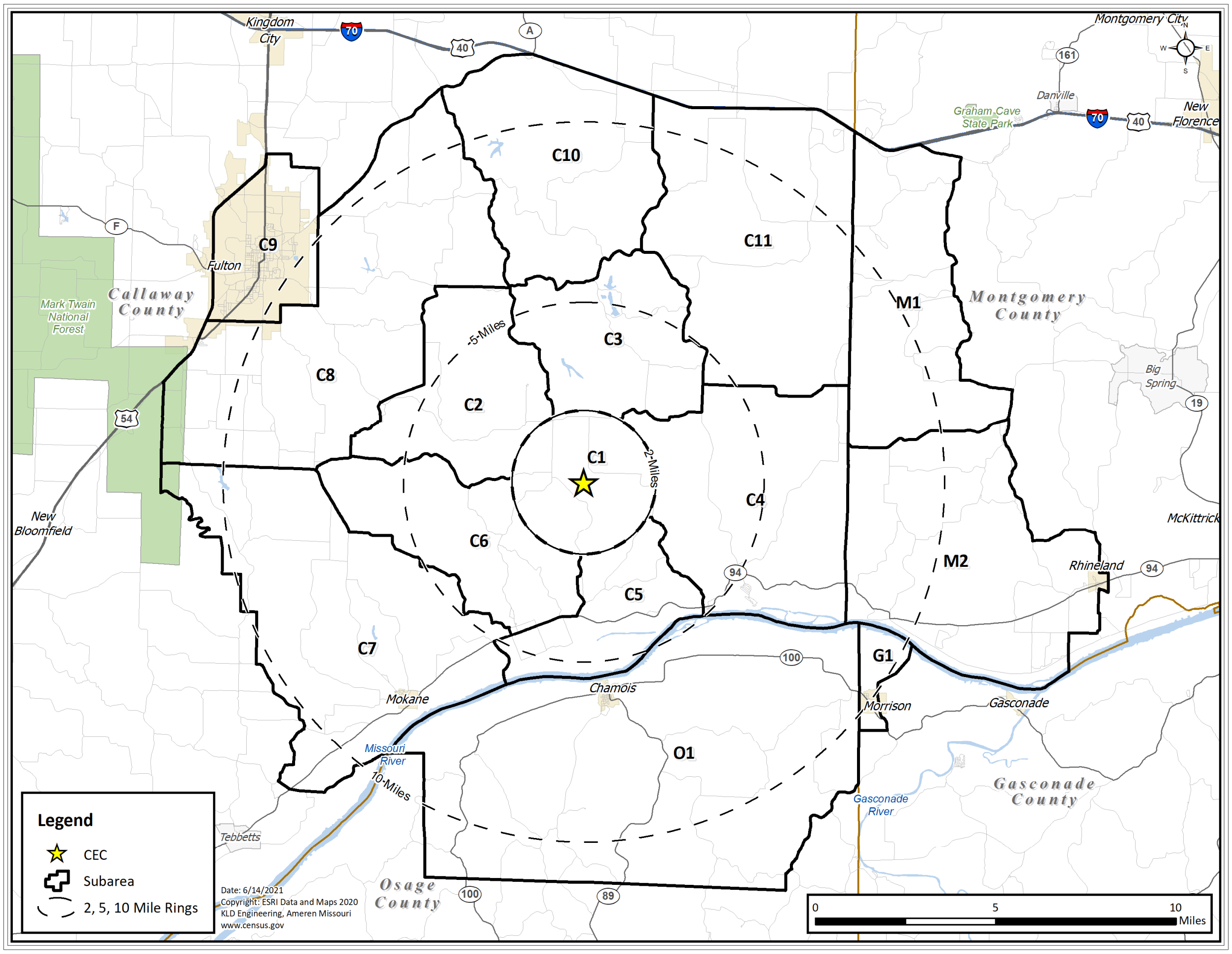
ENCLOSURE

CALLAWAY ENERGY CENTER
DEVELOPMENT OF EVACUATION TIME ESTIMATES

KLD ENGINEERING, P.C.

Callaway Energy Center

Development of Evacuation Time Estimates



Work performed for Ameren Missouri, by:

KLD Engineering, P.C.
1601 Veterans Memorial Highway, Suite 340
Islandia, NY 11749
e-mail: kweinisch@kldcompanies.com

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EXECUTIVE SUMMARY

This report describes the analyses undertaken and the results obtained by a study to develop Evacuation Time Estimates (ETE) for the Callaway Energy Center (CEC) located in Reform, Missouri. ETE are part of the required planning basis and provide Ameren Missouri and state and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, guidance is provided by documents published by Federal Governmental agencies. Most important of these are:

- Title 10, Code of Federal Regulations, Appendix E to Part 50 (10CFR50), Emergency Planning and Preparedness for Production and Utilization Facilities, NRC, 2011.
- Revision 1 of the Criteria for Development of Evacuation Time Estimate Studies, NUREG/CR-7002, February 2021.
- FEMA, "Radiological Emergency Preparedness Program Manual" (FEMA P-1028), December 2019.
- Development of Evacuation Time Estimates for Nuclear Power Plants, NUREG/CR-6863, January 2005.

Project Activities

This project began in September 2020 and extended over a period of 18 months. The major activities performed are briefly described in chronological sequence:

1. Conducted a virtual "kick-off" meeting with Ameren Missouri personnel.
2. Accessed U.S. Census Bureau data files for the year 2020.
3. Obtained the estimates of employees who reside outside the EPZ and commute to work within the EPZ from each county.
4. Studied Geographical Information Systems (GIS) maps of the area in the vicinity of the CEC, then conducted a detailed field survey of the highway network to observe roadway characteristics and note any roadway changes relative to the previous ETE study done in 2010.
5. Updated the analysis network representing the highway system topology and capacities within the Emergency Planning Zone (EPZ), plus a Shadow Region covering the region between the EPZ boundary and approximately 15 miles radially from the plant.
6. Designed and sponsored a demographic survey of residents within the EPZ to gather focused data needed for this ETE study that were not contained within the census database. The survey instrument was reviewed and modified by the licensee and offsite response organization (ORO) personnel prior to the survey.

