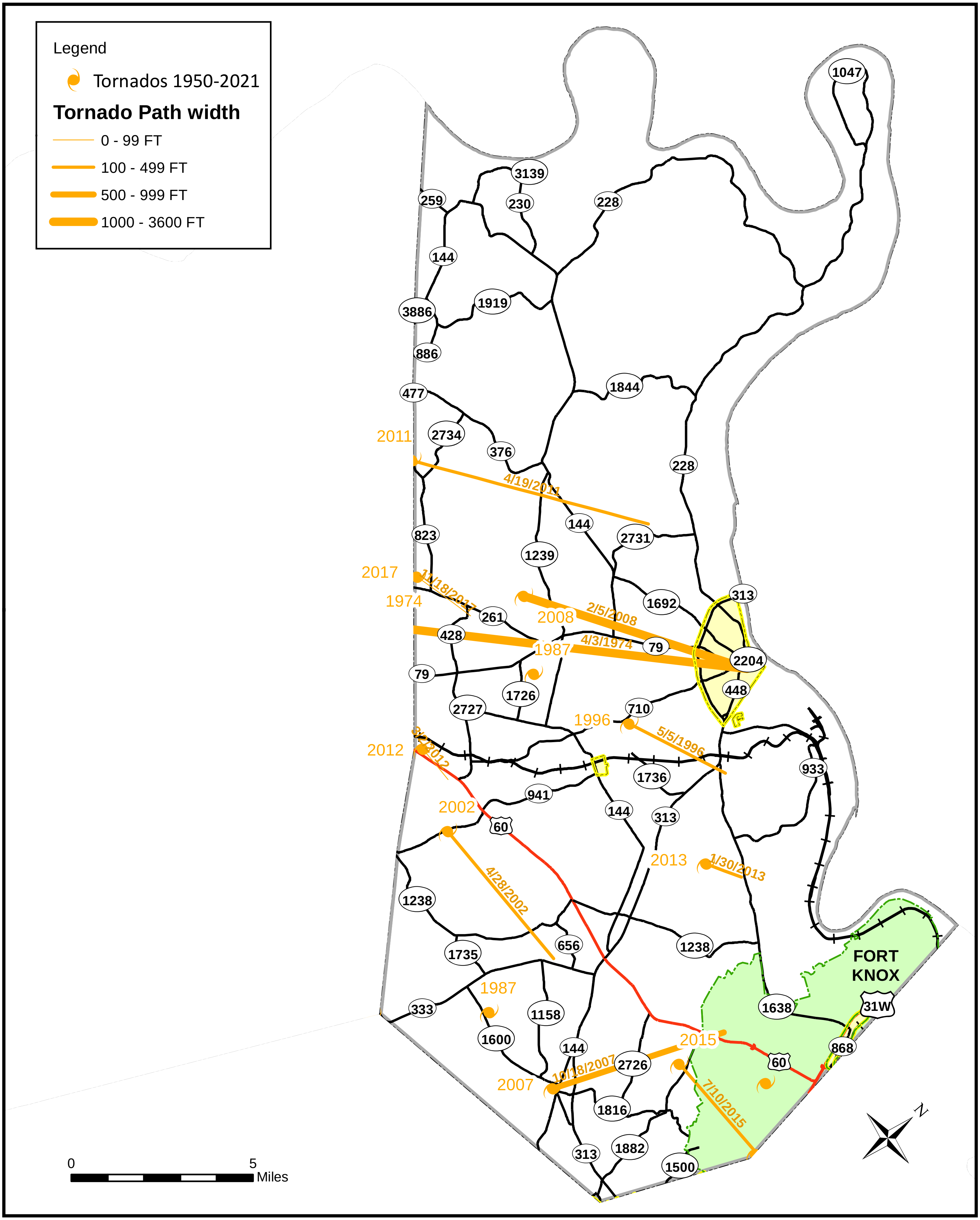

Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
55
429
2154
1404
49
84
3221
68
2744
208
10/1/1977
N
0
0.5
1
Miles

MEADE

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
COBURG	7/10/15	0	0	0	0	EF0
HAYSVILLE	11/18/17	0	1	200000	0	EF1

62a


Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
2011
4/19/2011
2017
11/18/2017
1974
4/3/1974
2008
2/5/2008
1987
1996
5/5/1996
2012
3/2/2012
2002
4/28/2002
2013
1/30/2013
1987
2015
7/10/2015
2007
10/18/2007
FORT KNOX
0
5
Miles
1047
3139
259
230
228
144
1919
3886
886
1844
477
2734
376
228
144
2731
823
1239
313
1692
261
428
79
2204
79
1726
448
2727
710
933
1736
941
144
313
60
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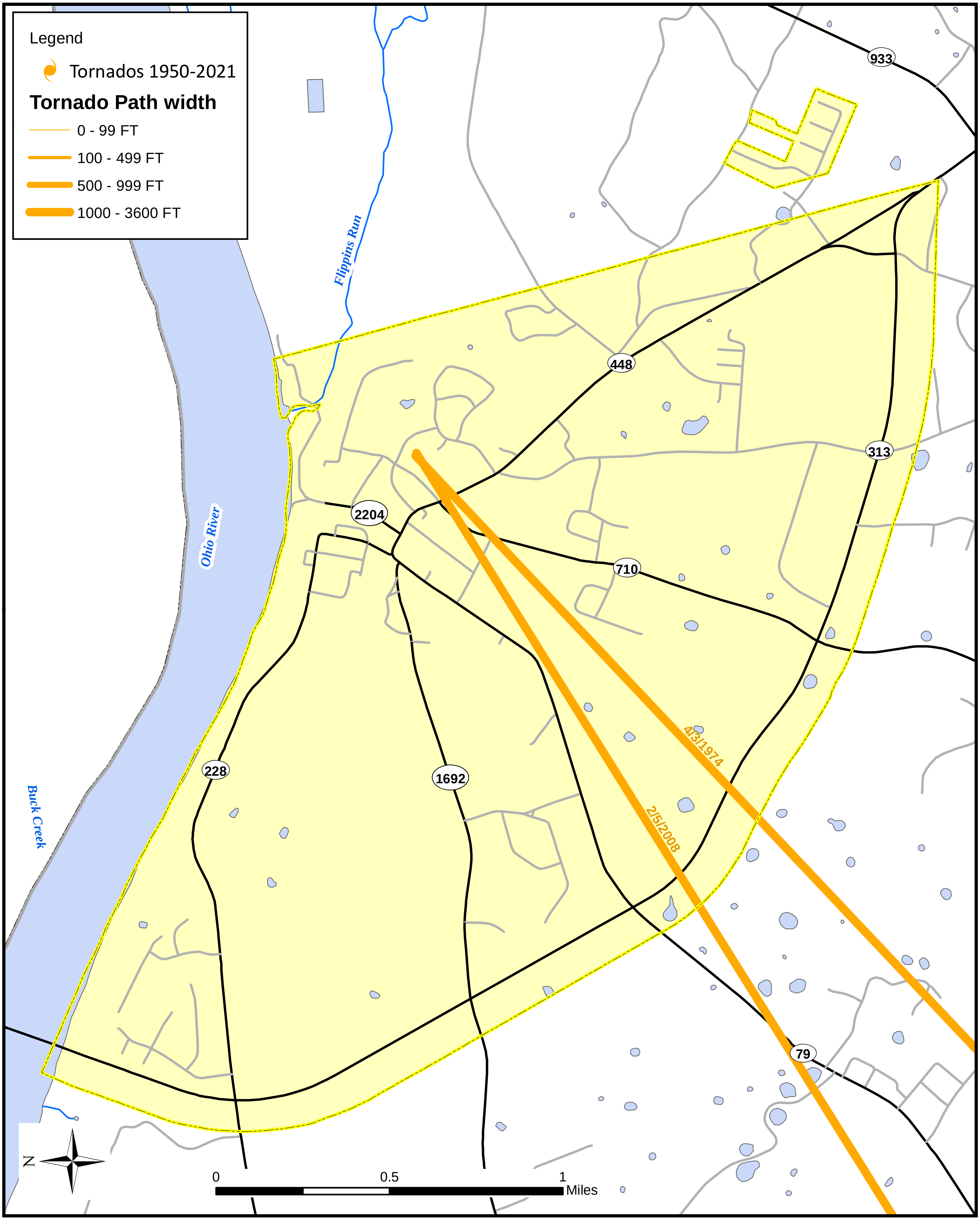
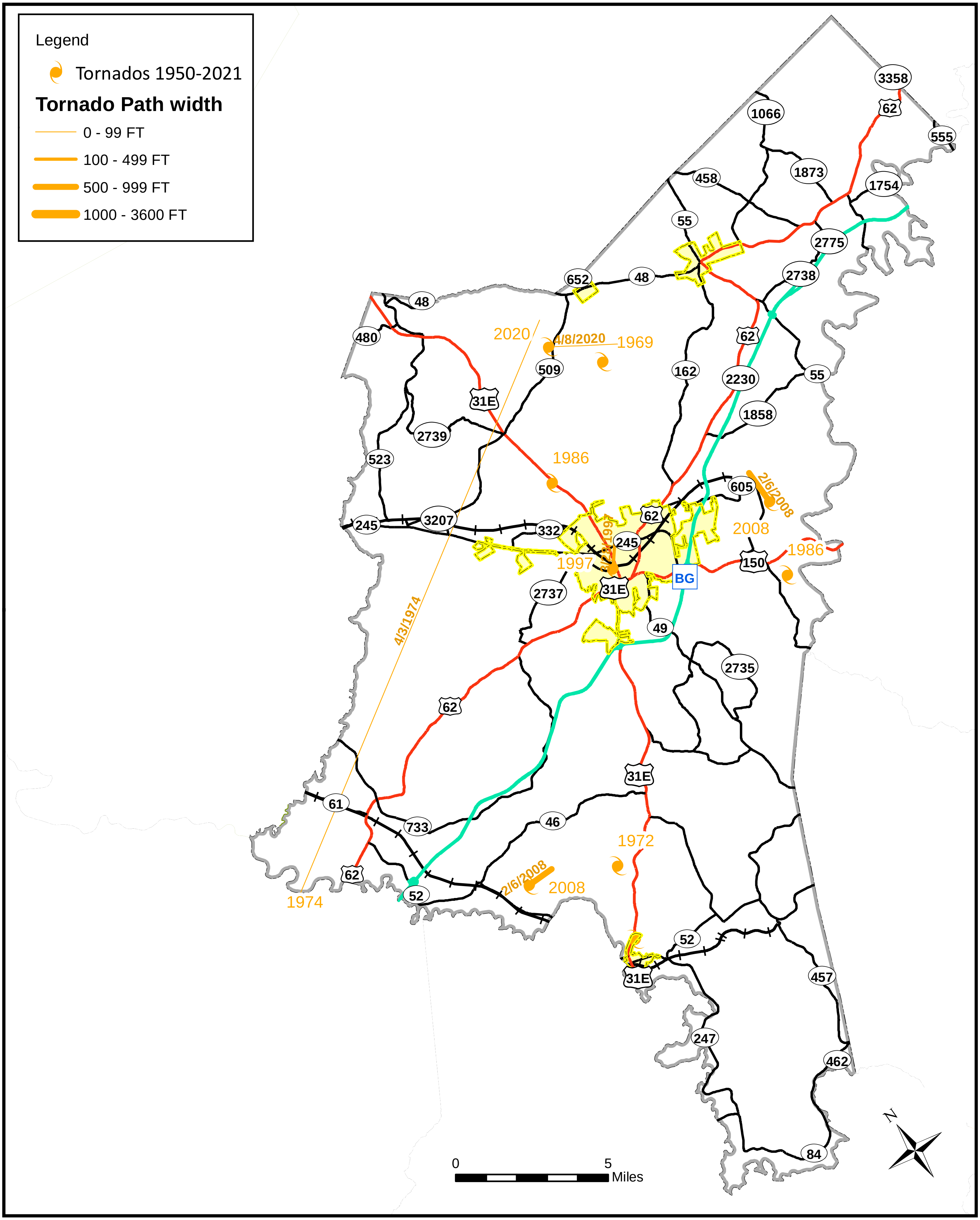
60
1816
313
1882
1500


62b
Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
Flippins Run
Ohio River
Buck Creek
933
448
313
2204
710
228
1692
79
4/3/1974
2/5/2008
N
0
0.5
1
Miles

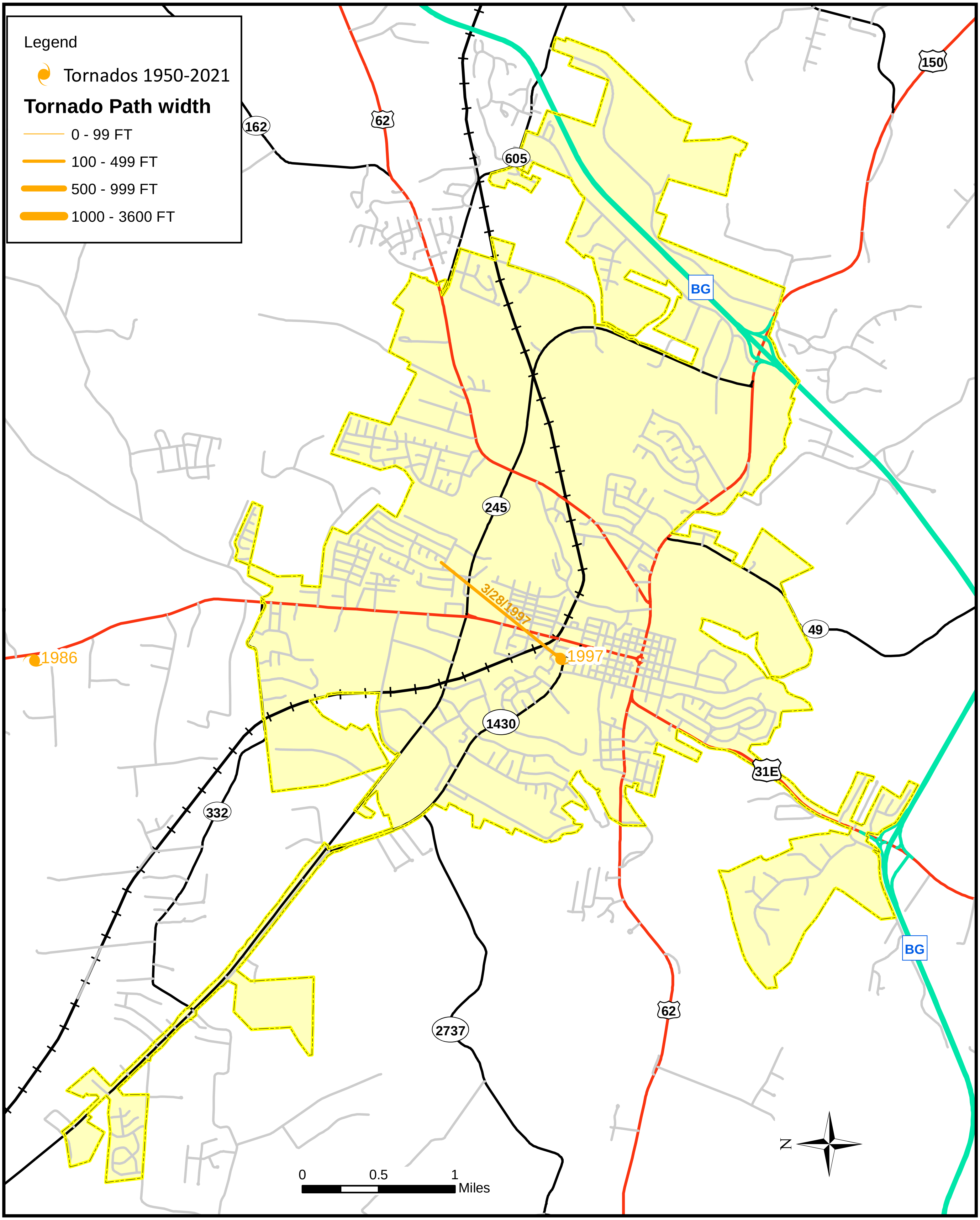
NELSON

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
FAIRFIELD	4/8/20	0	0	200000	0	EF1

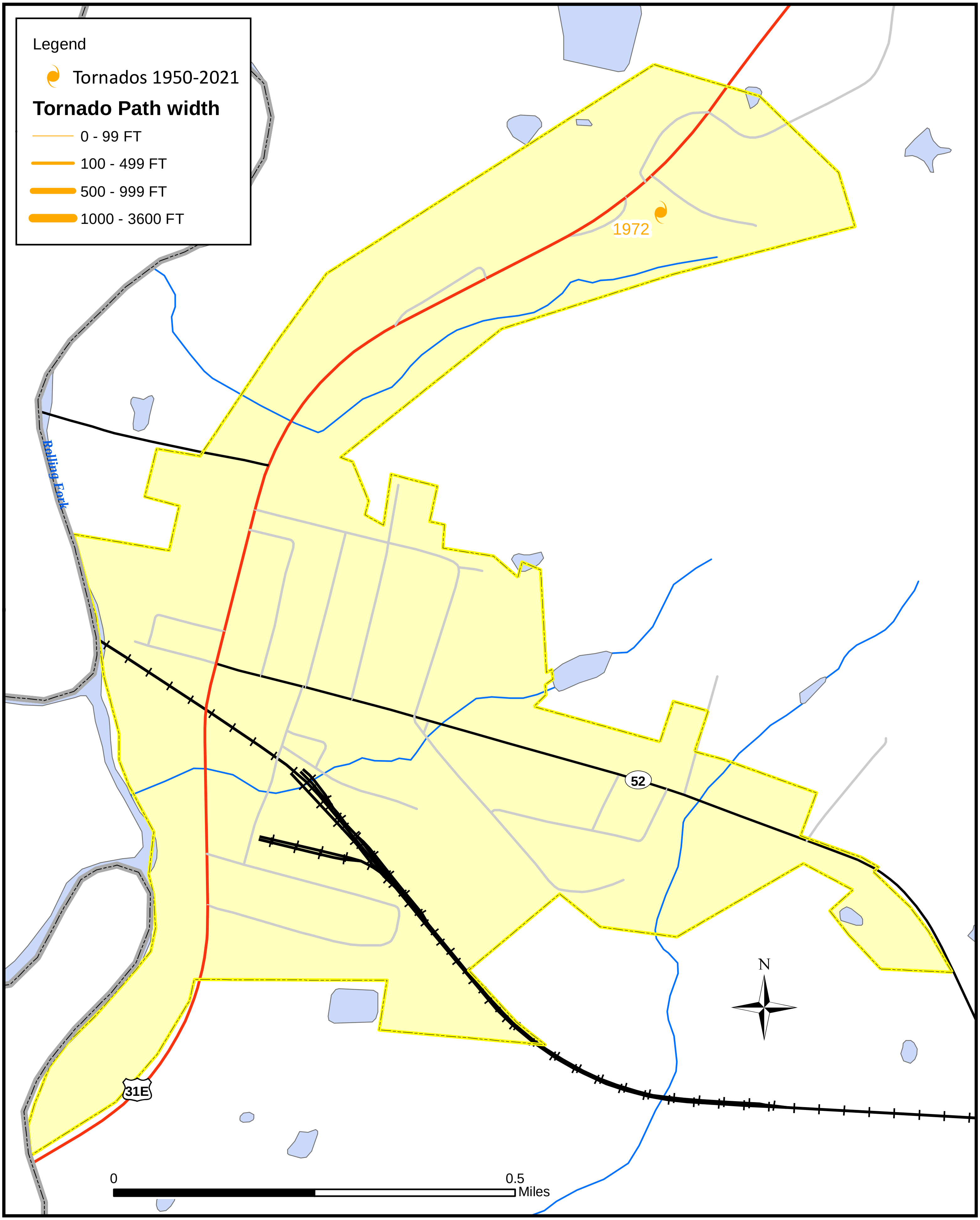
Damage from a Nelson County barn from an April 2020 tornado. *Source Nelson County Gazette.*


Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
2020
4/8/2020
1969
1986
1997
2/6/2008
2008
1986
4/3/1974
1974
2/6/2008
2008
1972
BG
0
5
Miles
N

BARDSTOWN
TORNADO

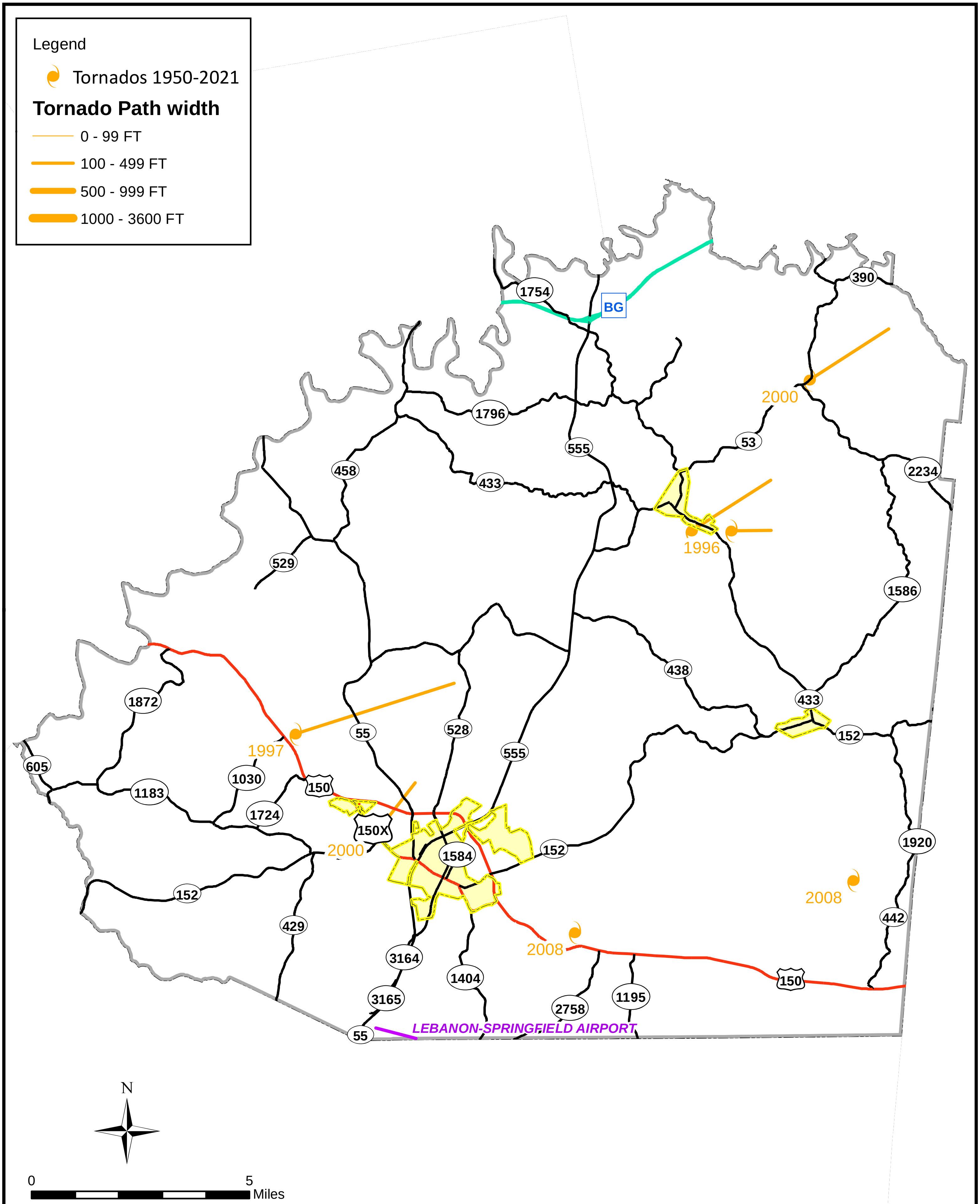


63c

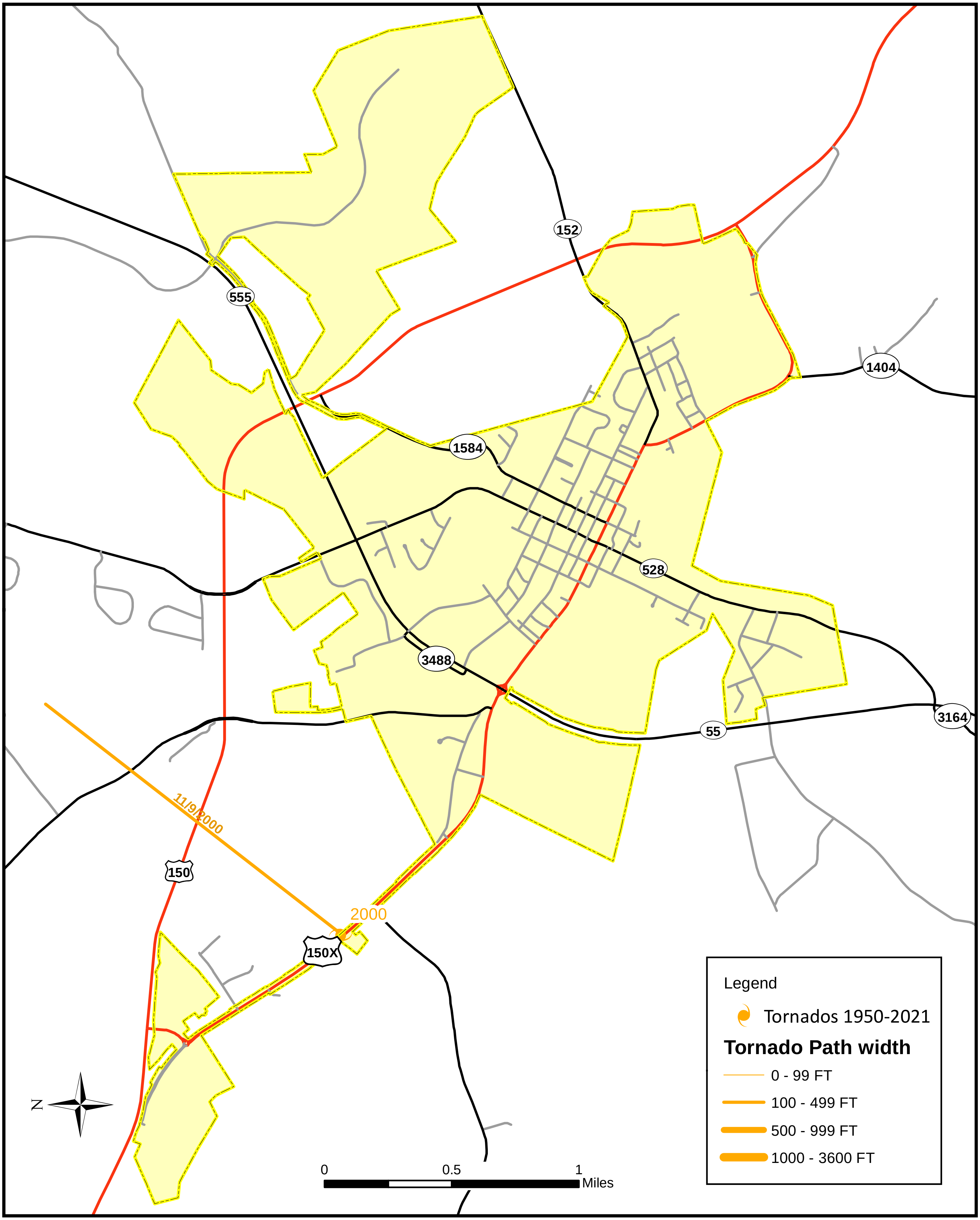

Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
1972
Rolling Fork
52
31E
N
0
0.5
Miles

WASHINGTON – No new events recorded from 1 July 2015 to May 14, 2021

64a


Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
1754
BG
390
1796
555
53
2000
458
433
2234
1996
529
1586
438
1872
433
152
1997
55
528
555
605
1030
150
1183
1724
150X
2000
1584
152
1920
152
2008
429
442
2008
3164
1404
150
3165
1195
2758
55
LEBANON-SPRINGFIELD AIRPORT
N
0
5
Miles

SPRINGFIELD
TORNADO



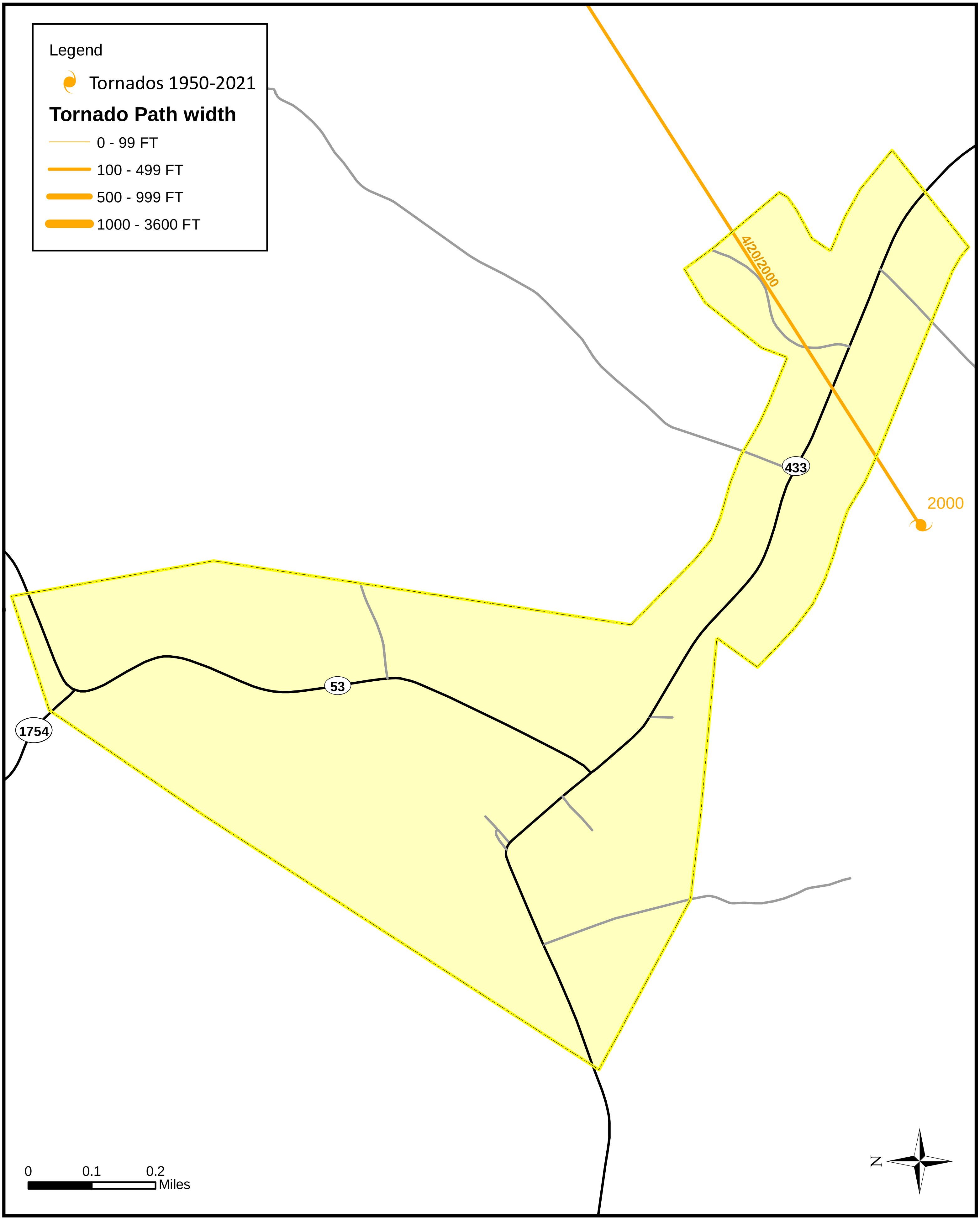

Legend
Tornados 1950-2021
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
4/20/2000
2000
433
53
1754
0
0.1
0.2
Miles
N

Table 3.3.2.2.4 - Summary of Tornado Data, Costs

TORNADOS	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDGE	$5,285,260	17	61.5	1.09	20.00	$85,939	$310,898	0.02	0.06	0.33	1.18
Cloverport	$900,000	2	61.5	1.00	7.00	$14,634	$450,000	0.02	0.50	0.11	3.50
Hardinsburg	$100,000	2	61.5	0.00	0.00	$1,626	$50,000	0.00	0.00	0.00	0.00
Irvington	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
GRAYSON	$56,783,213	16	62.5	3.00	23.09	$908,531	$3,548,951	0.05	0.19	0.37	1.44
Caneyville	$0	1	62.5	0.00	0.00	$0	na	0.00	na	0.00	na
Clarkson	$0	0	62.5	0.00	0.00	$0	na	0.00	na	0.00	na
Leitchfield	$50,000,000	1	62.5	0.00	16.00	$800,000	$50,000,000	0.00	0.00	0.26	16.00
HARDIN	$16,643,723	26	61.5	2.00	73.09	$270,630	$640,143	0.03	0.08	1.19	2.81
Elizabethtown	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
Radcliff	$650,000	2	61.5	0.00	0.00	$10,569	$325,000	0.00	0.00	0.00	0.00
Sonora	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
Upton	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
Vine Grove	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
West Point	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
LARUE	$5,210,111	12	69.5	0.00	19.12	$74,966	$434,176	0.00	0.00	0.28	1.59
Hodgenville	$220,000	2	69.5	0.00	0.00	$3,165	na	0.00	na	0.00	na
MARION	$920,833	13	61.5	0.00	4.15	$14,973	$70,833	0.00	0.00	0.07	0.32
Bradfordsville	$100,000	1	61.5	0.00	0.00	$1,626	$100,000	0.00	0.00	0.00	0.00
Lebanon	$100,000	1	61.5	0.00	0.00	$1,626	$100,000	0.00	0.00	0.00	0.00
Loretto	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
Raywick	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
MEADE	$6,342,324	14	61.5	31.00	268.07	$103,127	$453,023	0.50	2.21	4.36	19.15
Brandenburg	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
Ekron	$500,000	1	61.5	0.00	10.00	$8,130	$500,000	0.00	0.00	0.16	10.00
Muldraugh	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
NELSON	$2,233,978	14	61.5	1.00	28.15	$36,325	$159,570	0.02	0.07	0.46	2.01
Bardstown	$50,000	1	61.5	0.00	0.00	$813	$50,000	0.00	0.00	0.00	0.00
Bloomfield	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
Fairfield	$200,000	1	61.5	0.00	0.00	$3,252	na	0.00	na	0.00	na
New Haven	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
WASHINGTON	$1,840,007	11	61.5	0.00	5.15	$29,919	$167,273	0.00	0.00	0.08	0.47
Mackville	$0	0	61.5	0.00	0.00	$0	na	0.00	na	0.00	na
Springfield	$15,000	1	61.5	0.00	0.00	$244	$15,000	0.00	0.00	0.00	0.00
Willisburg	$70,000	2	60.5	0.00	4.00	$1,157	$35,000	0.00	0.00	0.07	2.00
LTADD	$95,259,449	123	63	38.09	440.82	$1,521,109	$774,467	0.61	0.31	7.04	3.58

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2015.

Table 3.3.2.2.5 - Summary of Tornado Data, Events

TORNADOS	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	17	61.5	8	11	14	3.62	27.64%	0.8	0.55	0.28
Cloverport	2	61.5	1	2	2	30.75	3.25%	0.1	0.1	0.04
Hardinsburg	2	61.5	1	2	2	30.75	3.25%	0.1	0.1	0.04
Irvington	0	61.5	0	0	0	0.00	0.00%	0	0	0
GRAYSON	16	62.5	6	7	5	3.91	25.60%	0.6	0.35	0.1
Caneyville	1	62.5	1	1	1	62.50	1.60%	0.1	0.05	0.02
Clarkson	0	62.5	0	0	0	0.00	0.00%	0	0	0
Leitchfield	1	62.5	0	1	1	62.50	1.60%	0	0.05	0.02
HARDIN	26	61.5	10	13	19	2.37	42.28%	1	0.65	0.38
Elizabethtown	0	61.5	0	0	0	0.00	0.00%	0	0	0
Radcliff	2	61.5	0	1	2	30.75	3.25%	0	0.05	0.04
Sonora	0	61.5	0	0	0	0.00	0.00%	0	0	0
Upton	0	61.5	0	0	0	0.00	0.00%	0	0	0
Vine Grove	0	61.5	0	0	0	0.00	0.00%	0	0	0
West Point	0	61.5	0	0	0	0.00	0.00%	0	0	0
LARUE	12	69.5	5	7	7	5.79	17.27%	0.5	0.35	0.14
Hodgenville	2	69.5	0	0	0	34.75	2.88%	0	0	0
MARION	13	61.5	4	6	5	4.73	21.14%	0.4	0.3	0.1
Bradfordsville	1	61.5	1	1	1	61.50	1.63%	0.1	0.05	0.02
Lebanon	1	61.5	0	1	1	61.50	1.63%	0	0.05	0.02
Loretto	0	61.5	0	0	0	0.00	0.00%	0	0	0
Raywick	0	61.5	0	0	0	0.00	0.00%	0	0	0
MEADE	14	61.5	7	9	10	4.39	22.76%	0.7	0.45	0.2
Brandenburg	0	61.5	0	0	0	0.00	0.00%	0	0	0
Ekron	1	61.5	0	1	1	61.50	1.63%	0	0.05	0.02
Muldraugh	0	61.5	0	0	0	0.00	0.00%	0	0	0
NELSON	14	61.5	3	4	9	4.39	22.76%	0.3	0.2	0.18
Bardstown	1	61.5	0	1	1	61.50	1.63%	0	0.05	0.02
Bloomfield	0	61.5	0	0	0	0.00	0.00%	0	0	0
Fairfield	1	61.5	1	1	1	61.50	1.63%	0.1	0.05	0.02
New Haven	0	61.5	0	0	0	0.00	0.00%	0	0	0
WASHINGTON	11	61.5	5	7	4	5.59	17.89%	0.5	0.35	0.08
Mackville	0	61.5	0	0	0	0.00	0.00%	0	0	0
Springfield	1	61.5	0	1	1	61.50	1.63%	0	0.05	0.02
Willisburg	2	61.5	1	2	2	30.75	3.25%	0.1	0.1	0.04
LTADD	123	63	48	64	73	0.51	196.41%	4.8	3.2	1.46

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

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Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2015.

3.3.2.3 <u>Severe Thunderstorms</u>

I. Background

Definition: Thunderstorm. The National Oceanic and Atmospheric Administration (NOAA) defines a thunderstorm as "a rain shower during which you hear thunder. Since thunder comes from lightning, all thunderstorms have lightning."

Severe Thunderstorm: NOAA classifies a thunderstorm as severe "when it contains one or more of the following: hail one inch or greater, winds gusting in excess of 50 knots (57.5 mph), or a tornado."

Cause and Types of Thunderstorms

Three basic ingredients are necessary for a thunderstorm to form: moisture, rising unstable air (air that keeps rising when given a nudge), and a lifting mechanism to provide the "nudge." Lifts can form from fronts, sea breezes or mountains. Upward moving air is an updraft. Cooler air tends to sink and produces downdraft winds. Downdraft winds can result in one of four different storms: single cell, multicell cluster, multicell line, or supercell.

When sun heats the surface of the earth, it warms the air above the ground. If this warm air is forced to rise because of "bumping" into cooler or damper air, it will continue to rise for as long as it weighs less and remains warmer than the air around it. As the air rises, it transfers heat from the earth's surface to the upper levels of the atmosphere; a process known as convection. The water vapor in the air begins to cool, releases heat, condenses and forms a cloud. This cloud gradually grows upward into areas where the temperature is below freezing. These Cumulonimbus clouds are also known as "thunderhead" clouds and produce lightning.

As a storm rises into freezing air, ice particles can form and grow by condensing vapor and collecting smaller liquid drops that haven't yet frozen (a state called "supercooled"). When two ice particles collide, they usually bounce off each other, but one particle can rip off a little bit of ice from another and grab some electric charge. When lots of these collisions build up big areas of electric charges, it causes a bolt of lightning and creates sound waves that are heard as thunder.

Thunderstorms can occur year-round and at all hours and happen in every US state. However, they are most likely to occur in the spring and summer months and during the afternoon and evening hours. It is estimated that approximately 1,800 thunderstorms occur across our planet every day. About 100,000 thunderstorms occur in the U.S. each year.

A typical thunderstorm is 15 miles in diameter and lasts an average of 30 minutes. All thunderstorms produce lightning and are dangerous. Lightning kills between 75 to 100 people annually. Lightning can also cause fires. In addition, thunderstorms can cause flash floods that kill more people each year than hurricanes, tornadoes, or lightning. Severe thunderstorms can produce hail up to the size of softballs that damages cars and property, and kills livestock caught out in the open. Strong, straight-line winds associated with thunderstorms knock down trees, power lines and mobile homes. Severe thunderstorms can spawn tornadoes with winds up to 300 mph that can destroy well-built man-made structures.

Shelf Cloud

A shelf cloud is a low, horizontal wedge-shaped cloud associated with a thunderstorm gust front or, occasionally, with a cold front. Shelf clouds can be attached to the front side of lines of storms or even a single storm. Usually, there isn't any persistent rotation on a vertical axis within shelf clouds or within individual cloud fragments that extend down from the shelf cloud. Shelf clouds often resemble snowplows, big waves or tsunamis and can look very threatening.

Meade County Thunderstorm, 10/27/2009, *Source: Meade County Emergency Management Office.*

Single Cell or Pulse Storm

A pulse storm is short-lived and usually lasts 30 to 60 minutes. Pulse storms are common in summer and are usually not severe. Pulse storms may produce heavy rain, thunder, lightning, and possible hail and gusty winds. Brief severe weather is possible during a pulse storm in the form of a microburst. These storms are moderately dangerous to the public and moderately to highly dangerous to aviation.

Multicell Cluster

A multicell cluster is a group of severe or non-severe cells in various stages of development. The most common of thunderstorms, mature thunderstorms are located near the center of the cluster, while dissipating thunderstorms exist on their downwind side. Each cluster may only last 20 minutes, but the storm itself may persist for hours. Multicell cluster storms are stronger than single cell storms, but much weaker than a supercell storm. A multicell cluster can produce moderate-sized hail, flash flooding, and weak tornados.

Multicell Line

A multicell line, also known as squall line, is an elongated line of severe thunderstorms that can form along and/or ahead of a cold front. It has the potential to produce heavy precipitation, hail, frequent lightning, strong straight-line winds, and possibly tornados and waterspouts. Severe weather in the form of strong straight-line winds can be expected in areas of the squall line where the line itself is in the shape of a bow echo and within that portion of the line that bows out the most. Tornados can be found along waves within the line echo wave pattern, or LEWP, where mesoscale low-pressure areas are present.

Supercells

Supercell storms are large, usually severe storms that form in an environment where wind speed or wind direction varies with height (an area of "wind shear"), and they have separate downdrafts and updrafts with a strong, rotating updraft ("mesocyclone"). A supercell storm can be 15 miles wide. Research shows that at least 90% of supercell storms cause severe weather. Sometimes these storms produce F3 or higher tornados, extremely large hail (4 inches in diameter), straight-line winds in excess of 80 mph and flash floods. Supercell storms are the most powerful type of thunderstorm and a danger to the public and aviation.

Visible Warning Signs of Thunderstorms

- Dark, towering, threatening clouds
- Distant lightning and thunder

General Facts

- The National Weather Service estimates that there approximately 1,800 thunderstorms daily, on our planet
- There are about 100,000 thunderstorms annually in the U.S. and about 10% of those are severe
- All thunderstorms are dangerous and produce lightning
- Lightning can reach a temperature of 53,540 degrees Fahrenheit; the surface of sun reaches 10,340 degrees Fahrenheit

Dangers Associated with Thunderstorms

- Cloud to ground lightning
- Hail
- Tornados and Waterspouts
- Flash Floods
- Downbursts (Downburst winds are generally very powerful and are often mistaken for wind speeds produced by tornados. These winds can destroy unstable or weakly constructed infrastructures, damaging agricultural crops, displacing automobiles, and crashing aircraft engaged in takeoff or landing.

Damaging Winds

According to the National Severe Storms Laboratory, severe and damaging winds can be produced by any type of thunderstorm, even one that is dying. There are several types of damaging wind as outlined below:

Straight-line wind is the term used to define any wind associated with a thunderstorm that is not a result of rotation and tornadic winds.

A **downdraft** is a small-scale column of air that rapidly sinks toward the ground.

A **downburst** is the result of a strong downdraft with horizontal dimensions larger than 2.5 miles that results in an outward burst of damaging wind on or near the ground. A downburst may begin as a microburst and spread out over a larger area. It can produce damage like a strong tornado.

A **microburst** is a small, concentrated downburst that produces an outward burst of damaging wind at the surface. They are usually small and last only 5 to 10 minutes, with wind speeds up to 168 mph.

The leading edge of rain-cooled air that clashes with warmer thunderstorm inflow is called a **gust front.** Gust fronts are characterized by a wind shift, temperature drop, and gusty winds out ahead of a thunderstorm. At times, these winds push up air above them and form a shelf cloud or detached roll cloud.

A **derecho** is a widespread, long-lived windstorm associated with a band of rapidly moving showers or thunderstorms. It consists of numerous microbursts, downbursts, and clusters of downbursts. A derecho includes winds of at least 58 mph or greater and a swath of damage that extends more than 240 miles, by definition.

A wall of dust that is pushed out along the ground from a thunderstorm downdraft at high speeds is called a **haboob**.

Table 3.3.2.3.1 - International Tornado Intensity Scale (TORRO)

Tornado Intensity	Description of Tornado and Windspeeds
T0	Light Tornado 17 – 24 m s-1 (39 – 54 mi h-1)
T1	Mild Tornado 25 – 32 m s-1 (55 – 72 mi h-1)
T2	Moderate Tornado 33 – 41 m s-2 (73 – 92 mi h-1)
T3	Strong Tornado 42 – 51 m s-1 (93 – 114 mi h-1)
T4	Severe Tornado 52 – 61 m s-1 (115 – 136 mi h-1)
T5	Intense Tornado

	62 – 72 m s-1 (127 – 160 mi h-1)
T6	Moderately Devastating Tornado 73 – 83 m s-1 (161 – 186 mi h-1)
T7	Strongly Devastating Tornado 84 – 95 m s-1 (187 – 212 mi h-1)
T8	Severely Devastating Tornado 96 – 107 m s-1 (213 – 240 mi h-1)
T9	Intensely Devastating Tornado 108 – 120 mi s-1 (241 – 269 mi h-1)
T10	Super Tornado 121 – 134 m s-1 (270 – 299 mi h-1)
Source: The Tornado and Storm Research Organization	

II. Analysis

To analyze severe thunderstorms as a threat to the Lincoln Trail Region, the generalized threat of thunderstorms was identified by reviewing historical data on wind and hail events.
The following tables outline the mean number of days precipitation and thunderstorms occur in an average year and the history of thunderstorms that have been recorded in a given county/jurisdiction within the Lincoln Trail region since 1960. The level of impact is evidenced through the number of lives lost or individual injuries recorded, as well as the estimated cost of property and crop damage based on information reported to the National Climate Data Center which was subsequently rolled into the National Centers for Environmental Information (NCEI). For the original plan, data was only available through 2003. The 2010 update provided data thru 30 June 2009. The 2015 update provided data from, 1 July 2009 to 30 June 2015. This update shows only individual events for the period 1 July 2015 through 14 May 2021. The summary tables show data for the entire period as reported by various sources. Note that there are many variations in recording the locations of the events over time. In the past this was typically done at a county level. More recently they have used nearest place names. Because of this, the records in the summation tables that pertain to individual incorporated areas, should not be considered all encompassing.