7. Data from the previous study was provided to the licensee and OROs for review. The OROs indicated the data pertaining to employment, transients, and special facilities (schools, medical facilities, correctional facilities) was still valid.
8. The traffic demand and trip-generation rates of evacuating vehicles were estimated from the gathered data. The trip generation rates reflect the estimated mobilization time (i.e., the time required by evacuees to prepare for the evacuation trip) computed using the results of the demographic survey of EPZ residents.
9. Following federal guidelines, the existing 15 Subareas within the EPZ were grouped within circular areas or "keyhole" configurations (circles plus radial sectors) that define a total of 44 Evacuation Regions (numbered R01 through R44).
10. The time-varying external circumstances were represented as Evacuation Scenarios, each described in terms of the following factors: (1) Season (Summer, Winter); (2) Day of Week (Midweek, Weekend); (3) Time of Day (Midday, Evening); and (4) Weather (Good, Rain, Snow). One special event scenario involving a refueling outage at the Callaway Energy Center site was considered. One roadway impact scenario was considered wherein a single lane was closed on Interstate (I)-70 eastbound (east of the plant) and westbound (west of the plant) for the duration of the evacuation.
11. Staged evacuation was considered for those regions wherein the 2-mile radius and sectors downwind to 5 miles are evacuated.
12. As per NUREG/CR-7002, Rev. 1, the Planning Basis for the calculation of ETE is:
    a. A rapidly escalating accident at the plant that quickly assumes the status of a general emergency wherein evacuation is ordered promptly, and no early protective action have been implemented such that the Advisory to Evacuate (ATE) is virtually coincident with the siren alert.
    b. While an unlikely accident scenario, this planning basis will yield ETE, measured as the elapsed time from the ATE until the stated percentage of the population exits the impacted Region, that represent "upper bound" estimates. This conservative Planning Basis is applicable for all initiating events.
13. If the emergency occurs while schools are in session, the ETE study assumes that the children will be evacuated by bus directly to reception centers located outside the EPZ. It is assumed that parents will pick up school children at day care facilities prior to the start of evacuation. The ETE for schoolchildren are calculated separately.
14. Evacuees who do not have access to a private vehicle will either ride-share with relatives, friends or neighbors, or be evacuated by buses provided by the counties in the EPZ. Those in schools will likewise be evacuated by bus. Separate ETE are calculated for schools, the transit-dependent evacuees, and for access and/or functional needs population.
15. Attended final meeting with Ameren Missouri personnel and county OROs to present final results of the study.

Computation of ETE

A total of 616 ETE were computed for the evacuation of the general public. Each ETE quantifies the aggregate evacuation time estimated for the population within one of the 44 Evacuation Regions to evacuate from that Region, under the circumstances defined for one of the 14 Evacuation Scenarios (44 x 14 = 616). Separate ETE are calculated for transit-dependent evacuees, including schoolchildren for applicable scenarios.

Except for Region R03, which is the evacuation of the entire EPZ, only a portion of the people within the EPZ would be advised to evacuate. That is, the ATE applies only to those people occupying the specified impacted region. It is assumed that 100 percent of the people within the impacted region will evacuate in response to this ATE. The people occupying the remainder of the EPZ outside the impacted region may be advised to take shelter.

The computation of ETE assumes that 20% of the population within the EPZ but outside the impacted region will elect to “voluntarily” evacuate. In addition, 20% of the population in the Shadow Region will also elect to evacuate. These voluntary and shadow evacuees could impede those who are evacuating from within the impacted region. The impedance that could be caused by voluntary and shadow evacuees is considered in the computation of ETE for the impacted region.

Staged evacuation is considered wherein those people within the 2-Mile Region evacuate immediately, while those beyond 2 miles, but within the EPZ, shelter-in-place. Once 90% of the 2-Mile Region is evacuated, those people beyond 2 miles begin to evacuate. As per federal guidance, 20% of people beyond 2 miles will evacuate (non-compliance) even though they are advised to shelter-in-place during a staged evacuation.

The computational procedure is outlined as follows:

- A link-node representation of the highway network is coded. Each link represents a unidirectional length of highway; each node usually represents an intersection or merge point. The capacity of each link is estimated based on the field survey observations and on established traffic engineering procedures.
- The evacuation trips are generated at locations called “zonal centroids” located within the EPZ and Shadow Region. The trip generation rates vary over time reflecting the mobilization process, and from one location (centroid) to another depending on population density and on whether a centroid is within, or outside, the impacted area.
- The evacuation model computes the routing patterns for evacuating vehicles that are compliant with federal guidelines (outbound relative to the plant), and then simulates the traffic flow movements over space and time. This simulation process estimates the rate that traffic flow exits the impacted region.

The ETE statistics provide the elapsed times for 90 percent and 100 percent, respectively, of the population within the impacted region, to evacuate from within the impacted region. These statistics are presented in tabular and graphical formats. The 90^{th} percentile ETE have been identified as the values that should be considered when making protective action decisions because the 100^{th} percentile ETE are prolonged by those relatively few people who take longer

to mobilize. This is referred to as the "evacuation tail" in Section 4.0 of NUREG/CR-7002, Rev. 1.

Traffic Management

This study modeled the comprehensive existing traffic management plans provided by the OROs. No additional Traffic Management is recommended based on observations of the simulations. Refer to Section 9 and in Appendix G.

Selected Results

A compilation of selected information is presented on the following pages in the form of figures and tables extracted from the body of the report; these are described below.

1. Table 3-1 presents the estimates of permanent resident population in each Subarea based on the 2020 Census data.
2. Table 6-1 defines each of the 44 Evacuation Regions in terms of their respective groups of Subarea.
3. Table 6-2 defines the Evacuation Scenarios.
4. Tables 7-1 and 7-2 are compilations of ETE. These data are the times needed to clear the indicated regions of 90 and 100 percent of the population occupying these regions, respectively. These computed ETE include consideration of mobilization time and of estimated voluntary evacuations from other regions within the EPZ and from the Shadow Region.
5. Tables 7-3 and 7-4 present ETE for the 2-Mile Region, when evacuating additional Subareas downwind to 5 miles for un-staged and staged evacuations for the 90th and 100th percentiles, respectively.
6. Table 8-2 presents ETE for the schoolchildren in good weather.
7. Table 8-5 presents ETE for the transit-dependent population in good weather.
8. Figure 6-1 displays a map of the CEC EPZ showing the layout of the 15 Subareas that comprise, in aggregate, the EPZ.
9. Figure H-8 presents an example of an Evacuation Region (Region R08) to be evacuated under the circumstances defined in Table 6-1. Maps of all Regions are provided in Appendix H.

Conclusions

- General population ETE were computed for 616 unique cases – a combination of 44 unique Evacuation Regions and 14 unique Evacuation Scenarios. Table 7-1 and Table 7-2 document these ETE for the 90th and 100th percentiles. These ETE range from 1:25 (hr:min) to 4:20 at the 90th percentile and the 100th percentile mirrors trip generation time for all scenarios.
- Inspection of Table 7-1 and Table 7-2 indicates that the 100th percentile ETE are significantly longer than those for the 90th percentile. This is the result congestion within the EPZ clearing prior to the completion of trip mobilization. As a result, the 100th percentile ETE is dictated by the time needed to mobilize (the "evacuation tail") and are therefore, substantially longer than the 90th percentile ETE. See Section 7.5 and Figures

7-8 through 7-21.