Table 3.3.2.3.2 - County Specific Data – Severe Thunderstorms, *Source: NCEI*

Breckinridge

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
Mystic	6/25/15	0	0	10000	0
Locust Hill	7/10/15	0	0	0	0
Buras	7/10/15	0	0	0	0
Sample	7/20/15	0	0	0	0
McQuady	12/23/15	0	0	0	0
Hardinsburg Arpt	3/31/16	0	0	15000	0
Harned	3/31/16	0	2	30000	0
N/A	4/2/16	0	0	5000	0
Cloverport	4/27/16	0	0	5000	0
Harned	4/27/16	0	0	0	0
Custer	5/1/16	0	0	0	0
Hardinsburg Arpt	5/10/16	0	0	0	0
Harned	5/10/16	0	0	6000	0
Harned	5/10/16	0	0	0	0
Harned	5/10/16	0	0	10000	0
Custer	5/10/16	0	0	0	0
Graysville	5/10/16	0	0	100000	0
Hardinsburg Arpt	5/10/16	0	0	0	0
Hardinsburg Arpt	5/10/16	0	0	0	0
Axtel	7/3/16	0	0	20000	0
Constantine	7/3/16	0	0	5000	0
Irvington	3/1/17	0	0	30000	0
Hardinsburg Arpt	4/5/17	0	0	0	0
Harned	4/5/17	0	0	0	0
Dugan	4/5/17	0	0	0	0
Hardinsburg	4/5/17	0	0	0	0
Irvington	4/5/17	0	0	20000	0
Hardinsburg Arpt	4/3/18	0	0	0	0
Garfield	4/3/18	0	0	15000	0
Cloverport	5/27/18	0	0	50000	0
Hardinsburg	6/10/18	0	0	0	0
Mystic	6/26/18	0	0	0	0
Cloverport	6/26/18	0	0	0	0
Madrid	6/26/18	0	0	15000	0

Mc Daniels	6/26/18	0	0	0	0
Harned	6/26/18	0	0	20000	0
Harned	6/26/18	0	0	50000	0
Bewleyville	6/26/18	0	0	0	0
Buras	6/26/18	0	0	0	0
Mc Daniels	7/20/18	0	0	0	0
Vanzant	8/15/18	0	0	3000	0
McQuady	8/15/18	0	0	40000	0
Tar Fork	8/15/18	0	0	1000	0
Raymond	8/15/18	0	0	15000	0
Cloverport	12/31/18	0	0	0	0
Stephensport	12/31/18	0	0	0	0
McQuady	6/5/19	0	0	0	0
Hardinsburg Arpt	6/5/19	0	0	15000	0
Mc Daniels	6/5/19	0	0	0	0
Garfield	6/21/19	0	0	20000	0
Stephensport	6/30/19	0	0	0	0
Cloverport	6/30/19	0	0	30000	0
Cloverport	6/30/19	0	0	0	0
Cloverport	6/30/19	0	0	0	0
McQuady	6/30/19	0	0	0	0
Mattingly	8/20/19	0	0	0	0
Raymond	1/11/20	0	0	0	0
Hardinsburg Arpt	1/11/20	0	0	0	0
Hardinsburg	3/28/20	0	0	20000	0

Grayson

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
Clarkson	6/18/15	0	0	0	0
Leitchfield	6/26/15	0	0	50000	0
Leitchfield	7/14/15	0	0	0	0
Caneyville	8/19/15	0	0	0	0
Short Creek	12/23/15	0	0	0	0
Short Creek	12/23/15	0	0	0	0
Leitchfield	12/23/15	0	0	0	0
Wax	12/23/15	0	0	0	0
N/A	4/2/16	0	0	0	0
Leitchfield	4/27/16	0	0	0	0

Short Creek	5/11/16	0	0	0	0
Spring Lick	5/26/16	0	0	0	0
Fentress Mc Mahon	6/23/16	0	0	0	0
Big Clifty	6/23/16	0	0	0	0
Big Clifty	7/7/16	0	0	0	0
Leitchfield	3/1/17	0	0	0	0
Black Rock	3/27/17	0	0	0	0
Meredith	5/20/17	0	0	0	0
Lilac	4/3/18	0	0	25000	0
Lilac	4/3/18	0	0	300000	0
Lilac	4/3/18	0	0	75000	0
Leitchfield	4/3/18	0	0	0	0
Skaggstown	4/3/18	0	0	75000	0
Big Clifty	7/20/18	0	0	0	0
Black Rock	6/30/19	0	0	0	0
Clarkson	7/2/19	0	0	0	0
Clarkson	7/2/19	0	0	0	0
Leitchfield	7/5/20	0	0	0	0
Church	6/21/21	0	0	0	0

Hardin

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
Glendale	6/19/15	0	0	5000	0
Elizabeth Town	6/19/15	0	0	0	0
Gaithers	6/26/15	0	0	2000	0
Rineyville	6/26/15	0	0	0	0
Rineyville	7/7/15	0	0	10000	0
Prichard Place	7/10/15	0	0	25000	0
Rineyville	12/23/15	0	0	0	0
Sonora	12/23/15	0	0	0	0
Vine Grove	3/27/16	0	0	10000	0
Rineyville	3/27/16	0	0	50000	0
Rogersville	3/31/16	0	0	0	0
N/A	4/2/16	0	0	10000	0
Crest	5/7/16	0	0	0	0
Vertrees	5/10/16	0	0	0	0
Perryville	5/10/16	0	0	0	0
Perryville	5/10/16	0	0	0	0

North Four Corners	5/10/16	0	0	0	0
Vine Grove	5/10/16	0	0	0	0
Long View	5/10/16	0	0	0	0
Vertrees	5/10/16	0	0	0	0
Rogersville	5/10/16	0	0	0	0
Vine Grove	5/10/16	0	0	0	0
Cecilia	5/10/16	0	0	0	0
Elizabeth Town	5/10/16	0	0	0	0
Colesburg	5/10/16	0	0	0	0
Kraft	5/11/16	0	0	0	0
Cecilia	7/6/16	0	0	15000	0
Elizabeth Town	7/6/16	0	0	0	0
Martin Box	7/6/16	0	0	0	0
Eastview	7/7/16	0	0	0	0
(Ftk)Godman Aaf Ft K	7/7/16	0	0	0	0
Vine Grove Jct	7/14/16	0	0	0	0
Elizabeth Town	9/10/16	0	0	8000	0
Perryville	10/20/16	0	0	50000	0
Perryville	10/20/16	0	0	0	0
Rineyville	10/20/16	0	0	0	0
Elizabeth Town	3/1/17	0	0	0	0
Vine Grove	3/1/17	0	0	50000	0
Rineyville	3/27/17	0	0	0	0
Rogersville	3/27/17	0	0	0	0
Long View	3/27/17	0	0	0	0
Howe Vly	3/27/17	0	0	0	0
Gaithers	3/30/17	0	0	0	0
Martin Box	3/30/17	0	0	0	0
Martin Box	4/5/17	0	0	0	0
Elizabeth Town	4/5/17	0	0	0	0
Elizabeth Town	4/5/17	0	0	25000	0
Elizabeth Town	4/5/17	0	0	25000	0
Elizabeth Town	4/5/17	0	0	15000	0
Vine Grove	4/3/18	0	0	0	0
Vine Grove	4/3/18	0	0	0	0
Nolin	4/3/18	0	1	20000	0
Nolin	4/3/18	0	0	50000	0
Glendale Jct	4/3/18	0	0	75000	0
Glendale	4/3/18	0	0	25000	0

Sonora	4/3/18	0	0	75000	0
Eastview	4/3/18	0	0	20000	0
Vine Grove	6/9/18	0	0	0	0
Colesburg	6/12/18	0	0	0	0
Colesburg	6/12/18	0	0	0	0
Martin Box	6/26/18	0	0	100000	0
Cecilia	6/26/18	0	0	0	0
Kraft	10/31/18	0	0	500000	0
Vertrees	6/21/19	0	0	15000	0
Gaithers	8/20/19	0	0	0	0
(Ftk)Godman Aaf Ft K	4/8/20	0	0	0	0
Sonora	6/11/21	0	0	0	0

Larue

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
Tanner	6/18/15	0	0	0	0
Mt Sherman	6/26/15	0	0	0	0
Hodgenville	7/10/15	0	0	0	0
Hodgenville	7/10/15	0	0	0	0
Hodgenville	7/13/15	0	0	0	0
Hodgenville	12/23/15	0	0	0	0
Hodgenville	12/23/15	0	0	0	0
N/A	4/2/16	0	0	5000	0
Attilla	5/10/16	0	0	0	0
Upton	5/10/16	0	0	0	0
Upton	5/26/16	0	0	0	0
Magnolia	7/7/16	0	0	0	0
Upton	3/1/17	0	0	25000	0
Hodgenville	4/30/17	0	0	0	0
Mathers Mill	6/23/17	0	0	100000	0
Mathers Mill	4/3/18	0	0	200000	0
Hodgenville	4/3/18	0	0	0	0
White City	4/3/18	0	0	25000	0
Buffalo	4/3/18	0	0	0	0
Mathers Mill	3/28/20	0	0	5000	0
Buffalo	7/5/20	0	0	0	0
Hodgenville	7/5/20	0	0	0	0
Hodgenville	7/5/20	0	0	0	0

Tonieville	7/5/20	0	0	0	0

Marion

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
Penicks	6/26/15	0	0	0	0
Lebanon	6/26/15	0	0	0	0
Raywick	7/13/15	0	0	0	0
Lebanon	7/14/15	0	0	0	0
Lebanon	7/14/15	0	0	0	0
Belltown	7/19/15	0	0	0	0
N/A	4/2/16	0	0	5000	0
Jessietown	5/10/16	0	0	0	0
Lebanon	6/23/16	0	0	0	0
Jessietown	6/23/16	0	0	0	0
Gravel Switch	10/20/16	0	0	0	0
Calvary	3/1/17	0	0	50000	0
Lebanon	4/5/17	0	0	0	0
St Francis	6/23/17	0	0	150000	0
Nurkes Spg	6/23/17	0	0	15000	0
Loretto	6/23/17	0	0	0	0
Loretto	6/23/17	0	0	0	0
Lebanon	6/23/17	0	0	0	0
Bradfordsville	6/23/17	0	0	10000	0
Loretto	4/3/18	0	0	10000	0
Bradfordsville	4/3/18	0	0	20000	0
Loretto	5/31/18	0	0	0	0
Lebanon	5/31/18	0	0	0	0
Penicks	5/31/18	0	0	0	0
Lebanon	6/12/18	0	0	5000	0
Belltown	6/26/18	0	0	0	0
Salleetown	6/26/18	0	0	0	0
Loretto	7/20/18	0	0	0	0
Lebanon	7/20/18	0	0	0	0
Penicks	7/20/18	0	0	0	0
Lebanon	8/7/18	0	0	0	0
Belltown	11/5/18	0	0	35000	0
Bradfordsville	6/29/20	0	0	0	0
St Mary	7/12/20	0	0	0	0

Meade

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
Garrett	6/21/15	0	0	3000	0
Garrett	6/21/15	0	0	10000	0
Battletown	6/26/15	0	0	0	0
Flaherty	6/26/15	0	0	0	0
Flaherty	6/26/15	0	0	1000	0
Rock Haven	6/26/15	0	0	1000	0
Muldraugh	6/26/15	0	0	0	0
Coburg	7/10/15	0	0	0	0
Rhodelia	12/23/15	0	0	0	0
Battletown	12/23/15	0	0	0	0
N/A	4/2/16	0	0	0	0
Brandenburg	4/27/16	0	0	5000	0
Ekron	5/10/16	0	0	0	0
Wolf Creek	4/5/17	0	0	0	0
Haysville	11/18/17	0	1	200000	0
Guston	11/18/17	0	0	20000	0
Rock Haven	5/31/18	0	0	0	0
Sirocco	6/11/18	0	0	0	0
Andyville	7/20/18	0	0	0	0
Midway	7/20/18	0	0	0	0
Brandenburg Station	7/20/18	0	0	15000	0
Andyville	9/8/18	0	0	15000	0
Payneville	12/31/18	0	0	0	0
Ekron	5/1/19	0	0	10000	0
Brandenburg	6/30/19	0	0	0	0
Concordia	4/8/20	0	0	0	0

Nelson

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
Culvertown	6/26/15	0	0	0	0
Coxs Creek	7/7/15	0	0	0	0
Bardstown	7/7/15	0	0	100000	0
Bourbon Spgs	7/10/15	0	0	30000	0
Boston	7/14/15	0	0	0	0

Fairfield	12/23/15	0	0	0	0
N/A	4/2/16	0	0	0	0
Boston	5/10/16	0	0	0	0
Samuels	5/10/16	0	0	0	0
Samuels	5/10/16	0	0	0	0
Bardstown	5/11/16	0	0	0	0
Bourbon Spgs	6/23/16	0	0	0	0
Bardstown	6/23/16	0	0	0	0
Bardstown	7/7/16	0	0	0	0
Fairfield	7/28/16	0	0	0	0
Coxs Creek	3/1/17	0	0	40000	0
Bardstown	3/1/17	0	0	0	0
Bloomfield	3/1/17	0	0	0	0
Coxs Creek	3/27/17	0	0	0	0
Fairfield	3/27/17	0	0	0	0
Coxs Creek	3/27/17	0	0	0	0
Boston	4/5/17	0	0	0	0
Boston	4/5/17	0	0	0	0
Bardstown	4/5/17	0	0	0	0
Fairfield	4/5/17	0	0	0	0
Bloomfield	4/5/17	0	0	0	0
Fairfield	4/5/17	0	0	0	0
Bardstown	4/30/17	0	0	0	0
Bloomfield	6/18/17	0	0	0	0
Balltown	6/23/17	0	0	0	0
Culvertown	6/23/17	0	0	0	0
Howardstown	4/3/18	0	0	0	0
Howardstown	4/3/18	0	0	0	0
Bloomfield	5/31/18	0	0	0	0
Bloomfield	6/11/18	0	0	0	0
Boston	6/12/18	0	0	5000	0
Early Times	6/26/18	0	0	15000	0
Bourbon Spgs	7/5/18	0	0	0	0
Bloomfield	7/5/18	0	0	0	0
Lenore	7/20/18	0	0	0	0
Coxs Creek	7/20/18	0	0	0	0
Chaplin	7/20/18	0	0	0	0
East Bardstown	7/20/18	0	0	0	0
Boston	10/31/18	0	0	0	0

Nazareth	10/31/18	0	0	0	0
Fairfield	4/8/20	0	0	200000	0
Bloomfield	6/21/2	0	0	0	0

Washington

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
	4/2/16	0	0	5000	0
St Catherine	5/10/16	0	0	0	0
Willisburg	5/10/16	0	0	0	0
Mackville	5/10/16	0	0	50000	0
Springfield	5/11/16	0	0	0	0
St Catherine	6/23/16	0	0	0	0
Fredricktown	6/23/16	0	0	0	0
Willisburg	7/8/16	0	0	0	0
Willisburg	3/27/17	0	0	75000	0
Willisburg	3/27/17	0	0	15000	0
Maud	4/29/17	0	0	0	0
Pulliam	4/30/17	0	0	0	0
Springfield	5/11/17	0	0	50000	0
St Catherine	6/23/17	0	0	0	0
Brush Grove	6/11/18	0	0	0	0
Cardwell	6/11/18	0	0	0	0
Mooresville	6/11/18	0	0	0	0
Kirkland	6/11/18	0	0	0	0
Battle	6/11/18	0	0	0	0
Cardwell	6/11/18	0	0	0	0
Mooresville	6/11/18	0	0	0	0
Polin	6/11/18	0	0	0	0
Battle	6/11/18	0	0	0	0
Kirkland	6/11/18	0	0	0	0
Pulliam	7/5/18	0	0	0	0
St Catherine	7/20/18	0	0	0	0
St Catherine	7/20/18	0	0	0	0
Cardwell	3/14/19	0	0	20000	0
Pulliam	4/8/20	0	0	0	0
St Catherine	7/12/20	0	0	0	0
Pleasant Grove	7/12/20	0	0	0	0
Willisburg	7/20/20	0	0	0	0

Table 3.3.2.3.3 - Summary of Thunderstorm/Winds Data, Costs

THUNDERSTORMS WINDS	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDGE	$1,761,803	265	60.5	0.25	4.21	$29,121	$6,648	0.00	0.00	0.07	0.02
Cloverport	$90,000	16	60.5	0	0	$1,488	$5,625	0.00	0.00	0.00	0.00
Hardinsburg	$155,000	35	60.5	0	0	$2,562	$4,429	0.00	0.00	0.00	0.00
Irvington	$105,000	7	60.5	0	0	$1,736	$15,000	0.00	0.00	0.00	0.00
GRAYSON	$1,740,288	225	62.5	0.25	6.62	$27,845	$7,735	0.00	0.00	0.11	0.03
Caneyville	$0	21	62.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Clarkson	$0	9	62.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Leitchfield	$202,000	27	62.5	0	0	$3,232	$7,481	0.00	0.00	0.00	0.00
HARDIN	$65,915,949	367	64.5	4.45	133.17	$1,021,953	$179,607	0.07	0.01	2.06	0.36
Elizabethtown	$153,000	44	64.5	0	0	$2,372	$3,477	0.00	0.00	0.00	0.00
Radcliff	$5,050,000	13	64.5	0	46	$78,295	$388,462	0.00	0.00	0.71	3.54
Sonora	$76,000	11	64.5	0	0	$1,178	$6,909	0.00	0.00	0.00	0.00
Upton	$0	1	64.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Vine Grove	$50,080,000	16	64.5	0	0	$776,434	$3,130,000	0.00	0.00	0.00	0.00
West Point	$0	4	64.5	0	0	$0	$0	0.00	0.00	0.00	0.00
LARUE	$1,869,787	217	60.5	1.32	11.6	$30,906	$8,617	0.02	0.01	0.19	0.05
Hodgenville	$150,000	29	60.5	0	0	$2,479	$5,172	0.00	0.00	0.00	0.00
MARION	$1,547,735	214	60.5	0.24	1.63	$25,582	$7,232	0.00	0.00	0.03	0.01
Bradfordsville	$30,000	4	60.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Lebanon	$175,000	35	60.5	0	0	$2,893	$5,000	0.00	0.00	0.00	0.00
Loretto	$20,000	9	60.5	0	0	$331	$2,222	0.00	0.00	0.00	0.00
Raywick	$0	3	60.5	0	0	$0	$0	0.00	0.00	0.00	0.00
MEADE	$1,959,733	234	61.5	3.45	46.26	$31,866	$8,375	0.06	0.01	0.75	0.20
Brandenburg	$77,000	25	61.5	0	0	$1,252	$3,080	0.00	0.00	0.00	0.00
Ekron	$10,000	6	61.5	0	0	$163	$1,667	0.00	0.00	0.00	0.00
Muldraugh	$10,000	5	61.5	0	0	$163	$2,000	0.00	0.00	0.00	0.00
NELSON	$1,794,130	295	60.5	0.3	12.58	$29,655	$6,082	0.00	0.00	0.21	0.04
Bardstown	$155,000	47	60.5	0	0	$2,562	$3,298	0.00	0.00	0.00	0.00
Bloomfield	$0	10	60.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Fairfield	$200,000	7	60.5	0	0	$3,306	$0	0.00	0.00	0.00	0.00
New Haven	$50,000	3	60.5	0	0	$826	$16,667	0.00	0.00	0.00	0.00
WASHINGTON	$1,668,572	200	60.5	0.22	3.58	$27,580	$8,343	0.00	0.00	0.06	0.02
Mackville	$225,000	5	60.5	0	0	$3,719	$45,000	0.00	0.00	0.00	0.00
Springfield	$120,000	18	60.5	0	0	$1,983	$6,667	0.00	0.00	0.00	0.00
Willisburg	$91,000	12	60.5	0	0	$1,504	$7,583	0.00	0.00	0.00	0.00
LTADD	$78,257,999	2017	64.5	10.48	219.65	$1,213,302	$38,799	0.16	0.01	3.41	0.11

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2015.

Table 3.3.2.3.4 - Summary of Thunderstorm/Winds Data, Events

THUNDERSTORMS WINDS	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	265	60.5	112	154	222	0.23	438.02%	11.2	7.7	4.44
Cloverport	16	60.5	8	10	10	3.78	26.45%	0.8	0.5	0.2
Hardinsburg	35	60.5	9	21	24	1.73	57.85%	0.9	1.05	0.48
Irvington	7	60.5	3	4	5	8.64	11.57%	0.3	0.2	0.1
GRAYSON	225	62.5	70	107	179	0.28	360.00%	7	5.35	3.58
Caneyville	21	62.5	13	21	21	2.98	33.60%	1.3	1.05	0.42
Clarkson	9	62.5	7	9	9	6.94	14.40%	0.7	0.45	0.18
Leitchfield	27	62.5	12	26	27	2.31	43.20%	1.2	1.3	0.54
HARDIN	367	64.5	137	206	310	0.18	568.99%	13.7	10.3	6.2
Elizabethtown	44	64.5	27	44	44	1.47	68.22%	2.7	2.2	0.88
Radcliff	13	64.5	3	12	13	4.96	20.16%	0.3	0.6	0.26
Sonora	11	64.5	6	10	10	5.86	17.05%	0.6	0.5	0.2
Upton	1	64.5	0	1	1	64.50	1.55%	0	0.05	0.02
Vine Grove	16	64.5	10	15	16	4.03	24.81%	1	0.75	0.32
West Point	4	64.5	3	4	4	16.13	6.20%	0.3	0.2	0.08
LARUE	217	60.5	60	88	160	0.28	358.68%	6	4.4	3.2
Hodgenville	29	60.5	18	29	29	2.09	47.93%	1.8	1.45	0.58
MARION	214	60.5	56	89	156	0.28	353.72%	5.6	4.45	3.12
Bradfordsville	4	60.5	4	4	4	15.13	6.61%	0.4	0.2	0.08
Lebanon	35	60.5	20	34	35	1.73	57.85%	2	1.7	0.7
Loretto	9	60.5	9	9	9	6.72	14.88%	0.9	0.45	0.18
Raywick	3	60.5	2	3	3	20.17	4.96%	0.2	0.15	0.06
MEADE	234	61.5	72	110	222	0.26	380.49%	7.2	5.5	4.44
Brandenburg	25	61.5	16	25	25	2.46	40.65%	1.6	1.25	0.5
Ekron	6	61.5	6	6	6	10.25	9.76%	0.6	0.3	0.12
Muldraugh	5	61.5	3	5	5	12.30	8.13%	0.3	0.25	0.1
NELSON	295	60.5	90	96	214	0.21	487.60%	9	4.8	4.28
Bardstown	47	60.5	24	46	47	1.29	77.69%	2.4	2.3	0.94
Bloomfield	10	60.5	9	9	9	6.05	16.53%	0.9	0.45	0.18
Fairfield	7	60.5	7	7	7	8.64	11.57%	0.7	0.35	0.14
New Haven	3	60.5	0	2	3	20.17	4.96%	0	0.1	0.06
WASHINGTON	200	60.5	50	77	142	0.30	330.58%	5	3.85	2.84
Mackville	5	60.5	3	5	5	12.10	8.26%	0.3	0.25	0.1
Springfield	18	60.5	7	17	17	3.36	29.75%	0.7	0.85	0.34
Willisburg	12	60.5	8	12	12	5.04	19.83%	0.8	0.6	0.24
LTADD	2017	64.5	647	927	1605	0.03	113.21%	64.7	46.35	32.1

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2015.

3.3.2.4 Severe Winter Storms

I. Background

Definitions:

Winter Storm: According to the National Severe Storms Laboratory (NSSL), a winter storm is an event in which the main types of precipitation are snow, sleet or freezing rain. A winter storm is a combination of heavy snow, blowing snow and/or dangerous wind chills. A winter storm can be a life-threatening event. A **severe winter storm** consists of one or more of the following elements: blinding wind-driven snow, extreme cold, icy roads, avalanches and downed trees and power lines. All winter storms can be dangerous and result in injuries, loss of life and property damage. The effects of a winter storm can impact a region for extended periods of time. Most deaths from winter storms are not a direct result of the storm itself, but rather a result of traffic accidents on icy roads, heart attacks while shoveling snow and hypothermia from prolonged exposure to cold.

Winter storms form just like any other storm at other times of the year. The right combination of ingredients is necessary for a winter storm to develop. The three basic components of a winter storm are cold air, lift and moisture. Below freezing temperatures in the clouds and near the ground are essential to make snow and/or ice. Lift is necessary to raise moist air to form clouds and cause precipitation. Lift occurs when warm air collides with cold air and is forced to rise over the cold dome. The boundary between a warm and cold air mass is called a front. Moisture must be present to form clouds and result in precipitation. Air moving across a lake or large body of water such as an ocean, is an excellent source of moisture.

Blizzard: A blizzard is a dangerous winter storm composed of a combination of blowing snow and wind that results in very low visibility. Heavy snowfalls and severe cold often accompany blizzards but are not required elements. At times, strong wind picks up ground snow and creates a ground blizzard. Blizzards contain winds over 35 mph and reduce visibility to ¼ miles or less for at least three hours.

Ice Storm: An ice storm results in the accumulation of at least .25” of ice on exposed surfaces. Ice storms create hazardous driving and walking conditions. Power outages and property damage can occur when tree branches and power lines snap under the weight of the accumulated ice.

Snow: Snowflakes are collections of ice crystals that cling to each other as they fall to the ground. Wintertime clouds will produce snow as long as the top layer of the storm is cold enough to create snowflakes. Precipitation will continue to fall as snow when the temperature remains at or below 0 degrees Celsius. The following is a summary of snow events:

- Snow Flurries: Light snow falling for a short duration and resulting in no accumulation or a light dusting
- Snow Shower: Snow falling at differing intensities for brief periods of time with some accumulation possible

- Snow Squall: A brief, intense snow shower, accompanied by strong and gusty winds with possible significant accumulation, defines a snow squall. This event usually occurs in the Great Lakes Region.
- Blowing Snow: Wind driven snow that reduces visibility and causes significant drifting. Blowing snow may occur when snow is falling and/or loose ground snow is picked up by the wind.

Sleet: Sleet occurs when snowflakes partially melt when falling through a shallow layer of warm air resulting in slushy drops that refreeze as they fall through a deep layer of freezing air above the surface and reach the ground as frozen rain drops that bounce on impact.

Freezing Rain/Ice Storm: Freezing rain occurs when snowflakes fall through a warmer layer of air and melt completely. When this rain falls through another thin layer of freezing air just above the surface of the ground, it doesn't have time to refreeze before hitting the ground. Because the rain is "supercooled," it instantly freezes upon contact with anything that is at or below 0 degrees C, and creates a glaze of ice on the ground, trees, power lines, or other objects. A significant accumulation of freezing rain lasting several hours, or more is called an ice storm.

2009 Ice Storm, Vine Grove. *Source: LTADD Archive*.

Facts

- Winter storms come in different sizes and are created by different combinations of atmospheric conditions and local geography but can occur anywhere in the United States.
- Winter storms usually occur between the end of October and the end of March in the U.S.
- Winter storms can last for days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures.
- The aftermath of a winter storm can impact a community or region for a day, weeks, or even months.

Effects

Snow and Ice Accumulation

Snow and ice accumulation on roads and surfaces can result in several adverse effects. Roads and sidewalks become dangerous and, at times, impassable resulting in vehicular accidents, falls, road closures, and delayed response time from emergency agencies. Snow and ice accumulation on trees, poles, power lines and roofs can result in falling debris that causes property damage and human injuries. People attempting to shovel snow can suffer injuries from their efforts as well. 70% of all weather-related injuries are the result of vehicle accidents. Black ice on roadways is another dangerous hazard, as is thawing and refreezing of snow and ice on surfaces.

Power Outages

Snow and ice events can result in area and regional power outages. Power outages can have a significant social and economic impact on an area and may last for an extended period. Fires and dangerous situations arise from the improper use of kerosene lamps and heaters, candles, and space heaters.

2009 Ice Storm, Nelson County. *Source: LTADD Archive*.

2009 Ice Storm, Vine Grove. *Source: LTADD Archive*.

Extreme Cold

Cold air outbreaks can send temperatures plummeting to single digits or lower and it is far more dangerous to be outside for prolonged periods of time. Some of the major threats are:

- Wind Chill: Wind chill is a measure of what the temperature outside *feels* like when wind speed is factored in. As wind speed increases, more heat can be removed from a body by the wind.
- Frostbite: Frostbite results from prolonged exposure to very cold air. Injury is caused by body tissue becoming frozen. Extremities such as fingers and toes are the most susceptible to frostbite.
- Hypothermia: Hypothermia is like frostbite and occurs when the body is exposed to prolonged cold. Hypothermia occurs when the body temperature drops below 95 degrees Fahrenheit.

Flooding
Depending on the amount of accumulation on the ground, flooding can result when ice and snow begin to melt as temperatures begin to rise.

Snow runoff flooding at White Mills (Hardin County) *Source: News-Enterprise, Neal Cardin Photo*.

II. Profile

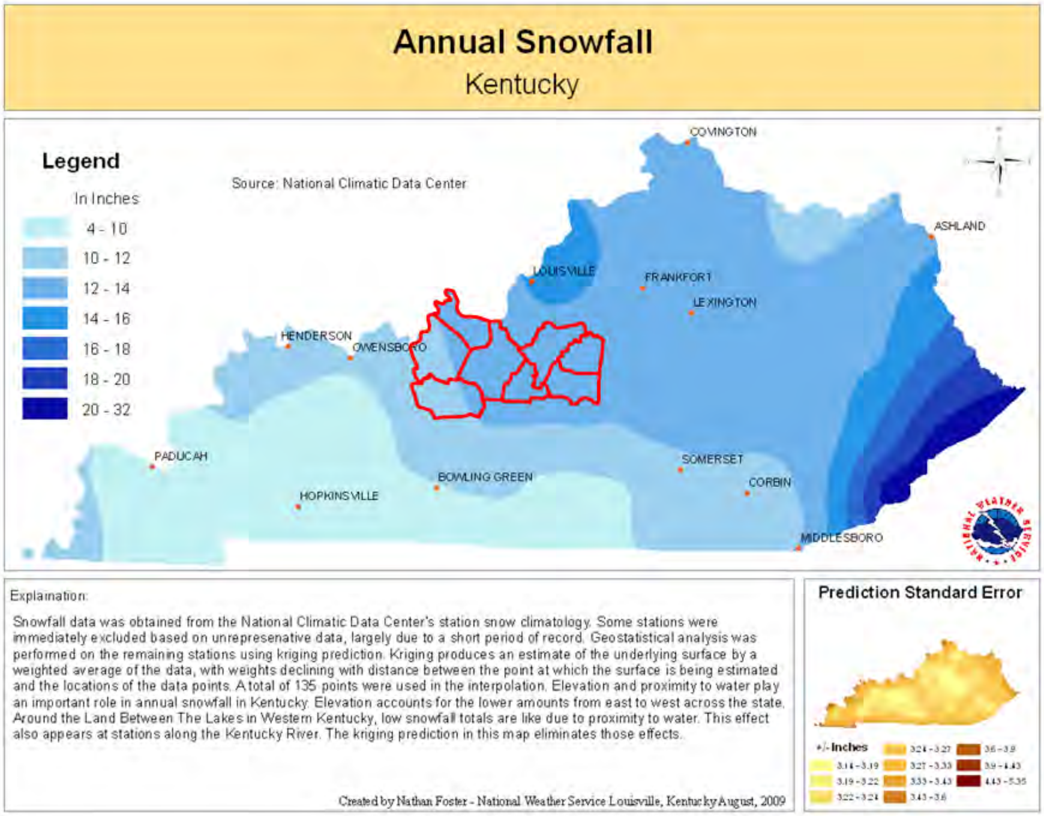
The Kentucky Mesonet data presented below shows minimum temperatures in the Lincoln Trail Region over the last 5 years. Cold temperatures and the severe weather conditions that often accompany them, make the region susceptible to severe winter storms.

Table 3.3.2.4.1

Minimum Temperature (F) Table for Lincoln Trail Region from 2016 to 2021 Source: Kentucky Mesonet							
Location	2016	2017	2018	2019	2020	2021	Average
Breckinridge	3.9	2.4	-1.9	3.3	11.5	1	3.37
Grayson	0.3	1.6	-1.6	2.9	10.7	0.3	2.37
Hardin	1.1	0.4	-2.7	4	9.5	-1.4	1.82
Larue	5.7	3.3	-2.2	5.8	9.5	4.7	4.47
Marion	2.4	-0.8	-5.9	1.9	10.5	4.9	2.17
Meade	0.3	1.4	-6.6	-2.1	8.2	-3.5	-0.39
Nelson	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Washington	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Average	2.28	1.38	-3.48	2.63	9.98	1	Five-year Average: 2.3

Note: Nelson County and Washington County lack data due to not having a Mesonet station within their borders.

Kentucky's geographic location makes it vulnerable to extreme winter weather. The State's proximity to the Gulf of Mexico, provides the moisture source for precipitation, while the region is far enough north to be influenced by polar air masses. Low-pressure systems can bring heavy snow to Kentucky that normally track eastward across the southern United States before tracking toward the northeast.



The Lincoln Trail Region is outlined in red above. Breckinridge and Grayson Counties fall predominately in the 10–12-inch range. Hardin, LaRue, Marion, Meade, Nelson, and Washington Counties fall entirely in the 12–14-inch range.

III. Analysis

The analysis for determining the threat of winter storms as a local hazard, involved identifying the conditions that produce winter storms, along with the types of severe winter weather that occur. Data was also tracked concerning the number of events that occur in the Region over time. Sources used to gather information include the National Weather Service, Kentucky Mesonet, the National Climatic Data Center, and Kentucky and County Emergency Management.

The Winter Storm of 2009 began on January 28, 2009, and left the Region devastated. Icy rain turned into solid ice that left the entire eight-county area without power, water, and phone service. Roads were closed and power lines and poles snapped. Many were without power for weeks and the cleanup effort ran well into the late summer months. The State declared a disaster and FEMA issued disaster declaration #1818. Mitigation money from this disaster enabled many local jurisdictions to purchase emergency backup generators, bury power lines, and replace or repair damaged bridges. The chart below illustrates the impact the local Counties reported because of the 2009 Ice Storm.

Table 3.3.2.4.2 – 2009 Winter Storm Impact

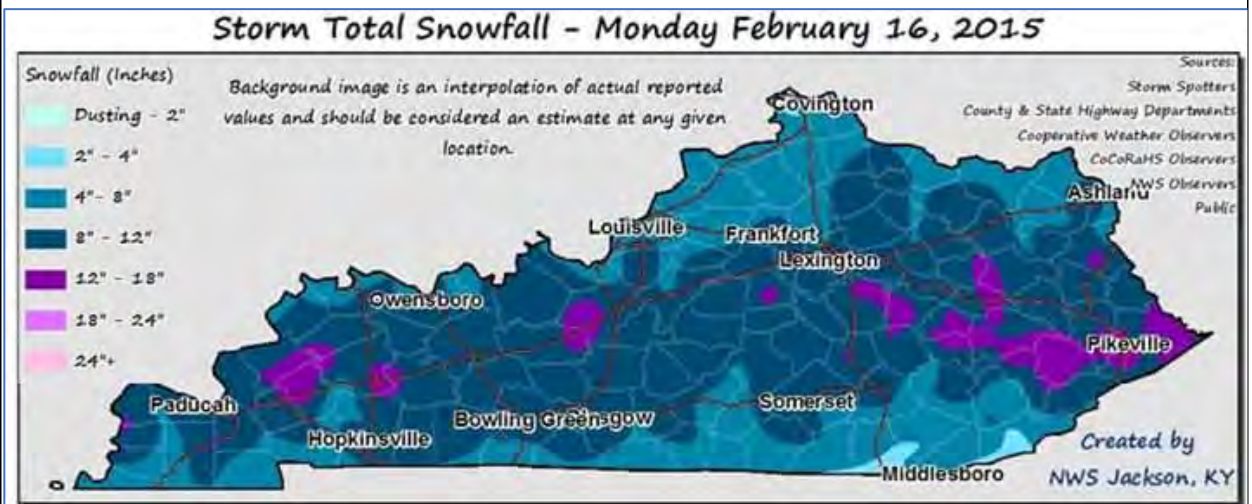
County	Days Without Power	Injuries Reported	Deaths Reported	Local Economic Impact*
Breckinridge	Up to 3 weeks	3	0	$1.2-1.5 million
Grayson	Up to 3 weeks	0	0	$2.2 million
Hardin	Up to 2 weeks	0	1	$1.2 million
LaRue	Up to 2 weeks	0	0	$600,000
Marion	Up to 1 week	2	0	$245,000
Meade	Up to 2 weeks	24	0	$1.2 million
Nelson	Up to 3 weeks	0	0	$260,000
Washington	Up to 3 weeks	1	0	$375,000
Totals		30	1	$7,280,000
** Reported by local government; Does not include private utility losses, or individuals' losses of property or wages*				

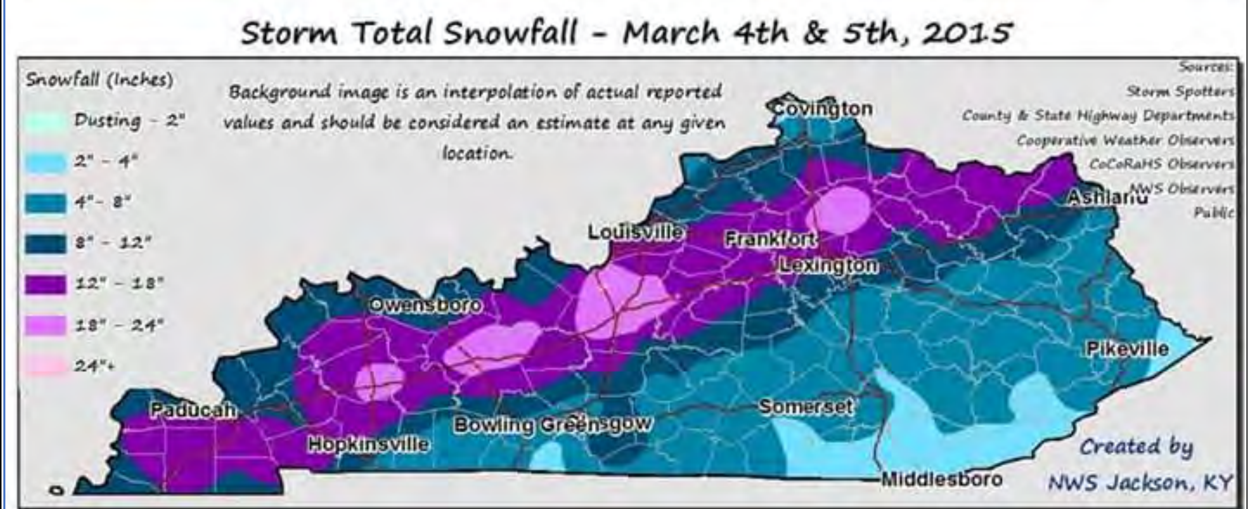
2015 Overturned snowplow in Meade County. *Source: Meade County Emergency Management.*

The winter of 2015 was another devastating one for this region. On February 21, Kentucky Mesonet data shows that between 18 and 19 inches of snow fell in the Hardin County area. Beginning on March 4, 2015, almost 30" of snow fell throughout the region and shut down I65 through Hardin County for over 14 hours. Thousands of cars, trucks and people were stranded on the interstate.

Table 3.3.2.4.3 - 2015 Winter Storm Snow Records

County	February 16, 2015 Snowfall Amount	March 4-5, 2015 Snowfall Amount	Record Place of March 4-5 Snow
Breckinridge	NA	20 inches	1st
Grayson	10 inches	16 inches	
Hardin	13.3 inches	23 inches	1st
LaRue	10 inches	18.3 inches	1st
Marion	11 inches	11 inches	2nd
Meade	8 inches	17 inches	1st
Nelson	13 inches	22 inches	2nd
Washington	12 inches	7.1 inches	
Source: National Weather Service – Louisville, KY			





The following tables detail the history of winter storms that have been recorded in a given county/jurisdiction within the Lincoln Trail region since 1993. The level of impact is evidenced through the number of lives lost or individual injuries reported, as well as the estimated cost of property and crop damage. This information is reported to the National Climate Data Center (NCDC) and subsequently rolled into the data of the National Centers for Environmental Information (NCEI). For the original plan, data was only available through 2003. The 2010 update provided data thru 30 June 2009. The 2015 update provided data from 1 July 2009 to 30 June2015. This update shows only individual events for the period 1 July 2015 through 14 May 2021. The summary tables show data for the entire periods covered by the various sources. Note that there are many variations in recording the locations of the events over time. In the past this was typically done at a county level. More recently, nearest place names have been used. Because of this, the records in the summation tables regarding the individual incorporated areas should not be considered all encompassing.

When reviewing the tables below, there may appear to be duplication of data across counties. This is due to the nature of a winter storm. One winter storm system most often affects multiple counties and is logged as one event but recorded in each county. Detailed individual county information is not always available; therefore, some data may not reflect the true impact at the county or city level.

Table 3.3.2.4.4 - County Specific Data – Winter Storms, *Source: NCEI*

Breckinridge Co.

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
BRECKINRIDGE (ZONE)	1/22/16	Heavy Snow	0	0	0	0
BRECKINRIDGE (ZONE)	2/14/16	Heavy Snow	0	0	0	0
BRECKINRIDGE (ZONE)	1/12/18	Winter Storm	0	0	0	0
BRECKINRIDGE (ZONE)	1/15/18	Winter Storm	0	0	0	0
BRECKINRIDGE (ZONE)	3/11/18	Winter Storm	0	0	0	0
BRECKINRIDGE (ZONE)	3/20/18	Winter Storm	0	0	0	0
BRECKINRIDGE (ZONE)	2/10/21	Ice Storm	0	0	0	0
BRECKINRIDGE (ZONE)	2/14/21	Winter Storm	0	0	0	0

Frozen trees in Breckinridge County in November 2018. *Source: Herald-News*

Grayson Co.

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
GRAYSON (ZONE)	1/20/16	Heavy Snow	0	0	0	0
GRAYSON (ZONE)	1/22/16	Heavy Snow	0	0	0	0
GRAYSON (ZONE)	2/14/16	Heavy Snow	0	0	0	0
GRAYSON (ZONE)	1/12/18	Winter Storm	0	0	0	0
GRAYSON (ZONE)	1/15/18	Winter Storm	0	0	0	0
GRAYSON (ZONE)	3/11/18	Winter Storm	0	0	0	0
GRAYSON (ZONE)	11/14/18	Ice Storm	0	0	0	0
GRAYSON (ZONE)	2/10/21	Winter Storm	0	0	0	0
GRAYSON (ZONE)	2/14/21	Winter Storm	0	0	0	0

Frozen scene in Grayson County during a January 2018 winter storm. *Source: K105 News*

Hardin Co.

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
HARDIN (ZONE)	1/22/16	Heavy Snow	0	0	0	0
HARDIN (ZONE)	2/14/16	Heavy Snow	0	0	0	0
HARDIN (ZONE)	1/12/18	Winter Storm	0	0	0	0
HARDIN (ZONE)	1/15/18	Winter Storm	0	0	0	0
HARDIN (ZONE)	3/11/18	Winter Storm	0	0	0	0
HARDIN (ZONE)	3/20/18	Winter Storm	0	0	0	0
HARDIN (ZONE)	11/14/18	Ice Storm	0	0	0	0
HARDIN (ZONE)	11/15/18	Ice Storm	0	0	0	0
HARDIN (ZONE)	11/15/18	Ice Storm	0	0	0	0
HARDIN (ZONE)	2/10/21	Ice Storm	1	1	0	0
HARDIN (ZONE)	2/14/21	Winter Storm	0	0	0	0

Downed powerline in Radcliff during a 2018 winter storm. *Source: The News-Enterprise*

LaRue Co.

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
LARUE (ZONE)	1/22/16	Heavy Snow	0	0	0	0
LARUE (ZONE)	2/14/16	Heavy Snow	0	0	0	0
LARUE (ZONE)	1/12/18	Winter Storm	0	0	0	0
LARUE (ZONE)	1/12/18	Winter Storm	0	0	0	0
LARUE (ZONE)	1/16/18	Winter Storm	0	0	0	0
LARUE (ZONE)	3/11/18	Winter Storm	0	0	0	0
LARUE (ZONE)	2/10/21	Ice Storm	0	0	0	0
LARUE (ZONE)	2/14/21	Winter Storm	0	0	0	0

Frozen roadway in LaRue County in January 2021. *Source: LaRue County Judge Executive, Blake Durrett*

Marion Co.

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
MARION (ZONE)	1/22/16	Heavy Snow	0	0	0	0
MARION (ZONE)	2/14/16	Heavy Snow	0	0	0	0
MARION (ZONE)	1/12/18	Winter Storm	0	0	0	0
MARION (ZONE)	1/16/18	Winter Storm	0	0	0	0
MARION (ZONE)	3/11/18	Winter Storm	0	0	0	0
MARION (ZONE)	2/10/21	Ice Storm	0	0	0	0
MARION (ZONE)	2/14/21	Winter Storm	0	0	0	0


Photo of snow-covered downtown Lebanon after a series of winter activity in February 2021. *Source: The Lebanon Enterprise.*

Meade Co.

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
MEADE (ZONE)	1/22/16	Heavy Snow	0	0	0	0
MEADE (ZONE)	2/14/16	Heavy Snow	0	0	0	0
MEADE (ZONE)	1/12/18	Winter Storm	0	0	0	0
MEADE (ZONE)	1/15/18	Winter Storm	0	0	0	0
MEADE (ZONE)	3/11/18	Winter Storm	0	0	0	0
MEADE (ZONE)	3/20/18	Winter Storm	0	0	0	0
MEADE (ZONE)	11/14/18	Ice Storm	0	0	0	0
MEADE (ZONE)	2/10/21	Ice Storm	0	0	0	0
MEADE (ZONE)	2/14/21	Winter Storm	0	0	0	0

School bus covered in ice in Meade County after the February 2021 Ice Storm. *Source: WDRB*

Nelson Co.

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
NELSON (ZONE)	1/22/16	Heavy Snow	0	0	0	0
NELSON (ZONE)	2/14/16	Heavy Snow	0	0	0	0
NELSON (ZONE)	1/12/18	Winter Storm	0	0	0	0
NELSON (ZONE)	1/16/18	Winter Storm	0	0	0	0
NELSON (ZONE)	3/11/18	Winter Storm	0	0	0	0
NELSON (ZONE)	3/20/18	Winter Storm	0	0	0	0
NELSON (ZONE)	11/14/18	Ice Storm	0	0	0	0
NELSON (ZONE)	2/10/21	Ice Storm	0	0	0	0
NELSON (ZONE)	2/14/21	Winter Storm	0	0	0	0

Snow- and ice-covered scene in Bardstown, Kentucky during the February 2021 winter weather. *Source: WDRB*

Washington Co.

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
WASHINGTON (ZONE)	1/22/16	Heavy Snow	0	0	0	0
WASHINGTON (ZONE)	2/14/16	Heavy Snow	0	0	0	0
WASHINGTON (ZONE)	1/12/18	Winter Storm	0	0	0	0
WASHINGTON (ZONE)	1/16/18	Winter Storm	0	0	0	0
WASHINGTON (ZONE)	3/11/18	Winter Storm	0	0	0	0
WASHINGTON (ZONE)	2/10/21	Ice Storm	0	0	0	0
WASHINGTON (ZONE)	2/14/21	Winter Storm	0	0	0	0

Vehicle accident involving an ice-covered bridge in Washington County in December 2020. *Source: The Springfield Sun.*

Table 3.3.2.4.5 - Summary of Winter Storm Data, Costs

SNOW & ICE	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDG	$1,411,082	46	61.5	0.31	1.83	$22,944	$30,676	0.01	0.01	0.03	0.04
Cloverport	$0	0									
Hardinsburg	$0	0									
Irvington	$0	0									
GRAYSON	$1,981,398	49	61.5	0.29	3.41	$32,218	$40,437	0.00	0.01	0.06	0.07
Caneyville	$0	0									
Clarkson	$0	0									
Leitchfield	$0	0									
HARDIN	$2,792,155	54	61.5	0.29	3.47	$45,401	$51,707	0.00	0.01	0.06	0.06
Elizabethtown	$0	0									
Radcliff	$0	0									
Sonora	$0	0									
Upton	$0	0									
Vine Grove	$0	0									
West Point	$0	0									
LARUE	$1,050,662	44	61.5	0.29	3.36	$17,084	$23,879	0.00	0.01	0.05	0.08
Hodgenville	$0	0									
MARION	$2,681,555	37	61.5	0.29	3.36	$43,603	$72,474	0.00	0.01	0.05	0.09
Bradfordsville	$0	0									
Lebanon	$0	0									
Loretto	$0	0									
Raywick	$0	0									
MEADE	$1,420,840	47	61.5	0.29	1.81	$23,103	$30,231	0.00	0.01	0.03	0.04
Brandenburg	$0	0									
Ekron	$0	0									
Muldraugh	$0	0									
NELSON	$2,307,155	48	61.5	1.29	3.47	$37,515	$48,066	0.02	0.03	0.06	0.07
Bardstown	$0	0									
Bloomfield	$0	0									
Fairfield	$0	0									
New Haven	$0	0									
WASHINGTON	$2,697,743	47	61.5	0.37	3.48	$43,866	$57,399	0.01	0.01	0.06	0.07
Mackville	$0	0									
Springfield	$0	0									
Willisburg	$0	0									
LTADD	$16,342,589	372	61.5	3.42	24.19	$265,733	$43,932	0.06	0.01	0.39	0.07

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2015.

Table 3.3.2.4.6 - Summary of Winter Storm Data, Events

SNOW & ICE	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	46	61.5	20	32	41	1.34	74.80%	2	1.6	0.82
Cloverport	0									
Hardinsburg	0									
Irvington	0									
GRAYSON	49	61.5	22	28	45	1.26	79.67%	2.2	1.4	0.9
Caneyville	0									
Clarkson	0									
Leitchfield	0									
HARDIN	54	61.5	26	32	50	1.14	87.80%	2.6	1.6	1
Elizabethtown	0									
Radcliff	0									
Sonora	0									
Upton	0									
Vine Grove	0									
West Point	0									
LARUE	44	61.5	18	23	40	1.40	71.54%	1.8	1.15	0.8
Hodgenville	0									
MARION	37	61.5	12	16	33	1.66	60.16%	1.2	0.8	0.66
Bradfordsville	0									
Lebanon	0									
Loretto	0									
Raywick	0									
MEADE	47	61.5	22	26	43	1.31	76.42%	2.2	1.3	0.86
Brandenburg	0									
Ekron	0									
Muldraugh	0									
NELSON	48	61.5	20	25	44	1.28	78.05%	2	1.25	0.88
Bardstown	0									
Bloomfield	0									
Fairfield	0									
New Haven	0									
WASHINGTON	47	61.5	15	19	39	1.31	76.42%	1.5	0.95	0.78
Mackville	0									
Springfield	0									
Willisburg	0									
LTADD	372	61.5	155	201	335	0.17	604.88%	15.5	10.05	6.7

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

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Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2015.

3.3.2.5 Lightning

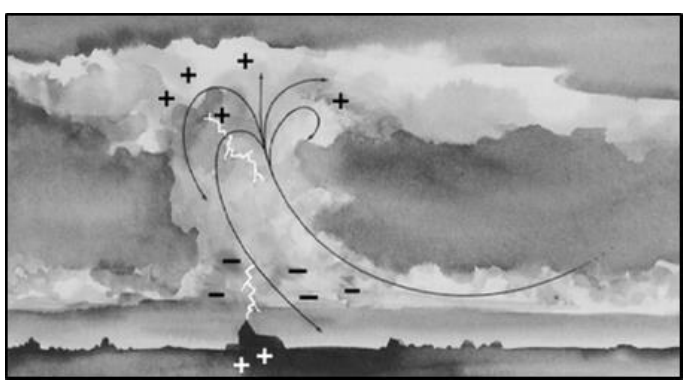
I. Background

Definition: Lightning is a sudden electrostatic discharge during an electrical storm between electrically charged regions of a cloud, between that cloud and another cloud, or between a cloud and the ground. This discharge temporarily equalizes the charged regions in the atmosphere and is called a strike if it hits the ground. Although lightning is always accompanied by thunder, distant lightning may be seen, but be too far away to be heard.

Formation of Lightning

Lightning is usually produced by cumulonimbus clouds, which have bases that are typically 0.6 to 1.25 miles above the ground and tops up to 9.3 miles in height. Lightning originates about 15,000 to 25,000 feet above sea level when raindrops are lifted upward until some of them convert to ice. Cloud to ground lightning begins in this mixed water and ice region. As these particles collide, they create an electric charge and these charges accumulate, filling up the entire cloud. Positive charges or protons form at the top of the cloud while the negative charges or electrons, form at the bottom of the cloud. Because opposites attract, this activity causes a positive charge to build up on the ground beneath the cloud. The electric charge on the ground builds up around anything that sticks up, such as mountains, people, or a single tree. The charge coming up from these points eventually connects with a charge coming down from the clouds and creates a lightning strike. As a charge moves downward from a cloud, it does so in 50-yard increments called step leaders. It keeps moving toward the ground in these steps and produces a channel along which the charge is deposited until it encounters something on the ground that is a good connection. Once a conductive channel form bridges the ionized air between the negative charges in the cloud and the positive charges on ground, a massive electrical discharge follows, and neutralization of the positive surface

Lightning strike in Brandenburg, 2008. *Source: Meade County Emergency Management.*



Source: National Oceanic and Atmospheric Administration; National Lightning Safety Institute charges occurs first. Then an enormous current of positive charges races up the channel toward the thundercloud. This is the “return stroke” and is the most luminous and noticeable part of the lightning discharge.

Types of Lightning

According to the National Oceanic and Atmospheric Administration (NOAA), there are three primary types of lightning. The type of lightning is determined by what is at the “ends” of a flash channel. Intracloud (IC) occurs within a single thundercloud; cloud-to-cloud (CC) starts and ends between two different “functional” thunderclouds; and cloud to ground (CG) lightning primarily starts in a thundercloud and terminates on the Earth’s surface. Occasionally, it may reverse direction, and run from the ground to a cloud. There are variations of each type of lightning such as “positive” versus “negative” CG flashes. Each has distinct characteristics that can be measured.

IC lightning is the most frequently occurring type of lightning. This kind of lightning may be observed at great distances at night and is often referred to as “heat lightning.”

CC lightning is sometimes referred to as “Anvil Crawler” due to its characteristic of originating from beneath or within the anvil and scrambling through the upper layers of the thunderstorm usually producing multiple branches of dramatic strokes.

CG lightning can occur with both positive and negative polarity. “Negative” lightning is the most common type of CG lightning and originates in the lower negatively charged portion of a thundercloud. Positive lightning originates in the positively charged anvil of the cumulonimbus and may travel several miles from the anvil of the thunderstorm horizontally before veering towards the ground. A positive lightning strike can occur anywhere within several miles of the thunderstorm anvil. Positive lightning makes up less than 5% of all lightning strikes. Positive lightning bolts are considerably hotter and longer than negative lightning. Ground to Cloud lightning is a type of CG lightning that is artificially triggered when tall, positively charged structures on the ground, such as towers on mountains, have been inductively charged by a negative cloud layer above, and is the origin of the lightning strike.

Lightning Dangers

Cloud to ground lightning can damage or destroy property and inanimate objects and can kill or injure people and animals. According to NOAA, lightning strikes the United States about 25 million times a year and has killed an average of 49 people annually. From 2015 to 2019 there have been 121 lightning fatalities in the United States. Almost all lightning occurs in summer but can strike at any time of the year. The following safety precautions are recommended:

- If you see lightning or hear thunder, seek safe shelter immediately, preferably in a building with plumbing and electricity or a metal-topped vehicle with the windows closed.
- Stay off corded phones.
- Avoid Plumbing, electrical equipment and cords, bodies of water or standing water.
- Stay away from windows and doors and stay off porches.
- Do not lie on concrete floors or lean against concrete walls.

- Stay away from trees.
- Stay away from groups of people in the open.
- Rubber soled shoes will not give a person any meaningful protection from lightning.
- A lightning flash is no more than one inch wide.

Vulnerability

Lightning is a hazard that should be taken very seriously. Knowledge about the effects of lightning will help save lives and prevent injuries from lightning. In addition to death and injuries to people and animals alike, lightning causes fires and property damage.

Fatalities and Injuries

In addition to fatalities due to lightning strikes, many injuries occur as well. The chart below illustrates U.S. lightning fatalities between 2010 and May of 2021.

Table 3.3.2.5.1 - U.S. Lightning Fatalities from 2010 to May of 2020			
Year	Male	Female	Total
2010	22	7	29
2011	19	7	26
2012	25	3	28
2013	17	6	23
2014	21	5	26
2015	17	11	28
2016	31	9	40
2017	15	1	16
2018	17	4	21
2019	15	5	20
2020	13	4	17
Source: NOAA and National Weather Service			

Injuries that occur from lightning strikes can range from cardiac arrest to personality changes, and include severe burns, brain damage, memory loss and other long-term effects. It should be noted that deaths and injuries to animals also occurs. The information below compares human fatalities to injury numbers between 1995 and 2013.

Table 3.3.2.5.2

Number of Deaths and Injuries Due to Lightning in the U.S. from 2010 to 2019		
Year	Deaths	Injuries
2010	29	182
2011	26	187
2012	28	139
2013	23	145
2014	26	154
2015	27	130
2016	38	120
2017	16	86
2018	20	82
2019	20	100
TOTAL	253	1325
Source: NOAA		

Fires and Damage

Fires and property damage result from lightning strikes every year. According to the Insurance Information Institute (III), lightning strikes cost homeowners in the United States about $920 million in 2019 alone, up 1.2% from 2018. The Insurance Information Institute estimates the average lightning claim in 2019 at $11,971, up 2.6% from 2018. The U.S. Department of Commerce and NOAA attributed $41.15 million in property damage as the result of lightning in 2019 and $0.01 million in crop damage, for a total of $41.16 million dollars in damages.

In addition to property damage, lightning starts fires. According to the National Fire Protection Association (NFPA), during the period from 2007 to 2011, U.S. local fire departments responded to an estimated average of 22,600 fires per year because of lightning. Fires started by lightning peak during summer months, are more common in the months of June through August, and usually occur later in the afternoon and early evening. In 2014, home and non-home structure fires started by lightning lead to property damage of $473 million dollars.

In the years 2008 – 2012, federal and state wildland firefighting agencies reported an average of 9,000 wildland fires started by lightning, to the National Interagency Fire Center. These fires tended to be larger than fires started by human causes. The average fire caused by lightning burned 402 acres, nine times the average area of 45 acres seen in fires caused by human action. Over the ten-year period from 2003 to 2012, forty-two U.S. firefighters were killed as the result of fighting fires caused by lightning strikes. According to data from the U.S. Forest Service, 44% of wildfires across the western United States was caused by lightning and wildfires stemming from lightning strikes were responsible for 71% of areas burned between 1992 and 2015.

The table below shows homeowners' insurance claims and payouts for lightning losses between 2017 and 2019.

Table 3.3.2.5.3

Homeowners Insurance Claims and Payouts for Lightning Losses from 2017 to 2019					
	2017	2018	2019	Percent Change 2018-2019	Percent Change 2017-2019
Number of Claims	85,020	77,898	76,860	-1.30%	-9.60%
Insured Losses ($ Millions)	$916.60	$908.90	$920.10	1.20%	0.38%
Average Cost Per Claim	$10,781	$11,668	$11,971	2.60%	11.00%
Source: Insurance Information Institute, State Farm®					

Lightning Facts:

- Lightning is a giant discharge of electricity accompanied by a brilliant flash of light and a loud crack of thunder.
- A spark of lightning can reach over 5 miles in length and raise the air temperature by as much as 50,000 degrees Fahrenheit.
- A lightning strike contains a hundred million electrical volts.
- The immense heat and other energy given off during a lightning stroke has been found to convert elements in compounds that are found in organisms and may have played a part in the evolution of living things.
- The odds of being struck by lightning in the U.S. in any given year is 1 in 700,00 while the odds of being struck in your lifetime is 1 in 3,000.
- Positive lightning is especially dangerous because it can strike away from the rain core, either ahead of or behind the thunderstorm and can strike as far as 5 to 10 miles from the storm.
- Victims of a lightning strike do not retain any charge and are not "electrified." It is safe to help them.
- An umbrella can increase your chance of being struck by lightning.

- Lightning often strikes the same place repeatedly if it is a tall, isolated object.
- Most lightning victims are in open areas or near a tree.
- Lightning can heat its path through the air to a temperature that is five times hotter than the surface of the sun.
- All thunderstorms contain lightning.
- Volcanic material thrust high into the atmosphere can trigger lightning.
- Lightning also occurs in extremely intense forest fires, surface nuclear detonations, heavy snowstorms, and in large hurricanes.

III. Analysis

To analyze lightning as a threat to the Lincoln Trail Region, the generalized threat of lightning was identified by reviewing historical data.

The following tables outline the occurrences of lightning that have been recorded in a given county/jurisdiction within the Lincoln Trail region since 1960. The level of impact is evidenced through the number of lives lost or individual injuries recorded, as well as the estimated cost of property and crop damage based on information reported to the National Climate Data Center which was subsequently rolled into the National Centers for Environmental Information (NCEI). For the original plan, data was only available through 2003. The 2010 update provided data through 30 June 2009. The 2015 update provided data from 1 July 2009 to 30 June 2015. This update shows only individual events for the period 1 July 2015 through 14 May 2021. The summary tables show data for the entire period as reported by various sources. Note that there are many variations in recording the locations of the events over time. In the past this was typically done at a county level. More recently, nearest place names have been used. Because of this, the records in the summation tables that pertain to individual incorporated areas, should not be considered all encompassing.

Table 3.3.2.5.4 - County Specific Data – Lightning, *Source: NCEI*

No Lightning events were recorded from 1 July 2015 to 15 May 2021 for Hardin, LaRue, Meade or Washington Counties.

Breckinridge Co.

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
MC Daniels	8/31/18	0	0	200000	0

Grayson Co.