- Fulton is the most congested area during an evacuation and the last location in the EPZ to exhibit traffic congestion is Martin Luther King Junior Boulevard/Missouri F. All congestion within the EPZ clears by 2 hours and 50 minutes after the ATE during Scenario 6 conditions (winter, weekday, midday with good weather). See Section 7.3 and Figures 7-3 through 7-7.
- The inspection of Table 7-3 and Table 7-4 indicates that a staged evacuation provides no benefits to evacuees from within the 2-Mile Region and adversely impacts many evacuees located beyond 2 miles from the CEC. Staged evacuation should not be Implemented. See Section 7.6 for additional discussion.
- The comparison of Scenarios 6 (winter, midweek, midday, good) and 13 (winter, midweek, midday, good) in Table 7-2 indicates that the Special Event – a refueling outage at the CEC – has little to no impact on the 90th and 100th percentile ETE. See Section 7.5 for additional discussion.
- Comparison of Scenarios 1 and 14 (summer, weekday, midday, in good weather) in Table 7-1 and Table 7-2 indicates that traffic accidents that reduce capacity on I-70 does not have a material impact on the 90th or 100th percentile ETE. See Section 7.5 for additional discussion.
- The average ETE for schools are shorter than the 90th percentile ETE for the general population for an evacuation of the entire EPZ (Region R03) under Scenario 6 conditions by 55 minutes. The average ETE for transit-dependent persons and access and/or functional needs persons exceeds the 90th percentile ETE by 25 minutes (in good weather) and 35 minutes, respectively. See Section 8.
- Table 8-1 indicates that there is sufficient transportation resources available to evacuate the school, transit dependent and access and/or functional needs populations within the EPZ in a single wave. As such, second wave ETE are not computed. See Section 8.
- The general population ETE at the 90th and 100th percentiles are greatly impacted when the base trip generation time (4 hours and 45 minutes) is increased or decreased by an hour due to the lack of traffic congestion within the EPZ and the ETE being dictated by trip generation time. See Section M.1 and Table M-1.
- The general population ETE is not impacted by the change in percentage of voluntary evacuation of vehicles in the Shadow Region. See Section M.2 and Table M-2.
- An increase in permanent resident population (EPZ plus Shadow Region) of 19% or greater results in an increase in the 90th percentile ETE by 25% for the 2-mile region (Region R01), which meets the federal criterion for performing a fully updated ETE between decennial Censuses. See Section M.3.

Table 3-1. EPZ Permanent Resident Population

Subarea	2010 Population	2020 Population
C1	90	62
C2	363	333
C3	441	455
C4	264	249
C5	86	75
C6	492	496
C7	1,406	1,434
C8	2,493	2,331
C9	12,112	11,869
C10	544	454
C11	239	254
G1	107	86
M1	181	171
M2	496	483
O1	859	806
EPZ TOTAL:	**20,173**	**19,558**
EPZ Population Growth (2010-2020):		**-3.05%**

Table 6-1. Description of Evacuation Regions

Radial Regions

Region	Description:	Subarea														
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R01	2-Mile Radius	X														
R02	5-Mile Radius	X	X	X	X	X	X									
R03	Full EPZ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Evacuate 2-Mile Region and Downwind to 5 Miles

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R04	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	X				X	X									
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	See Region R04														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)	See Region R04														
-	38 - 52	K, L, M	NE (3-Sector Keyhole)	See Region R04														
R05	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	X	X			X	X									
R06	60 - 75	L, M, N	ENE (3-Sector Keyhole)	X	X				X									
-	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	See Region R06														
-	83 - 97	M, N, P	E (3-Sector Keyhole)	See Region R06														
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)	See Region R06														
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)	See Region R06														

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R07	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	X	X	X			X									
R08	128 - 142	P, Q, R	SE (3-Sector Keyhole)	X	X	X												
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	**See Region R08**														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)															
-	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)															
-	173 - 187	R, A, B	S (3-Sector Keyhole)															
-	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)															
R09	195 - 210	A, B, C	SSW (3-Sector Keyhole)	X		X												
R10	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	X		X	X											
-	218 - 232	B, C, D	SW (3-Sector Keyhole)	**See Region R10**														
-	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)															
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)															
-	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)															
R11	263 - 277	D, E, F	W (3-Sector Keyhole)	X			X											

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R12	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	X			X	X										
-	285 - 300	E, F, G	WNW (3-Sector Keyhole)	**See Region R12**														
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)															
-	308 - 322	F, G, H	NW (3-Sector Keyhole)															
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)															
R13	330 - 345	G, H, J	NNW (3-Sector Keyhole)	X				X										
-	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	**See Region R04**														
-	353 - 7	H, J, K	N (3-Sector Keyhole)															
Evacuate 2-Mile Radius and Downwind to the EPZ Boundary																		
Region	**Wind Direction From: (Degrees)**	**Sectors:**	**Cardinal Compass Equivalent:**	**Subarea**														
				C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**G1**	**M1**	**M2**	**O1**
R14	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	X				X	X	X								X
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	**See Region R14**														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)															
-	38 - 52	K, L, M	NE (3-Sector Keyhole)															

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R15	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	X	X			X	X	X	X							X
R16	60 - 75	L, M, N	ENE (3-Sector Keyhole)	X	X				X	X	X							
R17	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	X	X				X	X	X	X						
-	83 - 97	M, N, P	E (3-Sector Keyhole)	**See Region R17**														
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)															
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)															
R18	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	X	X	X			X	X	X	X	X					
R19	128 - 142	P, Q, R	SE (3-Sector Keyhole)	X	X	X					X	X	X					
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	**See Region R19**														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)															
R20	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)	X	X	X					X	X	X	X				
R21	173 - 187	R, A, B	S (3-Sector Keyhole)	X	X	X					X		X	X				
R22	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)	X	X	X					X		X	X		X		
R23	195 - 210	A, B, C	SSW (3-Sector Keyhole)	X		X							X	X		X		
R24	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	X		X	X						X	X		X		
R25	218 - 232	B, C, D	SW (3-Sector Keyhole)	X		X	X							X		X		