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
Grayson	6/26/16	0	2	0	0

Local Story: Grayson County EMS workers struck by lightning outside ambulance in June of 2016. *Source WLKY*

Marion Co.

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
St Joseph	8/7/18	0	0	250000	0

Extension office in Marion County damaged by a lightning strike. *Source: The Lebanon Enterprise.*

Nelson Co.

Location	Date	Deaths Direct	Injuries Direct	Property Damage	Crop Damage
Bardstown	5/11/16	0	0	25000	0

House fire in Nelson County caused by a June 24th lightning strike. *Source: The Kentucky Standard*

Table 3.3.2.5.5 - Summary of Lightning Data, Costs

LIGHTNING	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDGE	$489,925	26	60.5	0.04	0.36	$8,098	$18,843	0.00	0.00	0.01	0.01
Cloverport											
Hardinsburg											
Irvington											
GRAYSON	$423,574	32	60.5	0.04	4.36	$7,001	$13,237	0.00	0.00	0.07	0.14
Caneyville											
Clarkson											
Leitchfield	$51,500	2	60.5	0	1	$851	$25,750	0.00	0.00	0.02	0.50
HARDIN	$869,962	34	60.5	1.11	2.36	$14,380	$25,587	0.02	0.03	0.04	0.07
Elizabethtown											
Radcliff	$100,000	1	60.5	0	0	$1,653	$100,000	0.00	0.00	0.00	0.00
Sonora											
Upton											
Vine Grove											
West Point											
LARUE	$61,022	33	60.5	0	0	$1,009	$1,849	0.00	0.00	0.00	0.00
Hodgenville											
MARION	$404,253	36	61.5	0.14	0.39	$6,573	$11,229	0.00	0.00	0.01	0.01
Bradfordsville											
Lebanon											
Loretto											
Raywick											
MEADE	$129,715	28	60.5	0	0	$2,144	$4,633	0.00	0.00	0.00	0.00
Brandenburg											
Ekron											
Muldraugh											
NELSON	$932,717	42	61.5	2.12	2.34	$15,166	$22,208	0.03	0.05	0.04	0.06
Bardstown	$55,000	4	61.5	0	1	$894	$13,750	0.00	0.00	0.02	0.25
Bloomfield											
Fairfield											
New Haven	$525,000	2	61.5	2	1	$8,537	$262,500	0.03	1.00	0.02	0.50
WASHINGTON	$223,179	36	61.5	0.12	0.34	$3,629	$6,199	0.00	0.00	0.01	0.01
Mackville											
Springfield											
Willisburg											
LTADD	$4,265,847	276	60.5	5.57	13.15	$70,510	$15,456	0.09	0.02	0.22	0.05

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2015.

Table 3.3.2.5.6 - Summary of Lightning Data, Events

LIGHTNING	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	26	60.5	1	1	9	2.33	42.98%	0.1	0.05	0.18
Cloverport										
Hardinsburg										
Irvington										
GRAYSON	32	60.5	2	2	12	1.89	52.89%	0.2	0.1	0.24
Caneyville										
Clarkson										
Leitchfield	2	60.5	1	1	2	30.25	3.31%	0.1	0.05	0.04
HARDIN	34	60.5	2	3	13	1.78	56.20%	0.2	0.15	0.26
Elizabethtown										
Radcliff	1	60.5	0	1	1	60.50	1.65%	0	0.05	0.02
Sonora										
Upton										
Vine Grove										
West Point										
LARUE	33	60.5	0	0	8	1.83	54.55%	0	0	0.16
Hodgenville										
MARION	36	61.5	1	1	8	1.71	58.54%	0.1	0.05	0.16
Bradfordsville										
Lebanon										
Loretto										
Raywick										
MEADE	28	60.5	0	0	11	2.16	46.28%	0	0	0.22
Brandenburg										
Ekron										
Muldraugh										
NELSON	42	61.5	2	6	16	1.46	68.29%	0.2	0.3	0.32
Bardstown	4	61.5	2	4	4	15.38	6.50%	0.2	0.2	0.08
Bloomfield										
Fairfield										
New Haven	2	61.5	0	1	2	30.75	3.25%	0	0.05	0.04
WASHINGTON	36	61.5	0	0	9	1.71	58.54%	0	0	0.18
Mackville										
Springfield										
Willisburg										
LTADD	267	61.5	8	13	86	0.23	434.15%	0.8	0.65	1.72

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

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Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2015.

3.3.2.6 Hail

I. Background

According to Merriam Webster, hailstones are layered and can be irregular and clumped together. Hail is composed of transparent ice or alternating layers of transparent and translucent ice at least 1 millimeter (0.039 inch) thick. This ice is deposited on the hailstone as it travels through the cloud. The ice is suspended aloft by air and strong upward motion until its weight is too much to be supported by the updraft and it falls to the ground. Although varied in size, the diameter of hail in the U.S. averages between 2.5cm (1 inch) and golf ball-sized (1.75 inches).

Hail stones in Meade Co. April 2015. *Source: Meade County Emergency Management. Photo Geraldine Shanahan.*

Hailstones larger than 2 cm (0.80 inch) are considered large enough to cause damage. In the United States, the National Weather Service will issue a severe thunderstorm warning if it predicts hail that is 2.5 cm (1 inch) or greater in diameter.

Any thunderstorm that produces hail that reaches the ground is known as a hailstorm. Hailstones can grow to 15 cm (6 inches) and weight more than 0.5 kilograms (1.1 pounds).

Formation

The National Center for Atmospheric Research states that hail is possible within most thunderstorms because it is produced by cumulonimbi and can occur within 2 nautical miles of the parent storm. Hail formation requires an environment of strong, upward air motion within the parent thunderstorm, high liquid content, great vertical extent, large water droplets, and lowered heights of the freezing level. Although hail and sleet are often confused for one another, and both are forms of solid precipitation, sleet falls generally in cold weather while hail growth is greatly inhibited at cold temperatures.

Facts

- The speed at which hail is falling when it hits the ground is determined by the size of the hailstone, the friction of the air it is falling through, the motion of the wind it is falling through, collisions with raindrops or other hailstones, and melting that occurs as the stones fall through warmer air.
- Speeds can range from 20 mph to 110 mph.
- The heaviest hailstone weighed 2.25 pounds and fell in the Gopalganj District of Bangladesh on April 14, 1986,
- The hailstone with the largest diameter officially measured 8 inches and fell in Vivian, South Dakota on July 23, 2010.
- The hailstone with the largest circumference officially measured 18.75 inches and fell in Aurora, Nebraska on June 22, 2003.
- Hailstones can accumulate, and depths of up to a meter have been reported.

- On July 29, 2010, a foot of hail accumulation was reported in Boulder, Colorado.

Source: National Weather Service and National Severe Storms Laboratory

Hazards/Vulnerability

According to the Federal Aviation Association, hail is one of the most significant thunderstorm hazards to aircraft. Hailstones that exceed .5 inches in diameter can cause serious damage to an aircraft within seconds. Accumulations of hailstones on the ground can be a major hazard to aircraft trying to land.

Table 3.3.2.6.1 - Hail Conversion Chart

Diameter of Hailstones (inches)	Description
0.50	Marble
0.70	Dime
0.75	Penny
0.88	Nickel
1.00	Quarter
1.25	Half Dollar
1.50	Walnut
1.75	Golf Ball
2.00	Hen Egg
2.50	Tennis Ball
2.75	Baseball
3.00	Tea Cup
4.00	Grapefruit
4.50	Softball

Accumulations of hailstones on the ground can also cause flooding by blocking drains, and hail carried by floodwaters can turn into a snow-like slush that accumulates at lower elevations. Accumulation of hailstones on streets and highways can cause traffic accidents.

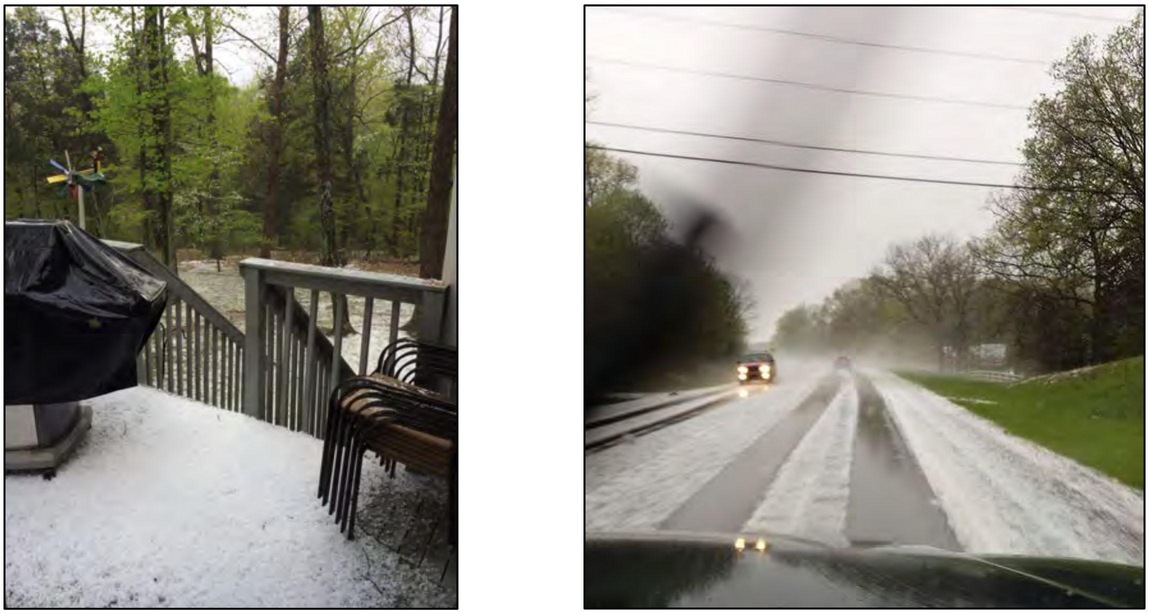
Hail can cause damage to automobiles, aircraft, skylights, glass, livestock, and most commonly, agricultural crops. Wheat, corn, soybeans, and tobacco crops are the most sensitive crops to hail damage. Hailstorms have historically been the cause of costly and deadly events throughout history.

TORRO Hailstorm Intensity Scale (www.torro.org.uk/hscale.php)

	Intensity Category	Typical Diameter (mm)	
H0	Hard Hail	5	No Damage
H1	Potentially Damaging	5 - 15	Slight general damage to plants, crops
H2	Significant	10 - 20	Significant damage to fruit, crops, vegetation
H3	Severe	20 - 30	Severe damage to fruit and crops, damage to glass & plastic structures, paint & wood scored
H4	Severe	25 - 40	Widespread glass damage, vehicle bodywork damage
H5	Destructive	30 - 50	Wholesale destruction of glass, tiled roof damage, significant risk of injury
H6	Destructive	40 - 60	Grounded aircraft bodywork dented, brick walls pitted
H7	Destructive	50 - 75	Severe roof damage, risk of injuries
H8	Destructive	60 - 90	Severe damage to aircraft bodywork (severest recorded in British Isles)
H9	Super Hailstorm	75 - 100	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open.
H10	Super Hailstorm	> 100	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open.

II. Analysis

To analyze Hail as a threat to the Lincoln Trail Region the generalized threat of hail was identified and historical data on it was researched. The sources of this information are the National Weather Service and the National Climatic Data Center. As the sub-committees reviewed data gathered from these two sources it became very clear that additional sources needed to be consulted. Property and crop damage was not included in the following tables. Insurance estimates from several local providers, indicated a drastically different scenario. For example, in 2002, straight-line winds hurled golf ball and larger size Hail causing an estimated $109M in damages to residential, commercial and city owned properties across the Lincoln Trail Region. Trees were reported down throughout the region. In Marion County, the hardest hit of the eight counties, an estimated two thirds of the county was affected. Thirty windows in the Marion County courthouse were damaged. One local insurance provider reported over 2000 auto and 1000 property claims due to hail.



Hail stones in Meade County, February, and March 2015. *Source: Meade County Emergency Management.*

Other local events of note:

Grayson, Hardin & LaRue Counties

4/26/2011 – National Weather Service reported hail of 2 inches or more. Damage was reported to buildings at Hardin County Fairgrounds. Storms also included confirmed tornados, wind, and flooding.

LaRue County

5/19/2013 - Sheriff's Department Reported: "The ground in some areas in LaRue County was white from the amount of hail that fell Sunday afternoon…the hail reached golf ball size."

Nelson County

4/5/2017 - Hail covered the ground with inches of depth covering most of the western & central part of Nelson County with a sudden downburst to stop every person, machine, or vehicle in motion for twenty minutes during the tantalizing storm.

Summary of Hail in the Lincoln Trail Region

Hailstorms do not adhere to geographic boundaries and have affected each of the eight counties in the Lincoln Trail Region. Many of these storms contained golf ball size or larger hail. The average hailstorm in the Lincoln Trail Region causes damage estimated to be $207,186 per event. The following tables summarize the history of hail events that have been recorded in a given county/jurisdiction within the Lincoln Trail Region since 1950. The impact of these storms is shown by the number of lives lost, individual injuries reported, and estimated economic losses. The level of impact is evidenced through the number of lives lost, individual injuries reported, and the estimated property and crop damage costs. This information was reported to the National Climate Data Center and subsequently rolled into data from the National Centers for Environmental Information (NCEI). Data for the original Regional Plan was only available through 2003. The 2010 update provided data through June 30, 2009. The 2015 update provided data from 1 July 2009 to 30 June 2015. This update shows only individual events for the period 1 July 2015 through 14 May 2021. The summary tables illustrate data for entire periods covered by the different sources. Note that there are many variations in recording the locations of the events over time. In the past, data was not recorded at a county level. More recently, scientists have used nearest place names. Because of this, data in the summation tables pertaining to individual incorporated areas should not be considered all encompassing.

Table 3.3.2.6.2 - County Specific Data – Hail, ***Source: NCEI***

BRECKINRIDGE

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROP. DAMAGE	CROP DAMAGE
CUSTER	5/1/16	0.75	0	0	0	0
HARDINSBURG ARPT	5/10/16	0.88	0	0	0	0
HARDINSBURG ARPT	5/10/16	1	0	0	0	0
HARDINSBURG ARPT	5/10/16	1	0	0	0	0
HARDINSBURG ARPT	4/5/17	0.88	0	0	0	0
HARNED	4/5/17	1.5	0	0	0	0
DUGAN	4/5/17	0.88	0	0	0	0
HARDINSBURG	4/5/17	0.75	0	0	0	0
MC DANIELS	7/20/18	1	0	0	0	0

GRAYSON

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROP. DAMAGE	CROP DAMAGE
SHORT CREEK	12/23/15	0.88	0	0	0	0
SPRING LICK	5/26/16	1.5	0	0	0	0
CLARKSON	7/2/19	1	0	0	0	0

HARDIN

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROP. DAMAGE	CROP DAMAGE
VERTREES	5/10/16	0.88	0	0	0	0
PERRYVILLE	5/10/16	1	0	0	0	0
NORTH FOUR CORNERS	5/10/16	0.88	0	0	0	0
LONG VIEW	5/10/16	0.75	0	0	0	0
VERTREES	5/10/16	1	0	0	0	0
ROGERSVILLE	5/10/16	0.75	0	0	0	0
CECILIA	5/10/16	0.88	0	0	0	0
KRAFT	5/11/16	0.75	0	0	0	0
RINEYVILLE	3/27/17	1	0	0	0	0
ROGERSVILLE	3/27/17	0.88	0	0	0	0
LONG VIEW	3/27/17	1	0	0	0	0
HOWE VLY	3/27/17	1	0	0	0	0
GAITHERS	3/30/17	0.88	0	0	0	0
MARTIN BOX	3/30/17	1	0	0	0	0
MARTIN BOX	4/5/17	0.88	0	0	0	0
ELIZABETH TOWN	4/5/17	1	0	0	0	0
VINE GROVE	4/3/18	1	0	0	0	0
VINE GROVE	4/3/18	1.75	0	0	0	0

LARUE

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROP. DAMAGE	CROP DAMAGE
HODGENVILLE	12/23/15	0.75	0	0	0	0
ATTILLA	5/10/16	1	0	0	0	0
UPTON	5/10/16	0.75	0	0	0	0
UPTON	5/26/16	0.88	0	0	0	0
HODGENVILLE	7/5/20	1	0	0	0	0
HODGENVILLE	7/5/20	1	0	0	0	0
TONIEVILLE	7/5/20	1	0	0	0	0

MARION

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROP. DAMAGE	CROP DAMAGE
RAYWICK	7/13/15	1.25	0	0	0	0
JESSIETOWN	5/10/16	1.25	0	0	0	0
GRAVEL SWITCH	10/20/16	1	0	0	0	0
LORETTO	7/20/18	1.25	0	0	0	0
LEBANON	7/20/18	1	0	0	0	0
PENICKS	7/20/18	1	0	0	0	0

MEADE

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROP. DAMAGE	CROP DAMAGE
BATTLETOWN	6/26/15	0.75	0	0	0	0
RHODELIA	12/23/15	1.75	0	0	0	0
BATTLETOWN	12/23/15	0.75	0	0	0	0
EKRON	5/10/16	1.75	0	0	0	0
WOLF CREEK	4/5/17	0.88	0	0	0	0
CONCORDIA	4/8/20	1	0	0	0	0
FAIRFIELD	12/23/15	0.75	0	0	0	0
BOSTON	5/10/16	1	0	0	0	0
COXS CREEK	3/27/17	1.5	0	0	0	0

NELSON

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROP. DAMAGE	CROP DAMAGE
FAIRFIELD	3/27/17	0.75	0	0	0	0
COXS CREEK	3/27/17	1	0	0	0	0
BOSTON	4/5/17	1.75	0	0	0	0
BOSTON	4/5/17	1	0	0	0	0
BARDSTOWN	4/5/17	1.75	0	0	0	0
FAIRFIELD	4/5/17	1	0	0	0	0
BLOOMFIELD	4/5/17	0.88	0	0	0	0
FAIRFIELD	4/5/17	1	0	0	0	0
HOWARDSTOWN	4/3/18	1.75	0	0	0	0
LENORE	7/20/18	2.5	0	0	0	0
COXS CREEK	7/20/18	2	0	0	0	0


Damage to a residential structure after an April 2017 Hailstorm in Nelson County. *Source: WLKY*

WASHINGTON

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROP. DAMAGE	CROP DAMAGE
MACKVILLE	5/10/16	2	0	0	50000	0
MAUD	4/29/17	1	0	0	0	0
SPRINGFIELD	5/11/17	1.75	0	0	50000	0
ST CATHERINE	7/20/18	1.75	0	0	0	0

Table 3.3.2.6.3 - Summary of Hail Data, Costs

HAIL	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDGE	$4,925,750	86	58.5	0.01	0.52	$84,201	$57,276	0.00	0.00	0.01	0.01
Cloverport	$0	8	58.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Hardinsburg	$15,000	18	58.5	0	0	$256	$833	0.00	0.00	0.00	0.00
Irvington	$0	7	58.5	0	0	$0	$0	0.00	0.00	0.00	0.00
GRAYSON	$2,438,935	87	57.5	0.01	0.5	$42,416	$28,034	0.00	0.00	0.01	0.01
Caneyville	$0	10	57.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Clarkson	$0	5	57.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Leitchfield	$0	19	56.5	0	0	$0	$0	0.00	0.00	0.00	0.00
HARDIN	$26,768,252	113	58.5	0.01	0.52	$457,577	$236,887	0.00	0.00	0.01	0.00
Elizabethtown	$0	20	58.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Radcliff	$0	4	58.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Sonora	$1,000	7	58.5	0	0	$17	$143	0.00	0.00	0.00	0.00
Upton	$0	1	58.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Vine Grove	$0	3	58.5	0	0	$0	$0	0.00	0.00	0.00	0.00
West Point	$0	2	58.5	0	0	$0	$0	0.00	0.00	0.00	0.00
LARUE	$1,969,355	66	65.5	0.06	0.56	$30,066	$29,839	0.00	0.00	0.01	0.01
Hodgenville	$0	8	65.5	0	0	$0	$0	0.00	0.00	0.00	0.00
MARION	$35,497,179	64	60.5	0.06	2.56	$586,730	$554,643	0.00	0.00	0.04	0.04
Bradfordsville	$0	1	60.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Lebanon	$30,000	7	60.5	0	2	$496	$4,286	0.00	0.00	0.03	0.29
Loretto	$0	3	60.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Raywick	$0	2	60.5	0	0	$0	$0	0.00	0.00	0.00	0.00
MEADE	$25,032,572	74	66.5	0.01	2.52	$376,430	$338,278	0.00	0.00	0.04	0.03
Brandenburg	$35,000	13	66.5	0	0	$526	$2,692	0.00	0.00	0.00	0.00
Ekron	$0	3	66.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Muldraugh	$0	0	66.5	0	0	$0		0.00	0.00	0.00	0.00
NELSON	$22,857,556	85	60.5	0.06	1.56	$377,811	$268,912	0.00	0.00	0.03	0.02
Bardstown	$0	17	60.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Bloomfield	$0	2	60.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Fairfield	$0	4	60.5	0	0	$0		0.00	0.00	0.00	0.00
New Haven	$0	4	60.5	0	0	$0	$0	0.00	0.00	0.00	0.00
WASHINGTON	$11,037,640	55	60.5	0.06	3.56	$182,440	$200,684	0.00	0.00	0.06	0.06
Mackville	$50,000	1	60.5	0	0	$826		0.00	0.00	0.00	0.00
Springfield	$200,000	7	60.5	0	3	$3,306	$28,571	0.00	0.00	0.05	0.43
Willisburg	$0	3	60.5	0	0	$0	$0	0.00	0.00	0.00	0.00
LTADD	$130,527,238	630	66.5	0.28	12.3	$1,962,816	$207,186	0.00	0.00	0.18	0.02

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2015.

Table 3.3.2.6.4 - Summary of Hail Data, Events

HAIL	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	86	58.5	45	61	73	0.68	147.01%	4.5	3.05	1.46
Cloverport	8	58.5	5	8	8	7.31	13.68%	0.5	0.4	0.16
Hardinsburg	18	58.5	12	17	18	3.25	30.77%	1.2	0.85	0.36
Irvington	7	58.5	4	7	7	8.36	11.97%	0.4	0.35	0.14
GRAYSON	87	57.5	37	57	75	0.66	151.30%	3.7	2.85	1.5
Caneyville	10	57.5	5	9	10	5.75	17.39%	0.5	0.45	0.2
Clarkson	5	57.5	5	5	5	11.50	8.70%	0.5	0.25	0.1
Leitchfield	19	56.5	9	18	19	2.97	33.63%	0.9	0.9	0.38
HARDIN	113	58.5	51	72	96	0.52	193.16%	5.1	3.6	1.92
Elizabethtown	20	58.5	13	20	20	2.93	34.19%	1.3	1	0.4
Radcliff	4	58.5	2	3	4	14.63	6.84%	0.2	0.15	0.08
Sonora	7	58.5	4	7	7	8.36	11.97%	0.4	0.35	0.14
Upton	1	58.5	1	1	1	58.50	1.71%	0.1	0.05	0.02
Vine Grove	3	58.5	3	3	3	19.50	5.13%	0.3	0.15	0.06
West Point	2	58.5	2	1	2	29.25	3.42%	0.2	0.05	0.04
LARUE	66	65.5	27	30	42	0.99	100.76%	2.7	1.5	0.84
Hodgenville	8	65.5	7	8	8	8.19	12.21%	0.7	0.4	0.16
MARION	64	60.5	18	24	37	0.95	105.79%	1.8	1.2	0.74
Bradfordsville	1	60.5	0	1	1	60.50	1.65%	0	0.05	0.02
Lebanon	7	60.5	4	7	7	8.64	11.57%	0.4	0.35	0.14
Loretto	3	60.5	2	3	3	20.17	4.96%	0.2	0.15	0.06
Raywick	2	60.5	2	2	2	30.25	3.31%	0.2	0.1	0.04
MEADE	74	66.5	26	46	56	0.90	111.28%	2.6	2.3	1.12
Brandenburg	13	66.5	8	13	13	5.12	19.55%	0.8	0.65	0.26
Ekron	3	66.5	1	3	3	22.17	4.51%	0.1	0.15	0.06
Muldraugh	0	66.5	0	0	0	0.00	0.00%	0	0	0
NELSON	85	60.5	36	53	61	0.71	140.50%	3.6	2.65	1.22
Bardstown	17	60.5	7	16	17	3.56	28.10%	0.7	0.8	0.34
Bloomfield	2	60.5	1	2	2	30.25	3.31%	0.1	0.1	0.04
Fairfield	4	60.5	4	4	4	15.13	6.61%	0.4	0.2	0.08
New Haven	4	60.5	1	3	4	15.13	6.61%	0.1	0.15	0.08
WASHINGTON	55	60.5	16	22	30	1.10	90.91%	1.6	1.1	0.6
Mackville	1	60.5	1	1	1	60.50	1.65%	0.1	0.05	0.02
Springfield	7	60.5	3	7	7	8.64	11.57%	0.3	0.35	0.14
Willisburg	3	60.5	1	3	3	20.17	4.96%	0.1	0.15	0.06
LTADD	630	65.5	256	365	470	0.10	961.83%	25.6	18.25	9.4

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

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Compilation of SHELDUS, NCDC & NCEI. 1967- June 30, 2015.

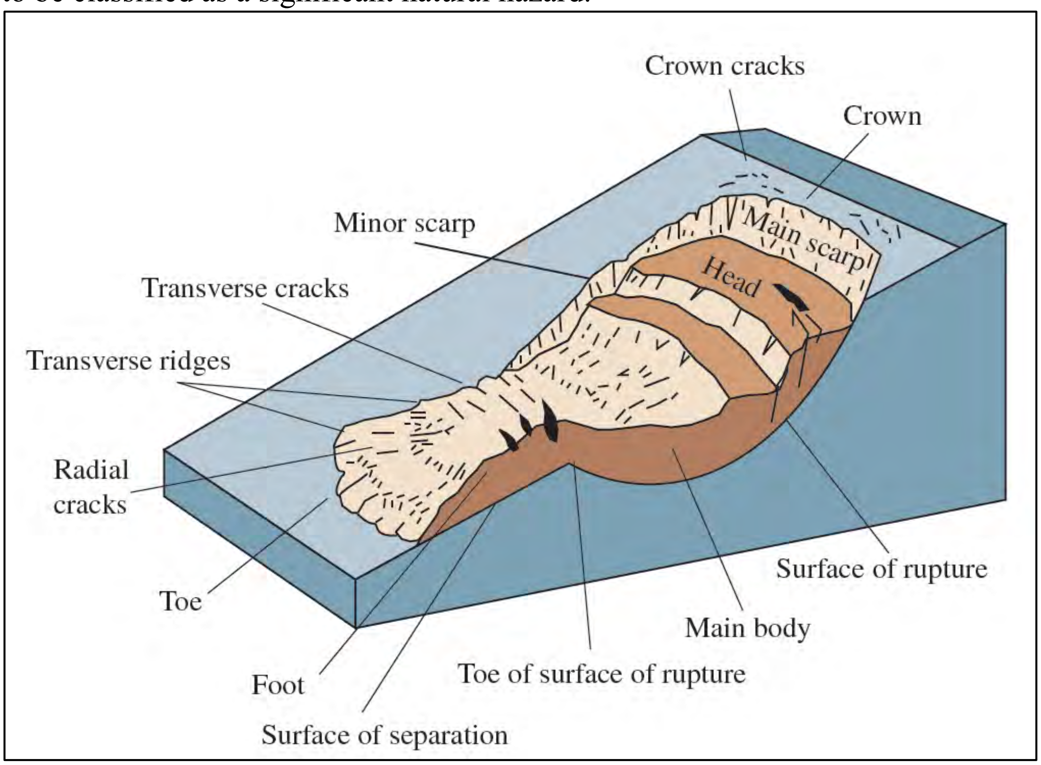
3.3.2.7 Landslides

I. Background

Definition

According to the United States Search and Rescue Task Force, "landslides are rock, earth, or debris flows on slopes due to gravity. They can occur on any terrain given the right conditions of soil, moisture, and the angle of the slope. Integral to the natural process of the earth's surface geology, landslides serve to redistribute soil and sediments in a process that can be in abrupt collapses or in slow gradual slides."

While there are numerous kinds of landslides, they can be triggered by rains, floods, earthquakes, and other natural events, as well as human-made causes such as grading, terrain cutting and filling, excessive development, and vibrations. The factors that cause landslides can be geophysical or man-made and can occur in developed areas, undeveloped areas, or any area where the terrain was altered for roads, houses, utilities, buildings, and even residential lawns. Landslides occur in all fifty states with varying frequency, and more than half of U.S. States have landslide rates sufficient to be classified as a significant natural hazard.



Slump-earth flow showing nomenclature, *Source: USGS Fact Sheet 2004-3072.*

Cause

Landslide is a term frequently used to mean any fairly rapid movement of rocks and sediment downslope. However, a more accurate term to use is "mass wasting." Mass wasting refers to a large variety of mass movement processes that wear away to the Earth's surface.

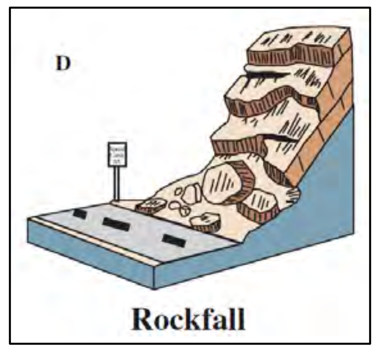
There are three main factors that control the type and rate of mass wasting that occurs at the Earth's surface:

- Slope gradient: The steeper the slope of the land, the more likely that mass wasting will occur.
- Slope consolidation: Sediments and fractured or poorly cemented rocks and sediments are weak, and more prone to wasting.
- Water: When slope materials become saturated with water, they may lose cohesion and begin to flow easily.

The three basic types of mass wasting are:

- Falls – rocks fall or bounce through the air
- Slides – rocks and/or sediment slide along the Earth's surface
- Flows – sediment flows across the Earth's surface

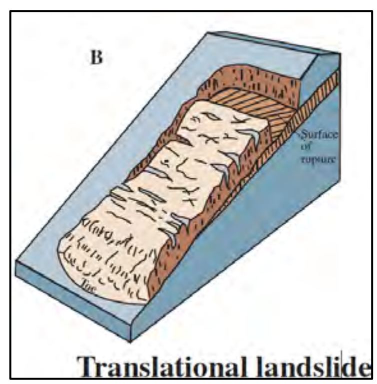
Falls occur as a result of weathering. Steep mountain or hillside slopes are constantly wasting away and are characterized by rocks falling and bouncing down slopes. These falls are triggered by freezing and thawing water, the growth of plants and their roots, earthquakes, or by people hiking on a slope. Falls occur in a matter of seconds, so they are difficult to observe.



USGS Fact Sheet 2004-3072.

Slides occur when a mass of slope material moves as an entire block. The most common form of a slide is a **slump**. A slump happens when a portion of the hillside moves downslope as a result of gravity.

A landslide is called a **flow** if the material moving downslope is being transported as a very thick fluid, rather than as a unified block of material.



USGS Fact Sheet 2004-3072.

Areas prone to landslides include:

- Existing landslides, old or recent
- On or at the base or top of slopes
- In or at the base of minor drainage hollows
- At the base or top of an old fill slope
- At the base or top of a steep cut slope

Areas that are generally safe from Landslides include:

- On hard, non-joined bedrock that has not moved in the past
- On relatively flat-lying areas away from slopes and steep riverbanks
- At the top or along the nose of ridges, set back from the tops of slopes

Features that may be present prior to a major landslide include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before

- New cracks or unusual bulges in the ground, street pavements or sidewalks
- Soil moving away from foundations
- Ancillary structures such as decks and patios tilting and/or moving relative to the main structure
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
- Offset fence lines
- Sunken or down dropped roadbeds
- Sudden decrease in creek water levels though rain is still falling or has just recently stopped.
- Sticking doors and windows, and visible open spaces; indication jambs and frames are out of plumb.


Landslide area in Nelson County along the Chaplin River. *Source: LTADD Archive.*

A landslide occurs when the stability of a slope changes from a stable condition to an unstable one. A change in slope stability can occur from several factors that act alone or in concert with one another. Natural causes of landslides include:

- Groundwater (pore water) pressure acting to destabilize a slope
- Loss or absence of vertical vegetative structure, soil nutrients and soil structure; all of these factors can be the result of a wildfire
- Erosion of the toe of a slope by rivers or ocean waves
- Intense rainfall
- Weakening of a slope due to saturation by melting snow and glaciers or by heavy rains
- Earthquakes that add loads to barely stable slopes or earthquake-caused liquefaction that destabilizes slopes
- Volcanic eruptions

Human activities that can affect the occurrence of a landslide include:

- Deforestation, cultivation, and construction that contributes to the destabilization of a fragile slope
- Vibrations from machinery or traffic
- Blasting
- Earthwork that alters the shape of a slope or contributes new loads on an existing slope
- Removal of deep-rooted vegetation that binds colluvium to bedrock in shallow soils
- Construction, agricultural or forestry activities that changes the amount of water which infiltrates the soil

Hazards/Vulnerability

According to the United States Geological Survey causes billions of dollars in damages to public and private property annually and kill multiple people in the United States annually. Landslides occur in all fifty of the states in the U.S. The casualties in the United States are caused primarily by rockfalls, rockslides, and debris flows. Natural disasters are a prime example of humans living in conflict with the environment. Because landslides can cause catastrophic damage and loss of life, it is imperative to have a good understanding of what causes disasters to prevent them from occurring or to avoid development in areas prone to disasters. Sustainable land management and development is an essential tool in reducing the negative impacts that can happen because of landslides.

Rockslide on the Blue Grass Parkway in Hardin County. *Source: Kentucky Geological Survey*

II. Analysis

It is helpful to understand the physiographic characteristics of the Lincoln Trail Region to analyze the risk of landslides in the area. The Kentucky Physiographic Regions map included, shows that our region lies in four Kentucky physiographic regions; the Knobs, the Western Coal Field, the Outer Bluegrass and the Mississippian Plateau or Western Pennyroyal. Each has distinct characteristics that define it and help determine the propensity for landslides. Information for this analysis comes from ARCGIS, Kentucky Geological Survey and historical information from County Emergency Management Agencies.

According to the Kentucky Geological Survey, Kentucky has a combination of steep slopes, excessive water amounts, geology, and slope modifications that are the main causes of landslides. There are over 2,300 landslides in the Kentucky Geological Survey Database. According to the Kentucky Geological Survey, landslides and rock fall cost the state over $4 million annually with a majority of this incurred by the Kentucky Transportation cabinet While damage totals specific to the Lincoln Trail Region are not documented, it is definite that some of Transportation Cabinets repairs were done on local roads. From 2003 to 2013, the Kentucky Hazard Mitigation Grant program funded or will fund projects to acquire landslide-damaged homes or to stabilize an area, totaling $5.3 million. In general, the State and local agencies that respond to or document landslides vary, and data pertaining to the collection, assessment, and documentation of occurrences is not consistent.

To date, Hazard Mitigation funds were used in Nelson County to buy out a home in danger of sliding down a slope. The property was purchased in 2006 and the structure demolished. The land was rezoned to green space in perpetuity. Meade County has imminent need to stabilize a bank slope on the Ohio River that threatens the local water supply, and Breckinridge County has project plans to stabilize slopes that threaten local roads.

Extent

While there are few documented reports of extensive damage because of landslide activity, the eight-county region has natural topographic and geologic features that render it susceptible to landslides when natural events such as ground water, intense rainfall, melting snow and seismic activity are factored in. This is substantiated by the 2006 *Landslide* review written by Yoshimatsu and Abe. Yoshimatsu and Abe identify the Analytical Hierarchic Process (AHP) as a method to determine areas susceptible to landslides. Aerial photographs of areas prone to landslides are "layered." Scores are assigned to each "layer" of the micro-topography and susceptibility to landslides is a function of the summation of scores assigned to each factor of the photographed micro-topography in the landslide prone area. Based on this technology, and the topographic features of the Lincoln Trail Area including karst topography, steep slopes, alluvial soils, and underground water movement, coupled with the regional propensity for heavy rains and melting snow; it can be determined that the region has the potential for landslide hazards.

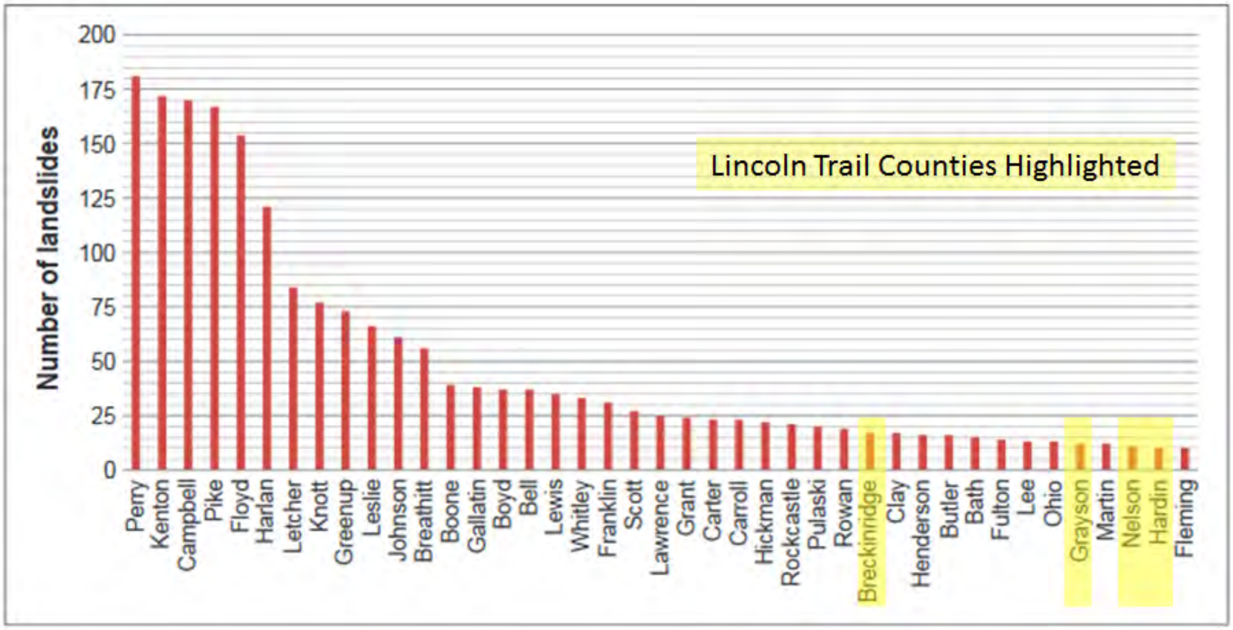
Table 3.3.2.7.1 - AHP Score of Ranking of Susceptibility of Landslides		
Susceptibility Level	**AHP Score**	**Percentage to Total Number of Landslides (%)**
Level 1 (High)	62 > AHP Score	5%
Level 2 (Slightly High)	38 < AHP Score	25%
Level 3 (Slightly Stable)	24 < AHP Score	30%
Level 4 (Stable)	AHP Score < 24	40%
Source: Yoshimatsu, H.; & Abe, S. (2006). "A Review of Landslide Hazards in Japan and Assessment of Their Susceptibility Using an Analytical Hierarchic Process (HP) Method." *Landslides*, 3, 149-158		

As previously cited, landslides in this region have the potential to destroy structures, interrupt transportation lines and decimate regional water sources.

Probability

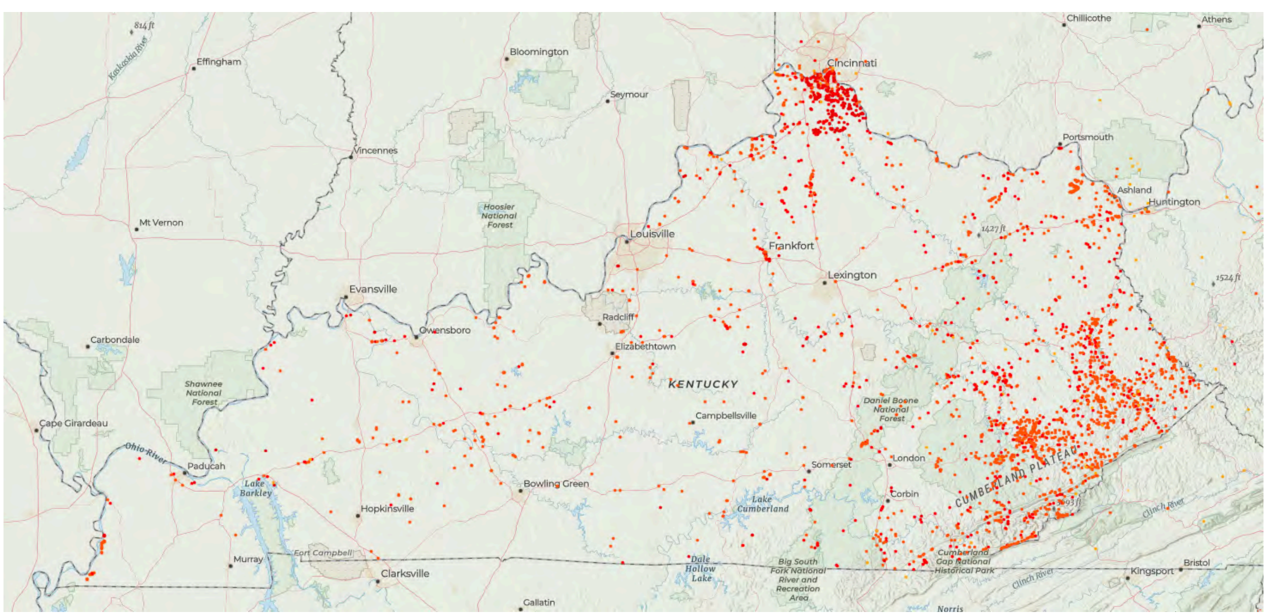
In 2011, Kentucky Geological Survey (KGS) began constructing a landslide inventory database. As of August 20, 2014, the Kentucky Landslide Inventory illustrated by chart 3.3.2.7.1 was completed. The inventory shows the number of documented landslides in the database per county for those counties with 10 or more landslides. In the Lincoln Trail Region there are 49 documented landslides: 16 in Breckinridge County, 12 in Grayson County, 11 in Nelson County and 10 in Hardin County. This yields approximately 3.5 years of data. A raw value for probability for an event occurrence for the Lincoln Trail Region would be historic recurrence interval of 0.07 and a historic frequency, chance per year of 1400%.

Chart 3.3.2.7.1 - KGS Landslide Inventory, Distribution of Landslides



Modified from “Distribution of landslides by county (10 or more landslides)”, *Source: KGS “Landslide Inventory: From Design to Application, 2014.*

Note that according to KGS, there is currently no best practice or standard methodology to develop a database that could effectively model landslide susceptibility or risk. Much depends on the ability to collect locations and occurrences. In 2021, a new inventory of landslides such as that shown in the table above has not been created. Below is a map with data from the USGS on recent landslides estimates in Kentucky. Each dot is an estimated landslide. Eastern Kentucky has more landslides according to the map, but the Lincoln Trail region does have some landslides.



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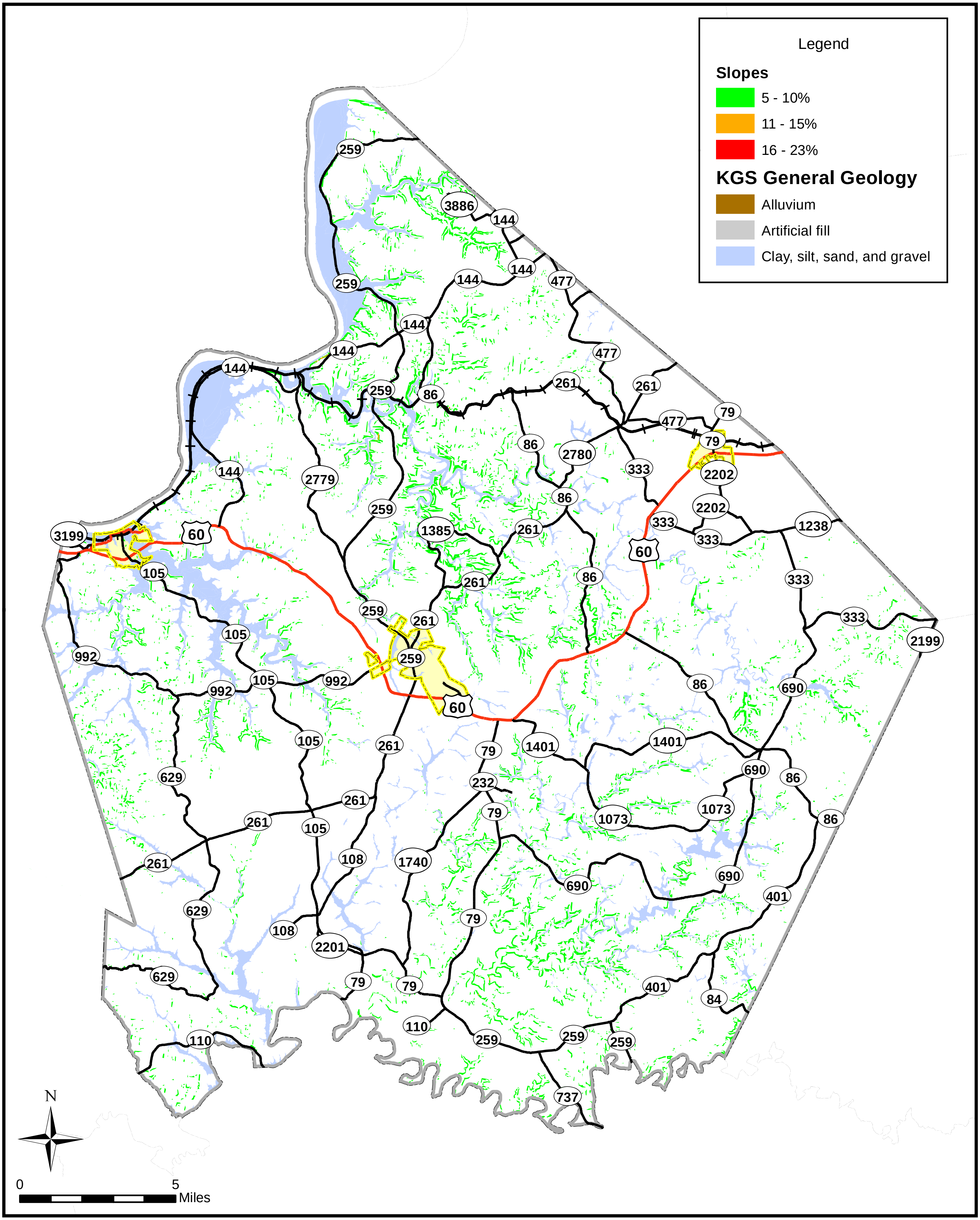
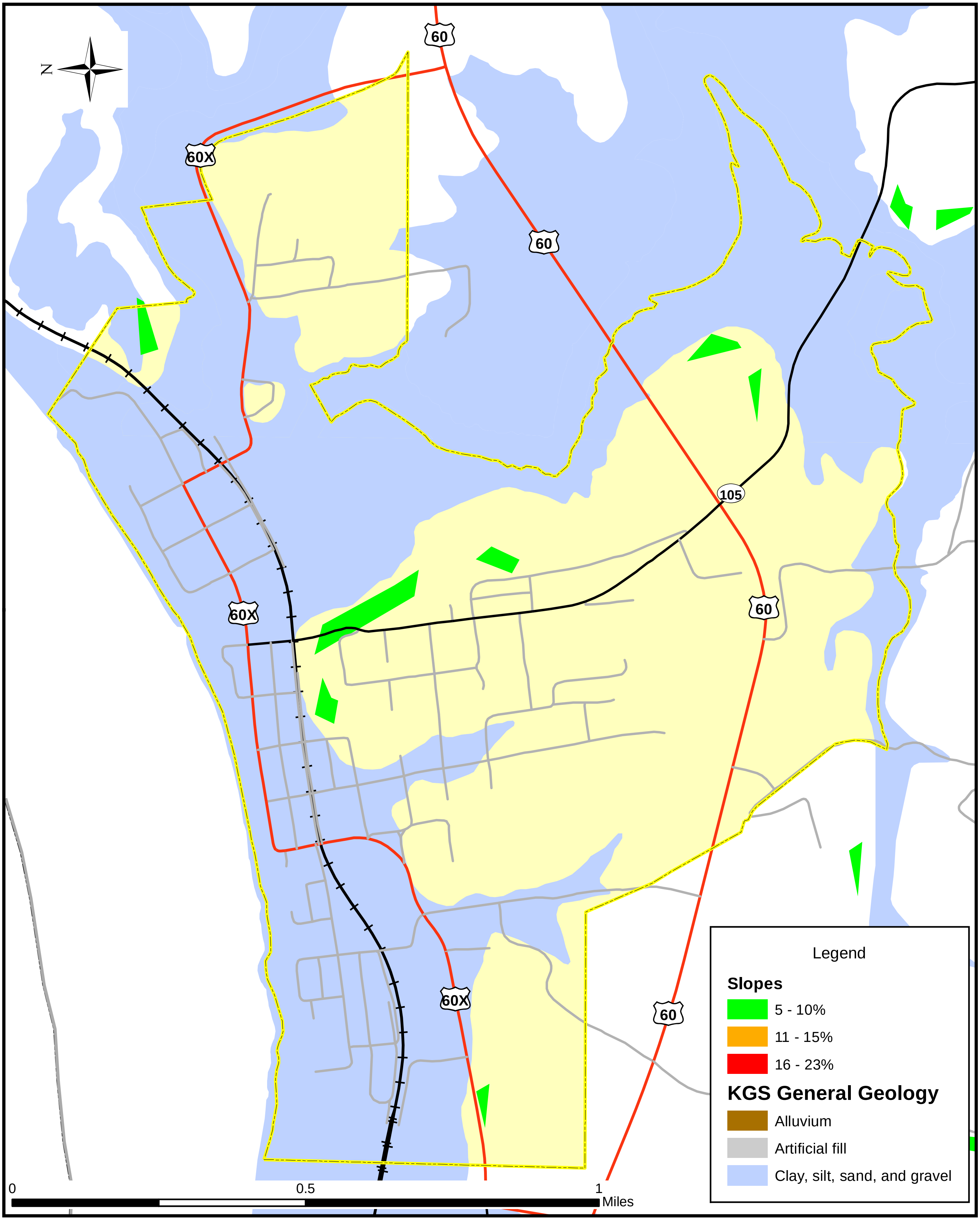

Legend
Slopes
5 - 10%
11 - 15%
16 - 23%
KGS General Geology
Alluvium
Artificial fill
Clay, silt, sand, and gravel
N
0
5
Miles