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R26	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)	X		X	X							X		X	X	
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)	**See Region R26**														
R27	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)	X		X	X							X	X	X	X	
R28	263 - 277	D, E, F	W (3-Sector Keyhole)	X			X							X	X	X	X	
R29	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	X			X	X						X	X	X	X	X
R30	285 - 300	E, F, G	WNW (3-Sector Keyhole)	X			X	X							X		X	X
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)	**See Region R30**														
-	308 - 322	F, G, H	NW (3-Sector Keyhole)															
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)															
R31	330 - 345	G, H, J	NNW (3-Sector Keyhole)	X				X							X			X
R32	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	X				X	X						X			X
R33	353 - 7	H, J, K	N (3-Sector Keyhole)	X				X	X									X

Staged Evacuation - 2-Mile Radius Evacuates, then Evacuate Downwind to 5 Miles																		
Region	**Wind Direction From: (Degrees)**	**Sectors:**	**Cardinal Compass Equivalent:**	**Subarea**														
				C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**G1**	**M1**	**M2**	**O1**
R34	5-Mile Radius			X	X	X	X	X	X									
R35	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	X				X	X									
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	**See Region R35**														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)	**See Region R35**														
-	38 - 52	K, L, M	NE (3-Sector Keyhole)	**See Region R35**														
R36	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	X	X			X	X									
R37	60 - 75	L, M, N	ENE (3-Sector Keyhole)	X	X				X									
-	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	**See Region R37**														
-	83 - 97	M, N, P	E (3-Sector Keyhole)	**See Region R37**														
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)	**See Region R37**														
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)	**See Region R37**														
R38	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	X	X	X			X									

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R39	128 - 142	P, Q, R	SE (3-Sector Keyhole)	X	X	X												
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	**See Region R39**														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)															
-	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)															
-	173 - 187	R, A, B	S (3-Sector Keyhole)															
-	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)															
R40	195 - 210	A, B, C	SSW (3-Sector Keyhole)	X		X												
R41	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	X		X	X											
-	218 - 232	B, C, D	SW (3-Sector Keyhole)	**See Region R41**														
-	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)															
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)															
-	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)															
R42	263 - 277	D, E, F	W (3-Sector Keyhole)	X			X											

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R43	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	X			X	X										
-	285 - 300	E, F, G	WNW (3-Sector Keyhole)	**See Region R43**														
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)															
-	308 - 322	F, G, H	NW (3-Sector Keyhole)															
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)															
R44	330 - 345	G, H, J	NNW (3-Sector Keyhole)	X				X										
-	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	**See Region R35**														
-	353 - 7	H, J, K	N (3-Sector Keyhole)															

Subarea(s) Evacuate	Subarea(s) Shelter-in-Place	Shelter-in-Place until 90% ETE for R01, then Evacuate

Table 6-2. Evacuation Scenario Definitions

Scenario	Season[1]	Day of Week	Time of Day	Weather	Special
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain/Light Snow	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain/Light Snow	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain/Light Snow	None
8	Winter	Midweek	Midday	Heavy Snow	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain/Light Snow	None
11	Winter	Weekend	Midday	Heavy Snow	None
12	Winter	Midweek, Weekend	Evening	Good	None
13	Winter	Midweek	Midday	Good	Special Event – Outage at the CEC
14	Summer	Midweek	Midday	Good	Roadway Impact – Lane Closure on I-70 Outbound in both directions

[1] Winter means that school is in session at normal enrollment levels (also applies to spring and autumn). Summer means that school is in session at summer school enrollment levels (lower than normal enrollment).

Table 7-1. Time to Clear the Indicated Area of *90* Percent of the Affected Population

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Midday		Midday		Evening	Midday			Midday			Evening	Midday	Midday
Region	Good Weather	Rain/Light Snow	Good Weather	Rain/Light Snow	Good Weather	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R02	2:45	2:45	2:35	2:35	2:35	2:45	2:45	4:00	2:40	2:40	4:00	2:35	2:20	2:45
R03	2:55	2:55	2:40	2:40	2:40	2:50	2:50	4:10	2:40	2:40	4:05	2:40	2:45	2:55
2-Mile Region and Keyhole to 5 Miles														
R04	2:35	2:35	2:35	2:35	2:35	2:35	2:35	3:40	2:35	2:35	3:55	2:35	1:45	2:35
R05	2:35	2:40	2:35	2:35	2:35	2:40	2:40	3:50	2:35	2:35	3:55	2:35	2:00	2:35
R06	2:35	2:35	2:35	2:35	2:35	2:35	2:35	3:50	2:35	2:35	3:55	2:35	1:55	2:35
R07	2:40	2:40	2:35	2:35	2:35	2:40	2:40	4:00	2:35	2:35	4:00	2:35	2:10	2:40
R08	2:35	2:35	2:35	2:35	2:30	2:35	2:35	3:45	2:35	2:35	3:55	2:35	1:55	2:35
R09	2:25	2:25	2:35	2:35	2:35	2:25	2:25	3:35	2:35	2:35	3:55	2:35	1:35	2:25
R10	2:35	2:35	2:35	2:35	2:35	2:35	2:35	3:50	2:35	2:40	4:00	2:35	1:50	2:35
R11	2:20	2:20	2:35	2:35	2:35	2:15	2:15	3:25	2:35	2:35	3:50	2:35	1:35	2:20
R12	2:25	2:25	2:35	2:35	2:35	2:25	2:25	3:30	2:35	2:35	3:55	2:35	1:35	2:25
R13	1:45	1:50	2:25	2:25	2:25	1:45	1:45	2:35	2:25	2:25	3:40	2:25	1:30	1:45
2-Mile Region and Keyhole to EPZ Boundary														
R14	2:50	2:55	2:40	2:40	2:40	2:50	2:50	4:10	2:40	2:40	4:00	2:40	2:35	2:50
R15	2:55	2:55	2:40	2:40	2:40	2:55	2:55	4:20	2:40	2:40	4:00	2:40	2:45	2:55
R16	2:50	2:55	2:40	2:40	2:40	2:50	2:50	4:15	2:40	2:40	4:05	2:40	2:40	2:50
R17	2:55	2:55	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:05	2:40	2:45	2:55
R18	2:55	2:55	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:05	2:40	2:45	2:55
R19	2:55	2:55	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:05	2:40	2:40	2:55
R20	2:55	2:55	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:05	2:40	2:40	2:55
R21	2:50	2:50	2:40	2:40	2:40	2:50	2:50	4:15	2:40	2:40	4:00	2:40	2:40	2:50
R22	2:50	2:50	2:40	2:40	2:40	2:50	2:50	4:15	2:40	2:40	4:00	2:40	2:40	2:50
R23	2:45	2:45	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:00	2:40	2:15	2:45
R24	2:45	2:45	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:00	2:40	2:20	2:45
R25	2:45	2:45	2:40	2:45	2:40	2:45	2:45	4:00	2:40	2:45	4:00	2:40	2:15	2:45
R26	2:50	2:50	2:45	2:45	2:45	2:50	2:50	4:10	2:45	2:45	4:05	2:45	2:25	2:50
R27	2:50	2:50	2:45	2:45	2:45	2:50	2:50	4:10	2:45	2:45	4:05	2:45	2:25	2:50
R28	2:45	2:45	2:40	2:45	2:40	2:45	2:45	4:05	2:40	2:45	4:00	2:40	2:15	2:45
R29	2:50	2:50	2:40	2:45	2:40	2:50	2:50	4:10	2:40	2:45	4:00	2:40	2:30	2:50
R30	2:50	2:50	2:40	2:45	2:40	2:50	2:50	4:05	2:40	2:45	4:00	2:40	2:25	2:50
R31	2:45	2:45	2:40	2:40	2:40	2:45	2:45	3:50	2:40	2:40	3:55	2:40	2:00	2:45
R32	2:45	2:45	2:40	2:40	2:40	2:45	2:45	4:00	2:40	2:40	4:00	2:40	2:20	2:45
R33	2:45	2:45	2:40	2:40	2:40	2:45	2:45	4:00	2:40	2:40	3:55	2:40	2:15	2:45

Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R34	2:45	2:45	2:50	2:50	2:50	2:45	2:45	4:05	2:50	2:50	4:00	2:50	2:20	2:45
R35	2:35	2:35	2:45	2:45	2:45	2:35	2:35	3:40	2:45	2:45	3:55	2:45	1:50	2:35
R36	2:40	2:40	2:45	2:45	2:45	2:40	2:40	3:50	2:45	2:45	3:55	2:45	2:00	2:40
R37	2:35	2:35	2:45	2:45	2:45	2:35	2:35	3:50	2:45	2:45	3:55	2:45	1:55	2:35
R38	2:40	2:40	2:45	2:45	2:45	2:40	2:40	4:00	2:45	2:45	4:00	2:45	2:10	2:40
R39	2:35	2:35	2:45	2:45	2:45	2:35	2:35	3:45	2:45	2:45	3:55	2:45	1:55	2:35
R40	2:25	2:25	2:45	2:45	2:45	2:25	2:25	3:35	2:45	2:45	3:55	2:45	1:45	2:25
R41	2:35	2:35	2:50	2:50	2:50	2:35	2:35	3:50	2:50	2:50	4:00	2:50	1:55	2:35
R42	2:20	2:20	2:50	2:50	2:50	2:20	2:20	3:25	2:50	2:50	3:55	2:50	1:40	2:20
R43	2:25	2:25	2:50	2:50	2:50	2:25	2:25	3:30	2:50	2:50	3:55	2:50	1:45	2:25
R44	1:50	1:50	2:40	2:40	2:40	1:50	1:50	2:40	2:40	2:40	3:50	2:40	1:30	1:50

Table 7-2. Time to Clear the Indicated Area of *100* Percent of the Affected Population

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Midday		Midday		Evening	Midday			Midday			Evening	Midday	Midday
Region	Good Weather	Rain/Light Snow	Good Weather	Rain/Light Snow	Good Weather	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R02	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R03	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
2-Mile Region and Keyhole to 5 Miles														
R04	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R05	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R06	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R07	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R08	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R09	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R10	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R11	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R12	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R13	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
2-Mile Region and Keyhole to EPZ Boundary														
R14	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R15	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R16	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R17	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R18	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R19	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R20	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R21	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R22	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R23	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R24	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R25	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R26	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R27	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R28	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R29	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R30	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R31	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R32	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R33	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55

Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R34	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R35	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R36	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R37	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R38	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R39	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R40	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R41	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R42	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R43	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R44	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50

Table 7-3. Time to Clear *__90__* Percent of the 2-Mile Region

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain/Light Snow	Good Weather	Rain/Light Snow	Good Weather	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region and 5-Mile Region														
R01	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R02	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
Unstaged Evacuation - 2-Mile Region and Keyhole to 5-Miles														
R04	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R05	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R06	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R07	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R08	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R09	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R10	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R11	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R12	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R13	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
Staged Evacuation - 2-Mile Region and Keyhole to 5-Miles														
R34	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R35	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R36	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R37	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R38	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R39	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R40	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R41	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R42	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R43	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R44	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25

Table 7-4. Time to Clear *100* Percent of the 2-Mile Region

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain/Light Snow	Good Weather	Rain/Light Snow	Good Weather	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region and 5-Mile Region														
R01	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R02	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
Unstaged Evacuation - 2-Mile Region and Keyhole to 5-Miles														
R04	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R05	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R06	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R07	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R08	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R09	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R10	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R11	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R12	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R13	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
Staged Evacuation - 2-Mile Region and Keyhole to 5-Miles														
R34	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R35	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R36	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R37	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R38	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R39	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R40	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R41	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R42	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R43	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R44	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45

Table 8-2. School Evacuation Time Estimates – Good Weather

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETA to R.C. (hr:min)
CALLAWAY COUNTY SCHOOLS									
Bartley Elementary School	90	15	1.5	37.4	2	**1:50**	22.6	23	**2:15**
Bush Elementary School	90	15	2.4	29.1	5	**1:50**	22.6	23	**2:15**
Fulton High School	90	15	1.6	45.6	2	**1:50**	26.1	26	**2:20**
Fulton Middle School	90	15	2.1	36.2	3	**1:50**	22.6	23	**2:15**
Kingdom Christian Academy	90	15	2.1	33.2	4	**1:50**	22.6	23	**2:15**
McIntire Elementary School	90	15	1.0	45.3	1	**1:50**	22.6	23	**2:15**
Missouri School for the Deaf	90	15	1.7	29.0	4	**1:50**	22.6	23	**2:15**
South Callaway R-II Elementary School	90	15	6.0	52.8	7	**1:55**	17.7	18	**2:15**
South Callaway R-II Middle School	90	15	6.0	52.8	7	**1:55**	17.7	18	**2:15**
South Callaway R-II High School	90	15	6.0	52.8	7	**1:55**	17.7	18	**2:15**
St. Peter's Catholic School	90	15	3.0	34.7	5	**1:50**	26.1	26	**2:20**
Westminster College	90	15	1.1	45.3	1	**1:50**	22.6	23	**2:15**
William Woods University	90	15	3.0	39.4	5	**1:50**	26.1	26	**2:20**
OSAGE COUNTY SCHOOLS									
Chamois High School	90	15	9.1	47.9	11	**2:00**	24.8	25	**2:25**
Osage County Chamois R-1 School District	90	15	9.1	47.9	11	**2:00**	24.8	25	**2:25**
					Maximum for EPZ:	**2:00**		**Maximum:**	**2:25**
					Average for EPZ:	**1:55**		**Average:**	**2:20**