126b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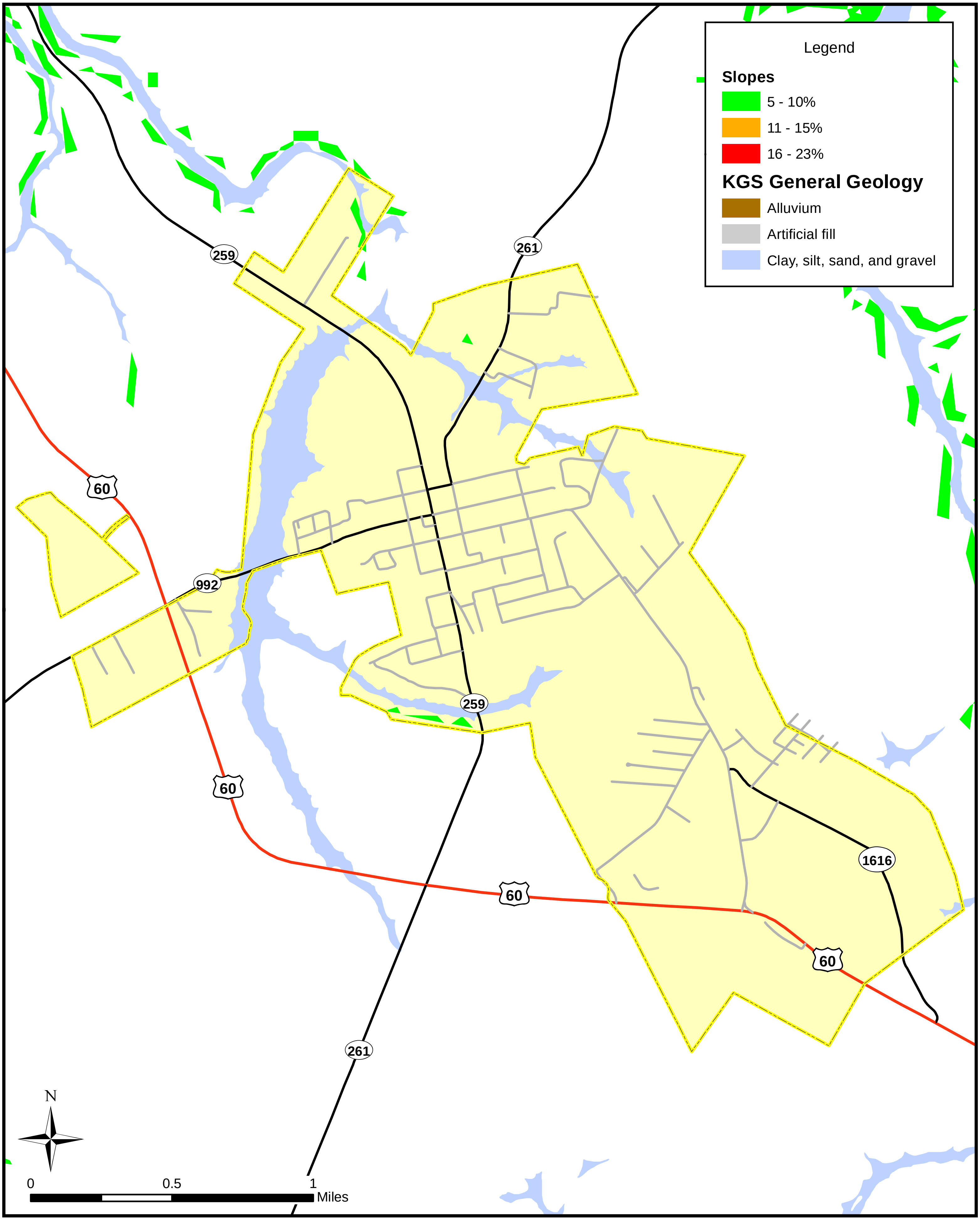
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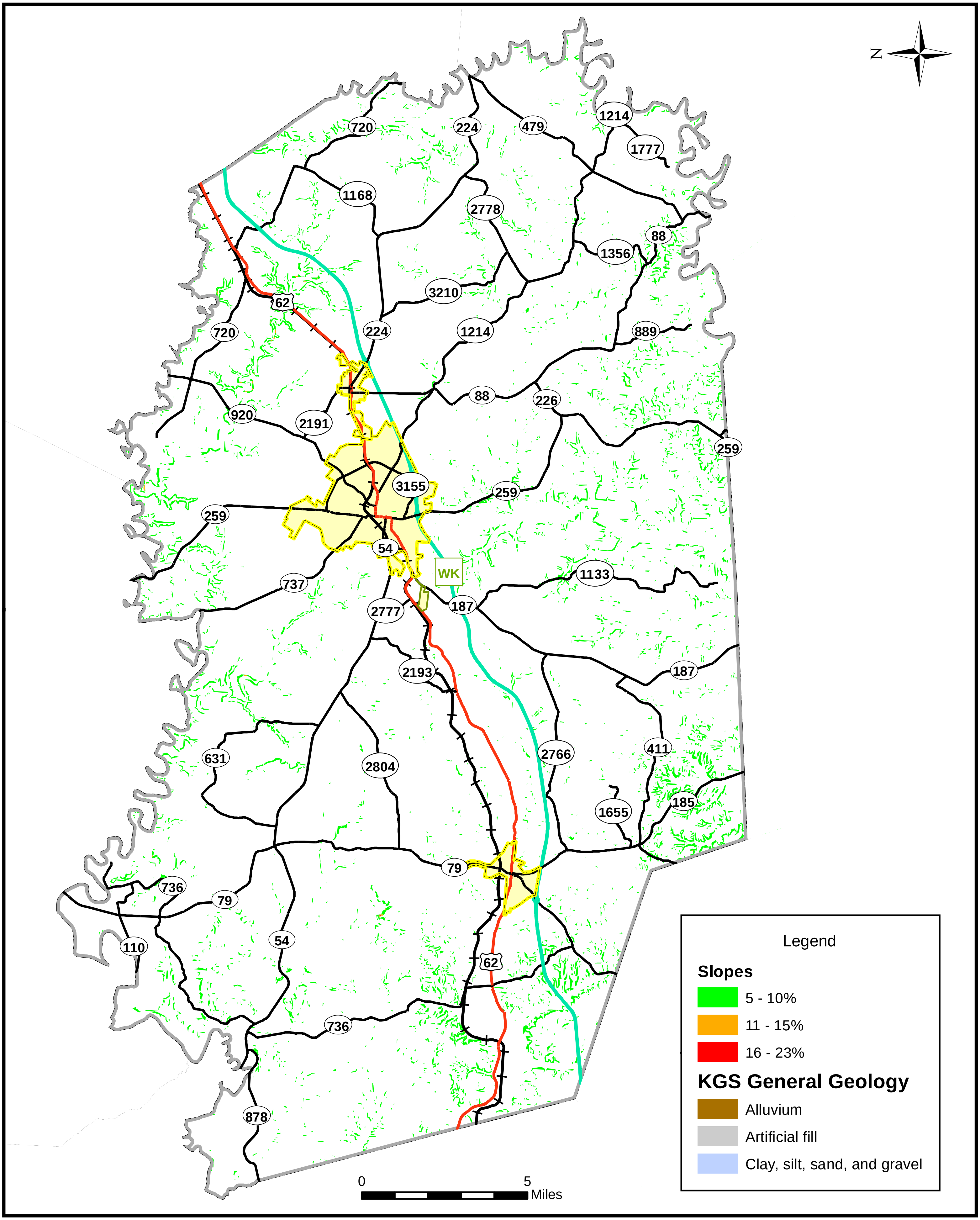
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WK
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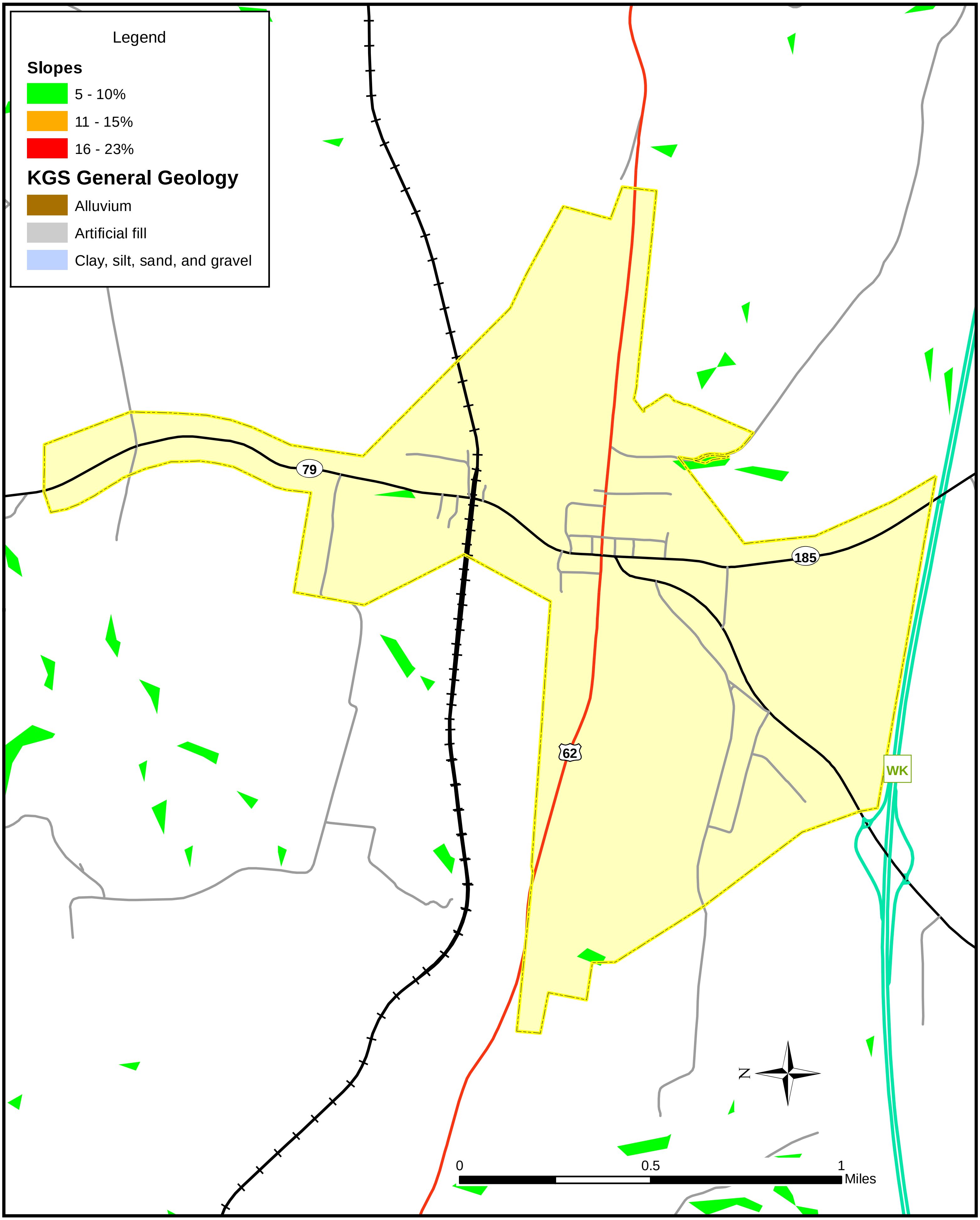
Miles

126e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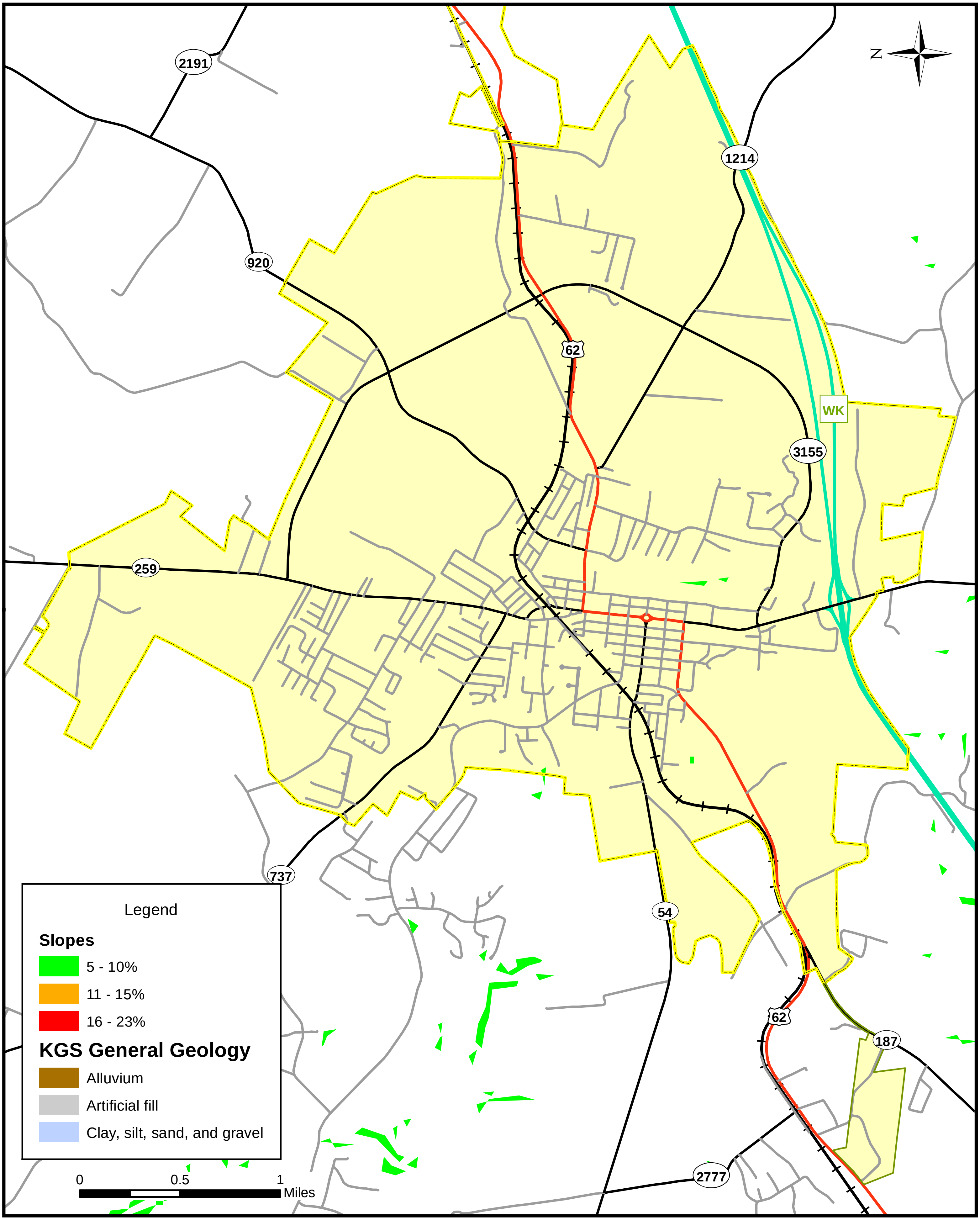
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Legend
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Miles
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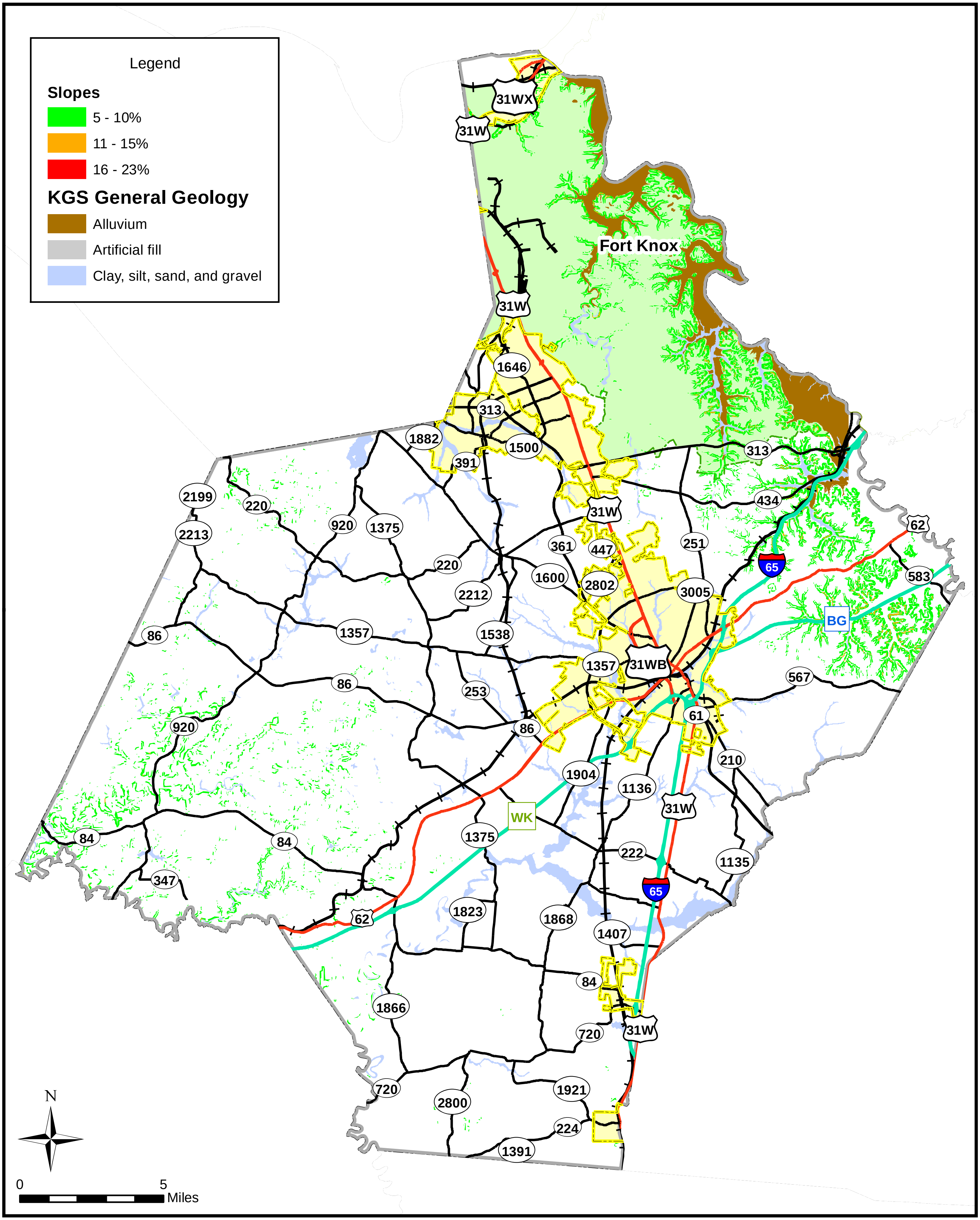
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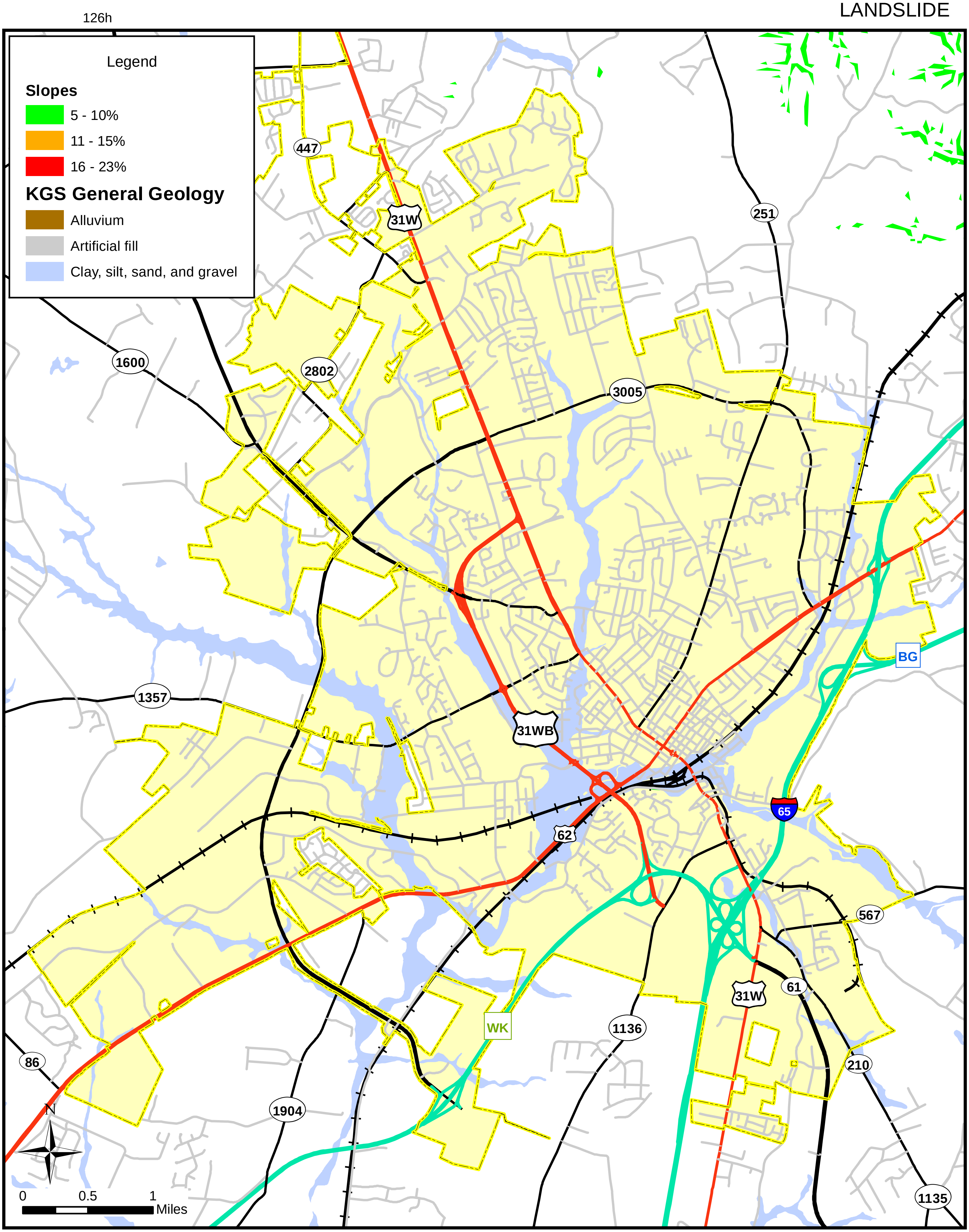
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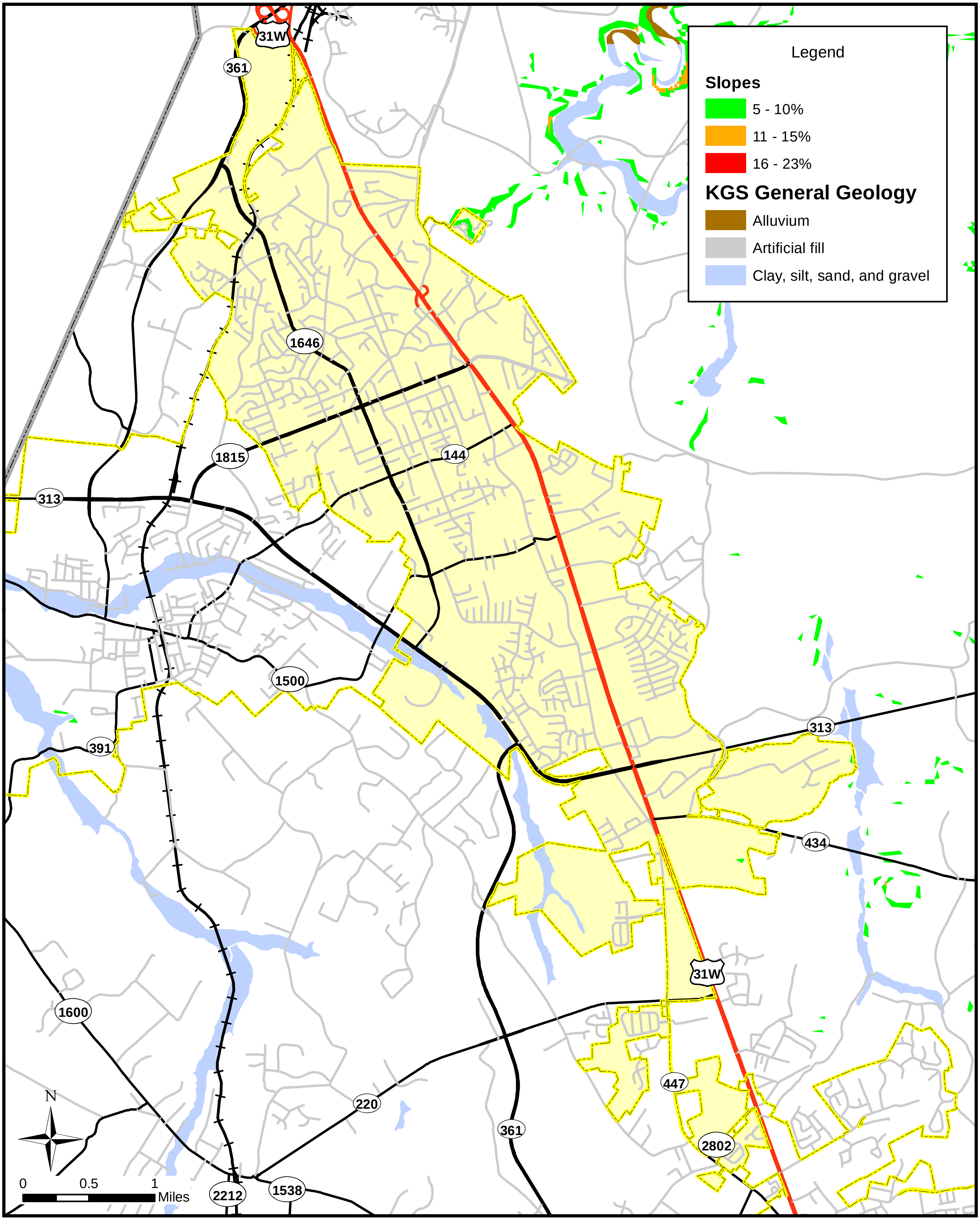
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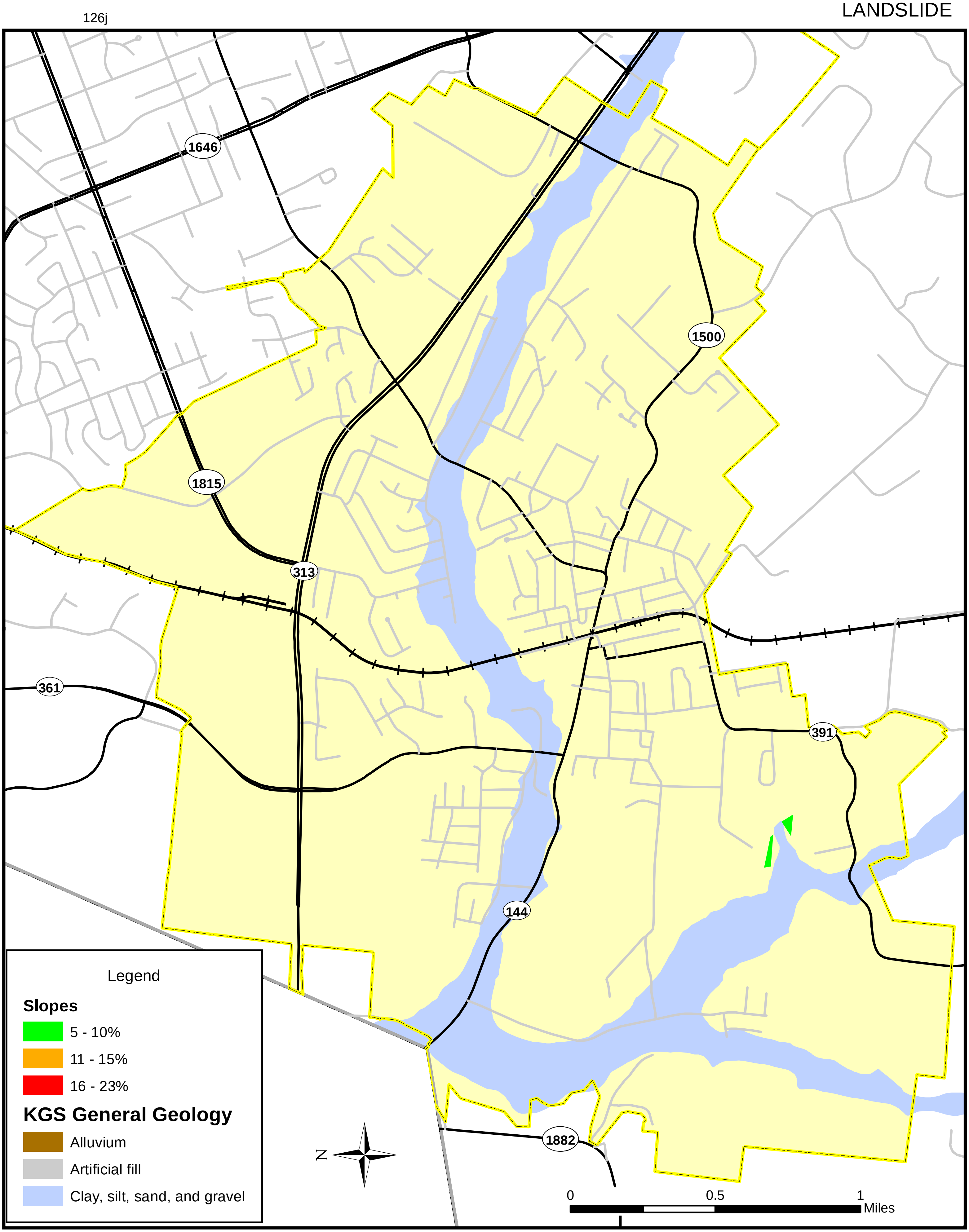
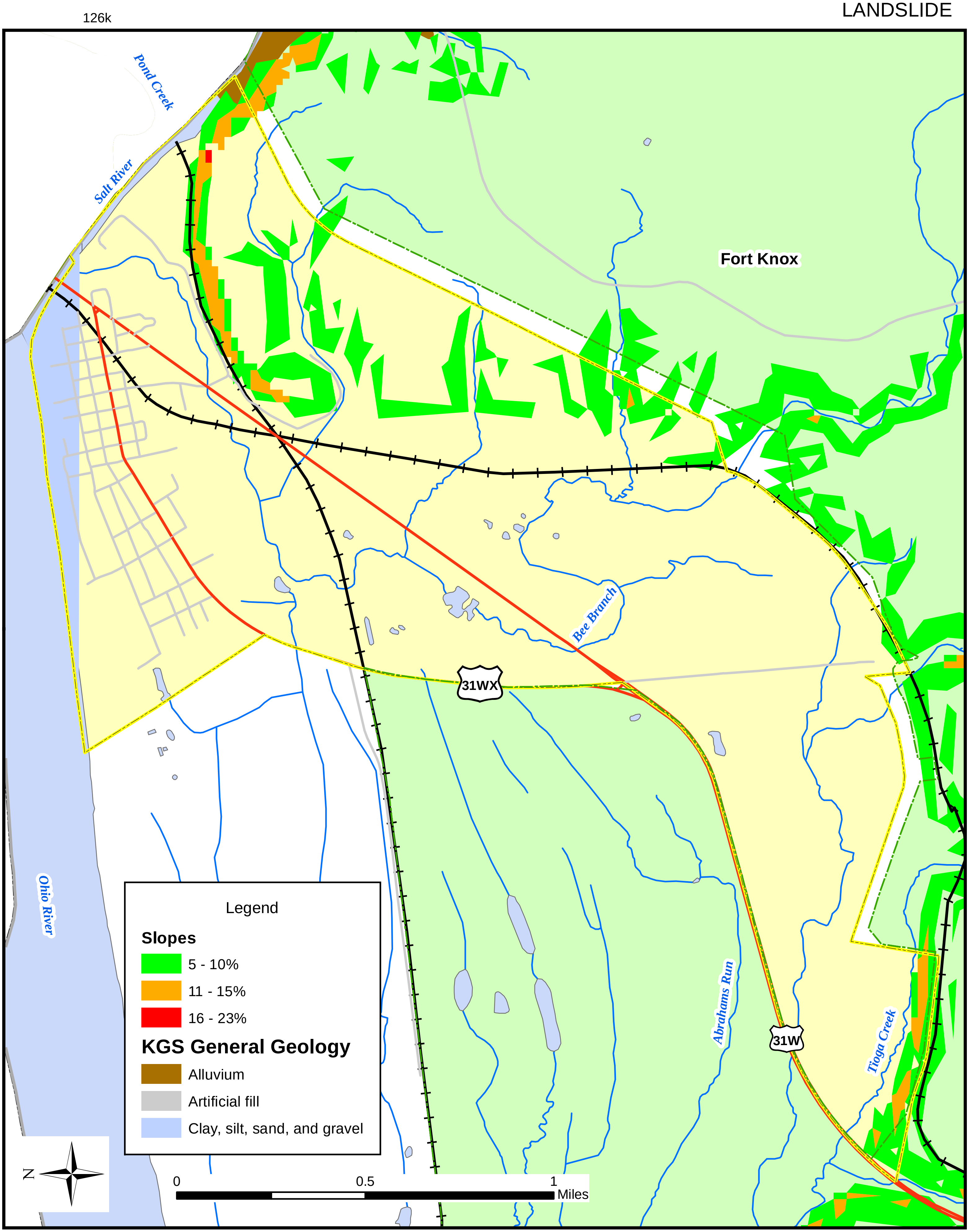
Miles

VINE GROVE
LANDSLIDE

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Salt River
Fort Knox
Bee Branch
31WX
Ohio River
Abrahams Run
31W
Tioga Creek
Legend
Slopes
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Clay, silt, sand, and gravel
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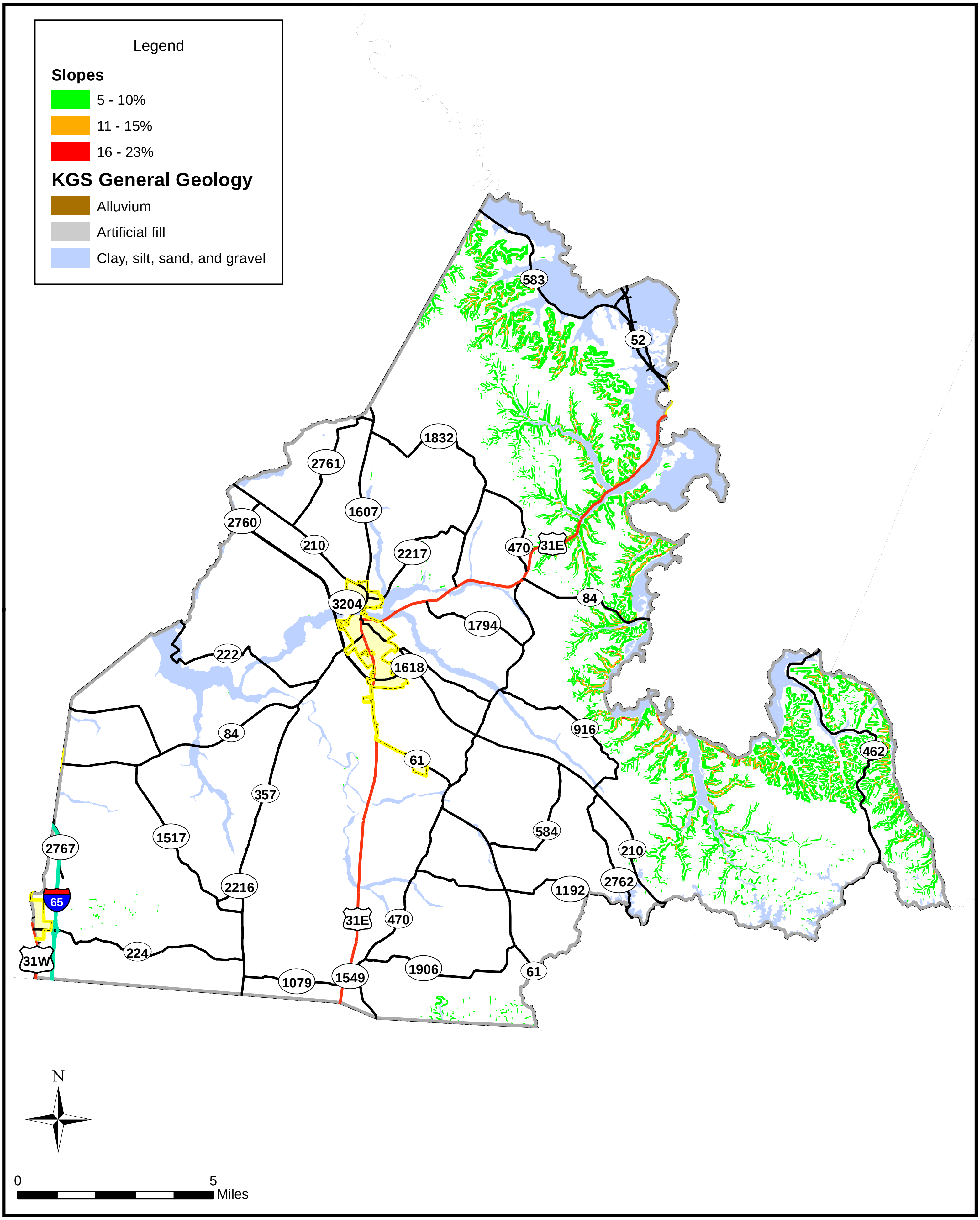
Miles

126l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Clay, silt, sand, and gravel
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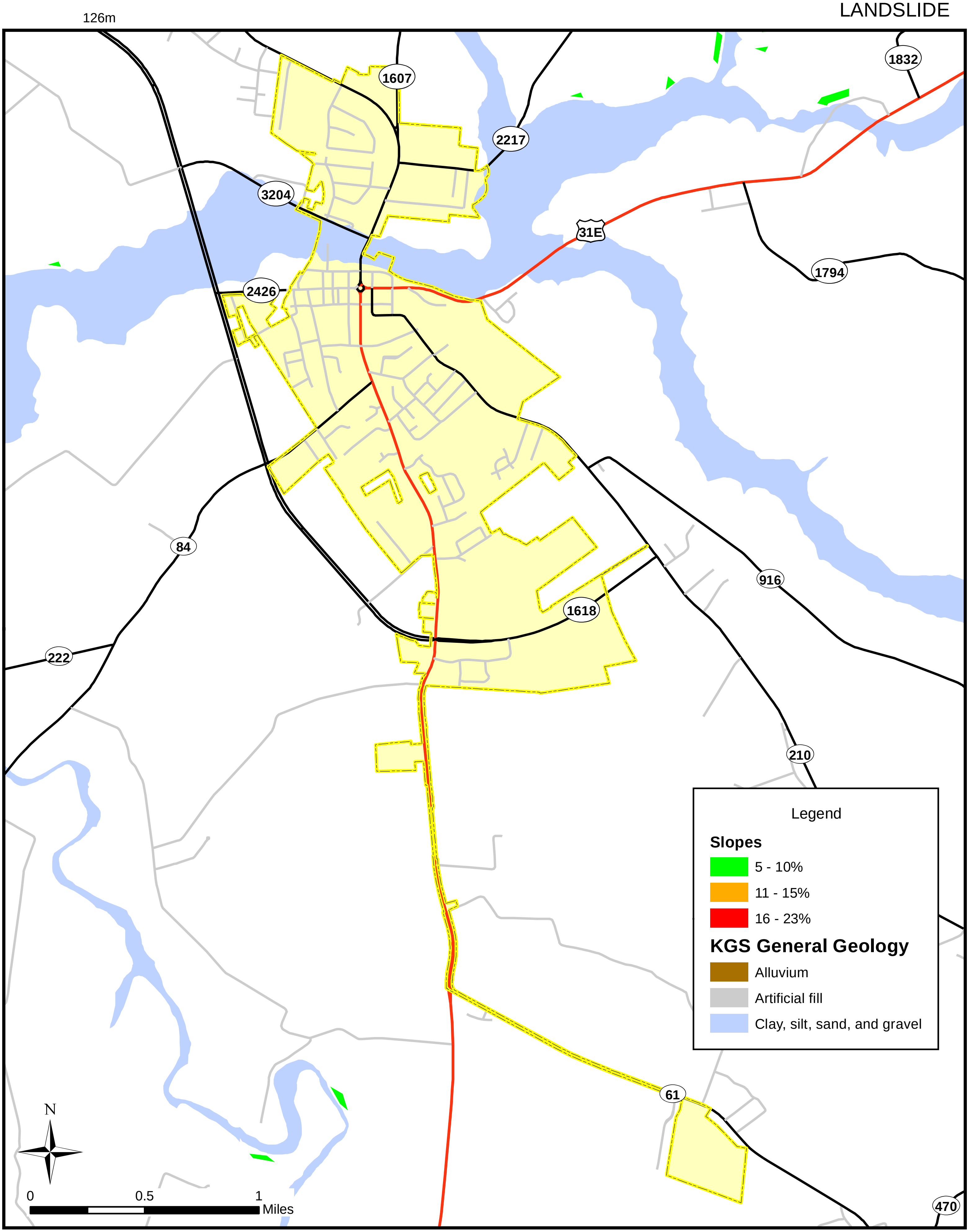
Miles

HODGENVILLE
LANDSLIDE



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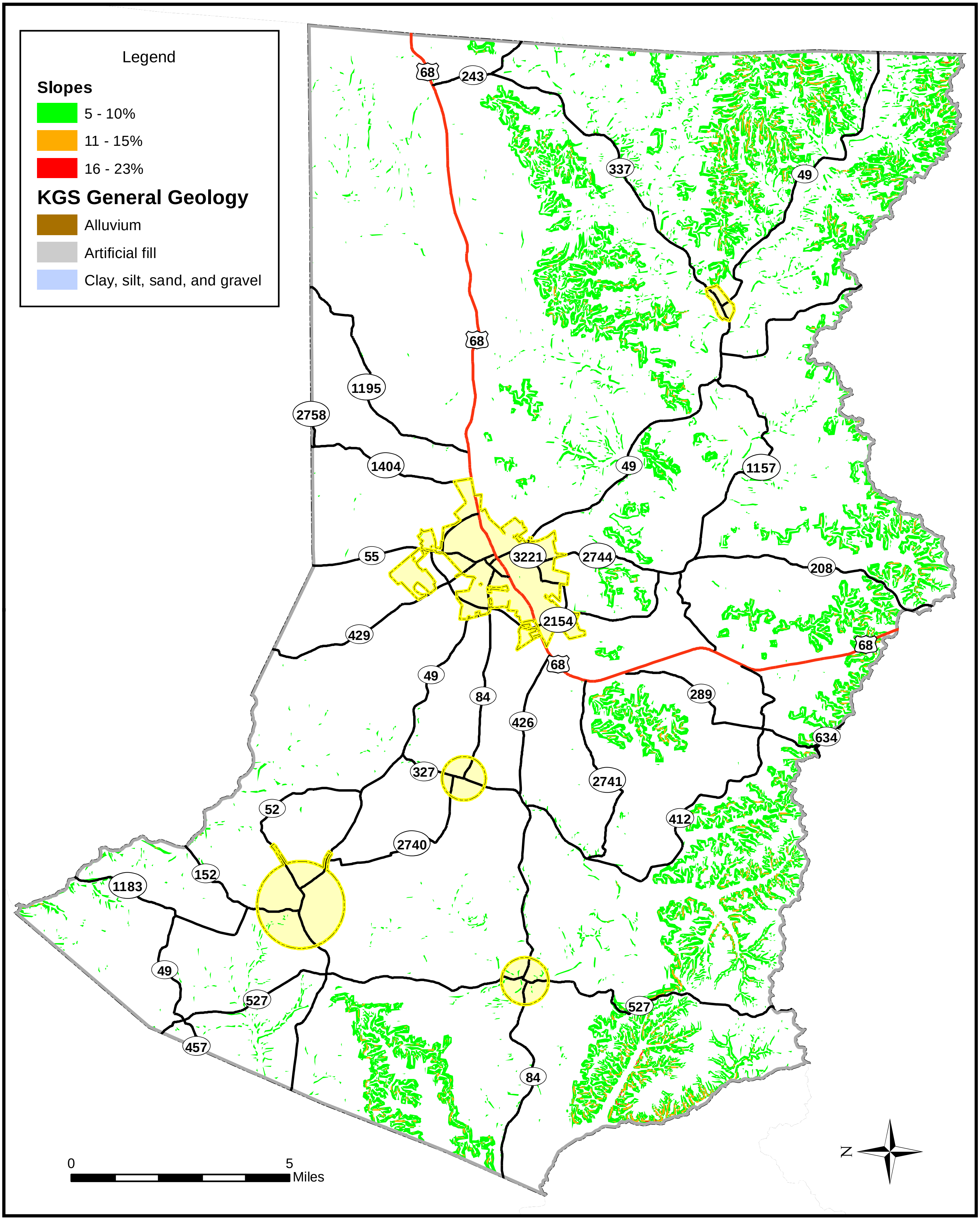
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1404
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68
49
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Miles
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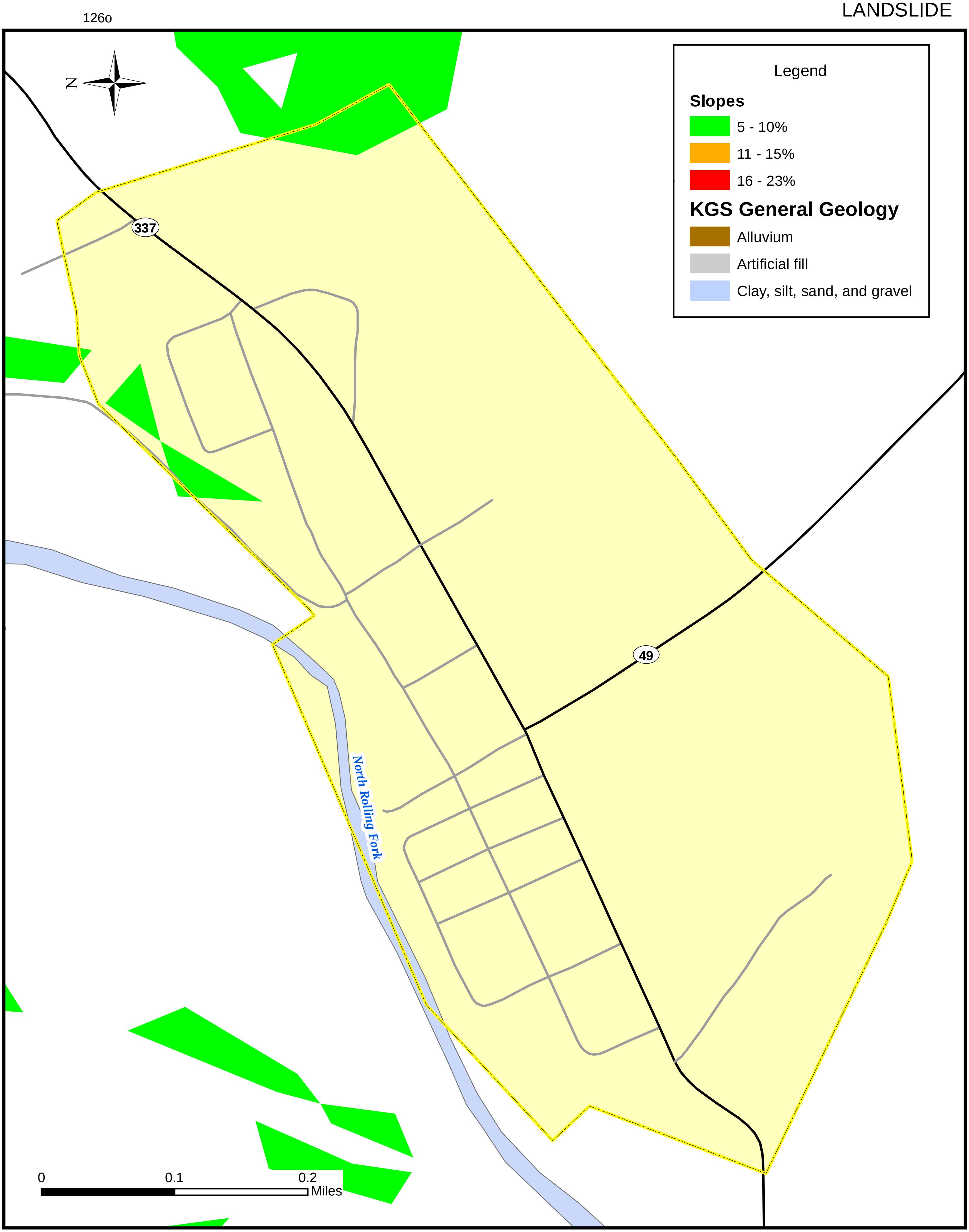
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337
49
North Rolling Fork
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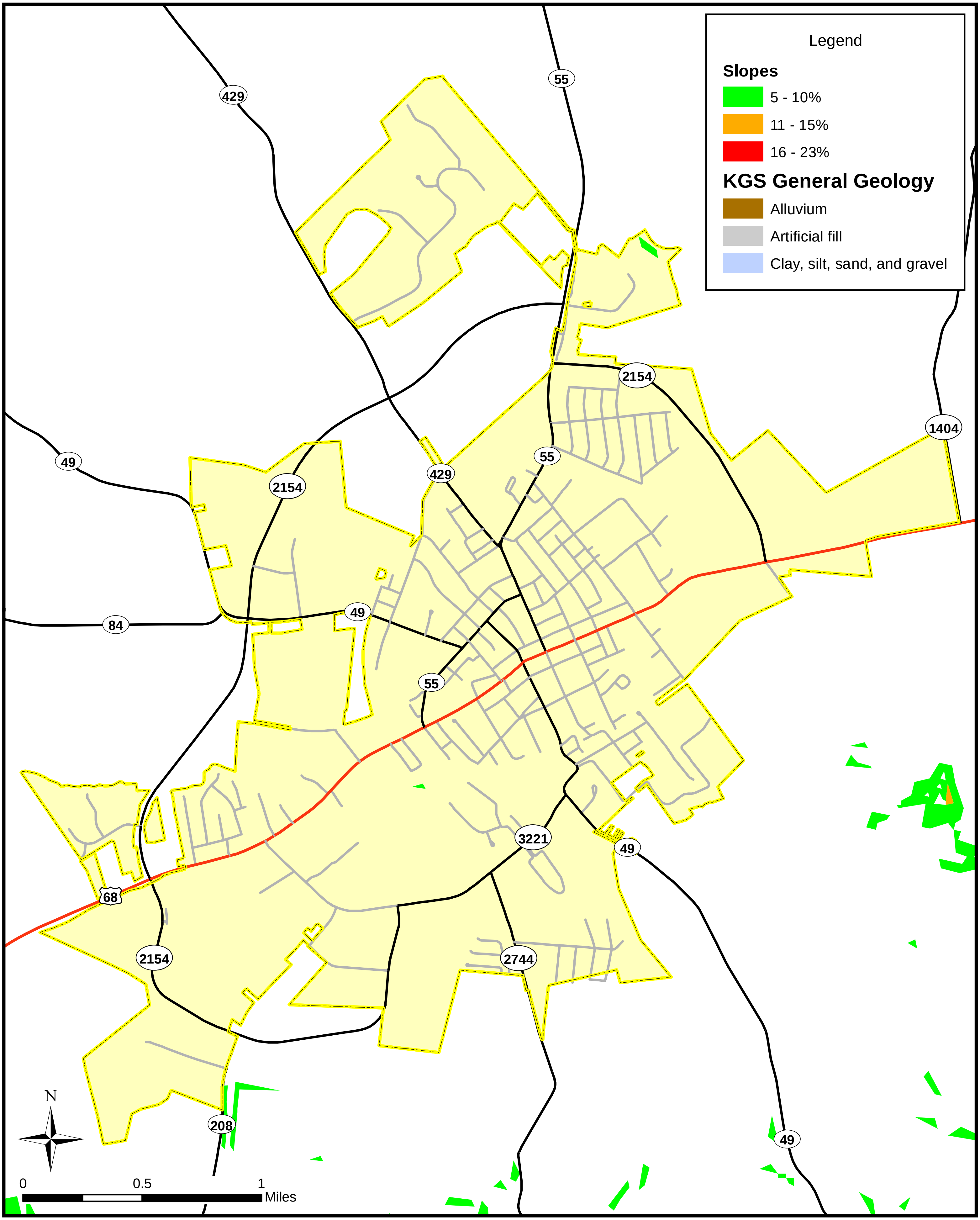
0.1
0.2
Miles

126p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Artificial fill
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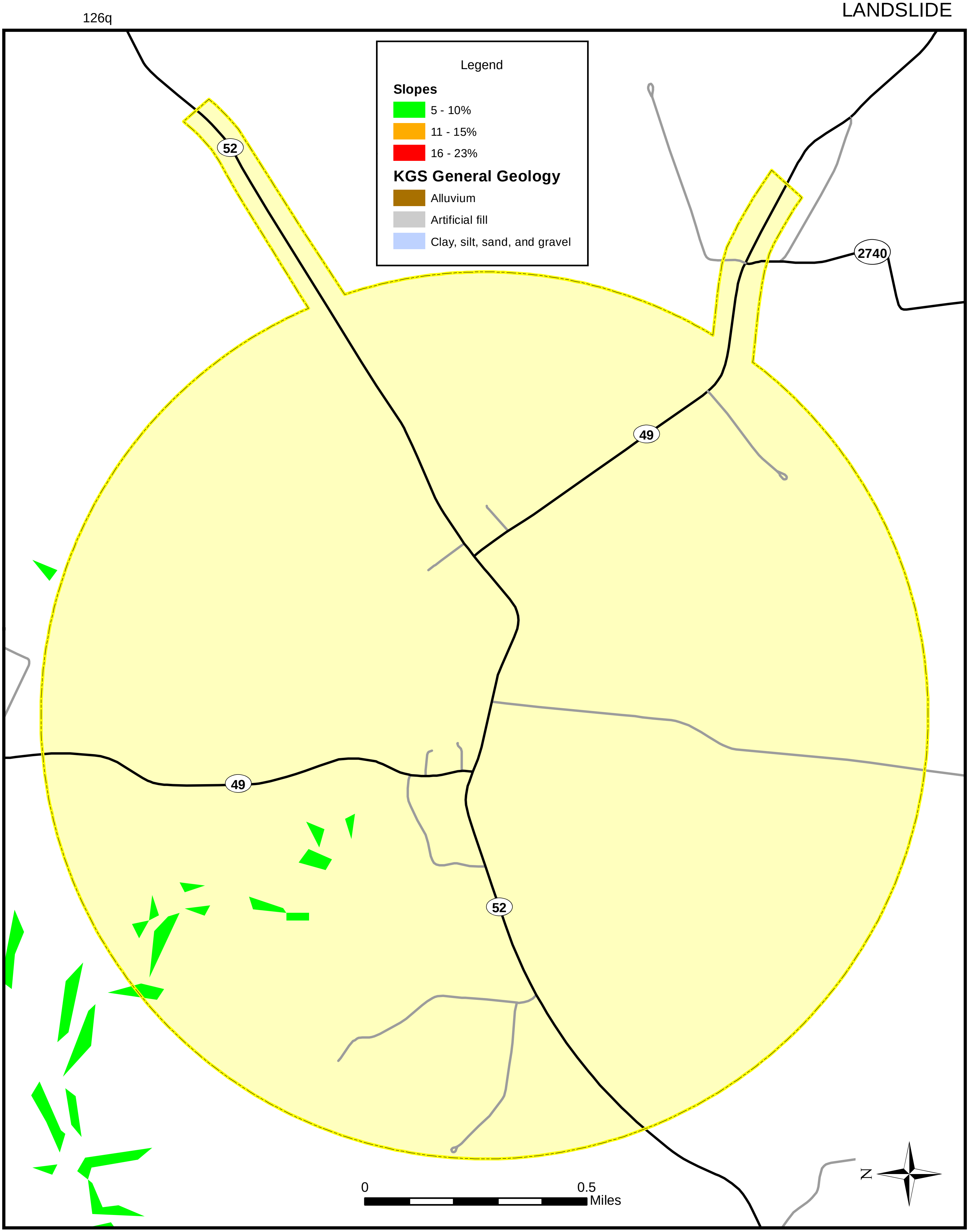
Miles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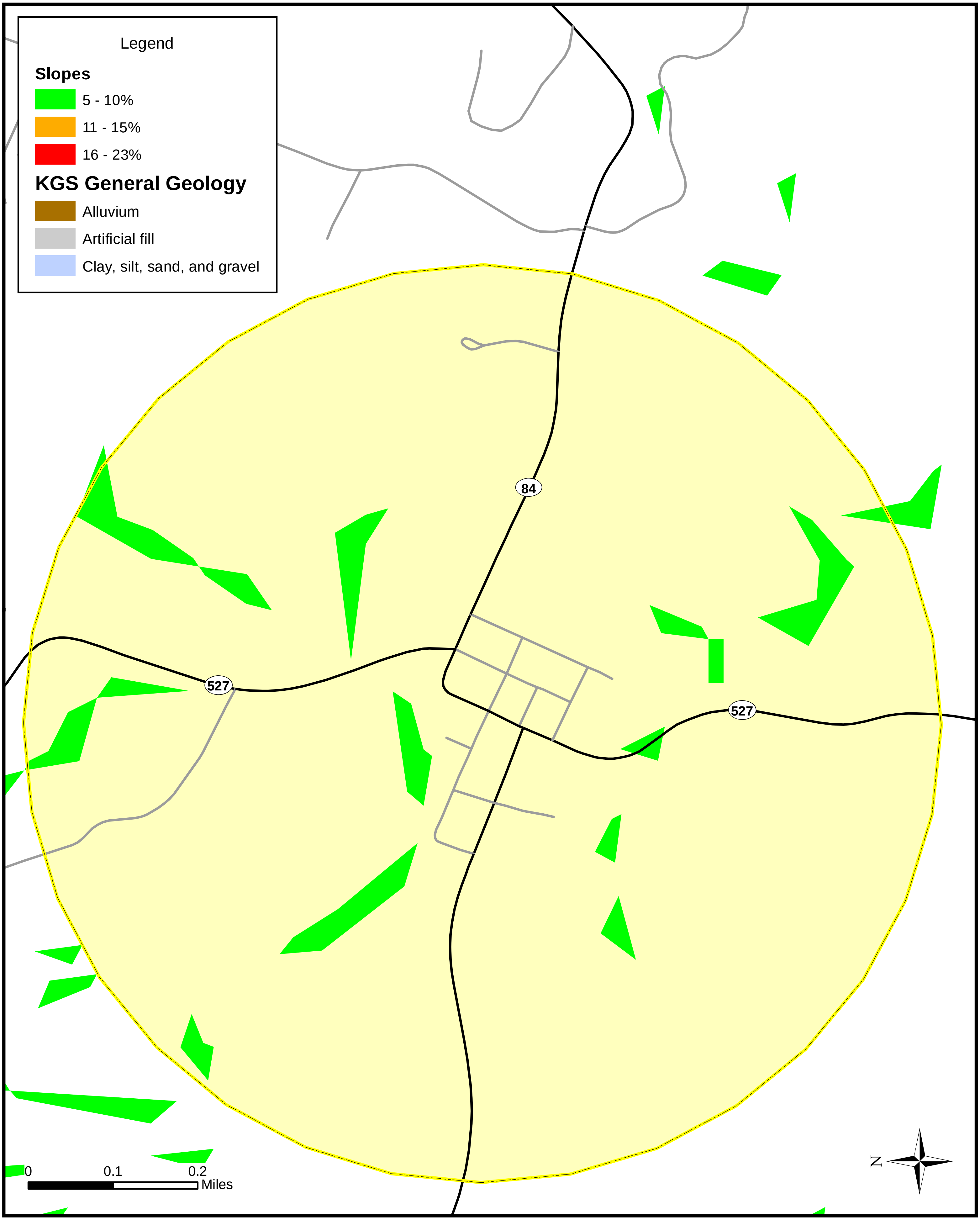
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Miles
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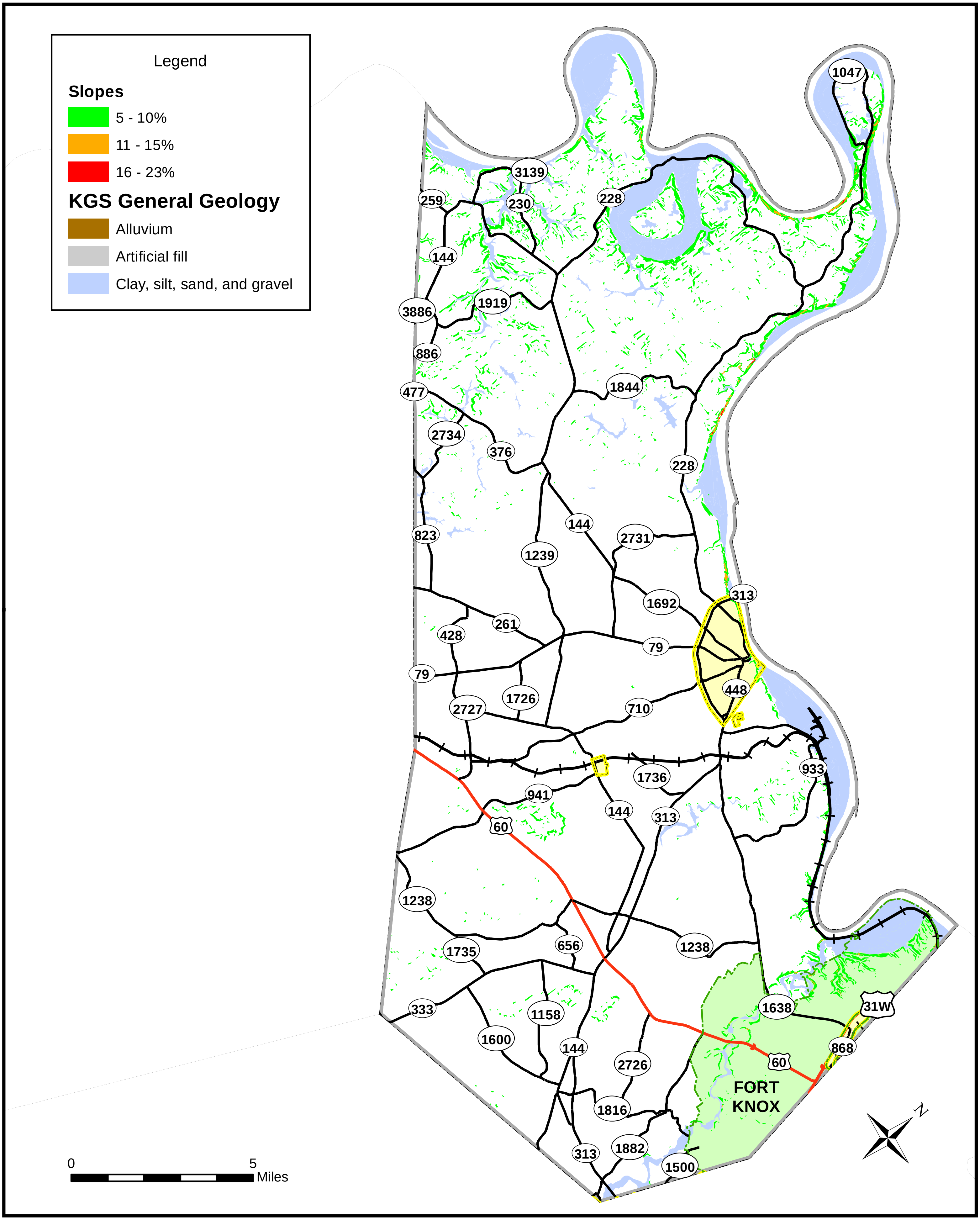
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Clay, silt, sand, and gravel
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230
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31W
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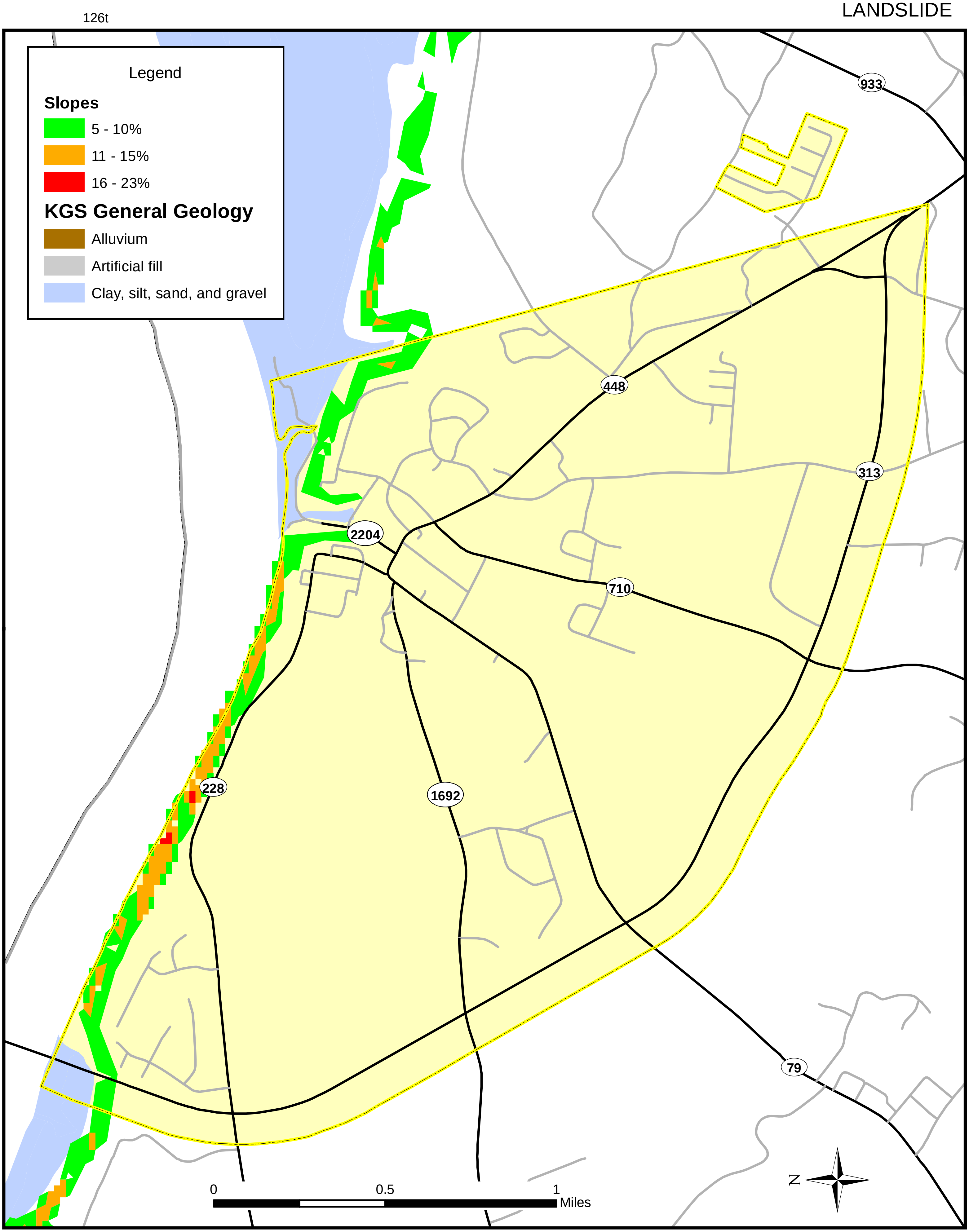
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Legend
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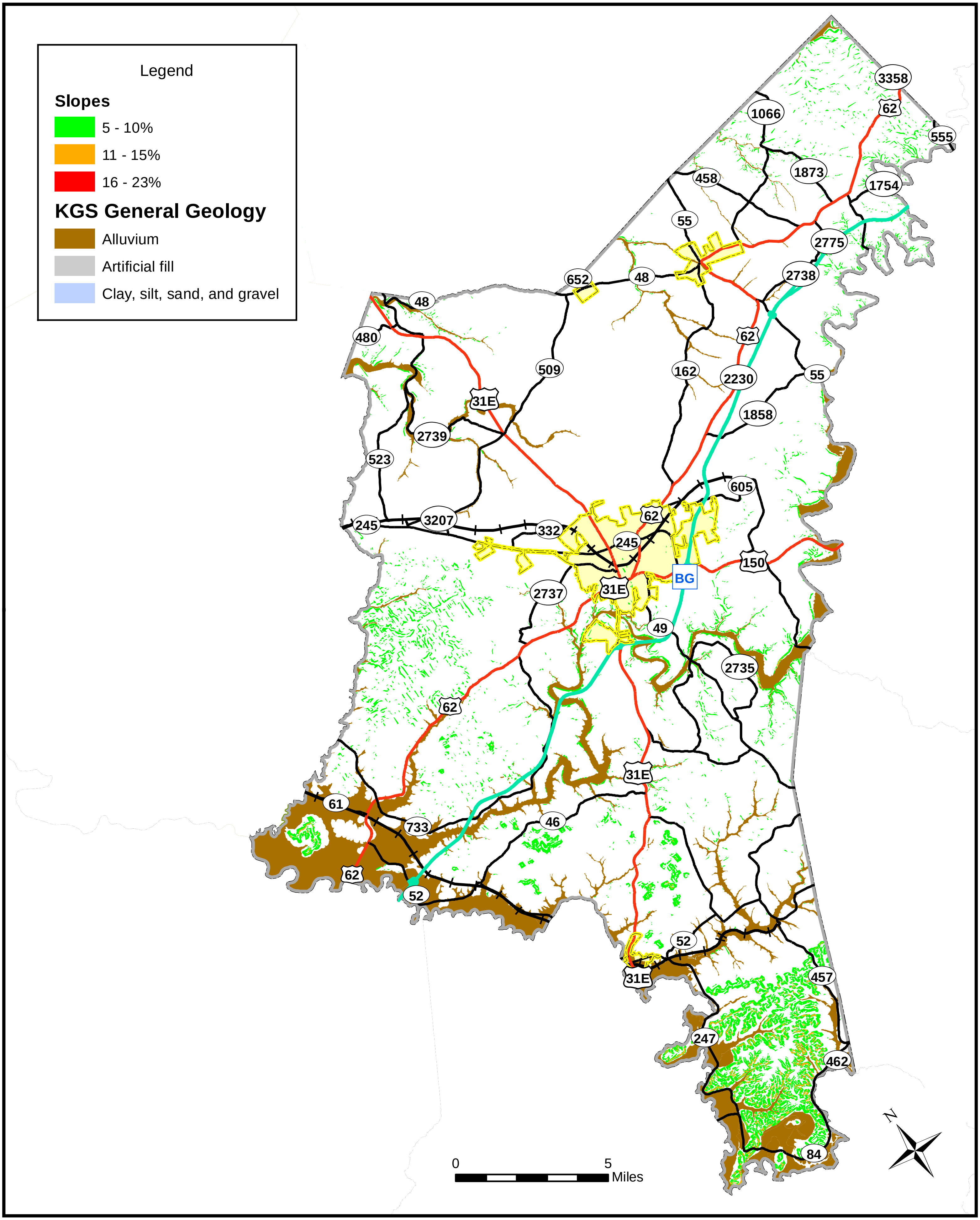
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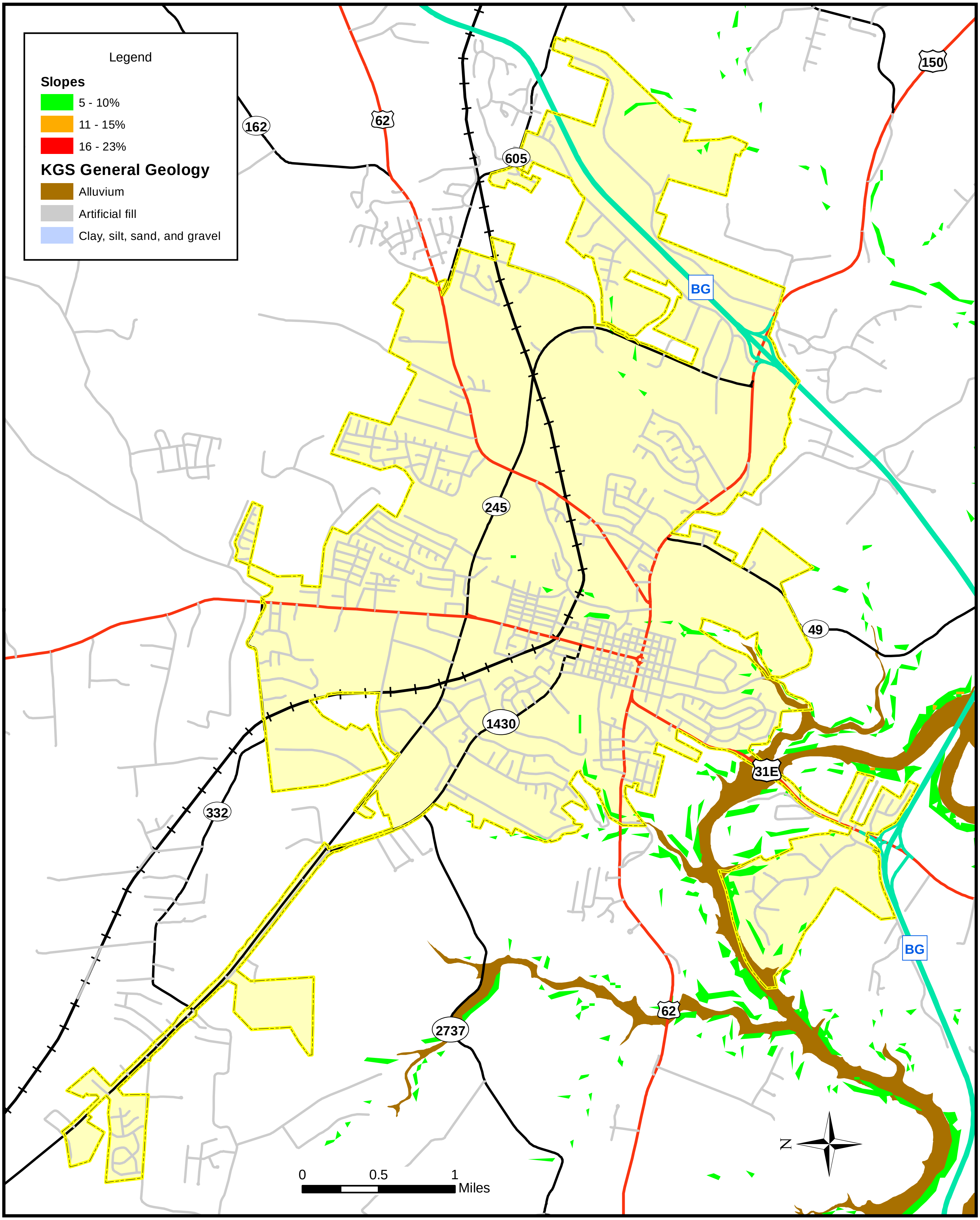
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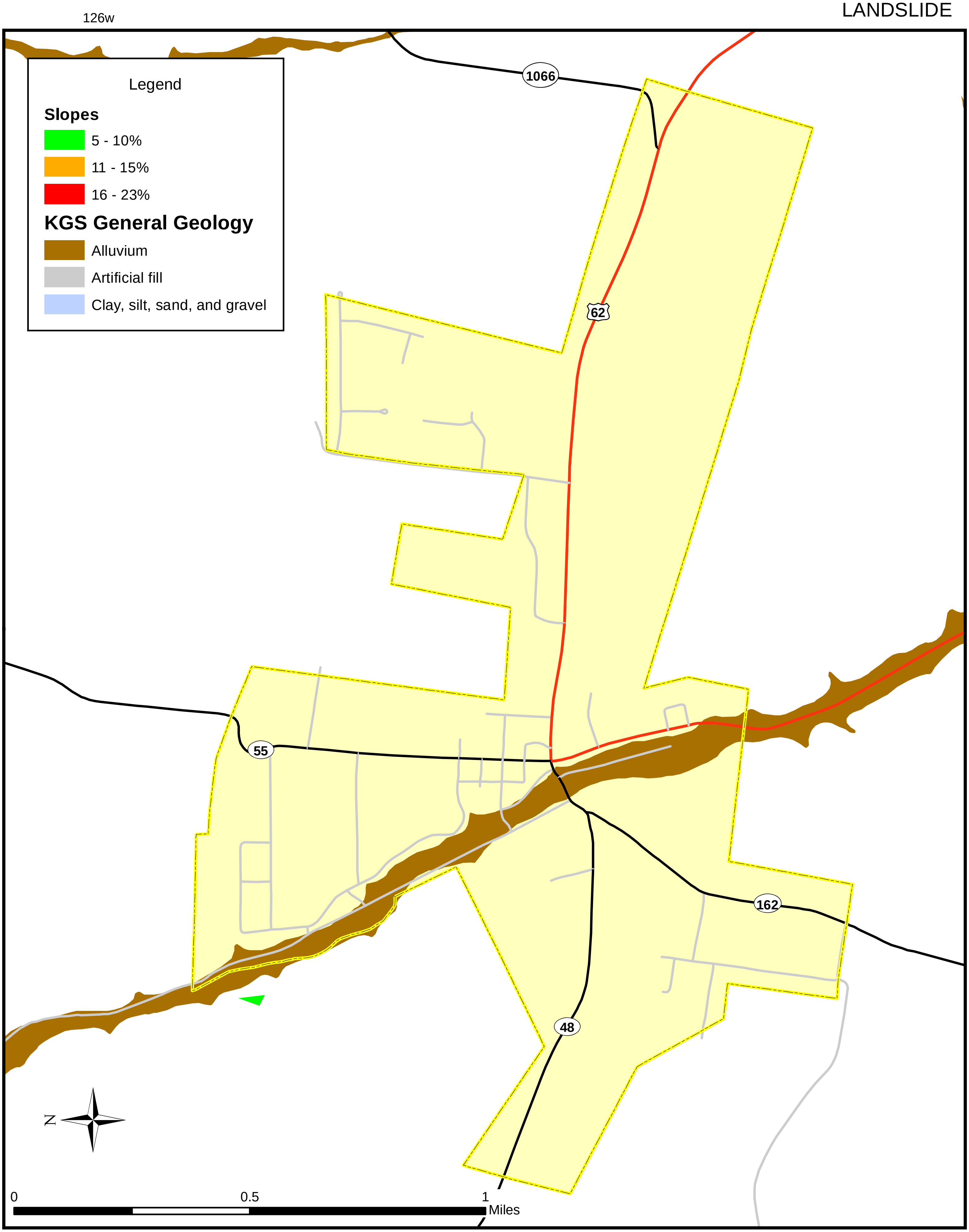
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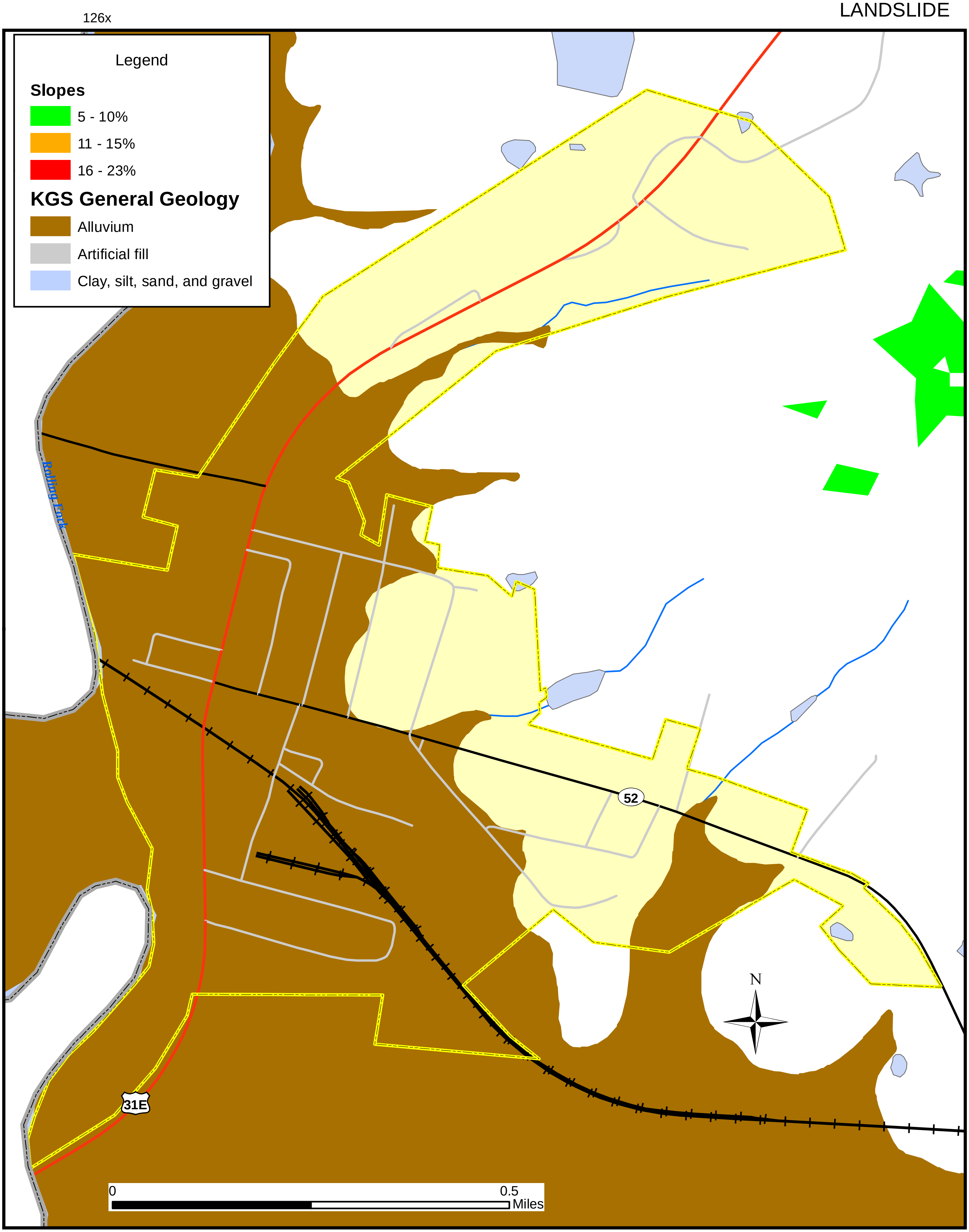
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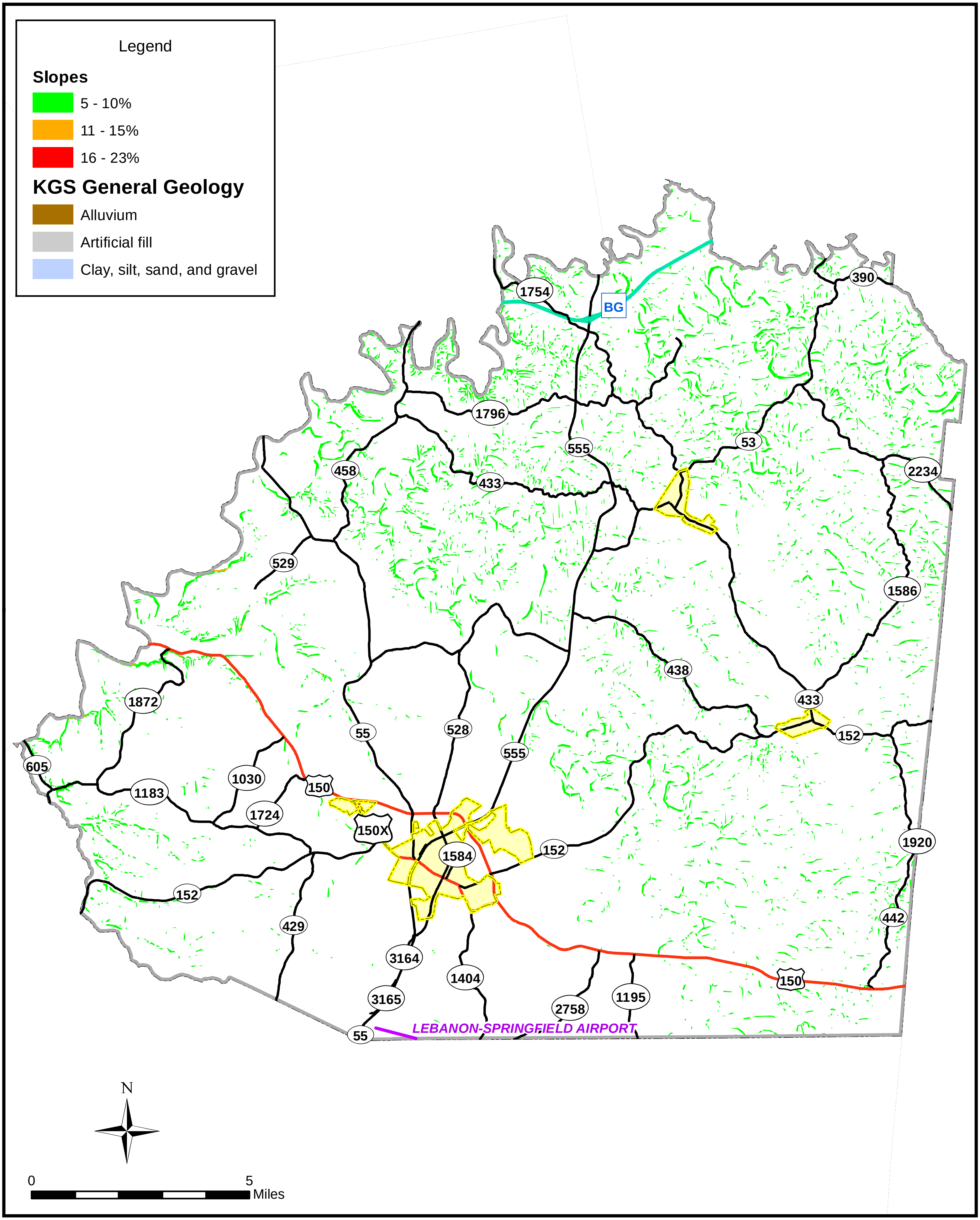
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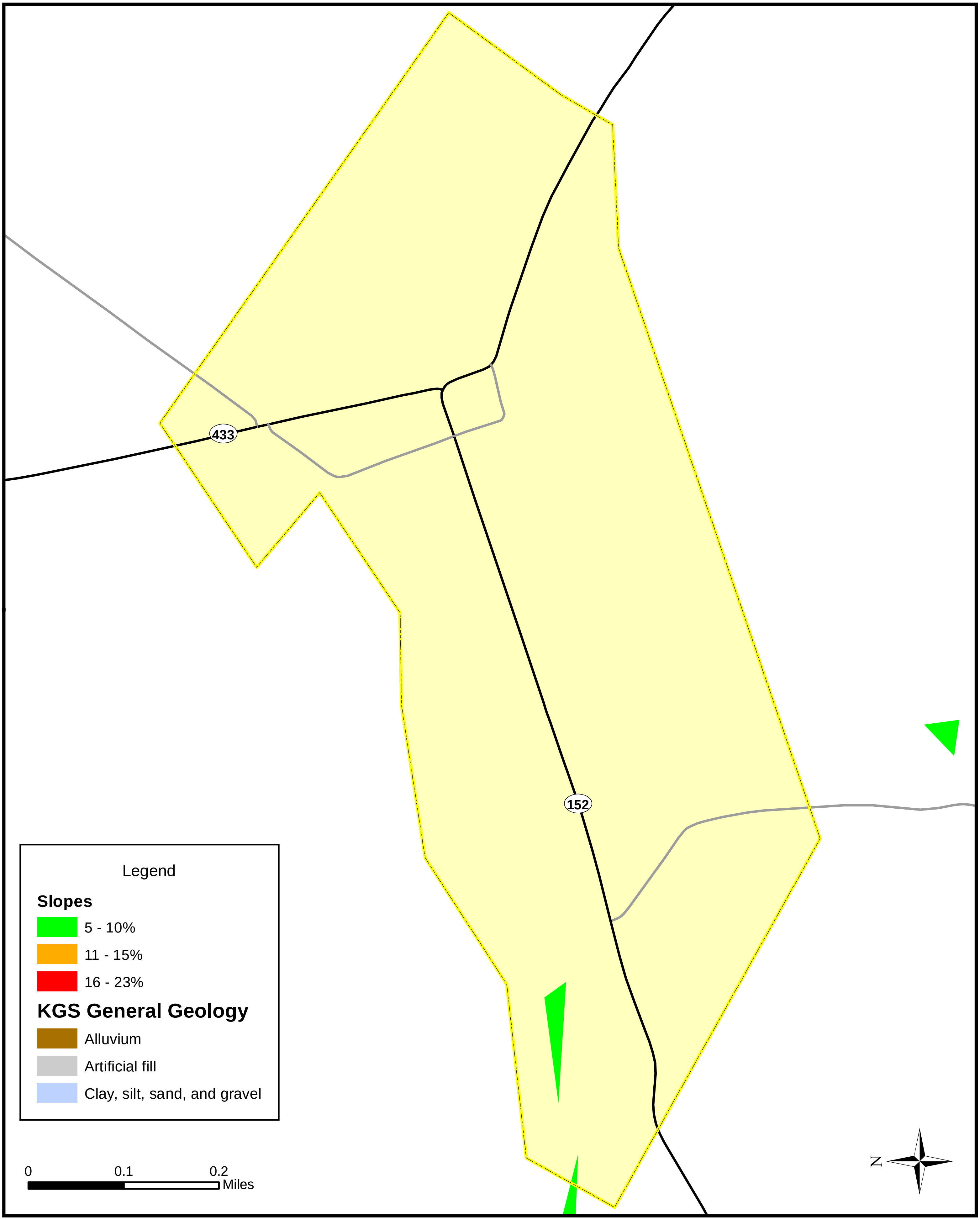
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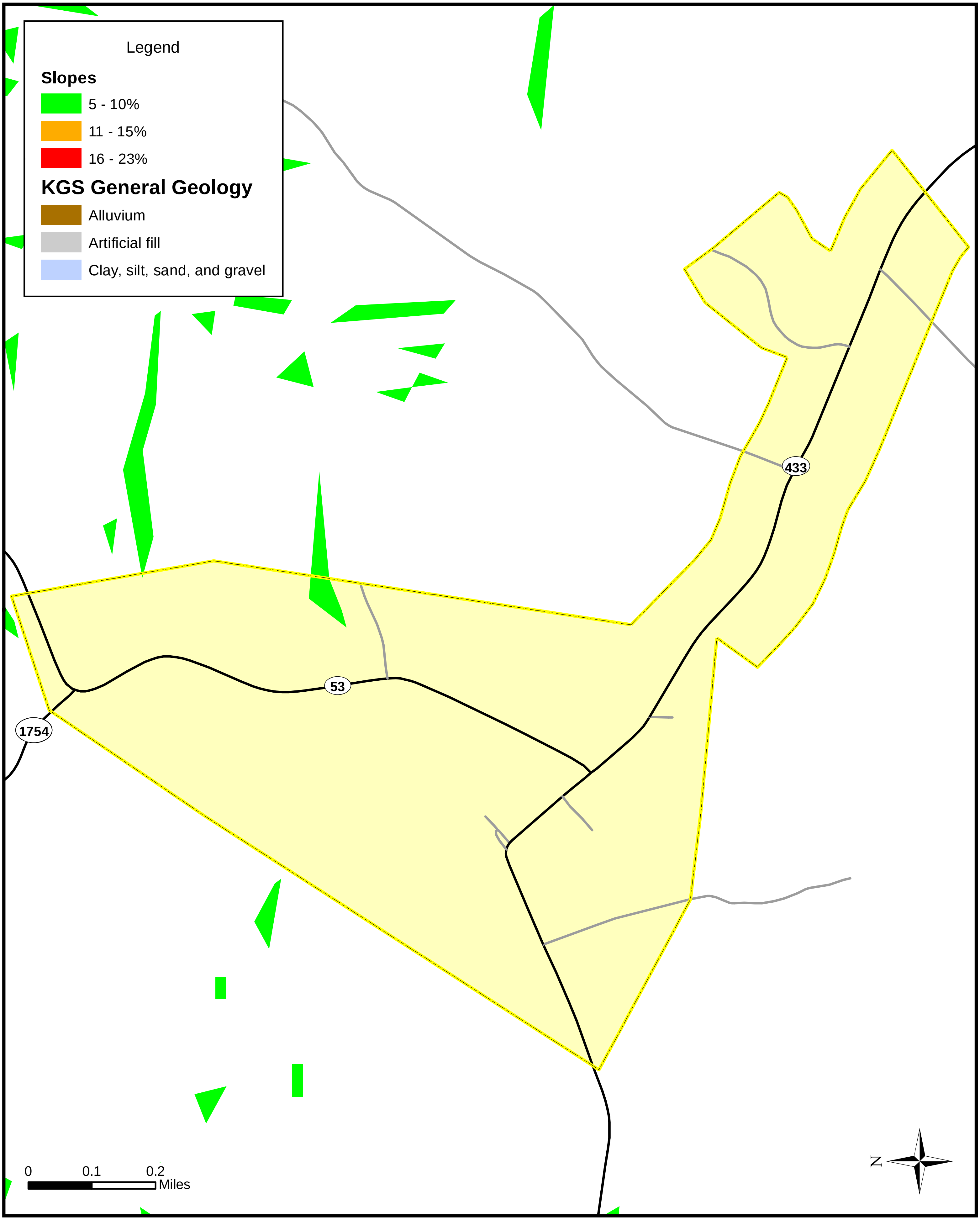
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KGS General Geology
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433
53
1754
N
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0.1
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Miles

3.3.2.8 <u>Karst/Sinkhole</u>

I. Background

Karst Topography:

According to the *Encyclopedia Britannica,* karst topography is characterized by barren, rocky ground, caves, sinkholes, underground rivers, and the absence of surface streams and lakes. This type of landscape results from the excavating effects of underground water movement on massive soluble limestone. While the term *Karst* originally was applied to a region of limestone on the Dalmatian coast of the Adriatic Sea, it has now been extended to mean all areas with similar features.

Karsts are found in widely scattered regions of the world such as the Causes of France; the Kwangsi area of China; the Yucatan Peninsula; and the Middle East, they are also found in Kentucky, Texas, Tennessee, Missouri, Pennsylvania, and Florida in the United States. Although the karst topography in Kentucky is mostly on limestone, it can also occur in different types of rock such as dolomite, gypsum, and salt.

Certain conditions promote karst development such as well-jointed, dense limestone near the ground surface, a moderate to heavy rainfall, and good groundwater circulation. Limestone or calcium carbonate is easily dissolved by slightly acidic water, which occurs widely in nature. Rain becomes slightly acidic as it passes through the air and picks up carbon dioxide (CO_2). Rainwater percolates along both horizontal and vertical cracks, dissolving the limestone and carrying it away in solution. Limestone pavements are produced when surface material is removed, and the vertical fissures along joints gradually widen and deepen, producing a grooved and jagged terrain. As the water continues to flow underground, it widens and deepens the cracks until they become cave systems or underground stream channels. All but a few of the cave areas in the world are areas of karst topography. A karst landscape is characterized by sinkholes, sinking streams, caves, and springs.

Kentucky is one of the most famous karst areas in the world. Much of the beautiful scenery throughout Kentucky is the result of the development of karst landscape. The springs and wells inherent to karst landscape, provide water to many Kentucky cities. About fifty-five percent of Kentucky is underlain by rocks that could develop karst, given enough time, and about thirty-eight percent of the state has some karst development. Twenty-five percent of the state is known to have well-developed karst features. Karst topography forms the world's longest cave system; the Mammoth Cave System in Kentucky is over 350 miles long.

Karst topography is found throughout the Lincoln Trail ADD region. Parts of Meade and Breckinridge Counties, in the vicinity of Irvington and Brandenburg have extensive areas of karst topography that can be seen by driving the roadways through these communities. Saunders Springs Nature Preserve in the Fort Knox Military Reservation just west of Radcliff is an excellent example of karst topography. In addition, many large springs can be found west of Fort Knox in Meade and Breckinridge Counties. There are springs and caves within Otter Creek Park in Meade

County and a spring at the Lincoln Birthplace National Historic Site in LaRue County called Sinking Spring.

Karst Geology

This old roadcut in the Salem Limestone (unit 2) reveals the dissolution process that creates underground cavities and, when the cavity roofs collapse, sinkholes. Photo by Dan Carey, Kentucky Geological Survey.

Limestone formation in Meade County, 2005.

Sinkholes

When a cave becomes large enough and its top extends close enough to the surface, the top collapses. This produces depressions called sinkholes. Sinkholes are characteristic features of karst topography. Sinkholes can coalesce into larger depressions called polje. Sinkholes collect surface water running off the surrounding land, and the runoff goes directly into the groundwater. A sinkhole is an area of ground that has no natural external surface drainage. When it rains, water stays inside the sinkhole and usually drains into the subsurface. Sinkholes vary in size from a few feet to hundreds of acres, and range in depth from between one foot to several hundred feet. Some sinkholes hold water to form natural ponds.

Types of Sinkholes

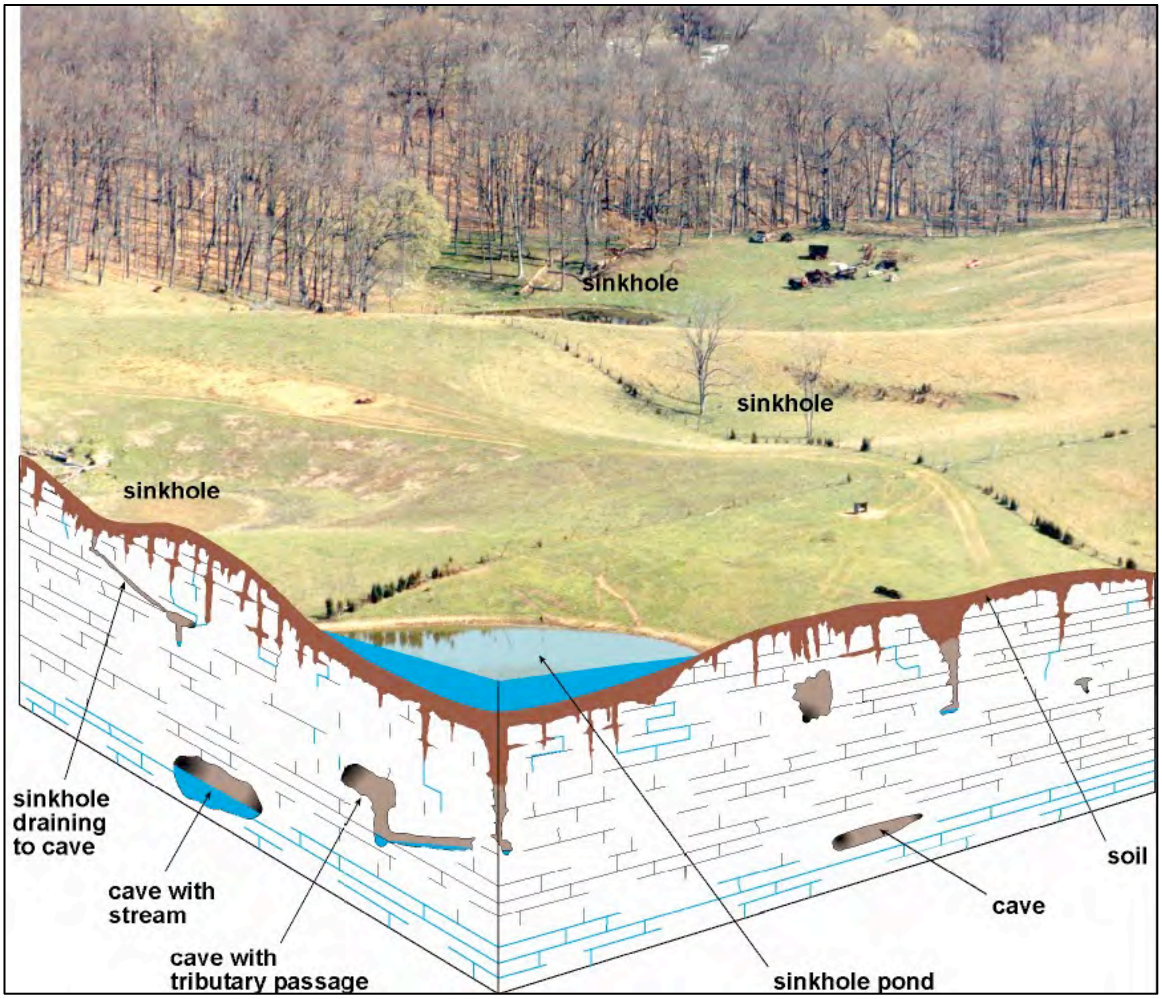
Dissolution sinkholes are formed when bedrock is dissolved and carried away underground. These sinkholes develop gradually, over time, with occasional episodes of soil or cover collapse.

Cover-subsidence sinkholes develop gradually where the covering sediments are permeable and contain sand. In areas where cover material is thicker or sediments contain more clay, cover-subsidence sinkholes are relatively uncommon, are smaller, and may go undetected for long periods.

Cover-collapse sinkholes can develop abruptly over a period of a few hours and cause catastrophic damage. These sinkholes occur where covering sediments contain a significant amount of clay. Over time, surface drainage, erosion, and deposition of a sinkhole turn it into a shallower bowl-shaped depression. Land Subsidence which can be a result of this action is included in a separate narrative at the end of this section.

Geologic Hazards in Karst

Human safety and economic losses are the results of most naturally occurring geologic hazards. There are two common karst-related geologic hazards: cover-collapse sinkholes and sinkhole flooding.



Karst System. *Source: Kentucky Geological Survey*

According to the Kentucky Geologic Survey, *cover-collapse* sinkhole occurs in the soil or other loose material overlying bedrock. As overlying soil is repeatedly wetted and dried, small amounts of soil are dislodged and carried away by the cave conduit draining the sinkhole. The collapse only occurs in the overlying soil, and not in the limestone bedrock.

Cover-collapse sinkholes can vary in size from 1 or 2 feet deep and wide, to tens of feet deep and wide. Soil thickness and cohesiveness determine the size of a cover-collapse sinkhole. Cover-collapse sinkholes in Kentucky are rarely more than 20 feet in diameter due to the thickness of soil, sand or clay, and bedrock fragments that overlay the limestone bedrock. Unlike cover-collapse sinkholes in Florida that swallow entire houses and businesses, that is unlikely to happen in Kentucky where the overlay is less dense. However, cover-collapse sinkholes in Kentucky do severely damage buildings, drain farm ponds, damage roads, and wreck farming equipment.

The most effective way to avoid cover-collapse sinkhole hazards and damage is to avoid buying or building a structure on any sinkhole that has been filled. Before buying property, look for previous damage such as foundation damage and/or door frames and windows that are out of square. Also check all surrounding land for shallow impressions and arch-shaped cracks in the soil.

Sinkhole flooding occurs when there is more precipitation than the conduits and caves can handle. Unlike a normal stream channel, the cave conduit channel has a fixed diameter and cannot expand as flow increases. There are two types of sinkhole flooding. In the first type, the sinkhole conduit may be constricted and unable to carry water away as fast as it flows in. This can occur when the throat of the sinkhole is clogged by trash and junk, soil eroded from fields or construction sites, and sometimes by rock fall within the conduit. Or, at times, the diameter of the conduit is too narrow to handle the volume of water flow. The second type of sinkhole flooding is caused by discharge capacity being limited farther downstream. This can happen when caves are blocked by trash or rock fall, have limited conduit size, or from back flooding from other sinkholes. Sinkholes that may drain normally during moderate rain, may become springs and discharge water from their throats during intense storms.


Sinkhole plain before a rain. Sinkhole plain after a rain.

Source: Kentucky Geological Survey

All structures built in a sinkhole or karst valley are prone to flooding, and little can be done to mitigate future flood damage, except to move the structure. Some sinkholes are so large, that it is difficult to determine that a building site is actually a closed depression. It is always the best practice to consult a topographical map, inspect an area to determine its relative elevation, look for previous signs of water damage, and research historic flooding events.

Probability/Impact

The Lincoln Trail Region is dotted with sinkholes and underlain by karst topography. Extensive mapping of the area has been incorporated into local land use plans and most of these karst/sinkhole sites have not been developed or had structures built on them. The maps included in this section illustrate how prevalent karst topography is in the Lincoln Trail Region. However, there is little quantitative data on historic sinkhole-related events that enables the prediction of the probability of occurrence, or to articulate the extent of impact that the hazard poses for the Lincoln Trail Region. The prevalence of karst topography in the region results in a 100% chance that either a sinkhole collapse or sinkhole flooding event could occur in any given year. Either scenario could result in the destruction or damage of structures and infrastructure and/or the loss of human life. The impact of local sinkhole hazards is exemplified by the Quiggins Sinkhole Flooding event. Since quantitative impact reports for sinkhole hazards do not exist within the Lincoln Trail Region, research must focus on the type of karst topography prevalent in the area. The region is mostly underlain with a system of roofed-over creeks as opposed to actual sinkholes. Consequently, most sinkhole related hazards have been those related to sinkhole flooding and have been aggregated into damages and hazard events associated with flooding. Thus, the Quiggins Sinkhole flooding stands as an identified example of the impact and existence of regional sinkhole hazards.

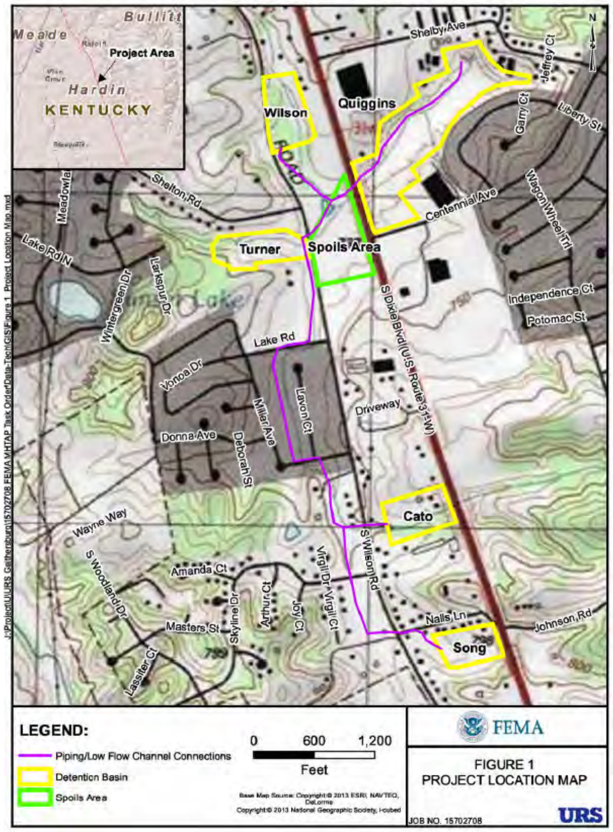
A large area sinkhole is in Radcliff in Hardin County. The significance and impact of the hazard was enough to justify the 2015 FEMA Hazard Mitigation Grant financing of a sinkhole mitigation project that exceeds $5 million. The Quiggins Sinkhole lies within the Happy Valley watershed and is concentrated around 24 acres of land. A primary hydrology study and FEMA environmental analysis used for the project's application relied on impacts to housing and public works within this area in the City of Radcliff. From this single event, hydrology studies determined damages based upon recurrence probability. Work to prevent sinkhole related flooding is currently underway and should improve water management in the area. The Quiggins Sinkhole Flood Mitigation Project will construct four retention basins and expand a fifth to mitigate the effects of widespread flooding. The Quiggins Sinkhole is one of 86 known sinkholes into which the City of Radcliff drains. Using the recurrence intervals cited, only impacts to housing and public works within the 24-acre site, for this one sinkhole were calculated.

Table 3.3.2.8.1 - Quiggins Sinkhole Impact Costs

Recurrence Interval	Housing Damages (In Dollars)	Public Works Damages (In $)	Total Damages (In Dollars)
200	$969,123	$91,697	$1,737,628
100	$623,019	$80,381	$1,296,687
50	$420,027	$69,455	$1,002,128
25	$264,344	$59,310	$761,419
10	$171,617	$46,824	$564,045
5	$56,176	$37,849	$373,388
2	$13,210	$27,704	$245,397
1	$358,408*	$19,900	$525,190
* Refers to "Less Than One-Year Damages"			

When adjusted for inflation, the total benefits of mitigating the impacts of one sinkhole, using assumptions of one representative hazard event that occurred in Radcliff in 2008, was calculated at $5,679,173.

Ongoing work on Quiggins Project, *Source: Greg Thompson, News-Enterprise, March 2016.*



Quiggins Sinkhole Flood Mitigation Project Location Map. *Source: FEMA Environmental Assessment Feb. 2015.*

In addition to sinkhole flooding effects, the prevalence of karst terrain within the Lincoln Trail Region must be considered when analyzing and thinking about the number and value of significant historic sites located in the area that may be situated on or near sinkholes. Rich in Lincoln history, the Lincoln Trail Region is home to many valuable historic sites such as the Joseph Holt House located on KY 144 in Breckinridge County and Lincoln's grandfather's homestead, the Lincoln Homestead, located outside of Springfield in Washington County. The Abraham Lincoln Birthplace, part of the National Parks system, is located outside of Hodgenville in LaRue County, on a site that was called the Sinking Springs Farm, an area underlain by twelve (12) sinkholes. All these sites are valuable historic sites, priceless and irreplaceable. The 2003 Executive Order 13287: Preserve America states: "The Federal government shall recognize and manage the historic properties in its ownership as assets that can support department and agency missions while contributing to the vitality and economic well-being of the Nation's communities." The federal government recognizes not only the intrinsic value of historic sites, but also the economic benefits associated with them that positively impact local property values, jobs, tourism, and revenue. Consequently, the impact of sinkhole collapse at the Birthplace site would have a significant financial impact far exceeding the hazard event itself.

Extent

To exemplify impact, the Radcliff Quiggins Sinkhole Flooding event was used and shall be used again to address the extent of a sinkhole/karst hazard. Based on one 2008 event, multiple hydrology studies and an environmental assessment conducted by FEMA, determined that it was feasible that over $5.5 million in damages could potentially result from the Quiggins Sinkhole in Radcliff. It was determined that the Quiggins Sinkhole was capable of discharging floodwaters at 11.9 cubic feet per second (cfs), analogous to the flow capacity of a 12-inch pipe. This could easily result in major flooding with as little as one inch of rainfall over a six-hour period according to FEMA's 2/12/2015 "Environmental Assessment: Quiggins Sinkhole Flood Mitigation Project. City of Radcliff, Hardin County, Kentucky, DR-KY-1818-0012."

3.3.2.8.1 Land Subsidence

NOTE: This section previously stood alone as a specific Hazard in the Lincoln Trail Hazard Mitigation Plans from 2005 & 2010. It has been moved to this section as of the 2015 Plan.

I. Background

According to the U.S. Geological Survey (USGS), land subsidence is defined as the gradual settling or sudden sinking of the Earth's surface due to subsurface movement of earth materials.

USGS goes on to say that while land subsidence is a global problem, it impacts the United States substantially. More than 17,000 square miles in 45 states, have been affected by subsidence. The principal causes of land subsidence are aquifer-system compaction, drainage of organic soils, underground mining, hydro-compaction, natural compaction, sinkholes, and thawing permafrost. More than 80% of land subsidence in the United States is a consequence of human impact on subsurface water, and is an often, overlooked environmental consequence of our land water-use practices. Increased development of our land and water resources threatens to exacerbate existing land-subsidence problems and initiate new ones.

Cause of Subsidence

Several causes of land subsidence have been identified and include dissolution of limestone, mining, extraction of natural gas, groundwater-related subsidence, faulting induced, isostatic subsidence, drainage of organic soils, and seasonal effects. This section will only describe those that have a potential of threat in the Lincoln Trail Region.

Dissolution of limestone occurs in karst terrains where dissolution of limestone by fluid flow in the subsurface causes the creation of voids or caves. When the roof of a void becomes too weak, it can collapse and overlying rock and earth fill fall into the void and causes subsidence on the surface. This type of subsidence can result in sinkholes that can be hundreds of meters deep.

Seasonal effects impact land subsidence. Many soils contain significant proportions of clay that are affected by changes in soil moisture due to their very small particle size. Seasonal drying of soils results in a reduction of soil volume and a lowering of the soil surface. If building foundations are above the level to which the seasonal drying reaches, they will move, and this can result in damage to the building in the form of tapering cracks. Trees and other vegetation can have a significant effect on local drying of soils. Cumulative drying over several years occurs as the tree grows and this can lead to the opposite of subsidence, known as heave or swelling of the soil, when the tree declines or is felled. As the cumulative moisture deficit is reversed, over a period that can last as many as 25 years, the surface level around the tree will rise and expand laterally. This can be more damaging to buildings unless the foundations have been strengthened or designed to cope with the effect.

II. Analysis

To analyze land subsidence as a hazard in the Lincoln Trail Region, much research was done. Sources included FEMA, the Kentucky Geological Survey, the United States Geological Survey and County Emergency Management Agencies.