Table 8-5. Transit-Dependent Evacuation Time Estimates – Good Weather

Bus Route Number	Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	ETA to R.C. (hr:min)
1	150	6.0	55.3	7	30	**3:10**	17.7	18	**3:30**
2	150	11.2	36.8	18	30	**3:20**	26.1	26	**3:50**
3	150	9.1	44.8	12	30	**3:15**	24.8	25	**3:40**
					Maximum ETE:	**3:20**		**Maximum ETE:**	**3:50**
					Average ETE:	**3:15**		**Average ETE:**	**3:40**

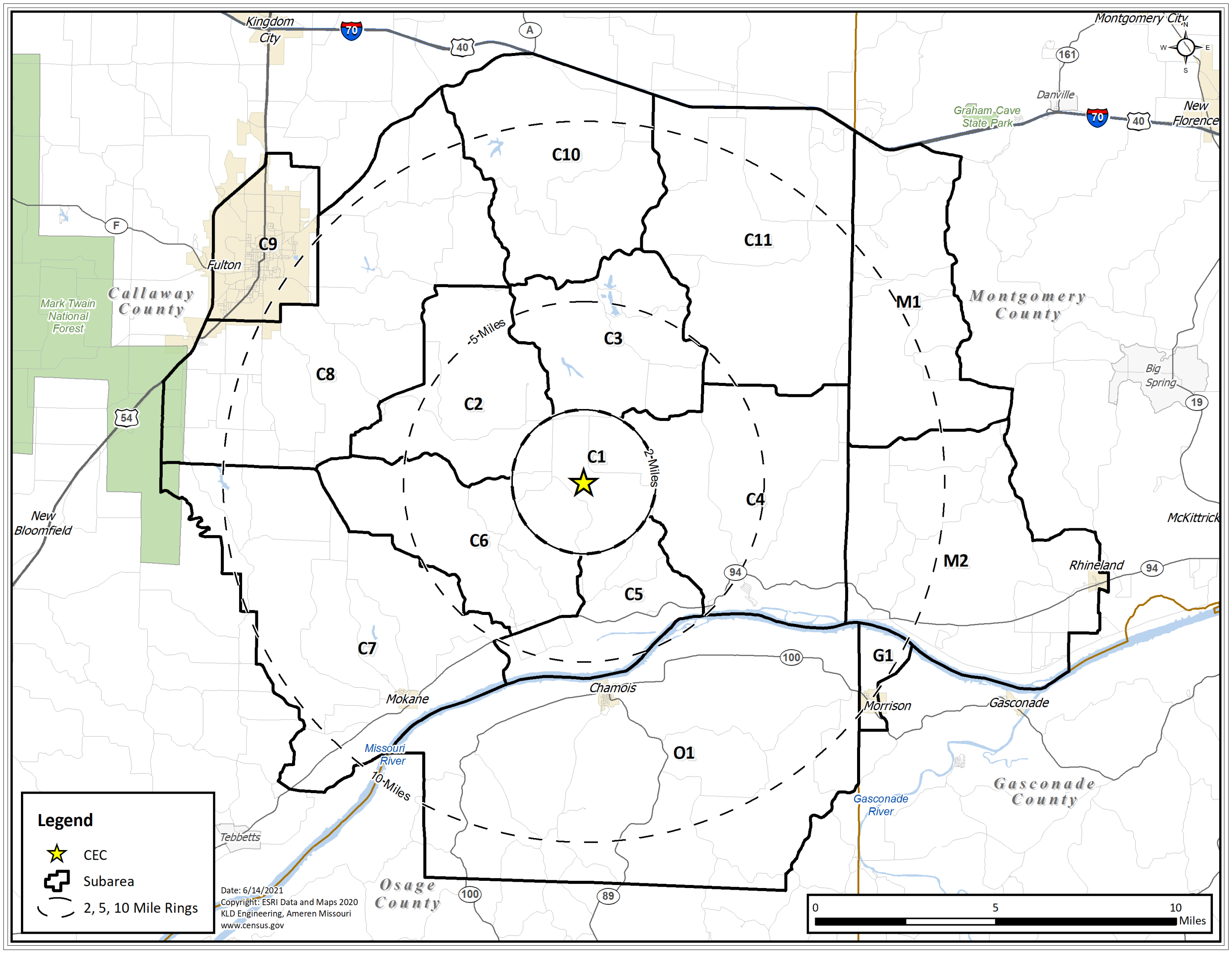

Figure 6-1. Subareas Comprising the Callaway Energy Center EPZ

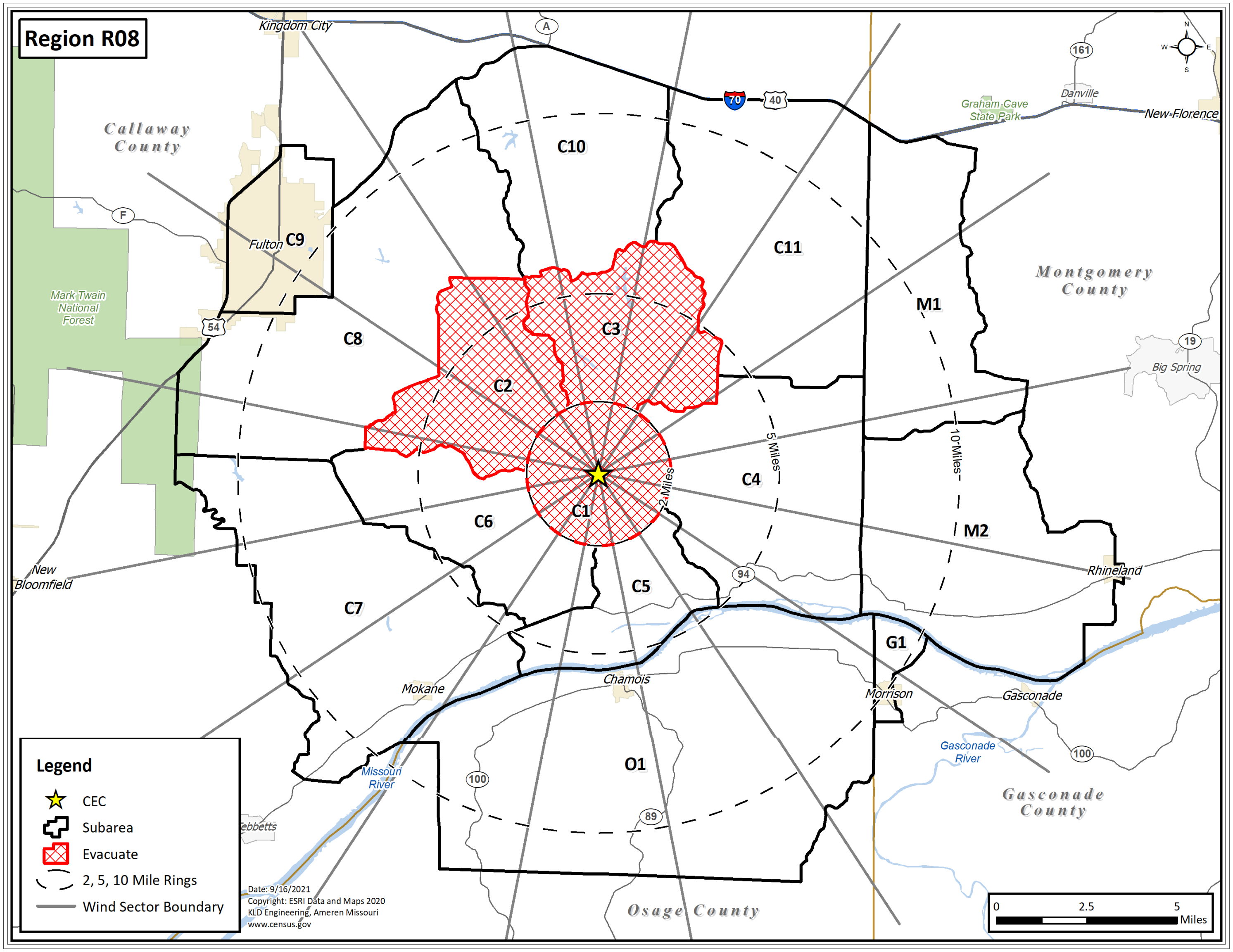

Figure H-8. Region R08

1 INTRODUCTION

This report describes the analyses undertaken and the results obtained by a study to develop Evacuation Time Estimates (ETE) for the Callaway Energy Center (CEC), located in Callaway County, ten miles southeast of Fulton, Missouri. This ETE study provides Ameren Missouri, state and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, guidance is provided by documents published by federal governmental agencies. Most important of these are:

- Title 10, Code of Federal Regulations, Appendix E to Part 50 (10CFR50), Emergency Planning and Preparedness for Production and Utilization Facilities, NRC, 2011.
- Revision 1 of the Criteria for Development of Evacuation Time Estimate Studies, NUREG/CR-7002, February 2021.
- FEMA, "Radiological Emergency Preparedness Program Manual" (FEMA P-1028), December 2019.
- Development of Evacuation Time Estimates for Nuclear Power Plants, NUREG/CR-6863, January 2005.

The work effort reported herein was supported and guided by local stakeholders who contributed suggestions, critiques, and the local knowledge base required. Table 1-1 presents a summary of stakeholders and interactions.

1.1 Overview of the ETE Process

The following outline presents a brief description of the work effort in chronological sequence:

1. Information Gathering:
   a. Defined the scope of work in discussions with representatives from Ameren Missouri.
   b. Attended project kickoff meeting with personnel from Ameren Missouri to identify issues to be addressed and resources available.
   c. Conducted a detailed field survey of the highway system and of area traffic conditions within the Emergency Planning Zone (EPZ) and Shadow Region.
   d. Obtained demographic data from the 2020 Census.
   e. Estimated the number of non-EPZ employees using data from the previous study.
   f. Conducted a random sample demographic survey of EPZ residents.
   g. Conducted a data collection effort to identify and describe schools, medical facilities, correctional facilities, transient attractions, major employers, transit

dependent residents, access and/or functional needs populations, transportation resources available and the special event.

2. Estimated distributions of trip generation times representing the time required by various population groups (permanent residents, employees, and transients) to prepare (mobilize) for the evacuation trip. These estimates are primarily based upon the random sample demographic survey.
3. Defined Evacuation Scenarios. These scenarios reflect the variation in demand, in trip generation distribution and in highway capacities, associated with different seasons, day of week, time of day and weather conditions.