Lincoln Trail Region Subsidence

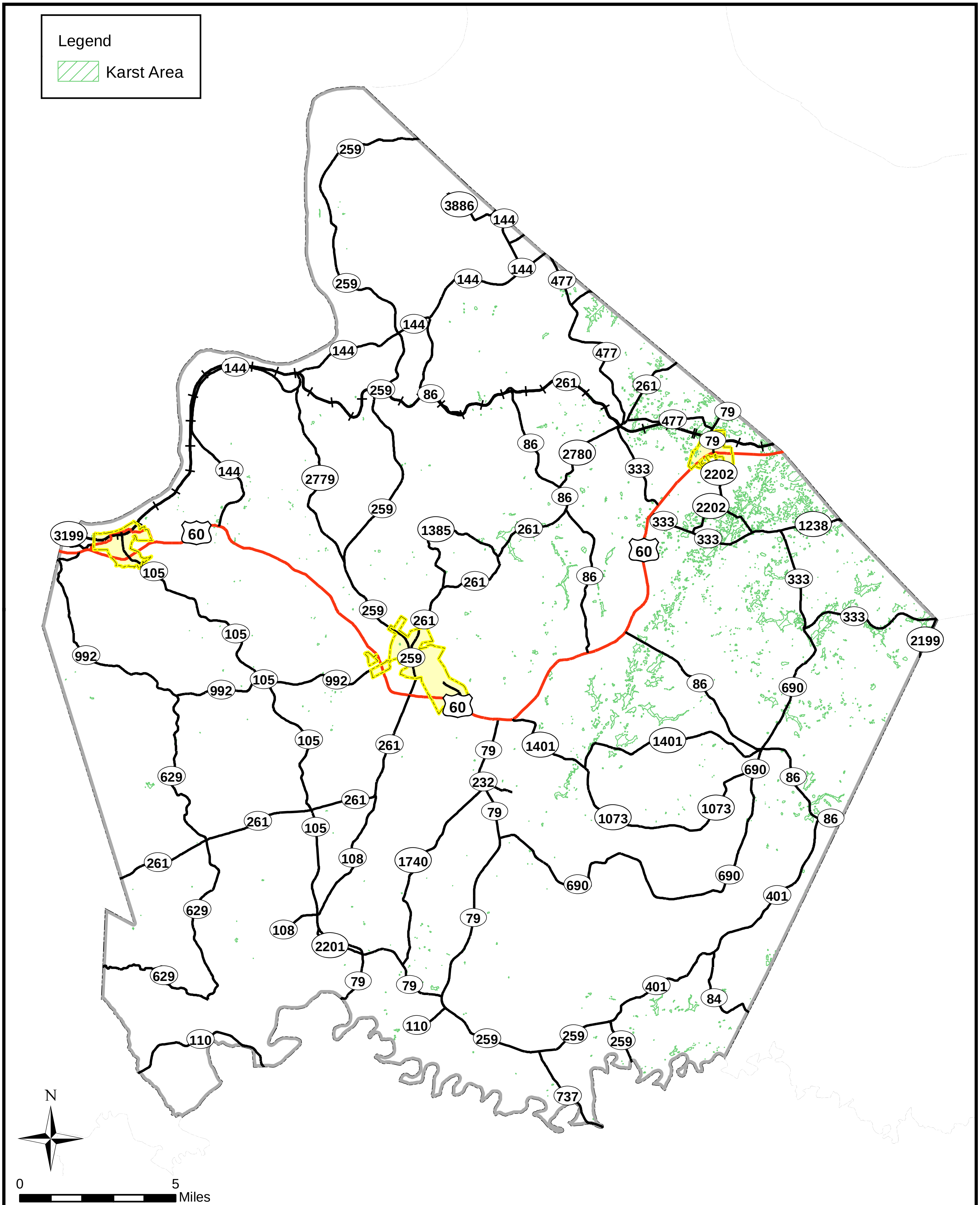
Subsidence is common in the Lincoln Trail Region, mostly as the result of erosion in areas along creek banks and in the karst topography. Quarry activity is common in the region, but the limestone rock extracted leaves highwalls that are fairly stable. Use of preventative agricultural practices and the proper use of land use management when siting construction projects will alleviate most of the effects of land subsidence in the Lincoln Trail region.

On the Ohio River in Meade County – Feb. 25, 2010,
Source: LTADD Archive.

Image of a calf being rescued from a sinkhole in Meade County in 2019. *Source: The News-Enterprise*.

Sinkhole that appeared in a shopping center parking lot in Elizabethtown in 2018. *Source: The News-Enterprise.*

135a



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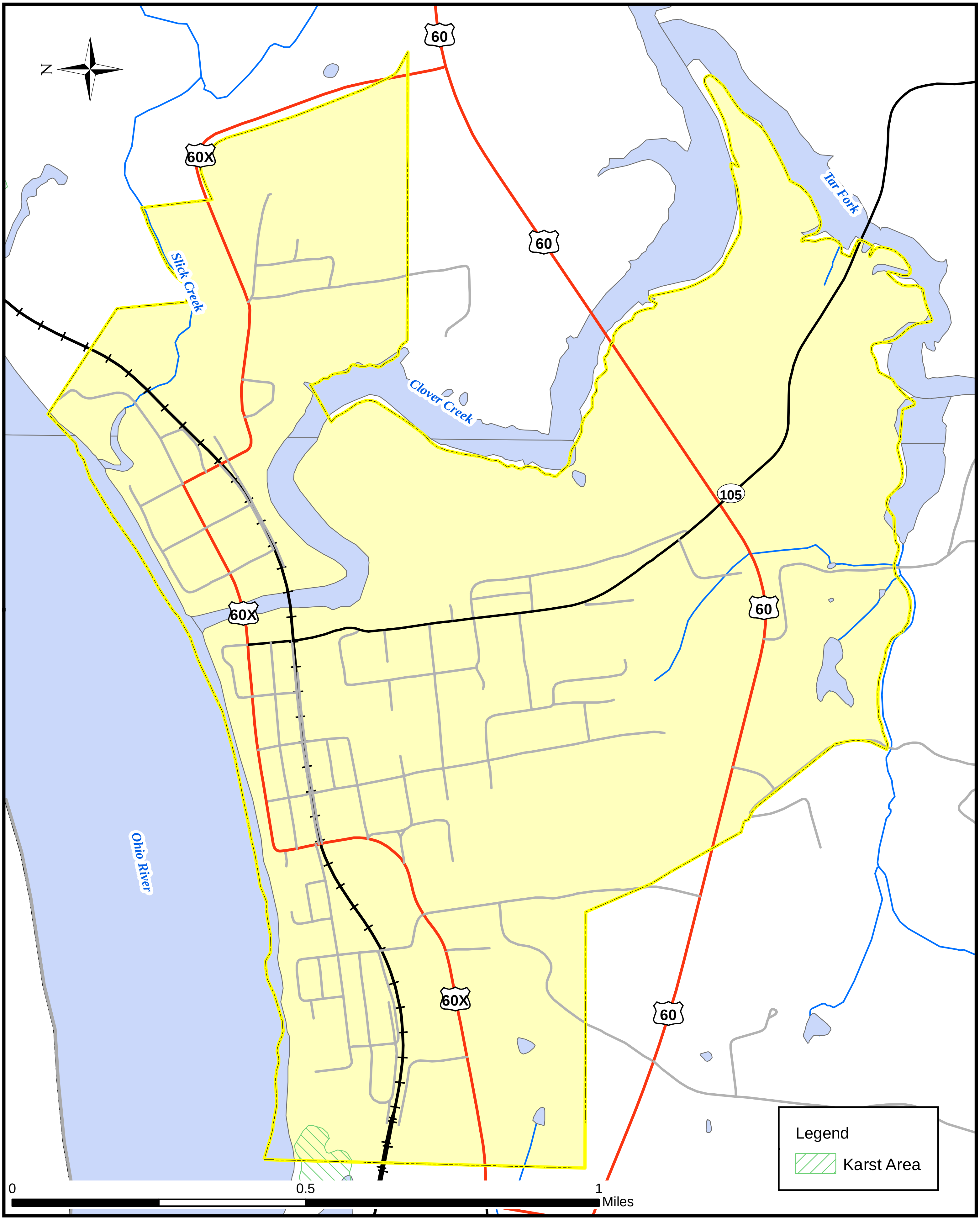

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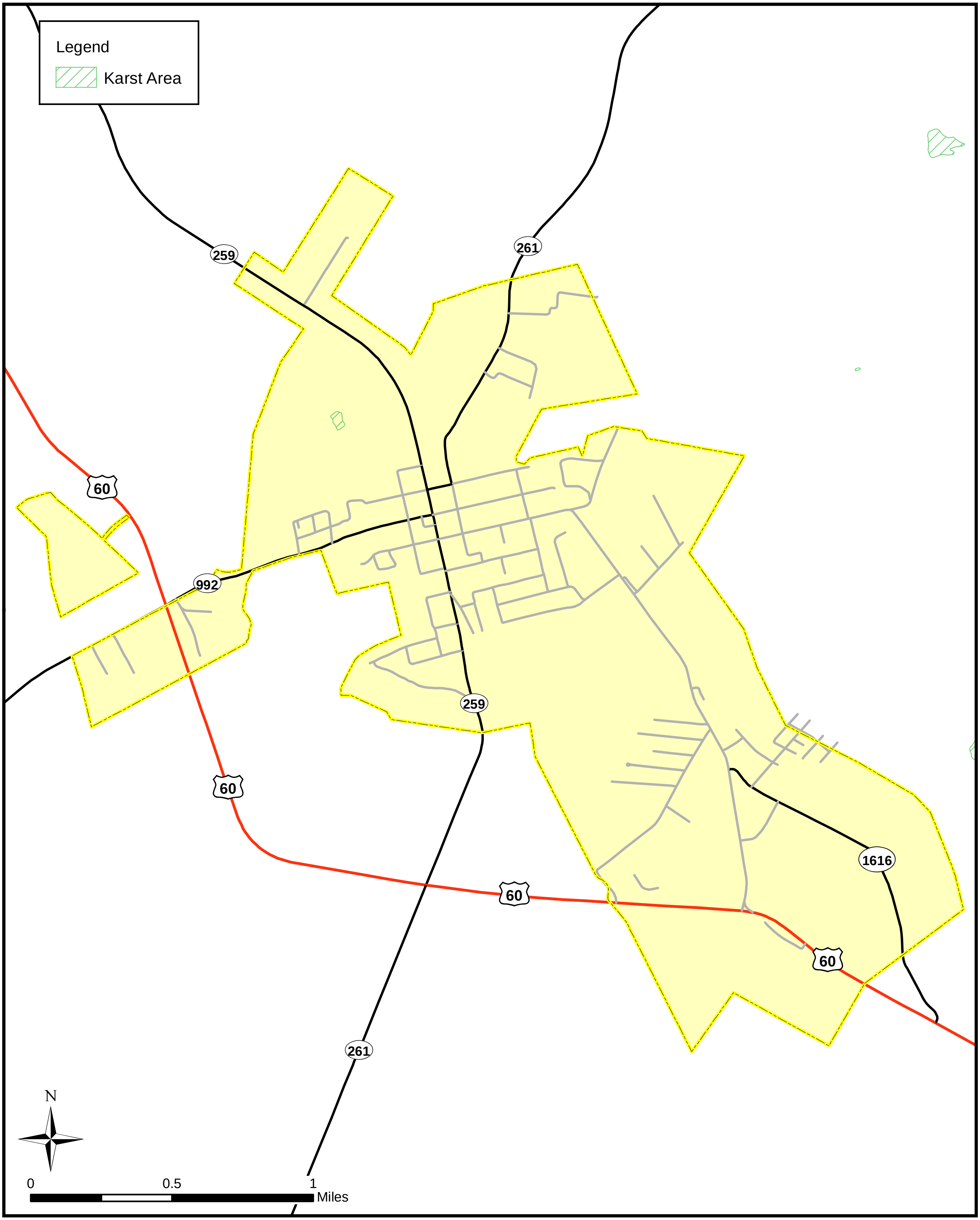
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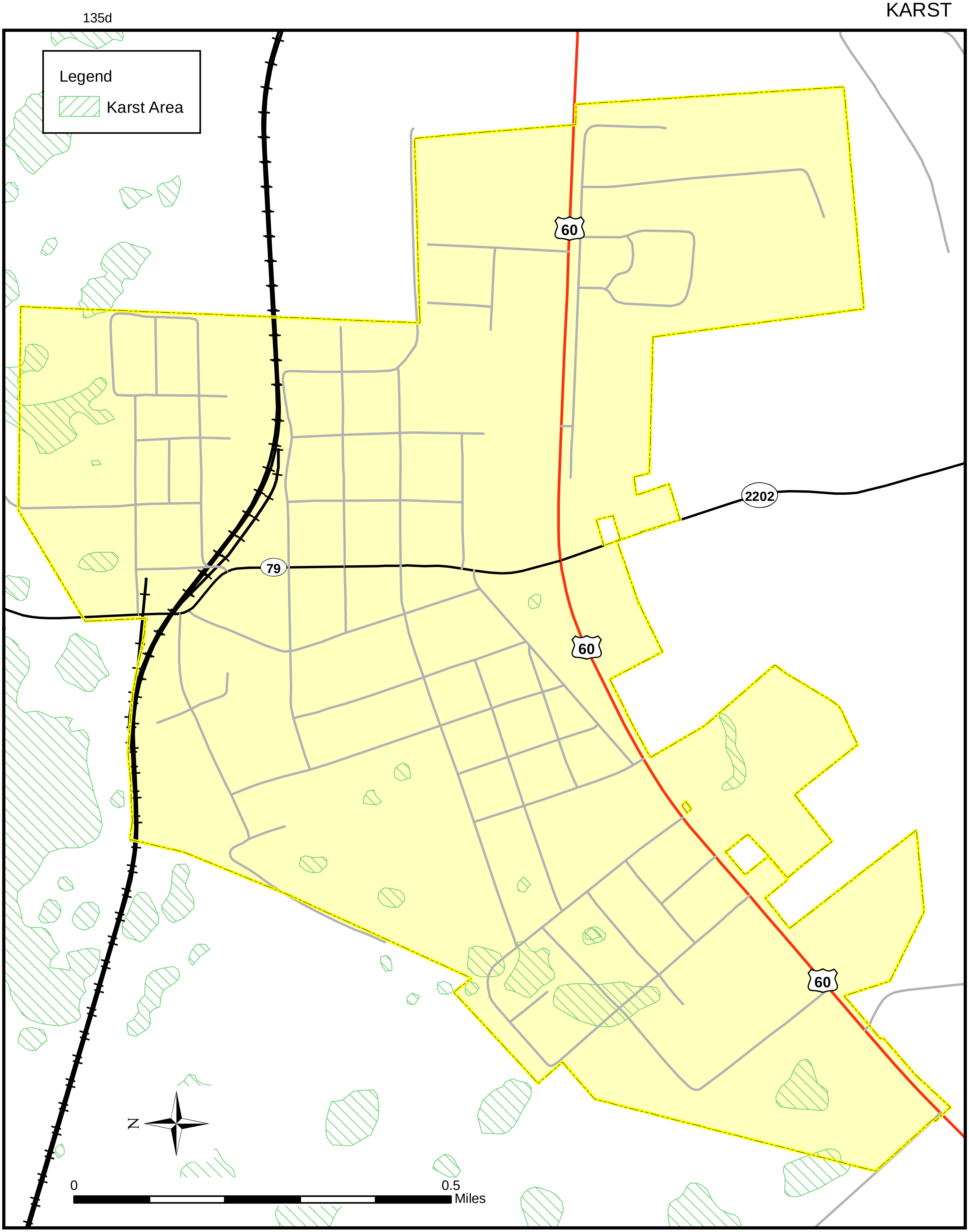
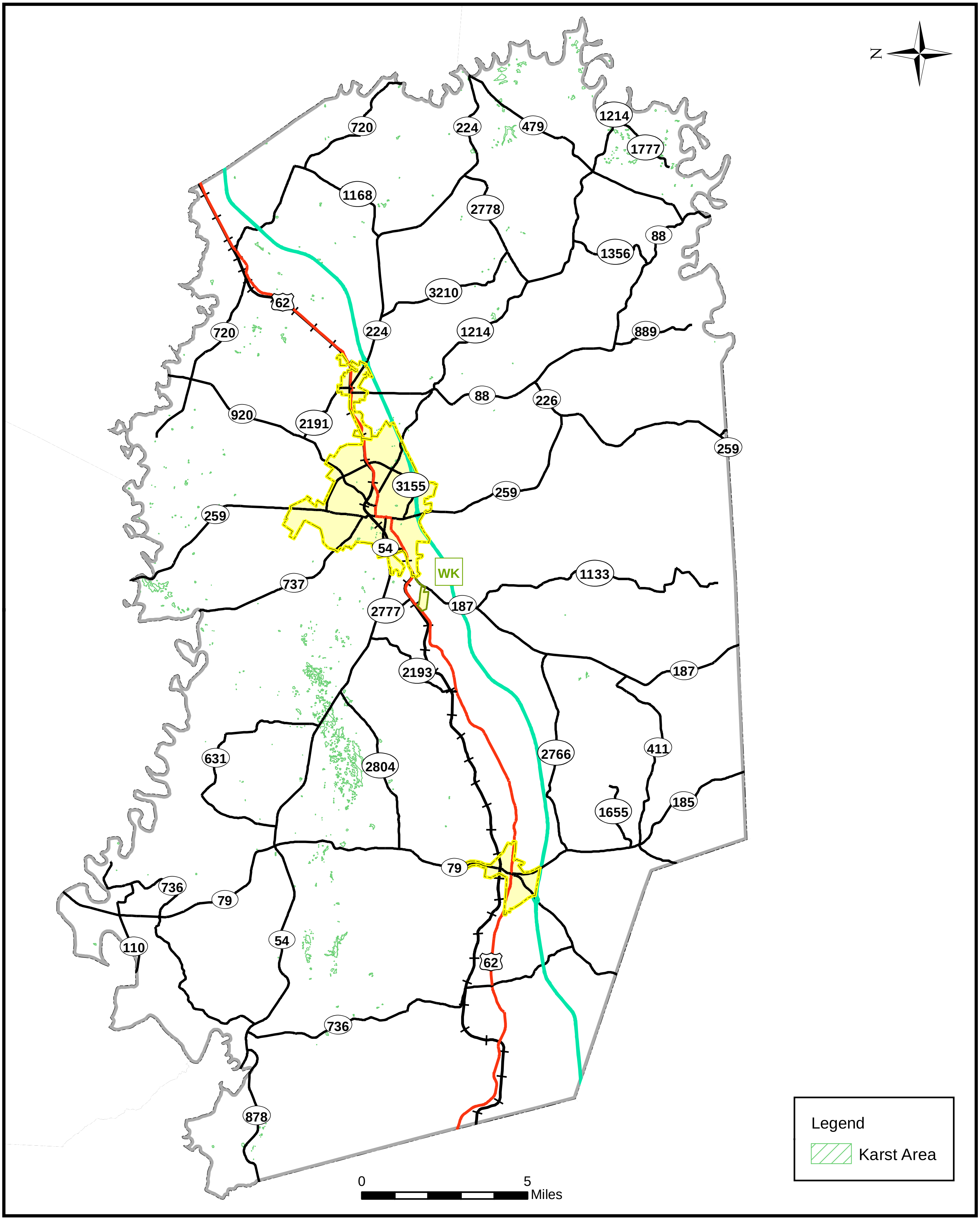
1
Miles

IRVINGTON
KARST



GRAYSON COUNTY
KARST



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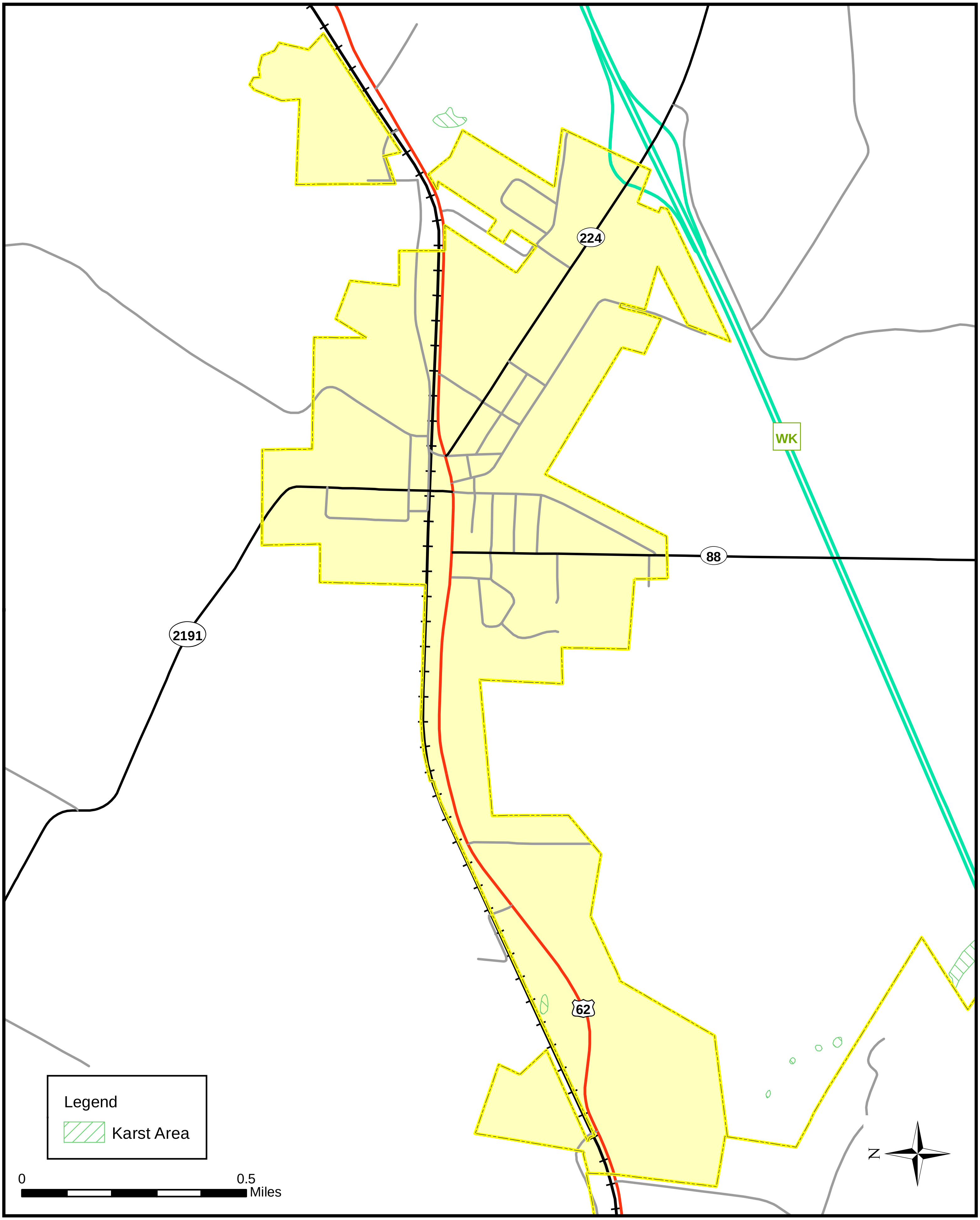

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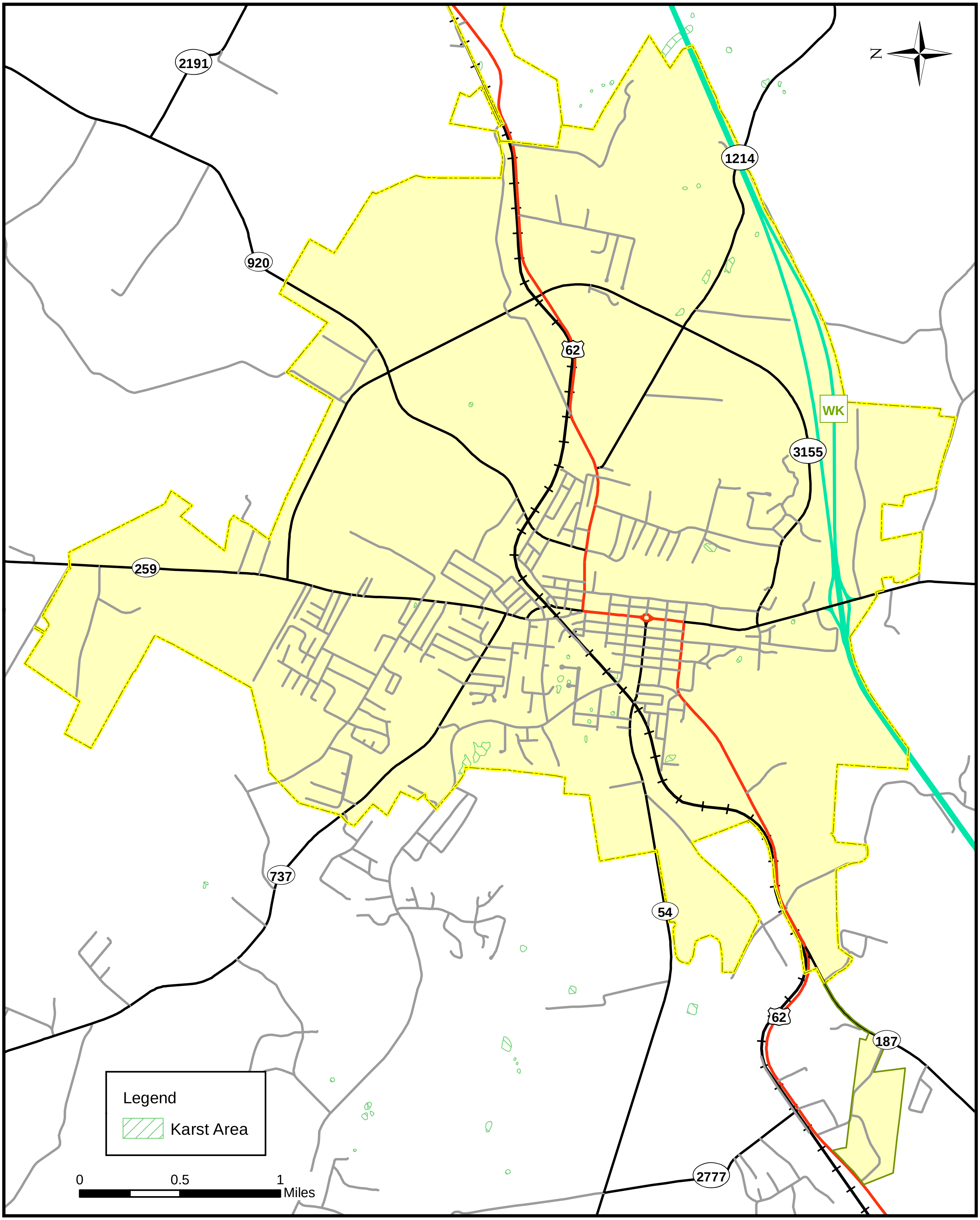
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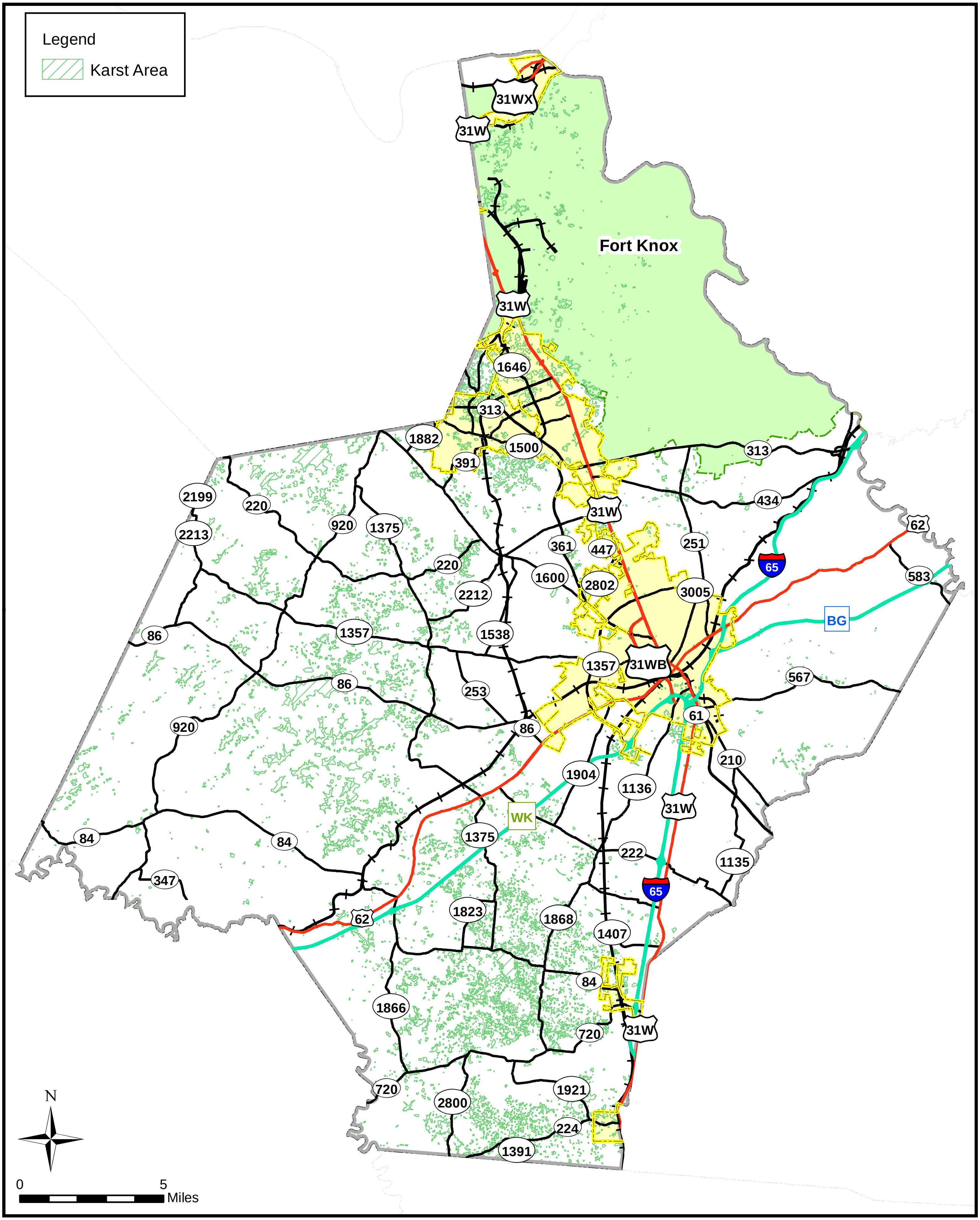
1
Miles

135h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447
251
62
65
583
1600
2802
3005
2212
BG
86
1357
1538
31WB
567
253
61
210
1904
1136
WK
84
1375
222
1135
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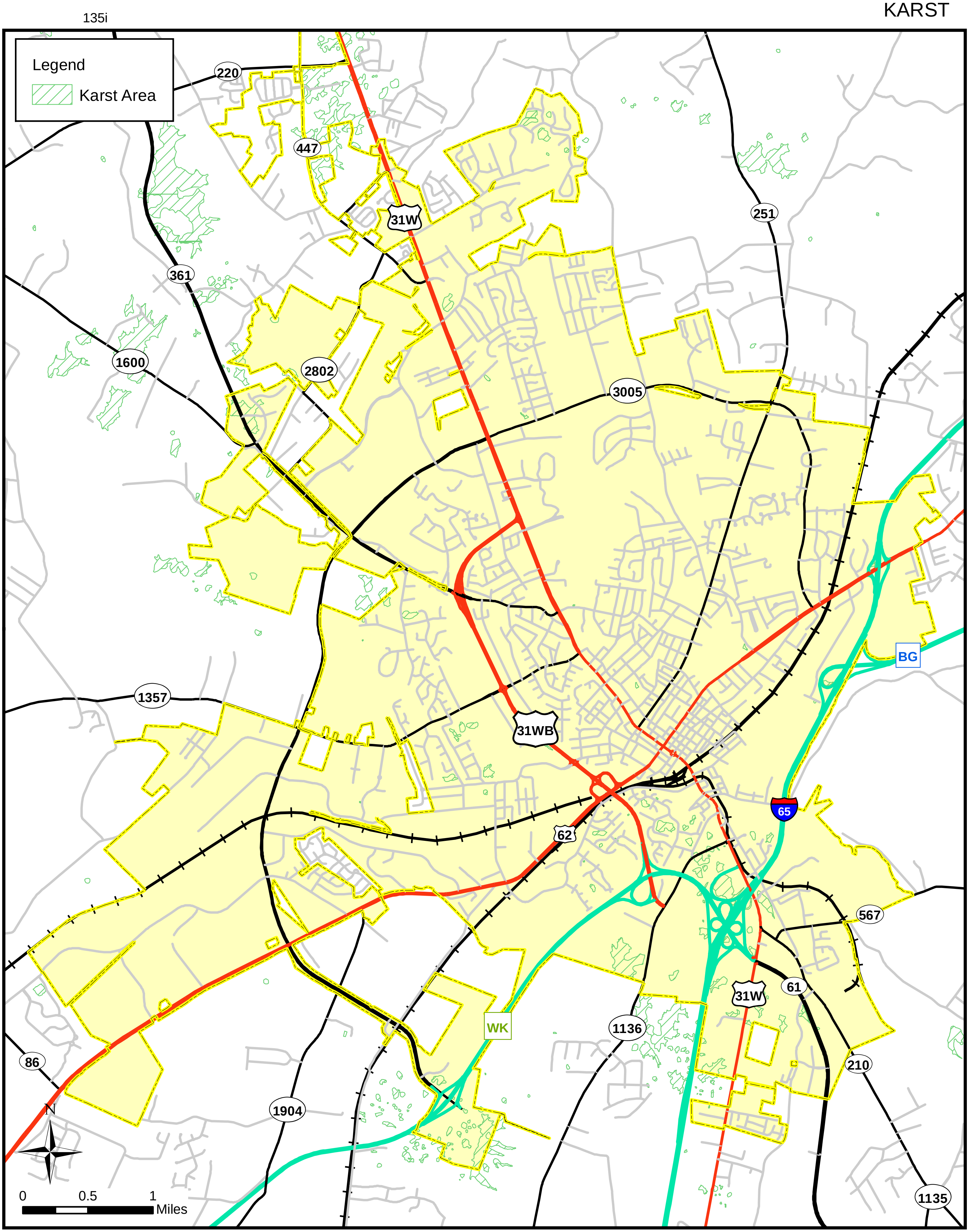
ELIZABETHTOWN
KARST



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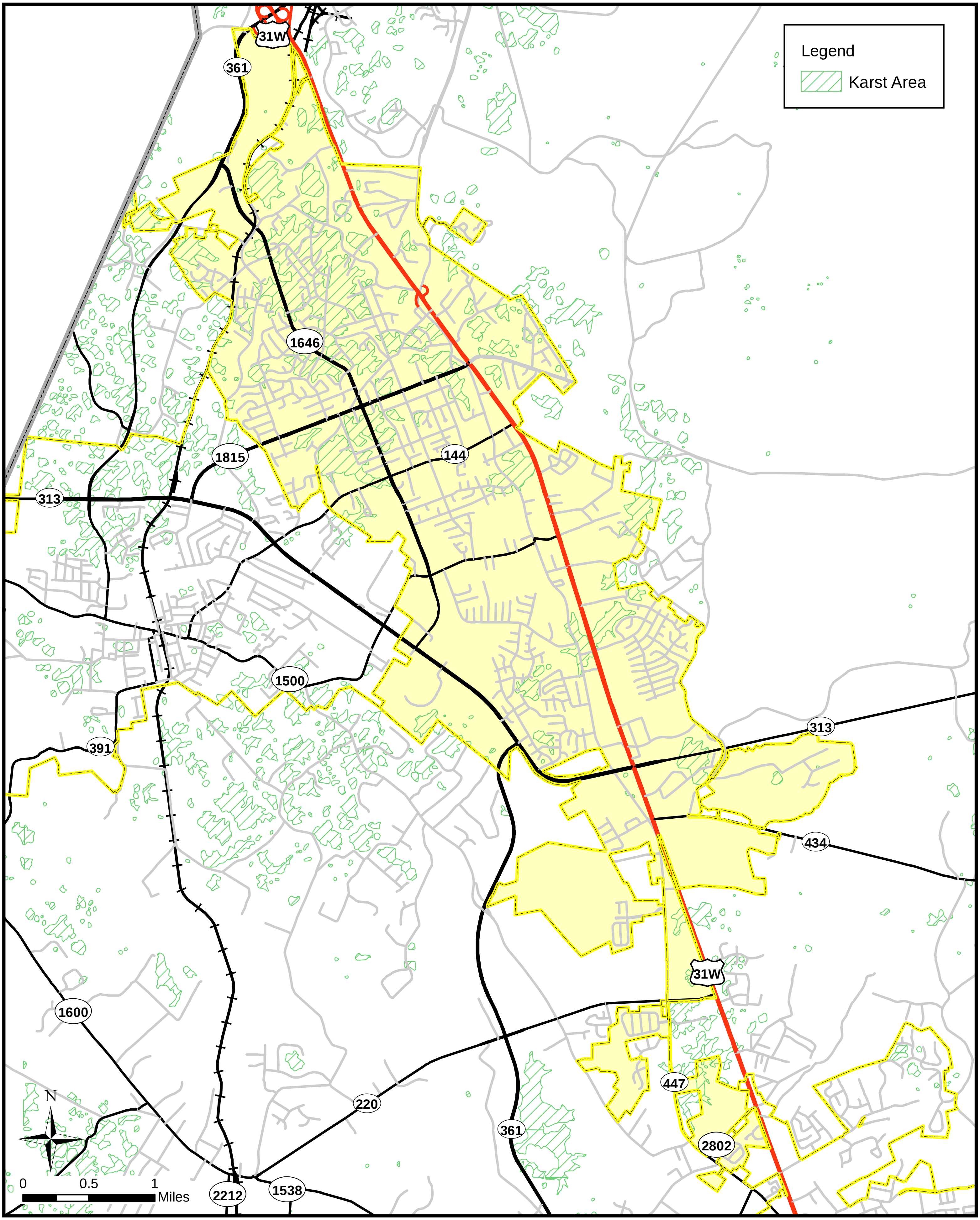
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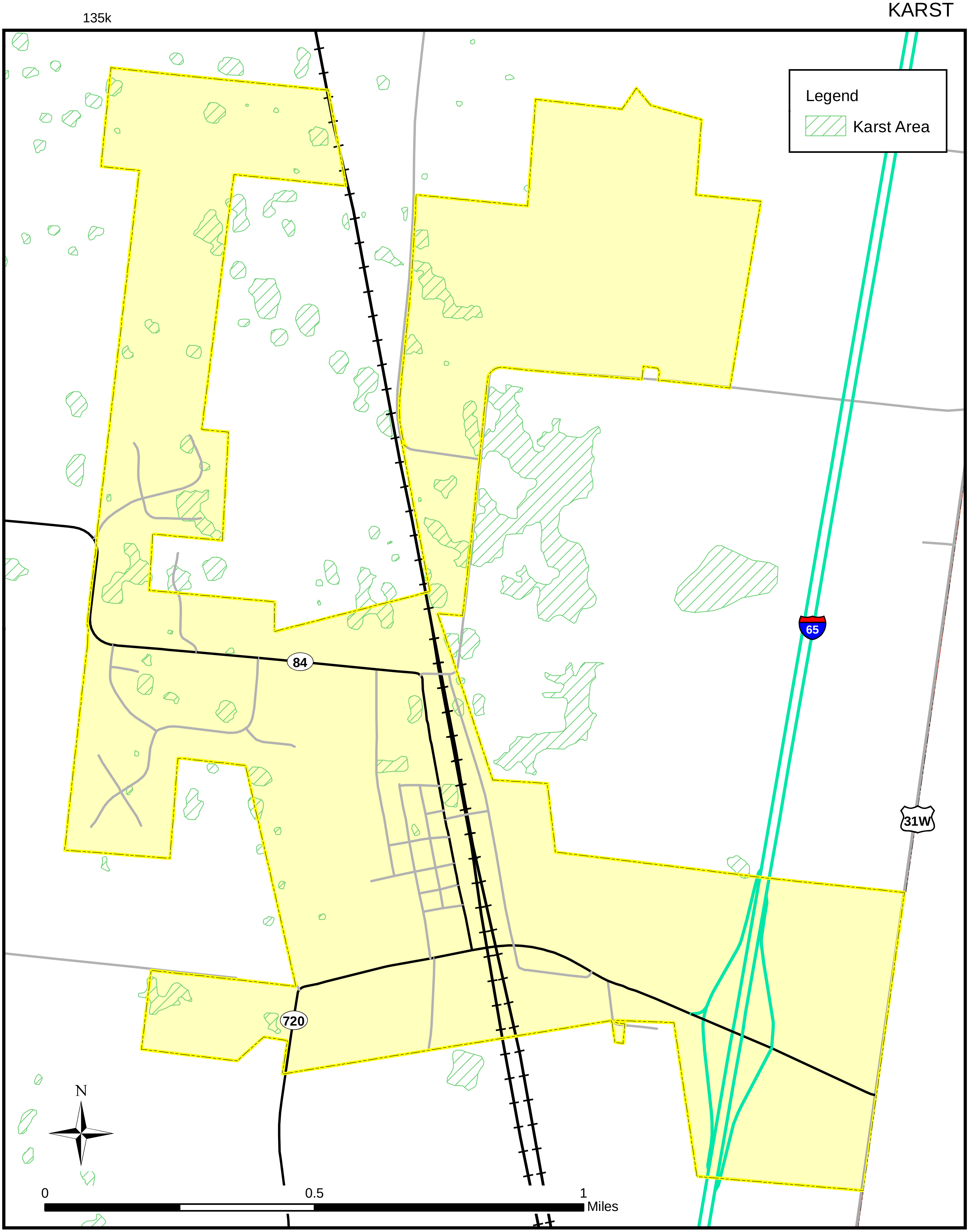
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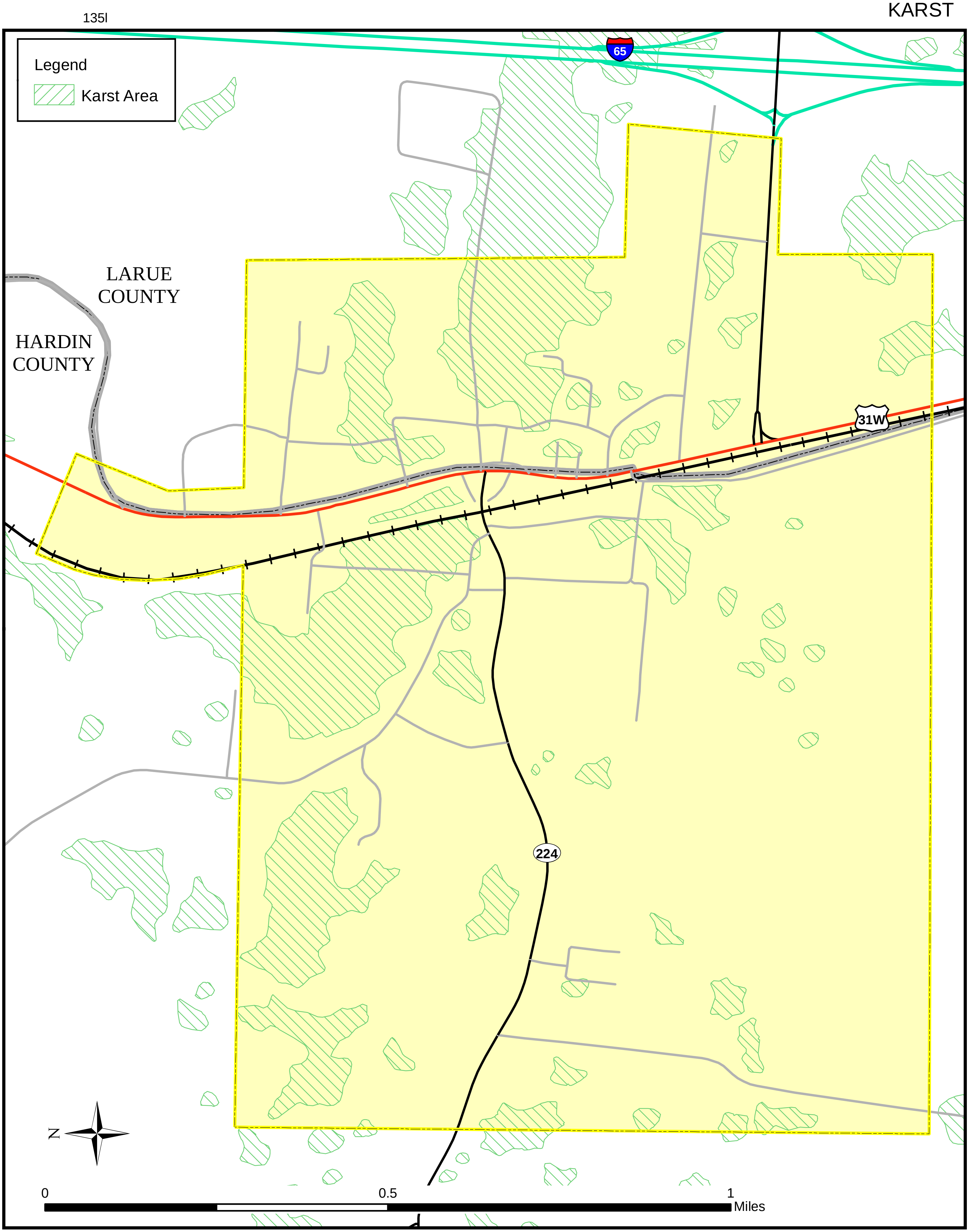
UPTON
KARST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LARUE
COUNTY
HARDIN
COUNTY
31W
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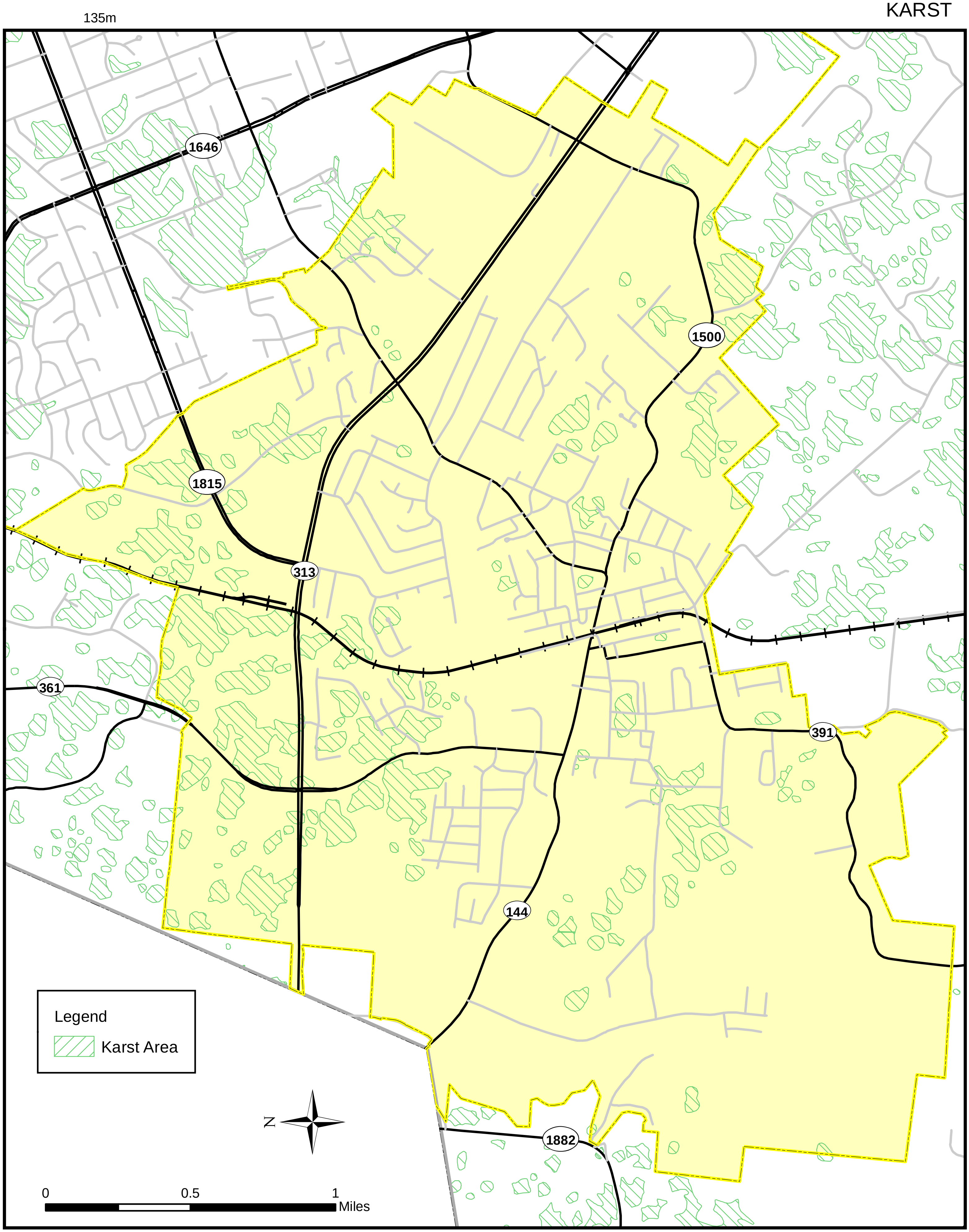
0.5
1
Miles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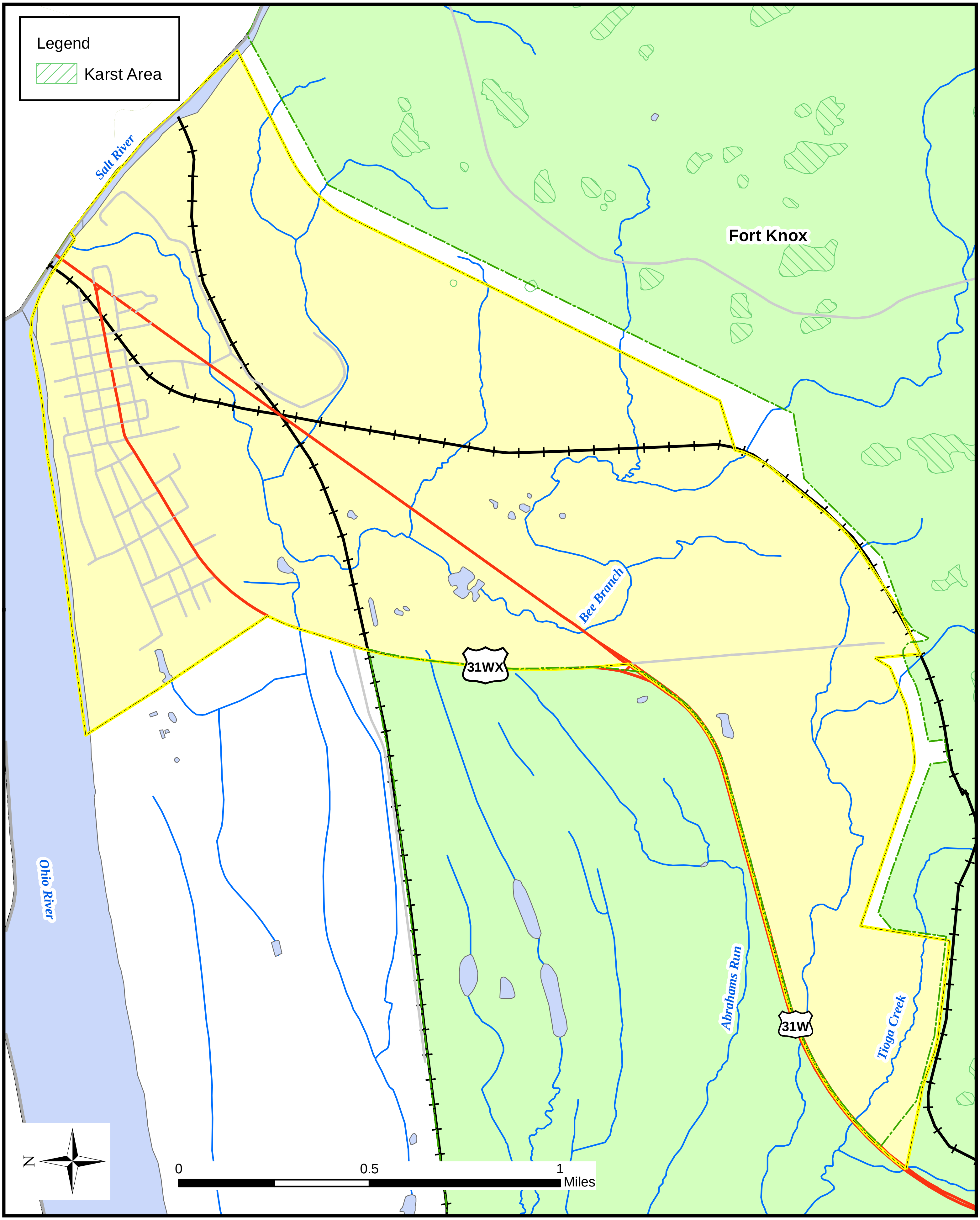
135n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Ohio River
Bee Branch
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Abrahams Run
31W
Tioga Creek
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Miles