4. Reviewed the existing traffic management plan to be implemented by local and state police in the event of an incident at the plant. Traffic control is applied at specified Traffic Control Points (TCPs) and Access Control Points (ACPs) located within the study area.
5. Used existing Subareas to define Evacuation Regions. The EPZ is partitioned into 15 Subareas along jurisdictional and geographic boundaries. "Regions" are groups of contiguous Subareas for which ETE are calculated. The configurations of these Regions reflect wind direction and the radial extent of the impacted area. Each Region, other than those that approximate circular areas, approximates a "key-hole section" within the EPZ as recommended by NUREG/CR-7002, Rev. 1.
6. Estimated demand for transit services for persons at schools, transit-dependent persons at home, and those with access and/or functional needs. (Medical and correctional facilities shelter in place.)
7. Prepared the input streams for the DYNEV II.
    a. Estimated the evacuation traffic demand, based on the available information derived from Census data, and from data provided by local and state agencies, Ameren Missouri and from the demographic survey.
    b. Updated the link-node representation of the evacuation network using the road survey and aerial imagery, which is used as the basis for the computer analysis that calculates the ETE.
    c. Applied the procedures specified in the 2016 Highway Capacity Manual (HCM 2016[1]) to the data acquired during the field survey and the link-node analysis network, to estimate the capacity of all highway segments comprising the evacuation routes.
    d. Calculated the evacuating traffic demand for each Region and for each Scenario.
    e. Specified selected candidate destinations for each "origin" (location of each "source" where evacuation trips are generated over the mobilization time) to

[1] Highway Capacity Manual (HCM 2016), Transportation Research Board, National Research Council, 2016.

support evacuation travel consistent with outbound movement relative to the location of the CEC.

8. Executed the DYNEV II model to determine optimal evacuation routing and compute ETE for all residents, transients and employees ("general population") with access to private vehicles. Generated a complete set of ETE for all specified Regions and Scenarios.
9. Documented ETE in formats in accordance with NUREG/CR-7002, Rev. 1.
10. Calculated the ETE for all transit activities including those for special facilities (schools, medical facilities, and correctional facilities), for the transit-dependent population and for the homebound access and/or functional needs population.

1.2 The Callaway Energy Center Location

The CEC is about 5 miles north of the Missouri River and 10 miles southeast of Fulton in Callaway County, Missouri. The site is approximately 80 miles west of St. Louis. The EPZ consists of portions of the counties of Callaway, Gasconade, Montgomery, and Osage. Figure 1-1 shows the location of the CEC relative to St. Louis, as well as the major population centers and roadways in the area.