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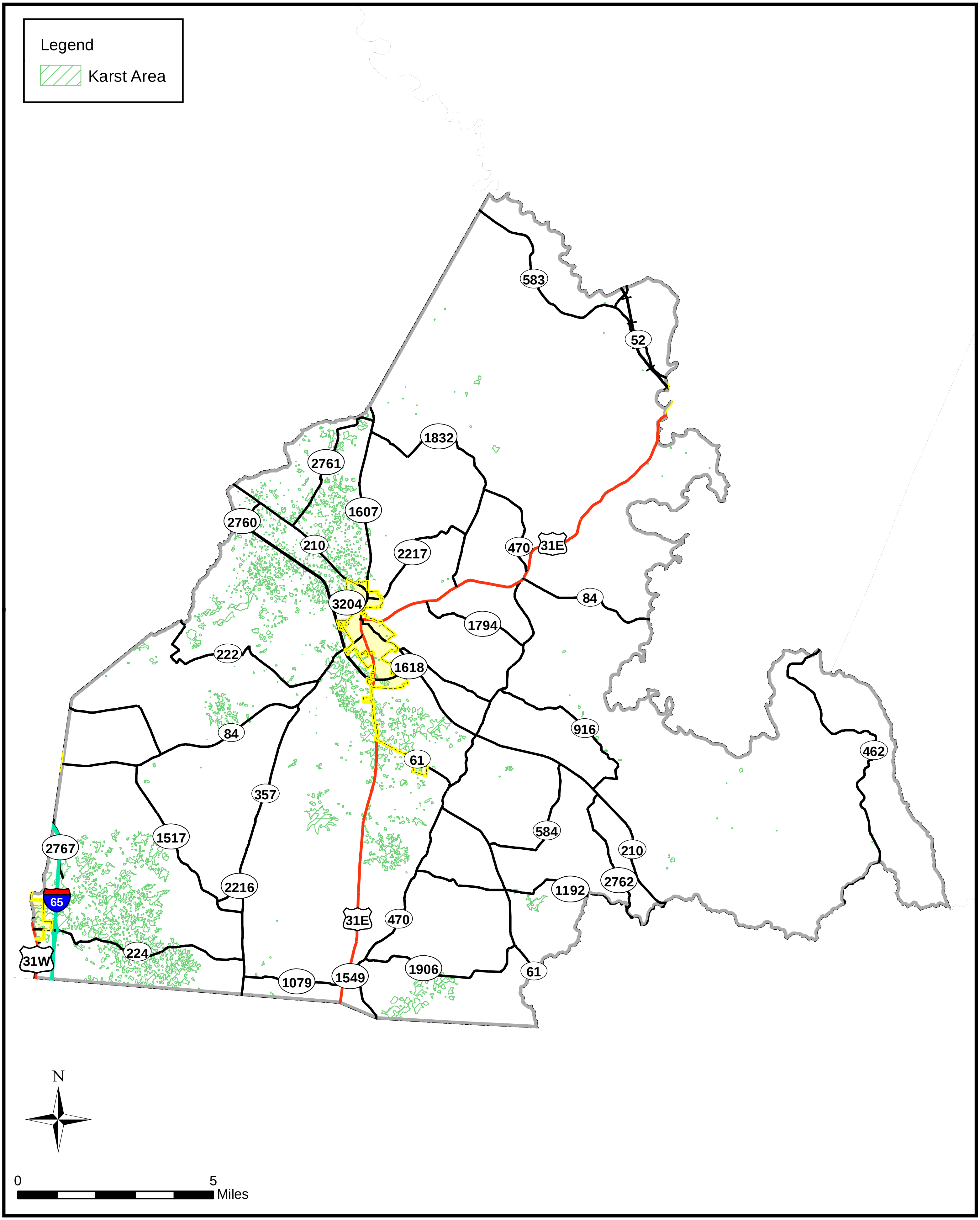
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462
357
584
1517
2767
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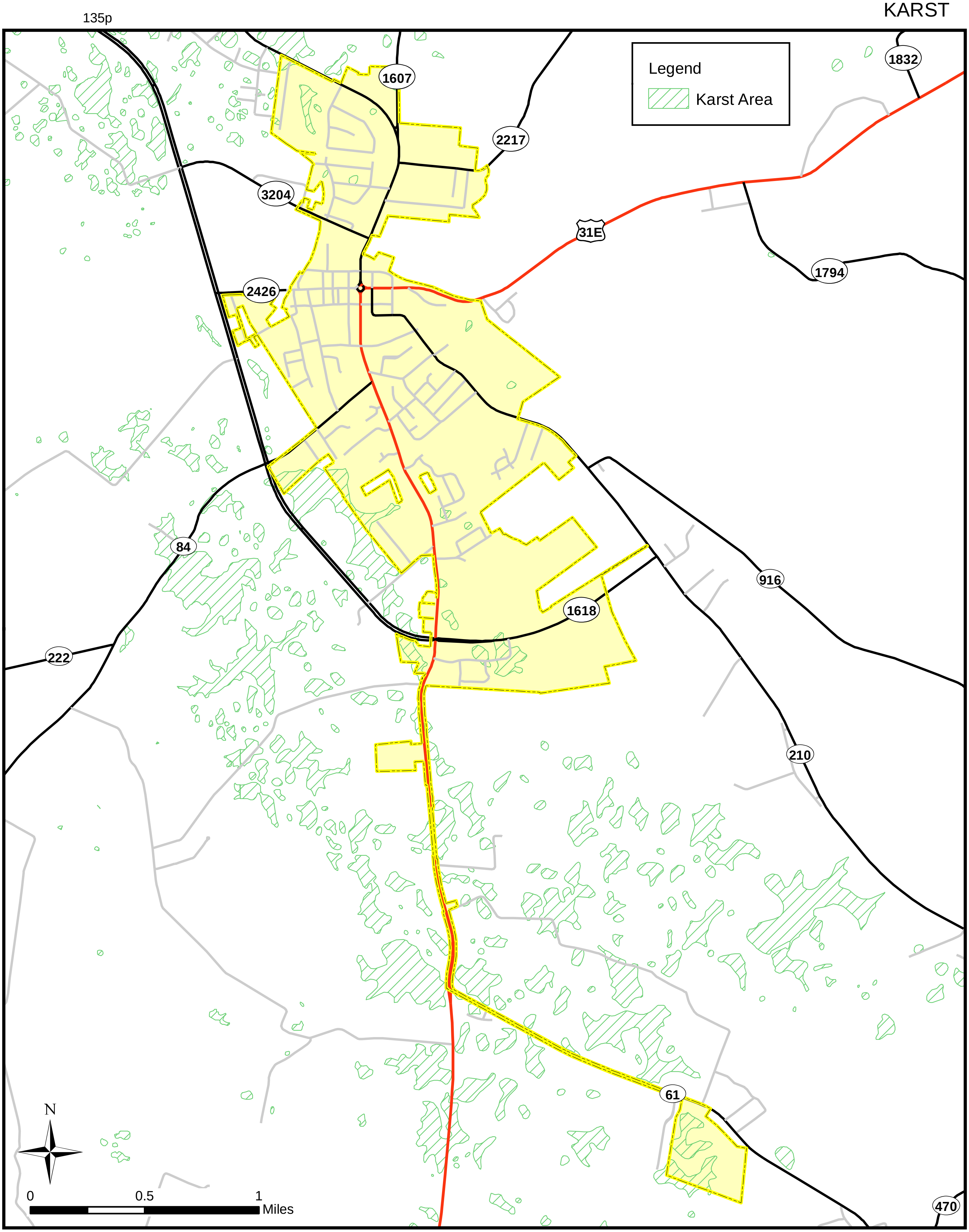
5
Miles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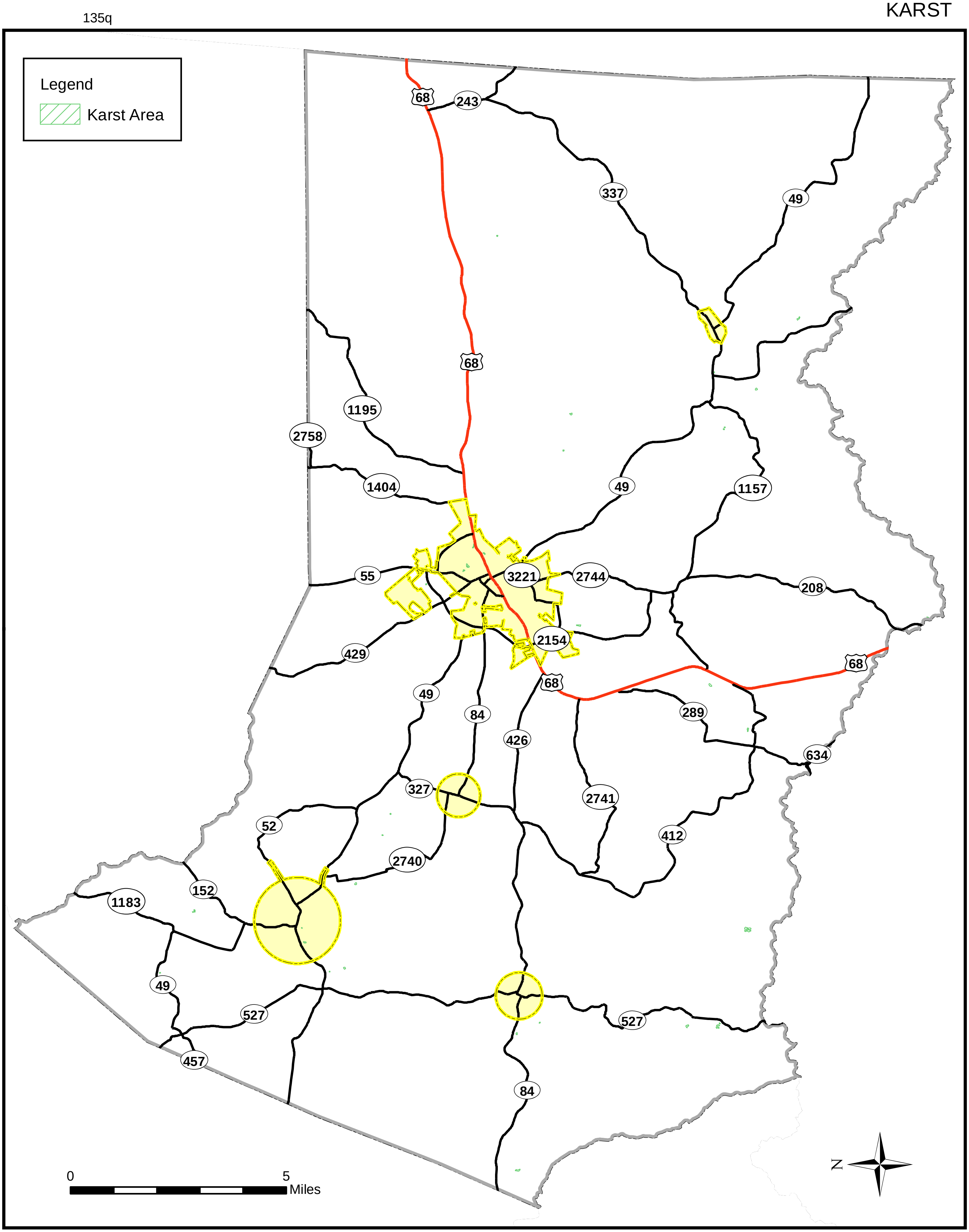
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2154
68
68
49
84
289
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5
Miles
N

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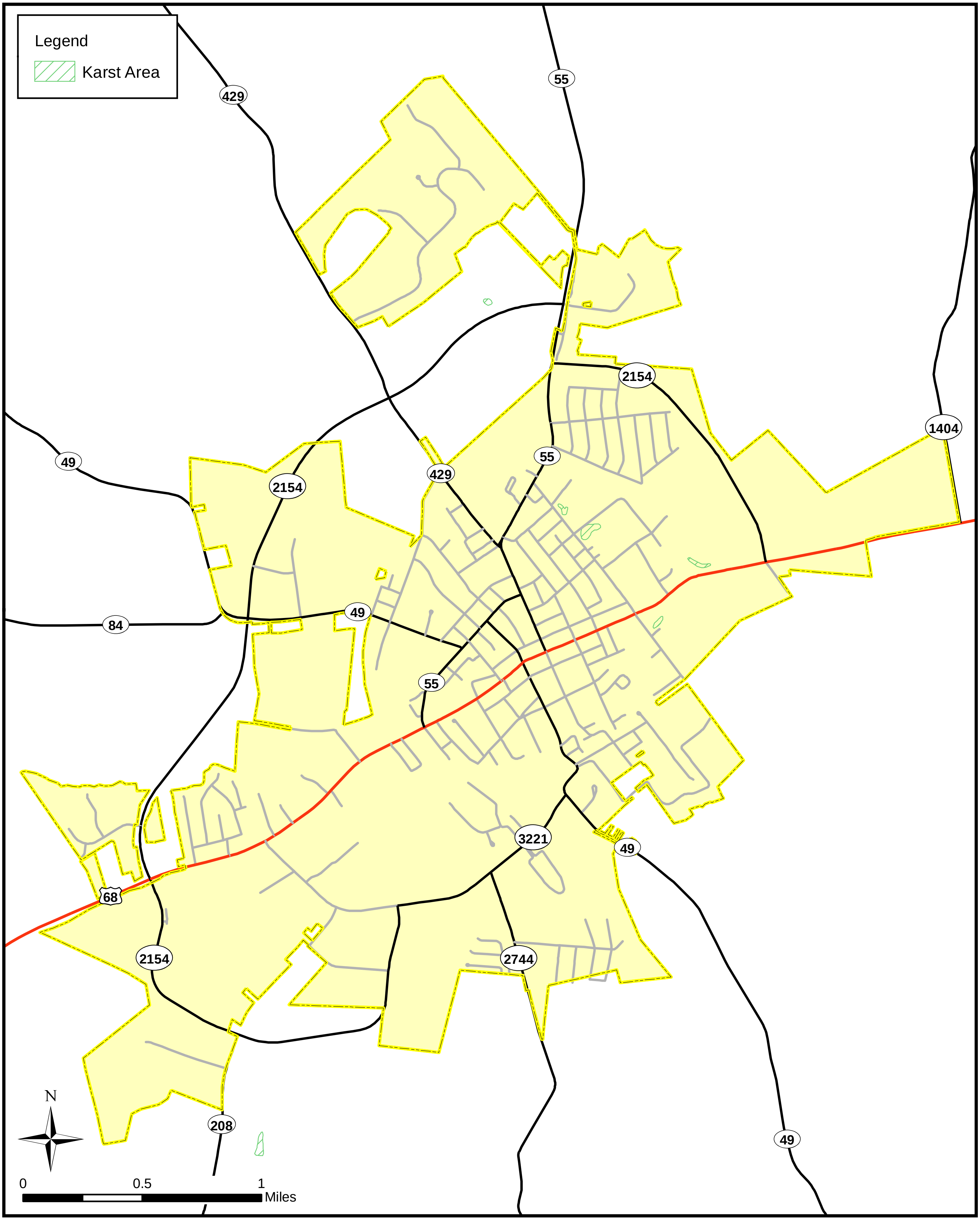
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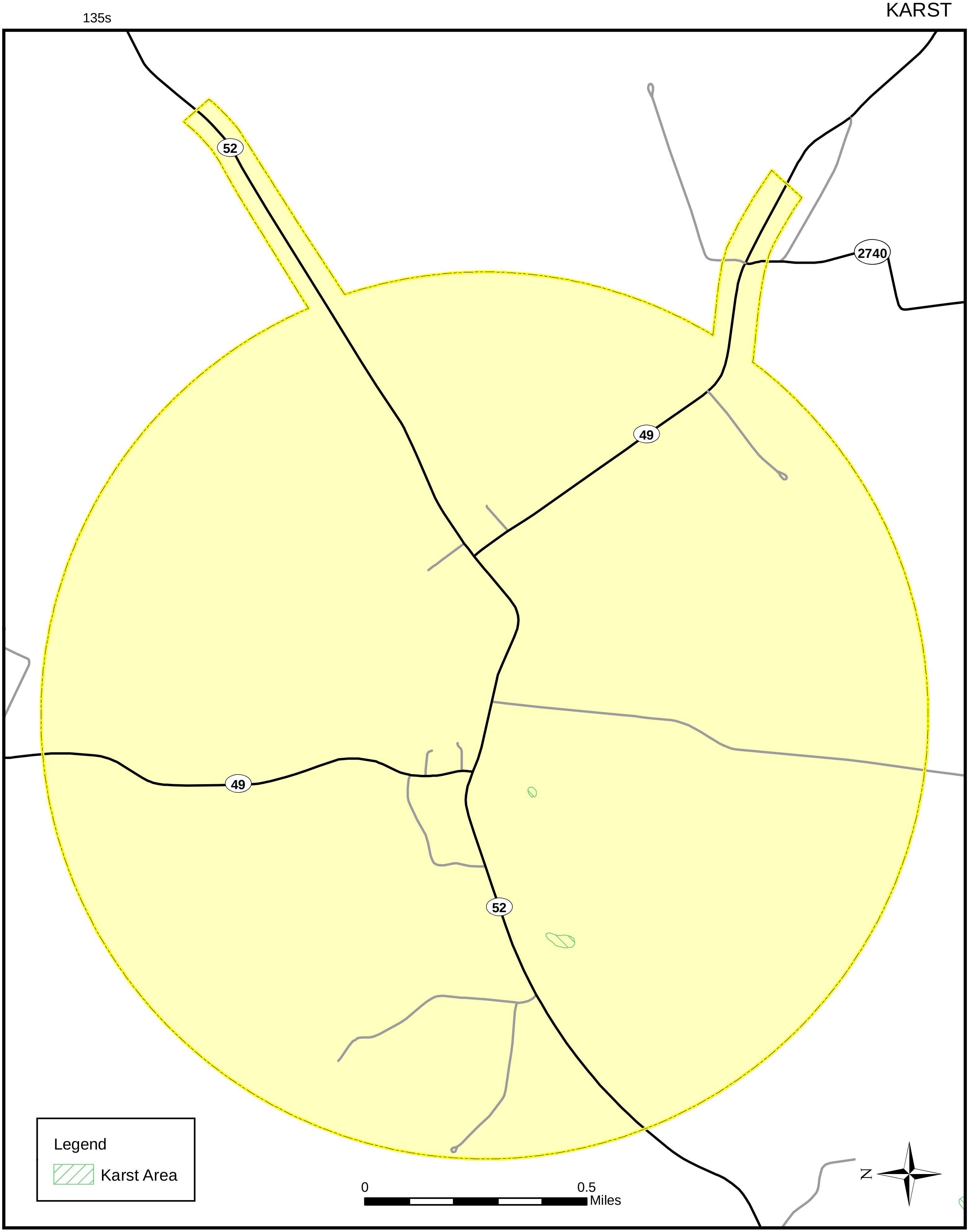
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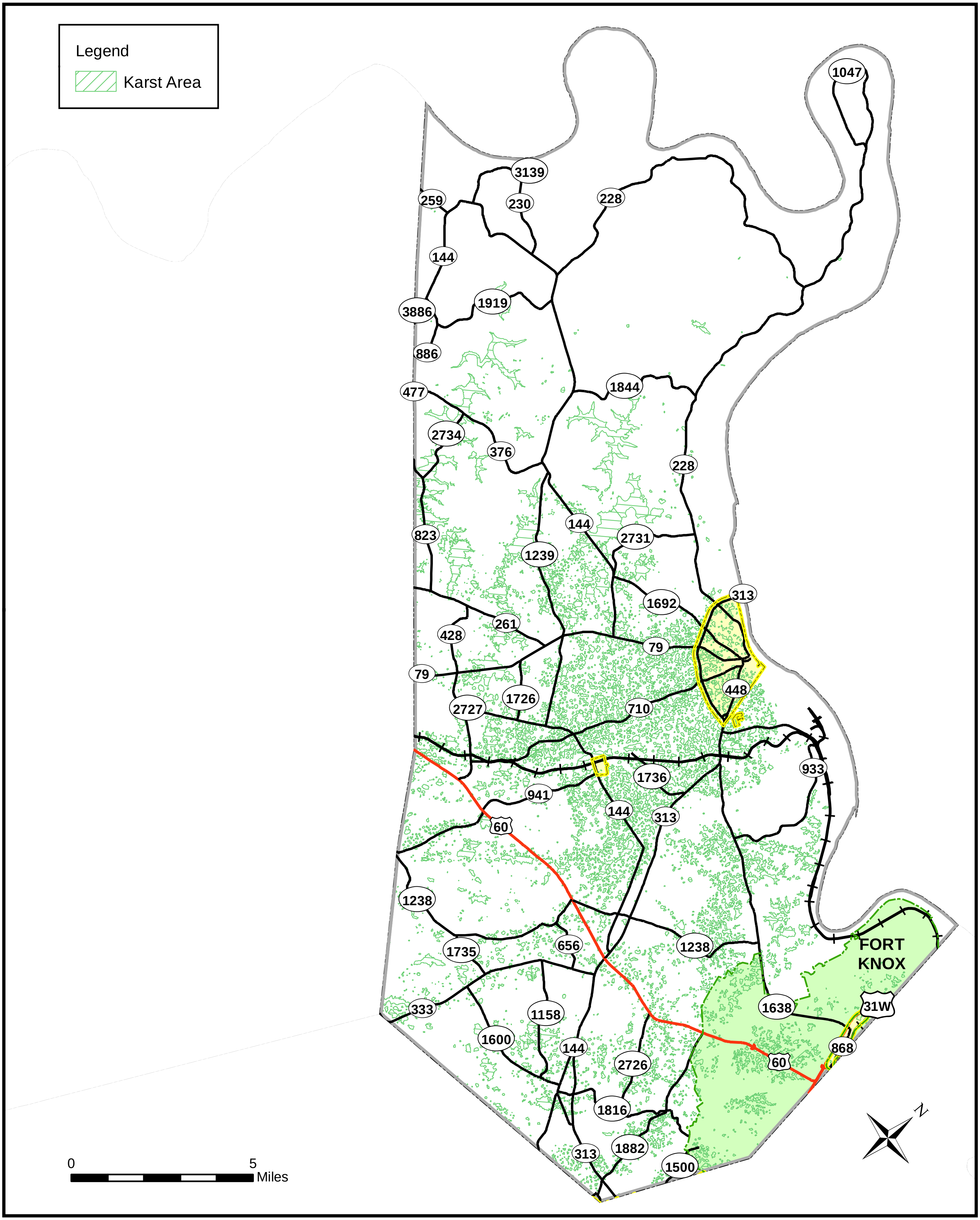
0.5
Miles
N

MEADE COUNTY
KARST



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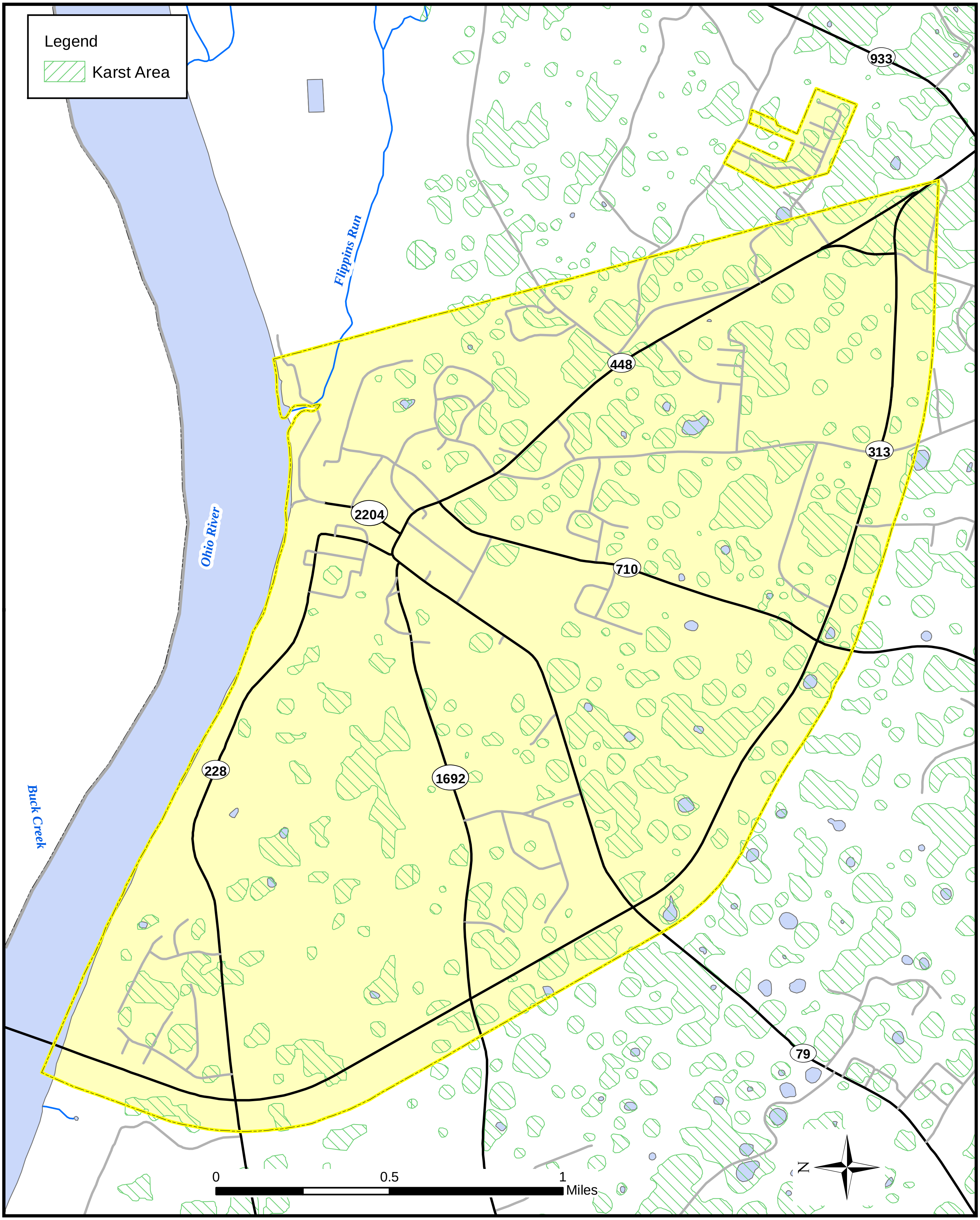
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313
2204
710
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79
Flippins Run
Ohio River
Buck Creek
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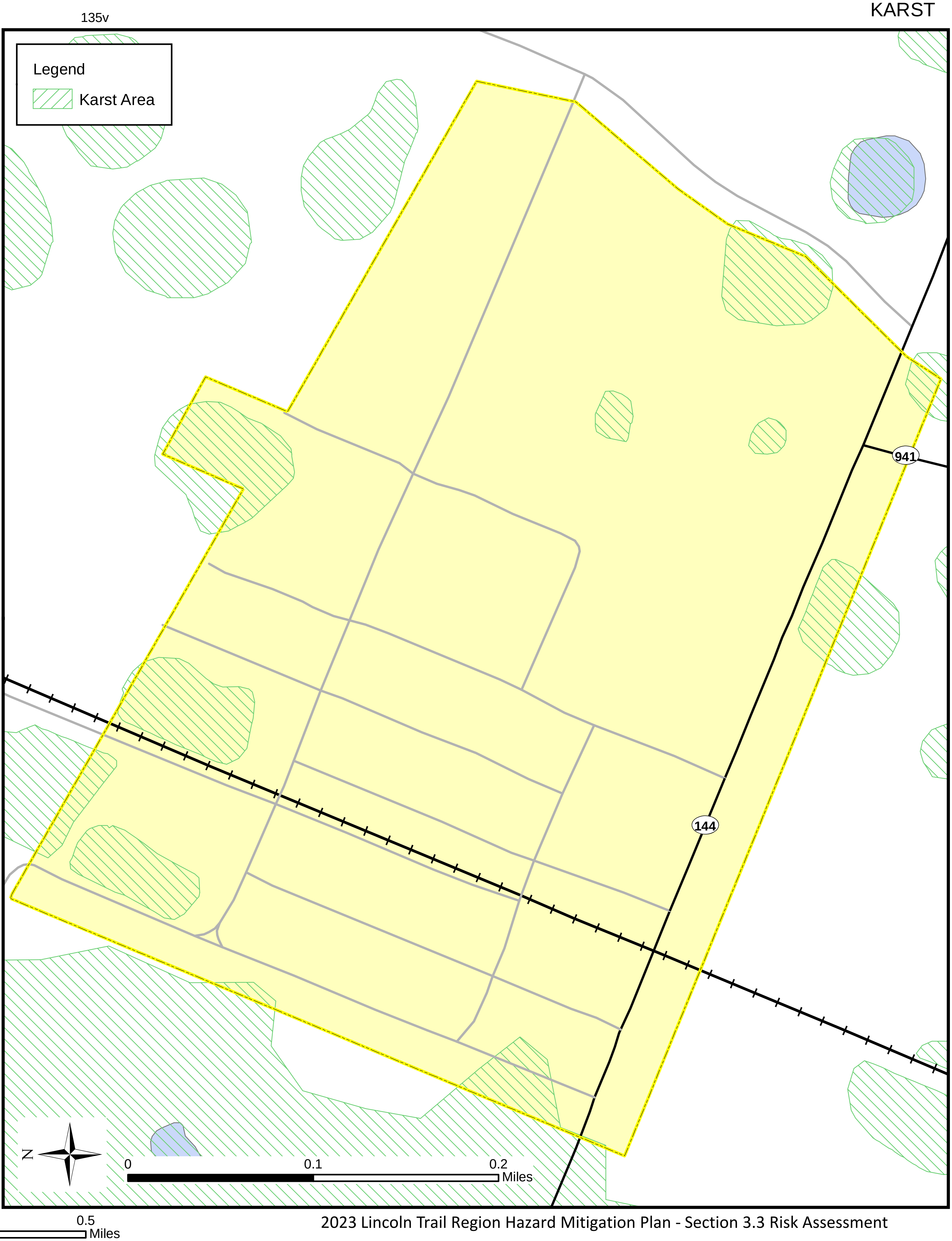
1
Miles
N

EKRON
KARST



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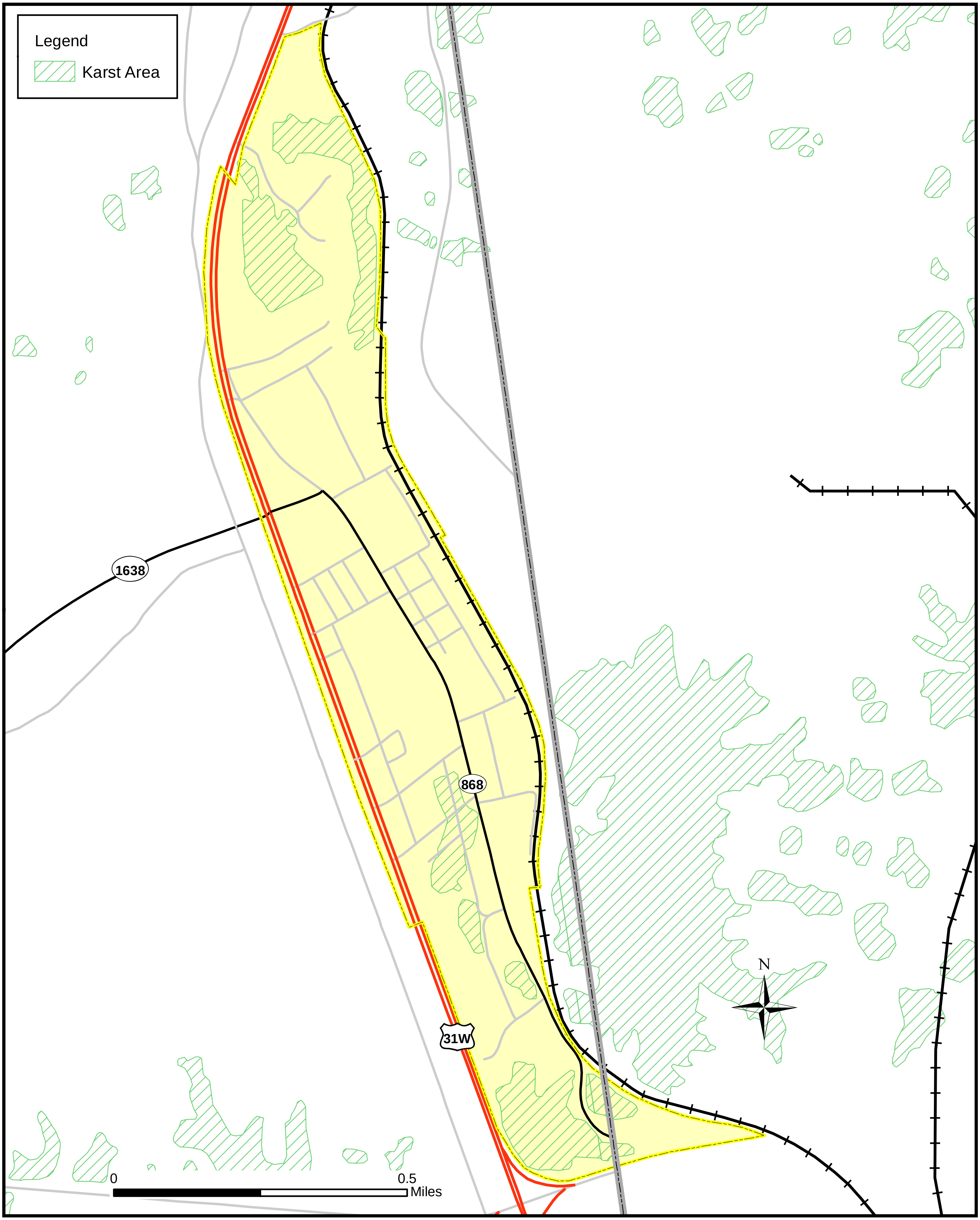

NELSON COUNTY
KARST

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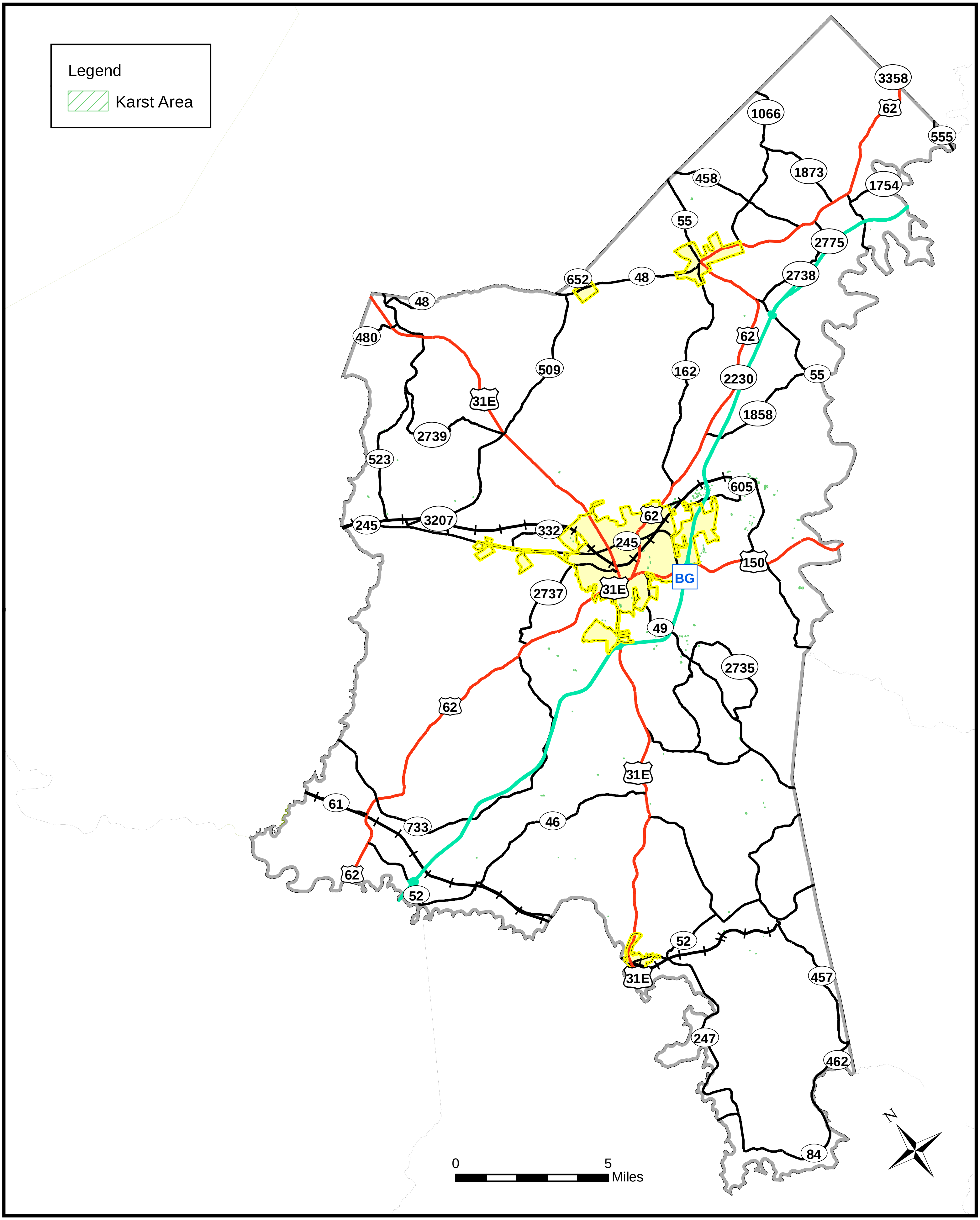

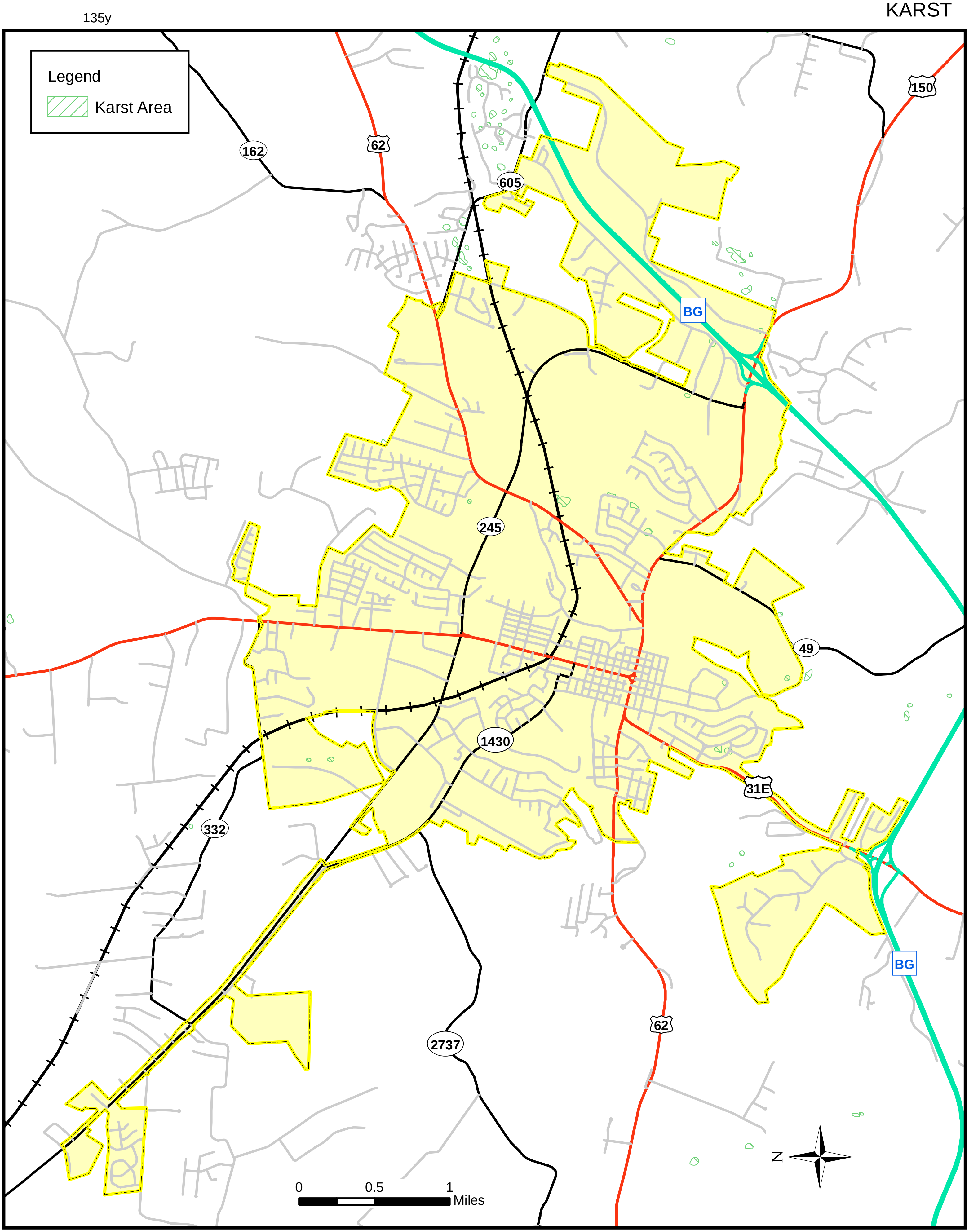
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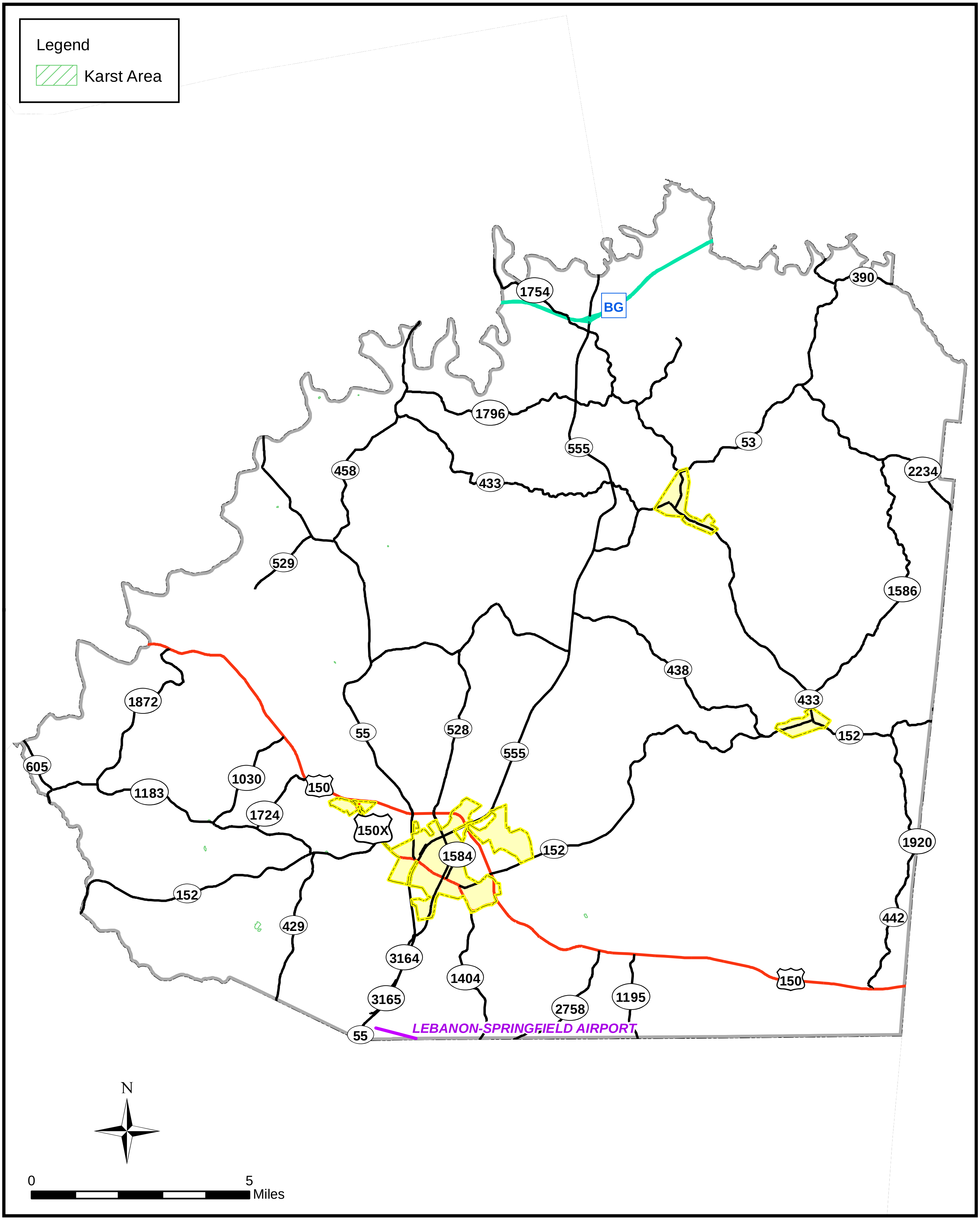
1
Miles

135z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152
555
605
1030
150
1183
1724
150X
1584
152
1920
152
429
442
3164
1404
150
3165
1195
2758
55
LEBANON-SPRINGFIELD AIRPORT
N
0
5
Miles

3.3.2.9 Drought

I. Background

The National Oceanic and Atmospheric Administration (NOAA) defines drought as a deficiency in precipitation over an extended period. It is a normal, recurrent feature of climate that occurs in virtually all climate zones. There are cases when drought develops relatively quickly and lasts a very short period, exacerbated by extreme heat and/or wind, and there are other cases when drought spans multiple years, or even decades.

The United States is vulnerable to the social, economic, and environmental impacts of drought. Historical weather records of United States indicate that there have been three or four major droughts over the last 100 years. Two of these disasters, the 1930's Dust Bowl drought and the 1950's drought, each lasted 5 to 7 years and covered large areas of the U.S.

According to the National Climatic Data Center (NCDC), during the 31 years prior to 2011, the United States has experienced 114 weather/climate disasters where overall damages/costs reached or exceeded $1 billion. The standardized losses for the entire 114 events exceeded $800 billion. During that period, there were 16 drought events that totaled $195 billion in losses: an average of slightly over $12 billion per each drought event.

Drought is a normal, recurring global occurrence in most parts of the world. Drought is among the earliest documented climatic events and tied to several biblical stories. Migrations of Hunter-gatherer populations in 9,500 BC Chile have been linked to drought, as has the exodus of early humans out of Africa and into the rest of the world about 135,000 years ago.

Measuring Drought

The Palmer Drought Index, sometimes called the Palmer Drought Severity Index (PDSI), is used to measure drought, and is based on recent precipitation and temperature. Developed by meteorologist Wayne Palmer, the index is based on a supply-and-demand model of soil moisture to measure the departure of the moisture supply. The index is most effective in determining long-term drought and not as good dealing with conditions over a period of weeks. The index uses 0 as normal with drought shown in terms of negative numbers. It also works to describe wet spells, using corresponding positive numbers. The PDSI is calculated based on precipitation and temperature data, as well as the local Available Water Content (AWC) of the soil.

NOAA utilizes the index to publish weekly, Palmer maps for the United States. Global Palmer data sets have been developed based on instrumental records beginning in the 19th century. The chart below illustrates the Palmer Drought Index.

Table 3.3.2.9.1 - Palmer Classifications	
4.0 or more	Extremely wet
3.0 to 3.99	Very wet
2.0 to 2.99	Moderately wet
1.0 to 1.99	Slightly wet
0.5 to 0.99	Incipient wet spell
0.49 to -0.49	Near normal
-0.5 to -0.99	Incipient dry spell
-1.0 to -1.99	Mild drought
-2.0 to -2.99	Moderate drought
-3.0 to -3.99	Severe drought
-4.0 or less	Extreme drought
Source: National Drought Mitigation Center	

An alternative method is the Drought Severity Classification used by the U.S. Drought Monitor service. (http://droughtmonitor.unl.edu/Home.aspx).
It uses a scale of D0-D4 that has a direct relationship to the Palmer method illustrated above.

Table 3.3.2.9.2

Drought Severity Classification

Category	Description	Possible Impacts	Palmer Drought Severity Index (PDSI)
D0	Abnormally Dry	Going into drought: ▪ short-term dryness slowing planting, growth of crops or pastures Coming out of drought: ▪ some lingering water deficits ▪ pastures or crops not fully recovered	-1.0 to -1.9
D1	Moderate Drought	▪ Some damage to crops, pastures ▪ Streams, reservoirs, or wells low, some water shortages developing or imminent ▪ Voluntary water-use restrictions requested	-2.0 to -2.9
D2	Severe Drought	▪ Crop or pasture losses likely ▪ Water shortages common ▪ Water restrictions imposed	-3.0 to -3.9
D3	Extreme Drought	▪ Major crop/pasture losses ▪ Widespread water shortages or restrictions	-4.0 to -4.9
D4	Exceptional Drought	▪ Exceptional and widespread crop/pasture losses ▪ Shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less

Source: http://droughtmonitor.unl.edu/AboutUs/ClassificationScheme.aspx

Types of Droughts

Droughts are typically defined in three main ways:

1. Meteorological droughts occur when there is a prolonged period with less than average precipitation. A meteorological drought usually precedes the other kinds of droughts.
2. Agricultural droughts affect crop production or the ecology of the range. An agricultural drought can occur independently with any change in precipitation levels when soil conditions and erosion, triggered by poorly managed agricultural endeavors, cause a shortfall in the amount of water available to the crops.
3. Hydrological droughts happen when water reserves available in sources such as aquifers, lakes, and reservoirs fall below the statistical average. A hydrological drought tends to show up more slowly because it involves stored water that is used, but not replenished. As with an agricultural drought, this type of drought can be triggered by more than just a loss of rainfall.

Hazards/Consequences of Drought

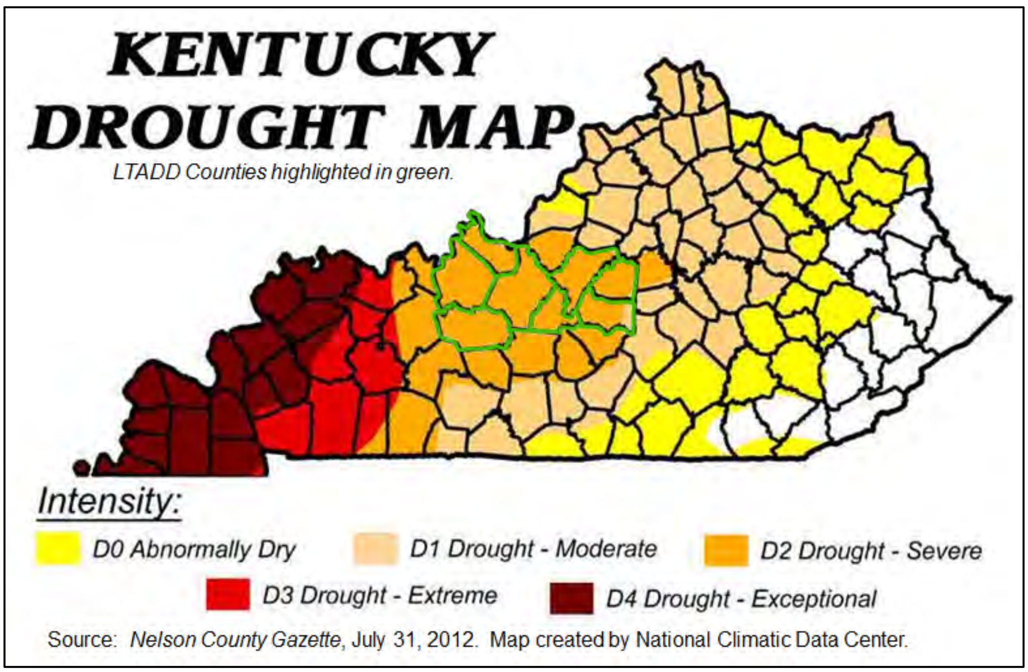
Periods of drought can cause significant environmental, agricultural, health, economic and social consequences. Subsistence farmers and populations dependent on water sources for food are more vulnerable to famine and diminished economic means. Drought can cause a reduction in overall water quality when reduced water flows increase contamination of remaining water sources. Other consequences of drought include:

- Reduced crop growth or yield productions and carrying capacity for livestock
- Dust bowls and landscape erosion
- Dust storms when drought reduces the water content of the soil
- Damage to terrestrial and aquatic life habitats
- Hunger and famine due to reduced food crops
- Malnutrition, dehydration, and related diseases
- Mass migration of humans and wildlife resulting in displaced people and animals
- Reduced electricity because of low water flow through hydroelectric dams
- Water shortages for residential and industrial users
- Snake migration that results in increased snakebites
- Social unrest
- Wildfires are more common during periods of drought and often result in loss of life and widespread property damage
- Exposure and oxidation of acid sulfate soils due to falling surface and groundwater levels
- Navigable waters can become unsafe for navigation because of drought
- Degradation of the environment in the form of erosion and ecological damage may occur as the result of drought

II. Profile

According to NOAA, there have been 52 recorded drought events in Kentucky since 1996. Three of these droughts caused serious damage to agricultural crops. In 1996, drought affected 20 Western Kentucky Counties and crop damage was estimated at $154 million. In 2002, 22 counties were affected by drought with damages estimated at $70 million. The drought of 2012 was a Level 2 drought in 24 Kentucky Counties and a Level 1 drought in an additional 66 Counties. The entire State was at least abnormally dry. Total crop production for State was at 47% of the usual annual yield and crop damage was severe. There was widespread shortage of animal feed as well. There were no deaths attributed to these drought events, however, they did affect agriculture, tourism, wildlife, residential and commercial water use, recreation, wildlife habitat, increased wildfires, electric power generation and water quality. Since the 2012 drought events the state has not experienced significant drought events.

The map below illustrates the widespread effect and severity of the 2012 drought in Kentucky.



North Rolling Fork at Bradfordsville, Summer 2008. *Source: LTADD Archive.*

The chart below outlines significant drought events in Kentucky since May of 1930. The Lincoln Trail Region lies within the Central region of the Commonwealth. The 2012 drought affected the entire State with PDSI ratings ranging from -0.5 to -3.99.

Table 3.3.2.9.2 - Significant Kentucky Drought Events			
Time Period	Location/Region	PDSI Rating	Crop Losses
May 1930 – December 1931	Bluegrass, Central, East, West	-4.73	NA
Fall 1939 – Spring 1942	Central, Bluegrass, East	-3.97	NA
Summer 1952 – Winter 1955	West, Bluegrass, Central	NA	NA
Summer 1996	West	NA	$154 million
Summer 2002	West	NA	$70 million
Summer 2007	Statewide	-2.75	Unknown
Fall 2008	Statewide	-2.75	Unknown
Spring/Summer 2012	Statewide	-0.5 to -3.99	Unknown
Source: NOAA, KY Energy and Environment Cabinet			

III. Analysis

To analyze drought as a hazard threat to the Lincoln Trail Region, research was done to determine what constitutes a drought and the far-reaching effects that it has. Historical events were researched and documented as well. Resources for information gathered include NOAA, the National Weather Service, the National Climatic Data Center, the National Drought Mitigation Center and the Commonwealth of Kentucky Energy and Environment Cabinet.
While drought events are not easily captured and reported, the table above is evidence of their occurrence. The back-to-back droughts of 2007 and 2008 were a hardship on local farmers and the 2012 drought adversely impacted the entire State.

Heat in concert with lack of precipitation often exacerbates drought conditions. The Kentucky Mesonet data below tracks maximum temperatures for the region over the last five years.

Table 3.3.2.9.3

Max Temperature Table for Lincoln Trail Region from 2016 to 2021 Source: Kentucky Mesonet							
Location	2016	2017	2018	2019	2020	2021 (through May 17)	Average
Breckinridge Co.	94.1	93.3	93.2	95.4	90.8	82.6	91.57
Grayson Co.	93.6	93.5	93.4	95.2	90.6	81.7	91.33
Hardin Co.	94.4	94	94.4	95.6	92.3	81.6	92.05
Larue Co.	91.9	91.6	93	95	89.9	81.1	90.41
Marion Co.	94.7	94.3	93.8	95.8	91.1	79.6	91.55
Meade Co.	92.5	92.4	93.1	95.3	91.5	80.9	90.95
Nelson Co.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wahsinton Co.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Average	93.53	93.18	93.48	95.38	91.03	80.98	91.31

Kentucky Mesonet data for local precipitation over the last five years is included below. The region will closely monitor and track Mesonet data to help track drought conditions specific to the eight-county area.

Table 3.3.2.9.4

Precipitation Data table for Lincoln Trail Region from 2016 to 2021 Source: Kentucky Mesonet							
Location	2016	2017	2018	2019	2020	2021 (through May 17)	Total
Breckinridge Co.	48.22"	54.47"	65.61"	61.2"	56.61"	22.2"	308.31"
Grayson Co.	55.7"	56"	60.65"	62"	61.09"	24.73"	320.17"
Hardin Co.	46.71"	56.04"	63.26"	60.29"	51.35"	20.01"	297.66"
Larue Co.	52.25"	53.69"	63.24"	60.54"	52.4"	22"	304.12"
Marion Co.	50.35"	43.86"	70.34"	61.48"	54.99"	21.96"	302.98"
Meade Co.	43.6"	50.5"	65.03"	59.05"	51.95"	20.5"	290.63"
Nelson Co.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wahsinton Co.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Average	49.47"	52.43"	64.68"	60.76"	54.73"	21.9"	

Table 3.3.2.9.6 Summary of Drought Index Data

Average Percentage of area in each drought category for each county, January 2016 to May 2021						
Location	None	Abnormally Dry (D0)	Moderate Drought (D1)	Severe Drought (D2)	Extreme Drought (D3)	Exceptional Drought (D4)
Breckinridge	91.5	8.5	5.23	2.17	0	0
Grayson	89.75	10.25	4.87	2.17	0	0
Hardin	90.79	9.12	5.13	2.38	0	0
Larue	88.61	11.39	5.05	2.22	0	0
Marion	88.4	11.6	4.65	2.29	0	0
Meade	91.18	8.18	5.21	2.07	0	0
Nelson	91.1	8.9	4.11	1.99	0	0
Washington	90.14	9.86	4.25	2.19	0	0
LTADD Average	90.18	9.72	4.81	2.18	0	0

Source: U.S. Drought Monitor (http://droughtmonitor.unl.edu/MapsAndData/DataTables.aspx)

Note: This data is based on the "Traditional Statistics" and may include multiple data in each category. It is possible to have a higher percent area for a higher category. Thus, it may exceed 100% for any given area. This data is over a very short time span, so it has limited use at this time to predict drought probability or correlate with any loss data. However, in the future further monitoring and data collection may yield more robust analysis.

3.3.2.10 Earthquakes

I. Background

According to the United State Geological Survey (USGS), an earthquake is "what happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. The location below the earth's surface where the earthquake starts is called the hypocenter, and the location directly above it on the surface of the earth is called the epicenter." This phenomenon results in a shaking, trembling, or concussion of the earth, often accompanied by a rumbling noise. The seismicity, seismism, or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time.

At times, an earthquake will be preceded by a foreshock. A foreshock is smaller than an actual earthquake and will occur in the same place as the larger earthquake that follows. A foreshock cannot be identified as such until the larger earthquake has happened. The larger earthquake is called the mainshock and may be followed by aftershocks. Aftershocks are smaller earthquakes that follow a mainshock and can continue for weeks or months after the mainshock.

USGS explains "the earth has four major layers: the inner core, outer core, mantle and crust. The crust and the top of the mantle make up a thin skin on the surface of our planet. However, this skin is not all in one piece, it is made up of many pieces like a puzzle covering the surface of the earth. These pieces are slowly moving around, sliding past one another, and bumping into one another. These pieces are called tectonic plates, and the edges of the plates are called the plate boundaries. The plate boundaries are made up of many faults, and most of the earthquakes around the world occur in these faults. Since the edges of the plates are rough, they get stuck while the rest of the plate keeps moving. When the plate has moved far enough, the edges unstick on one of the faults and there is an earthquake."

When the edges of the fault are stuck together, the rest of the block keeps moving, and the energy that would normally allow the blocks to slide past one another is being stored up. The force of the moving blocks eventually overcomes the friction of the jagged edges of the faults and causes them to break apart. All of the stored-up energy is released and radiates outward from the fault in all directions as seismic waves. The seismic waves shake the ground as they move through it and as the waves reach the earth's surface, they shake the ground and anything on it.

Measuring Earthquakes

There are three scales for measuring the intensity of an earthquake. The *Mercalli scale* was invented in 1902 by Guiseppe Mercalli and uses observations of the people who experience the earthquake to estimate its intensity. This scale was subjective and dependent on the opinions of witnesses.

In 1934, Charles Richter developed the *Richter scale*. The Richter scale measured the magnitude of an earthquake using a formula based on amplitude of the largest wave recorded on a specific type of seismometer and the distance between the earthquake and the seismometer. Richter's scale was specific to earthquakes in California, but other scales, based on wave amplitudes and total earthquake duration, were developed for use in other situations and were consistent with Richter's scale.

The following chart compares equivalents for the Mercalli scale to the Richter scale and identifies some of the hazards associated with earthquakes.

Table 3.3.2.10.1 - Modified Mercalli Intensity Scale		
Mercalli Intensity	**Equivalent Richter Magnitude**	**Witness Observations**
I	1.0 to 2.0	Felt by very few people; barely noticeable.
II	2.0 to 3.0	Felt by a few people, especially on upper floors.
III	3.0 to 4.0	Noticeable indoors, especially on upper floors, but may not be recognized as an earthquake.
IV	4.0	Felt by many indoors. May feel like heavy truck passing by.
V	4.0 to 5.0	Felt by almost everyone, some people awakened. Small objects moved, trees and poles may shake.
VI	5.0 to 6.0	Felt by everyone. Difficult to stand. Some heavy furniture moved, some plaster falls. Chimneys may be slightly damaged.
VII	6.0	Slight to moderate damage in well-built ordinary structures. Considerable damage to poorly built structures. Some walls may fall.
VIII	6.0 to 7.0	Little damage in specially built structures. Considerable damage to ordinary buildings, severe damage to poorly built structures. Same walls collapse.
IX	7.0	Considerable damage to specially built structures, buildings shifted off foundations. Ground cracked noticeably. Wholesale destruction. Landslides.
X	7.0 to 8.0	Most masonry and frame structures and their foundations destroyed. Ground badly cracked. Landslides. Wholesale destruction.
XI	8.0	Total damage. Few, if any structures standing. Bridges destroyed. Wide cracks in ground. Waves seen on ground.
XII	8.0 or greater	Total damage. Waves seen on ground. Objects thrown up into the air.
Source: Michigan Technological University		

As the chart below illustrates, earthquakes are also categorized ranging from minor to great, depending on magnitude.

Table 3.3.2.10.2 - Earthquake Magnitude Classes	
Class	**Magnitude**
Great	8 or more
Major	7.0 – 7.9
Strong	6.0 – 6.9
Moderate	5.0 – 5.9
Light	4.0 – 4.9
Minor	3.0 – 3.9
Source: Michigan Technological University	

Table 3.3.2.10.3 - Earthquake Magnitude Scale		
Magnitude	**Earthquakes Effects**	**Estimated Number Each Year**
2.5 or less	Usually not felt but can be recorded by seismograph.	900,000
2.5 to 5.4	Often felt, but only causes minor damage.	30,000
5.5 to 6.0	Slight damage to buildings and other structures.	500
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious Damage.	20
8.0 or greater	Great earthquake. Can totally destroy communities near the epicenter.	One every 50 to 10 years
Source: Michigan Technological University		

The newest scale for measuring the magnitude of an earthquake is the **Moment Magnitude Scale**. The moment magnitude scale is based on the total moment release of the earthquake. Moment is a product of the distance a fault moved, and force required to move it. The moment magnitude scale estimates are about the same as Richter magnitudes for small and large earthquakes, but only the moment magnitude scale is capable of measuring M8 (read 'magnitude 8') and greater events accurately.

Causes/Prevention of Earthquakes

Earthquakes occur naturally due to the makeup of the earth and the constant movement that takes place between its tectonic plates. These quakes cannot be predicted ahead of time. However, scientists have mapped the major fault lines in the world and know where the greatest likelihood of an earthquake will occur.

While we cannot prevent natural earthquakes from occurring, we can significantly mitigate their effects by identifying hazards, avoid building structures in hazardous areas, building safer structures, and educating the public on earthquake safety. Earthquakes caused by human activity have been documented in the United States and various locations around the world. Earthquakes resulting from human activity include impoundment of reservoirs, surface and underground mining, withdrawal of fluids and gas from the subsurface, and the injection of fluids into underground formations. Most man-made earthquakes are small and present little hazard, larger and potentially damaging man-made earthquakes have occurred in the past.

Hazards, resulting from man-made earthquakes, can be mitigated by minimizing or eliminating the human activity that causes them.

Effects of Earthquakes

The effects of earthquakes include, but are not limited to, the following:

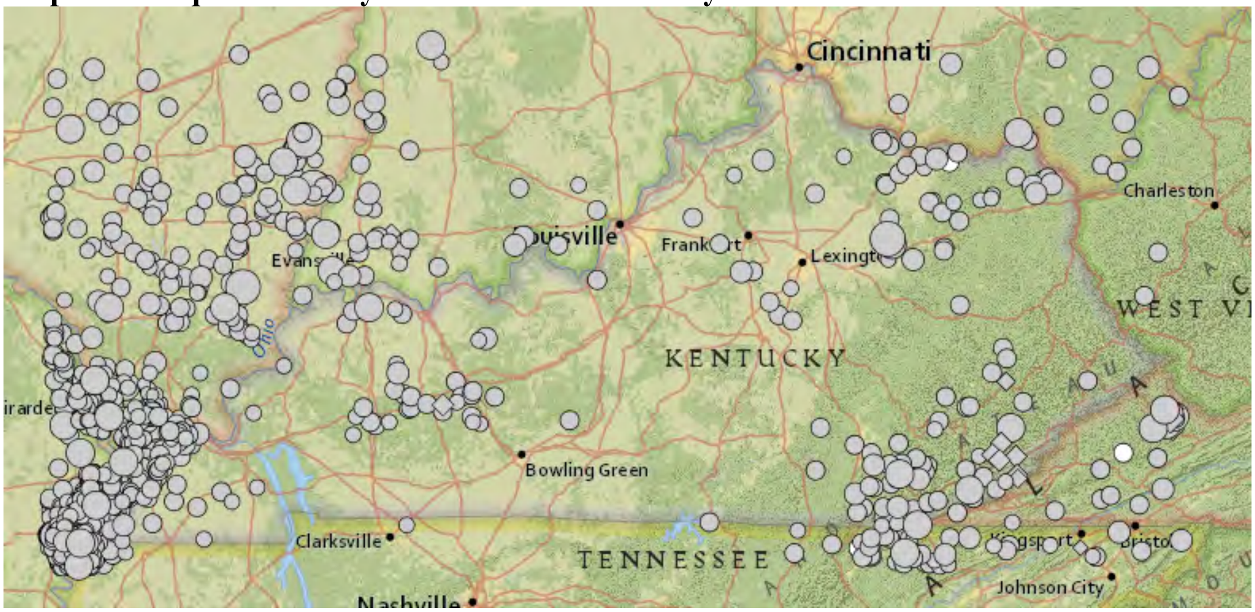
- Shaking and ground rupture are the main effects of an earthquakes. This will result in damage to buildings and other rigid structures. The severity of the local effect will depend on the complex combination of the earthquake magnitude, the distance of the site from the epicenter, and the local geological and geomorphological conditions, which may amplify or reduce wave propagation. The degree of ground shaking is measured by ground acceleration. Ground rupture is a major risk for large engineering structures such as dams, bridges, and nuclear power stations.
- Fires can result from earthquakes when shaking or ground rupture damages electrical power or gas lines. When water mains rupture as the result of an earthquake, it becomes very difficult to stop the spread of fire once it is started.
- Landslide and avalanches can be the effect of an earthquake when the quake results in slope instability.
- Soil liquefaction occurs when shaking, water-saturated granular material (such as sand) temporarily loses its strength and changes from a solid form into a liquid. This can cause structures to sink into the ground and collapse upon themselves.
- Tsunamis are long-wavelength, long-period sea waves produced by the sudden or abrupt movement of large volumes of water. This can occur when an earthquake takes place under a sea or other large body of water. Large waves produced by an earthquake can overrun nearby coastal areas in a matter of minutes. Tsunamis can also travel thousands of kilometers across open-ocean and wreak destruction on far shores hours after the earthquake that generated them.
- Floods may be a secondary effect of earthquakes if dams are damaged or destroyed. Earthquakes may also cause landslips to dam rivers, which collapse and cause floods.
- Human impacts because of an earthquake include injury and loss of life, road and bridge damage, general property damage, and collapse or destabilization of buildings. The aftermath of an earthquake may bring disease, lack of necessities and higher insurance premiums.

II. Profile

Kentucky Earthquake History

Most earthquake activity in Kentucky has occurred in the western portion of the State near the New Madrid seismic zone. As early as 1779, 1791 and 1792 earthquake activity were recorded in the northern and eastern portions of Kentucky. Between 1811 and 1812, about 2,000 to 3,000 tremors were felt in Kentucky from an initial shock on December 16, 1811.

Map of earthquake activity in and around Kentucky 1901-2021

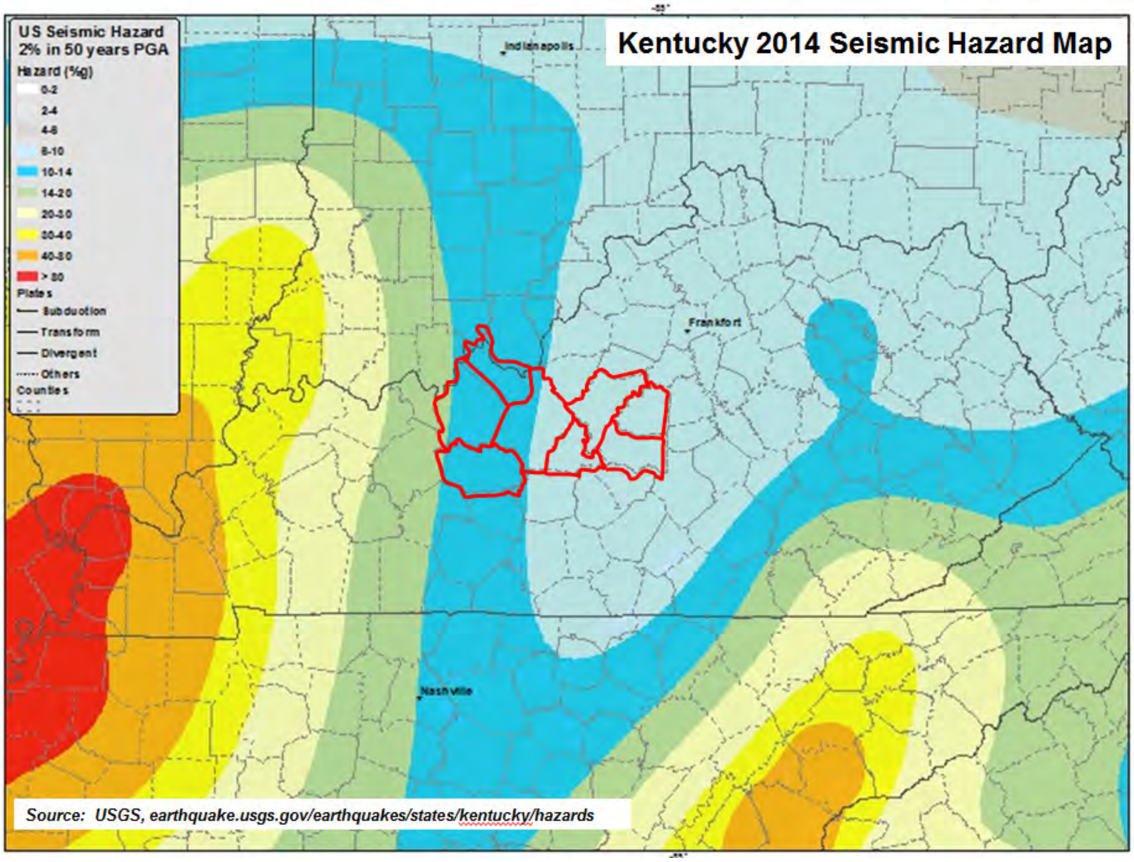


Source: USGS

Over the next 100 years, a few moderate earthquakes occurred in the State. A shock at Columbus, Kentucky on March 12, 1878, caused a section of bluff on the Mississippi River to cave in. On October 26, 1915, an earthquake at Mayfield was reported to have shaken pictures from walls. A sharp earthquake, with an epicenter near the mouth of the Ohio River, occurred on December 7, 1915, and shook western Kentucky and adjoining regions. It was an intensity V to VI and was felt over an area of 60,000 square miles.

Other earthquake events were recorded in 1841, 1916, 1915 and 1924. About 75,000 square miles of land in Kentucky, Illinois, Indiana, and Tennessee were affected by an earthquake, on September 2, 1925. The epicenter of the quake was near Henderson and landslides were noted in

Slight damage was reported near Middlesboro Kentucky as the result of an intensity V earthquake on January 1, 1954. The earthquake that occurred on November 9, 1968, was measured as an intensity VII, and did considerable masonry damage at the City Building in Henderson, Kentucky which was about 50 miles east, southeast of the epicenter. On January 20, 2020, a 3.8 magnitude earthquake with its epicenter in Tennessee could be felt 40 miles away in parts of eastern Kentucky. Earthquakes in Kentucky are common, but they are often not strong enough to be felt. the damage reports. At Louisville, about 100 miles away, a chimney fell, and a house reportedly sank.



Kentucky Earthquake Map From 2011-2021

Source: volcanicdiscovery.com

III. Analysis

The data below is from the United States Geological Survey and depicts the chance of a major earthquake (5.0 to 9.2) in each of the Lincoln Trail Region's eight counties within a 50km area, within the next 50 years.

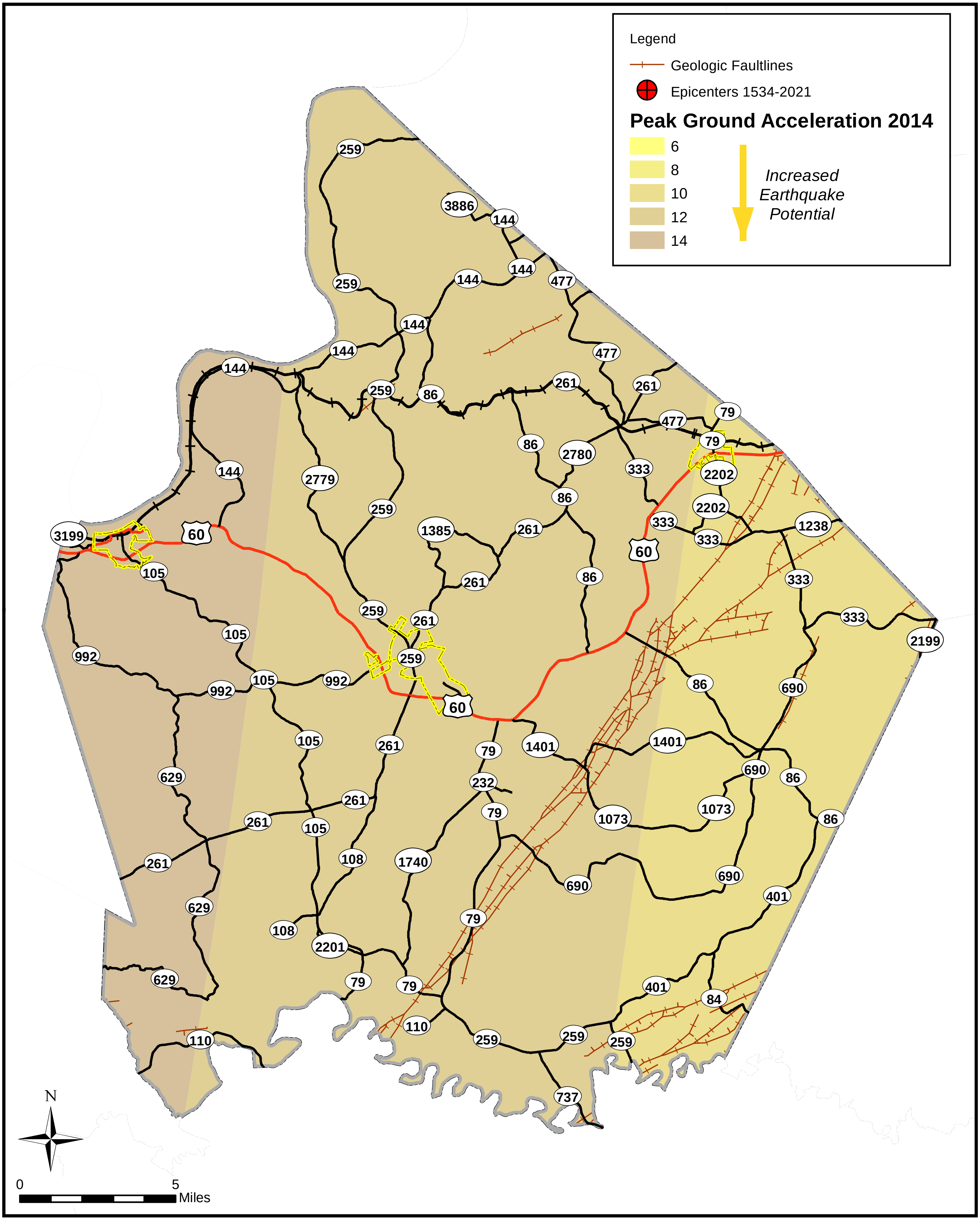
Table 3.3.2.10.4 - Earthquake Chance for the Lincoln Trail Region Counties	
County	**Chance of Major Earthquake within Next 50 years**
Breckinridge	1.09%
Grayson	0.73%
Hardin	0.50%
LaRue	0.30%
Marion	0.30%
Meade	0.83%
Nelson	0.39%
Washington	0.41%
Source: USGS Database	

There is little likelihood that any part of the Lincoln Trail Region will experience a disaster because of an earthquake. However, the region must plan preparedness measures, and mitigate hazards by educating the public on earthquakes, using wise land use guidelines and by avoiding activities that increase the chance of creating a man-made earthquake.

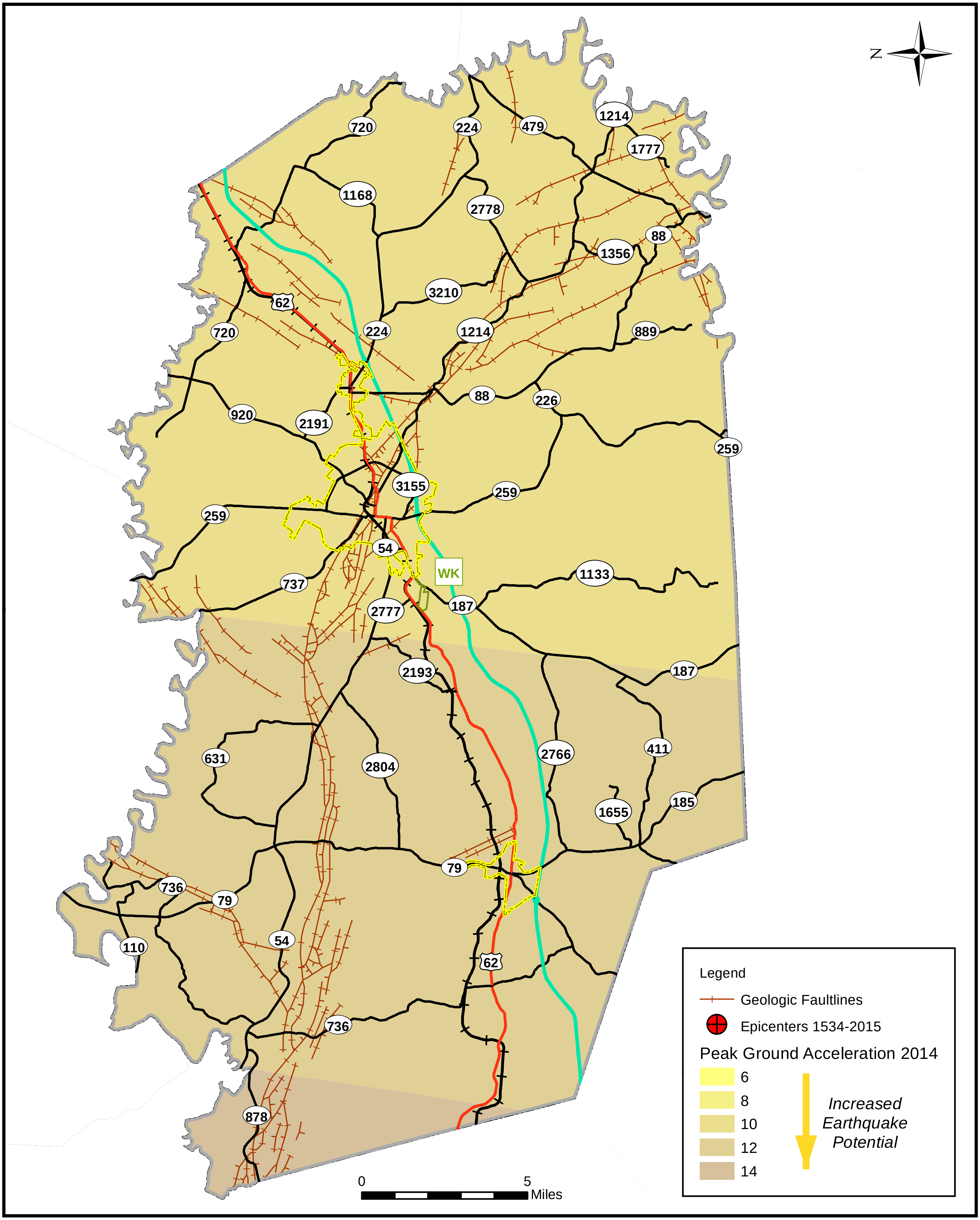
There have been no recorded earthquakes with its epicenter in the region since the 2010 update was published per USGS. Source: earthquake.usgs.gov/earthquakes/search.

The following maps illustrate the few documented historic earthquakes that have had their epicenter in the Lincoln Trail Region. It also shows the potential for future events by portraying the Peak Ground Acceleration (PGA) values in shades of yellow and alluvial soils that have a higher potential for liquefaction. The PGA in the region decreases from west to east. The faults that exist in the Region are very old and inactive but are portrayed on the map by the black, ticked lines for reference.

149a


Legend
Geologic Faultlines
Epicenters 1534-2021
Peak Ground Acceleration 2014
6
8
10
12
14
Increased Earthquake Potential
N
0
5
Miles

GRAYSON COUNTY
EARTHQUAKE



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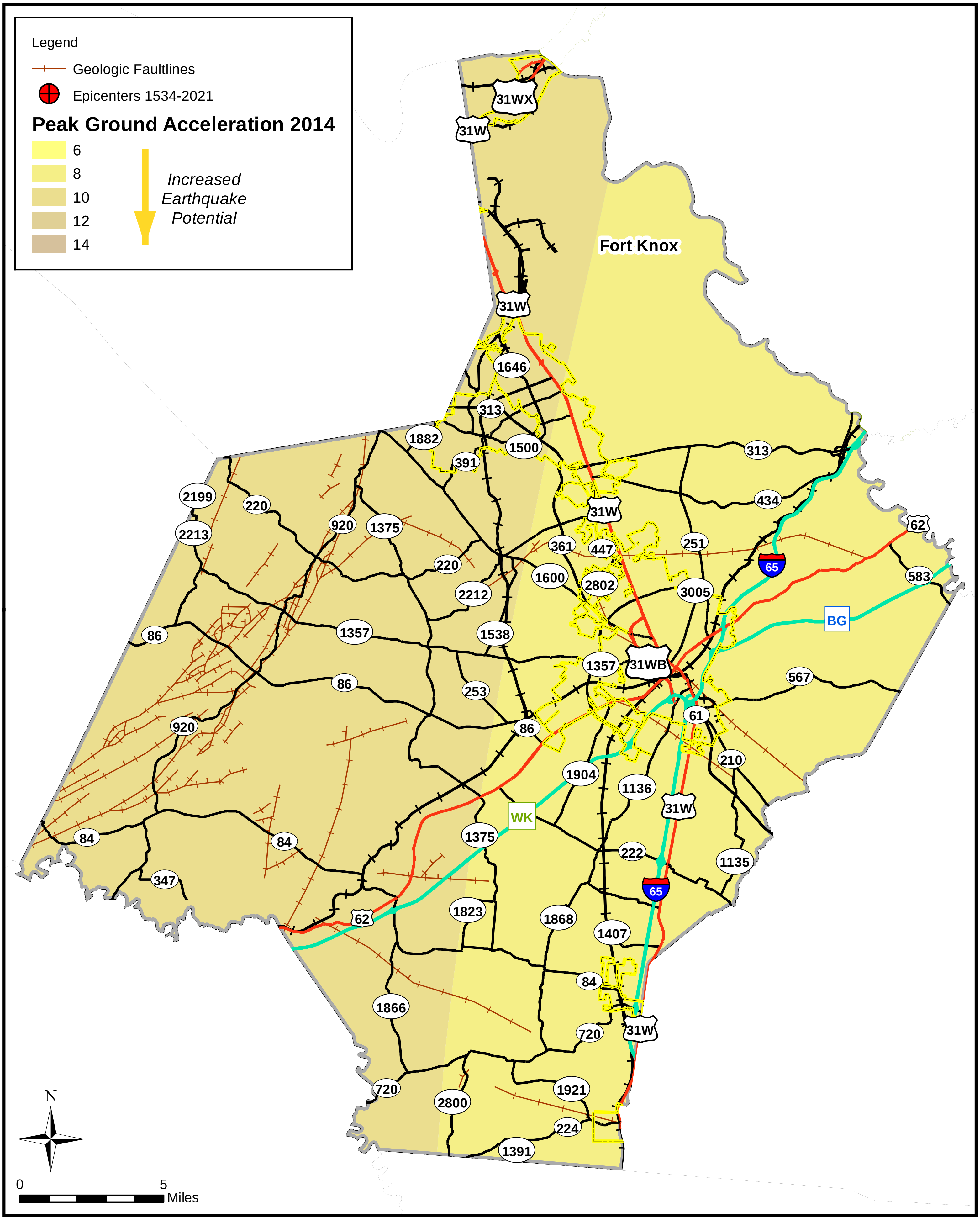
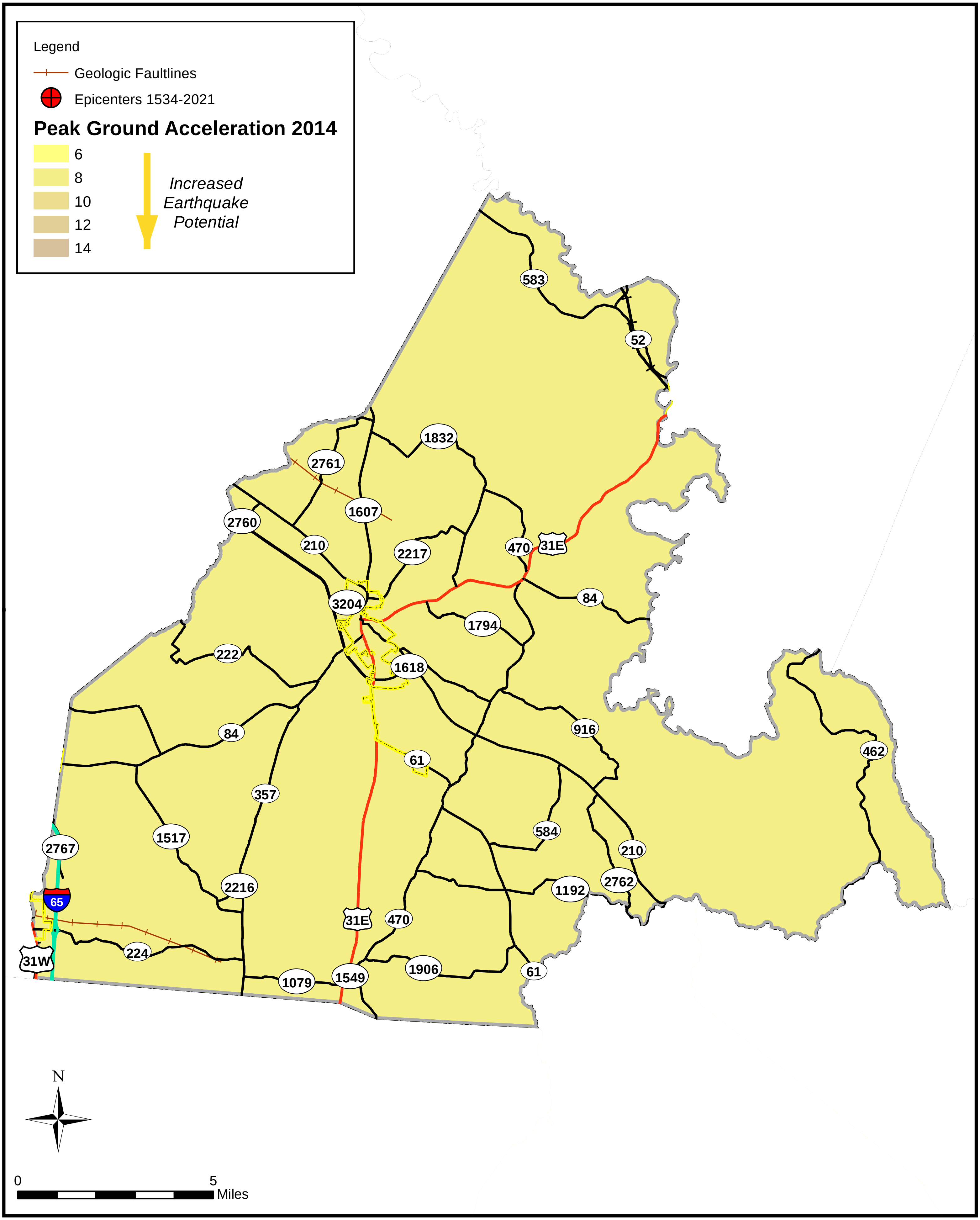

Legend
Geologic Faultlines
Epicenters 1534-2021
Peak Ground Acceleration 2014
6
8
10
12
14
Increased Earthquake Potential
Fort Knox
31WX
31W
1646
313
1882
1500
391
2199
220
2213
920
1375
361
447
251
434
62
220
1600
2802
3005
65
583
2212
BG
86
1357
1538
1357
31WB
567
86
253
61
86
920
210
1904
1136
31W
WK
84
84
1375
222
1135
347
65
62
1823
1868
1407
84
1866
720
31W
720
1921
2800
224
1391
N
0
5
Miles

149d


Legend
Geologic Faultlines
Epicenters 1534-2021
Peak Ground Acceleration 2014
6
8
10
12
14
Increased Earthquake Potential
583
52
1832
2761
1607
2760
210
2217
470
31E
84
3204
1794
222
1618
916
462
84
61
357
584
1517
210
2767
2216
2762
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31E
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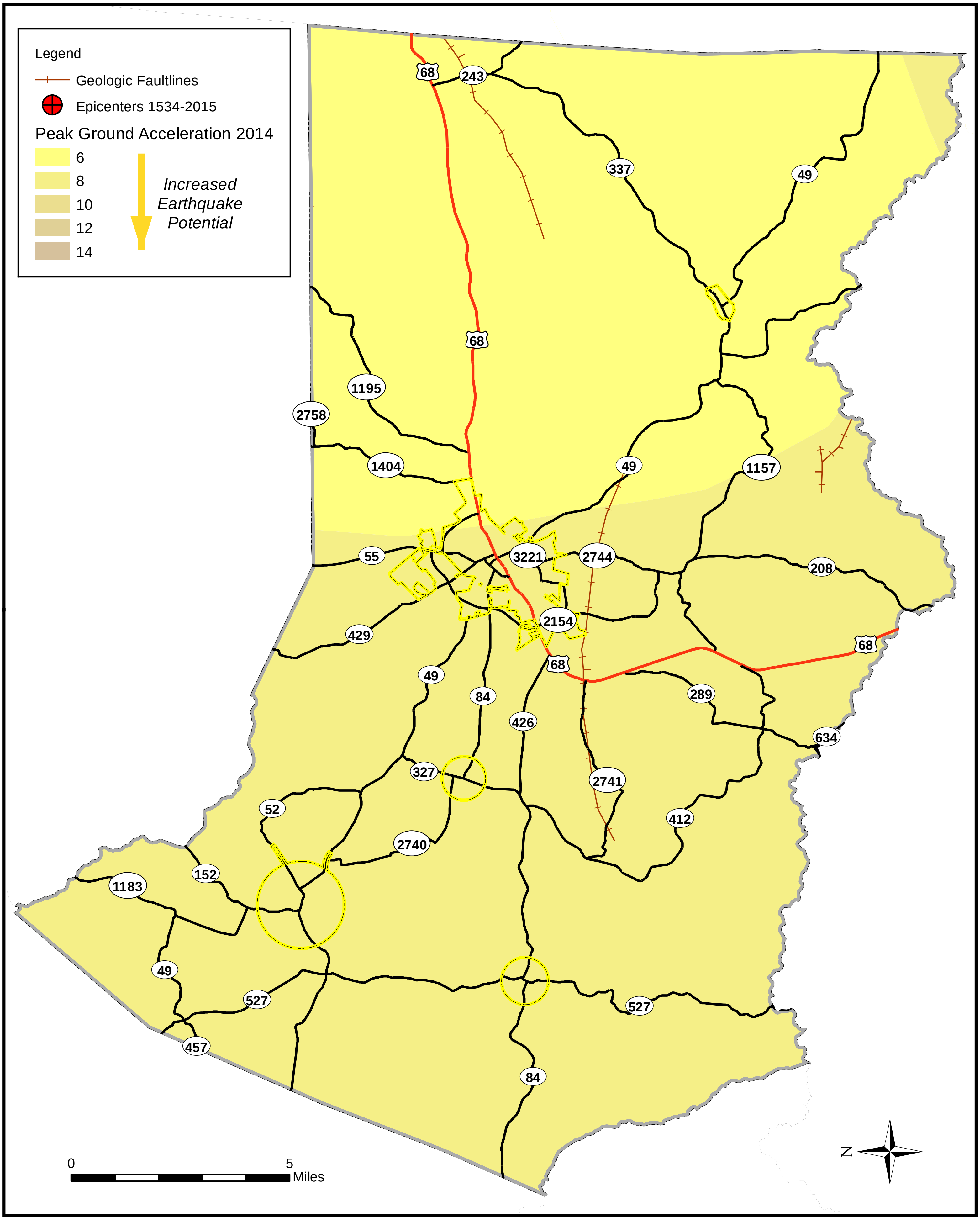
224
31W
1906
61
1079
1549
N
0
5
Miles

149e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Geologic Faultlines
Epicenters 1534-2015
Peak Ground Acceleration 2014
6
8
10
12
14
Increased Earthquake Potential
68
243
337
49
1195
2758
1404
1157
55
3221
2744
208
429
2154
68
49
84
289
426
634
327
2741
52
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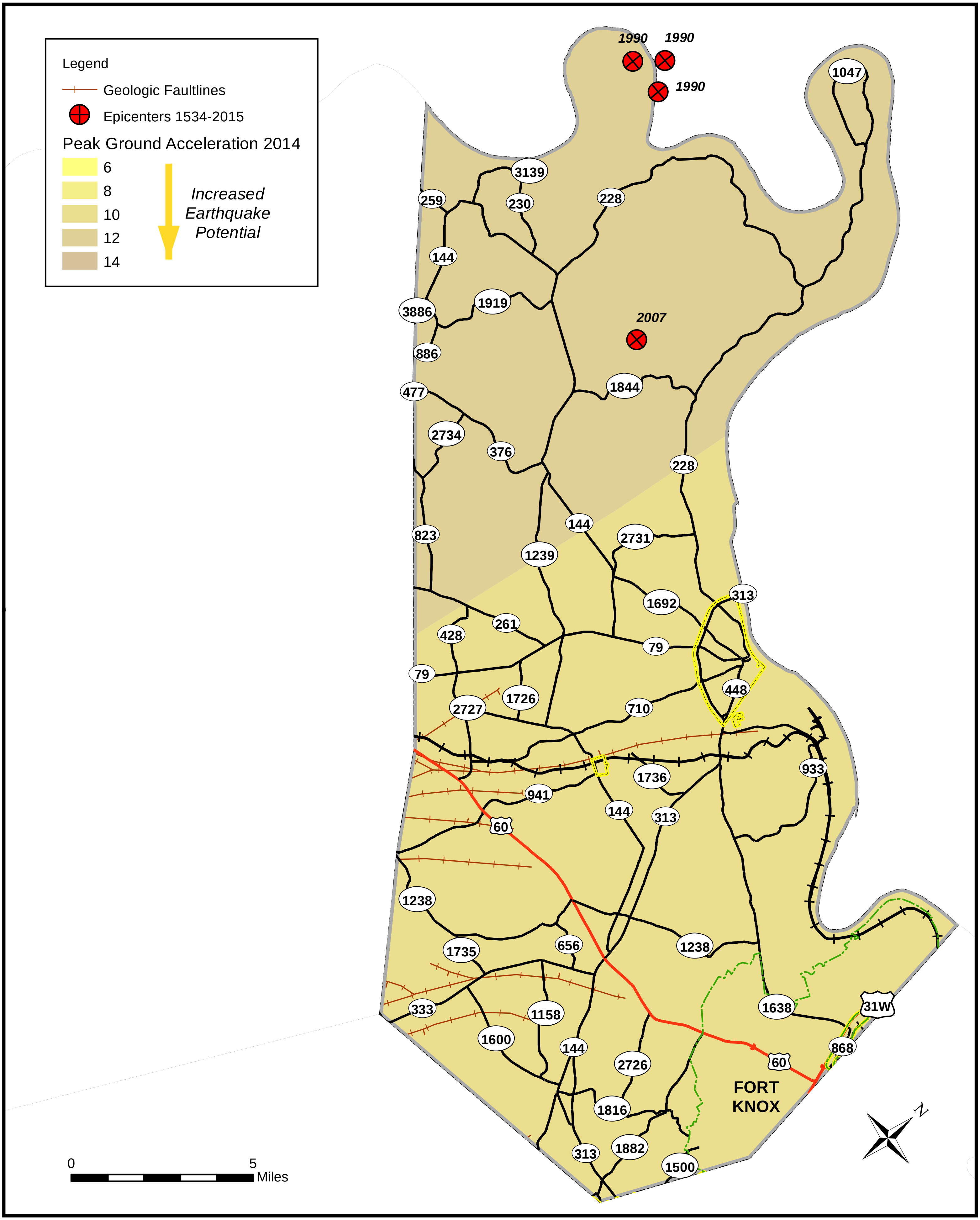
152
1183
49
527
527
457
84
0
5
Miles
N

MEADE COUNTY
EARTHQUAKE



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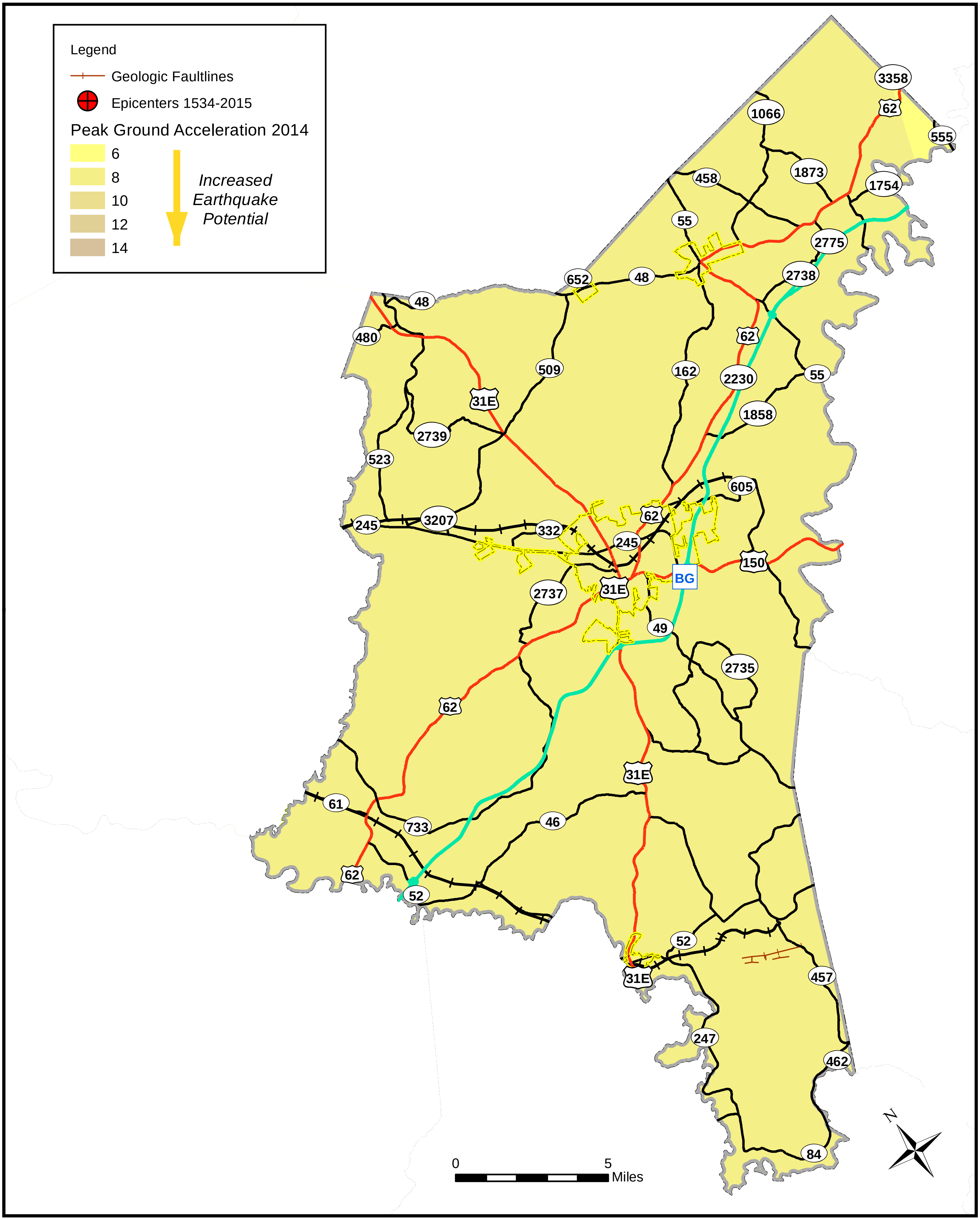
Legend
Geologic Faultlines
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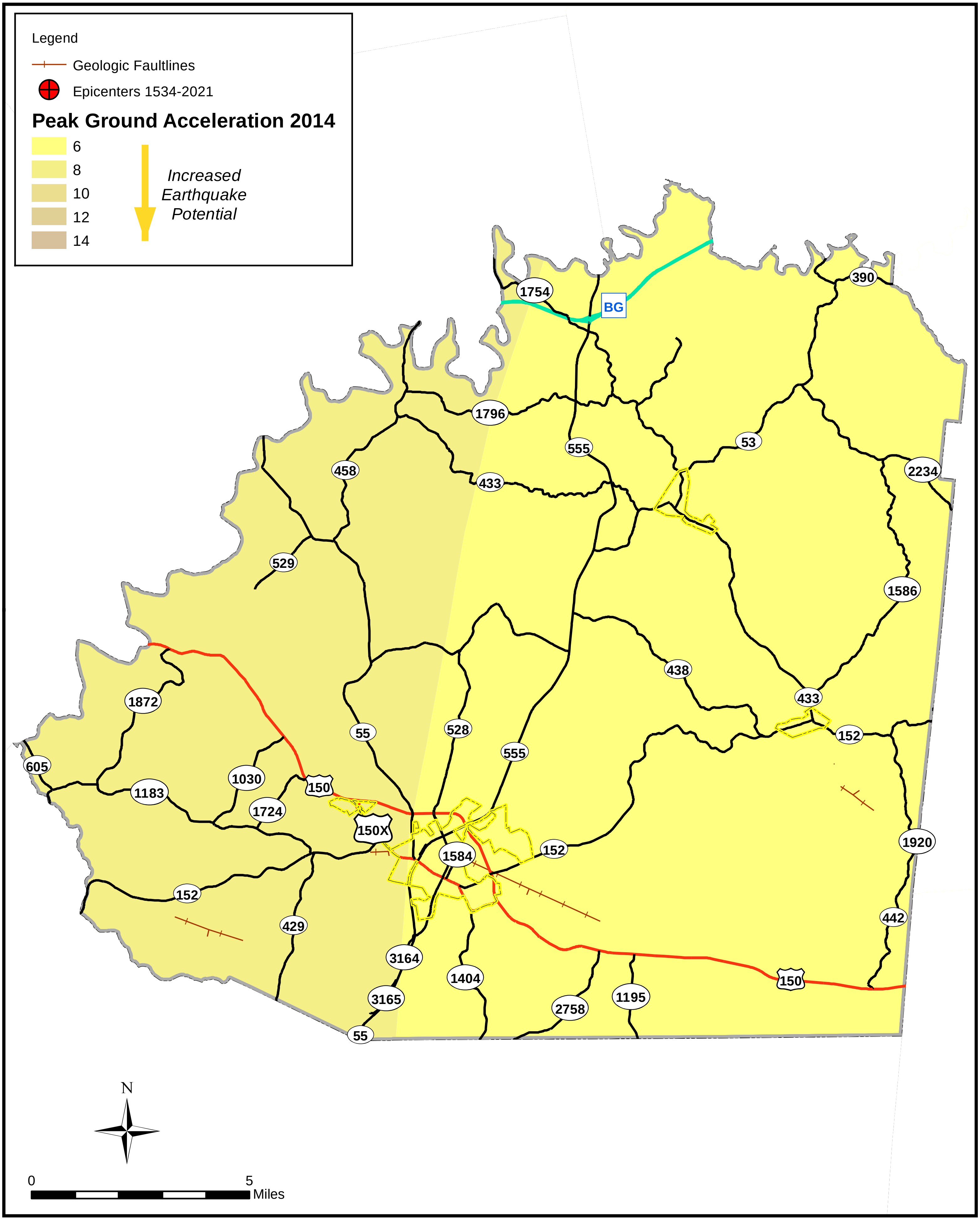
Peak Ground Acceleration 2014
6
8
10
12
14
Increased Earthquake Potential
BG
0
5
Miles
N

149h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Geologic Faultlines
Epicenters 1534-2021
Peak Ground Acceleration 2014
6
8
10
12
14
Increased Earthquake Potential
1754
BG
390
1796
555
53
2234
458
433
529
1586
438
433
1872
55
528
555
152
605
1030
150
1183
1724
150X
1584
152
1920
152
429
442
3164
1404
150
3165
2758
1195
55
N
0
5
Miles

3.3.2.11 <u>Hurricane</u>

I. Background

Merriam-Webster defines a hurricane as "an extremely large, powerful and destructive storm with very strong winds that occurs especially in the western part of the Atlantic Ocean." Typically, a hurricane is considered a tropical storm with winds of 74 miles per hour or greater. The storm or cyclone is accompanied by rain, thunder, and lightning.

Hurricanes are unique. Unlike any other storms on earth, hurricanes can be viewed from space as powerful, tightly coiled weather systems. Also called cyclones; the general term for all circulating weather systems, the storms move counterclockwise in the Northern Hemisphere over tropical waters. There are three classes of tropical cyclones:

1. **Tropical Depression** - A tropical depression is an organized system of clouds and thunderstorms with a defined circulation and maximum sustained winds of 38 mph or less.

2. **Tropical Storm** - A tropical storm is an organized system of strong thunderstorms with a defined circulation and maximum sustained wind of 39 to 73 mph.

3. **Hurricane** - A hurricane is an intense tropical storm with a well-defined circulation and maximum sustained winds of 74 mph or greater. In the western Pacific, hurricanes are called typhoons," and similar storms in the Indian Ocean are called cyclones.

The National Atmospheric and Oceanic Agency (NOAA) further defines the attributes of a hurricane. "Hurricanes are products of the tropical oceans and atmosphere. Powered by heat from the sea, they are steered by the easterly trade winds and the temperate westerlies, as well as by their own ferocious energy. Around their core, winds grow with great velocity, generating violent seas. Moving ashore, they sweep the ocean inward while spawning tornadoes and producing torrential rains and floods. Each year on average, ten tropical storms (of which six become hurricanes) develop over the Atlantic Ocean, Caribbean Sea, or Gulf of Mexico. Many of these remain over the ocean. However, about five hurricanes strike the United States coastline every 3 years. Of these five, two will be major hurricanes (category 3 or greater on the Saffir-Simpson Hurricane Scale)."

Saffir-Simpson Hurricane Scale and Associated Damages

The intensity of a hurricane is measured by 5 categories. The following scale provides examples of the impacts and damages associated with each category in the United States.

Table 3.3.2.11.1 - Saffir-Simpson Hurricane Wind Scale		
Category	**Wind Speed (mph)**	**Damage**
1	74 - 95	Very dangerous winds will produce some damage
2	96 - 110	Extremely dangerous winds will cause extensive damage
3	111 - 129	Devastating damage will occur
4	130 - 156	Catastrophic damage will occur
5	> 156	Catastrophic damage will occur
Source: NOAA - National Hurricane Center		

II. Analysis

Hurricanes in Kentucky

Although catastrophic damage can result from hurricanes, the geographic location of the Lincoln Trail Region and Kentucky precludes the State from experiencing this level of damage.

However, in September of 2008, Hurricane Ike caused widespread damage across eleven states including Arkansas, Illinois, Indiana, Kentucky, Michigan, Missouri, New York, Ohio, Pennsylvania, Tennessee, and West Virginia. Although the storm made landfall in Texas and Louisiana, the effects were even felt in parts of Ontario due to the incredible strength and size of Ike.

In Kentucky, the Louisville area declared a state of emergency due to major damage, and the Louisville International Airport was temporarily closed. A utility spokesperson indicated that the area suffered its worst power outage in 30 years as a result of Ike. Near Covington, the Cincinnati – Northern Kentucky International Airport was also temporarily closed, and the control tower evacuated. An apartment building in Covington also lost its entire roof. The Kentucky Governor declared a statewide state of emergency and many schools were closed or delayed in the first 3 days following the storm. Statewide, over 600,000 customers lost electricity because of the winds, and a boy was struck and killed by a blown tree limb in Simpsonville. In the time since these events there have been no hurricane events that have had major weather-related effects on the state.

3.3.2.12 <u>Tsunami</u>

I. Background

The Nation Oceanic and Atmospheric Administration defines a tsunami as "a series of ocean waves generated by sudden displacements in the sea floor, landslides, or volcanic activity. In the deep ocean, the tsunami wave may come gently ashore or may increase in height to become a fast-moving wall of turbulent water several meters high."

While a tsunami cannot be mitigated, the impact of a tsunami can be mitigated through public education, community preparedness, timely warnings, and effective response efforts.

Tsunami waves do not resemble normal sea waves. Instead of appearing as a normal breaking wave, a tsunami may initially resemble a rapidly rising tide. Tsunamis usually consist of a series of waves with periods ranging from minutes to hours, arriving in a "wave train." The height of waves can be tens of meters in large events. The impact of tsunamis is limited to coastal areas, but their destructive force can be disastrous and may affect entire ocean basins.

II. Analysis

Due to the geographic location of Kentucky and the eight-county Lincoln Trail Region, tsunamis do not pose a threat to Kentucky jurisdictions.