1.3 Preliminary Activities

These activities are described below.

Field Surveys of the Highway Network

In 2020, KLD personnel drove the entire highway system within the EPZ and the Shadow Region which consists of the area between the EPZ boundary and approximately 15 miles radially from the plant. The characteristics of each section of highway were recorded. These characteristics are shown in Table 1-2.

Video and audio recording equipment were used to capture a permanent record of the highway infrastructure. No attempt was made to meticulously measure such attributes as lane width and shoulder width; estimates of these measures based on visual observation and recorded images were considered appropriate for the purpose of estimating the capacity of highway sections. For example, Exhibit 15-7 in the HCM 2016 indicates that a reduction in lane width from 12 feet (the "base" value) to 10 feet can reduce free flow speed (FFS) by 1.1 mph – not a material difference – for two-lane highways. Exhibit 15-46 in the HCM 2016 shows little sensitivity for the estimates of Service Volumes at Level of Service (LOS) E (near capacity), with respect to FFS, for two-lane highways.

The data from the audio and video recordings were used to create detailed geographic information systems (GIS) shapefiles and databases of the roadway characteristics and of the traffic control devices observed during the road survey; this information was referenced while preparing the input stream for the DYNEV II System. Roadway types were assigned based on the following criteria:

- Freeway: limited access highway, 2 or more lanes in each direction, high free flow speeds
- Freeway ramp: ramp on to or off of a limited access highway
- Major arterial: 3 or more lanes in each direction
- Minor arterial: 2 or more lanes in each direction
- Collector: single lane in each direction
- Local roadway: single lane in each direction, local road with low free flow speeds

As documented on page 15-6 of the HCM 2016, the capacity of a two-lane highway is 1,700 passenger cars per hour in one direction. For freeway sections, a value of 2,250 vehicles per hour per lane is assigned, as per Exhibit 12-37 of the HCM 2016. The road survey has identified several segments which are characterized by adverse geometrics on two-lane highways which are reflected in reduced values for both capacity and speed. These estimates are consistent with the service volumes for LOS E presented in HCM 2016 Exhibit 15-46. These links may be identified by reviewing Appendix K. Link capacity is an input to DYNEV II which computes the ETE. Further discussion of roadway capacity is provided in Section 4 of this report.

Traffic signals are either pre-timed (signal timings are fixed over time and do not change with the traffic volume on competing approaches) or are actuated (signal timings vary over time based on the changing traffic volumes on competing approaches). Actuated signals require detectors to provide the traffic data used by the signal controller to adjust the signal timings. These detectors are typically magnetic loops in the roadway, or video cameras mounted on the signal masts and pointed toward the intersection approaches. If detectors were observed on the approaches to a signalized intersection during the road survey, detailed signal timings were not collected as the timings vary with traffic volume. TCPs or ACPs at locations which have control devices are represented as actuated signals in the DYNEV II system.

If no detectors were observed, the signal control at the intersection was considered pre-timed, and detailed signal timings were gathered for several signal cycles. These signal timings were input to the DYNEV II system used to compute ETE, as per NUREG/CR-7002, Rev. 1 guidance.

Figure 1-2 presents the link-node analysis network that was constructed to model the evacuation roadway network in the EPZ and Shadow Region. The directional arrows on the links and the node numbers have been removed from Figure 1-2 to clarify the figure. The detailed figures provided in Appendix K depict the analysis network with directional arrows shown and node numbers provided. The observations made during the field survey and aerial imagery was used to calibrate the analysis network.

Demographic Survey

An online demographic survey was undertaken to gather information needed for the ETE study. Appendix F presents the survey instrument, the procedures used, and tabulations of data compiled from the survey returns.

These data were utilized to develop estimates of vehicle occupancy to estimate the number of evacuating vehicles during an evacuation and to estimate elements of the mobilization process. This database was also referenced to estimate the number of transit-dependent residents.

Computing the Evacuation Time Estimates

The overall study procedure is outlined in Appendix D. Demographic data were obtained from several sources, as detailed later in this report. These data were analyzed and converted into vehicle demand data. The vehicle demand was loaded onto appropriate "source" links of the analysis network using GIS mapping software. The DYNEV II system was then used to compute ETE for all Regions and Scenarios.

Analytical Tools

The DYNEV II System that was employed for this study is comprised of several integrated computer models. One of these is the DYNEV (DYnamic Network EVacuation) macroscopic simulation model, a new version of the IDYNEV model that was developed by KLD under contract with the Federal Emergency Management Agency (FEMA).

DYNEV II consists of four sub-models:

- A macroscopic traffic simulation model (for details, see Appendix C).
- A Trip Distribution (TD), model that assigns a set of candidate destination (D) nodes for each "origin" (O) located within the analysis network, where evacuation trips are "generated" over time. This establishes a set of O-D tables.
- A Dynamic Traffic Assignment (DTA), model which assigns trips to paths of travel (routes) which satisfy the O-D tables, over time. The TD and DTA models are integrated to form the DTRAD (Dynamic Traffic Assignment and Distribution) model, as described in Appendix B.
- A Myopic Traffic Diversion model which diverts traffic to avoid intense, local congestion, if possible.

Another software product developed by KLD, named UNITES (UNIfied Transportation Engineering System) was used to expedite data entry and to automate the production of output tables.

The dynamics of traffic flow over the network are graphically animated using the software product, EVAN (EVacuation ANimator), developed by KLD. EVAN is GIS based, and displays statistics such as LOS, vehicles discharged, average speed, and percent of vehicles evacuated, output by the DYNEV II System. The use of a GIS framework enables the user to zoom in on areas of congestion and query road name, town name and other geographical information.

The procedure for applying the DYNEV II System within the framework of developing ETE is outlined in Appendix D. Appendix A is a glossary of terms.

For the reader interested in an evaluation of the original model, I-DYNEV, the following references are suggested:

- NUREG/CR-4873 – Benchmark Study of the I-DYNEV Evacuation Time Estimate Computer Code
- NUREG/CR-4874 – The Sensitivity of Evacuation Time Estimates to Changes in Input

Parameters for the I-DYNEV Computer Code

The evacuation analysis procedures are based upon the need to:

- Route traffic along paths of travel that will expedite their travel from their respective points of origin to points outside the EPZ.
- Restrict movement toward the plant to the extent practicable and disperse traffic demand so as to avoid focusing demand on a limited number of highways.
- Move traffic in directions that are generally outbound, relative to the location of the plant.

DYNEV II provides a detailed description of traffic operations on the evacuation network. This description enables the analyst to identify bottlenecks and to develop countermeasures that are designed to represent the behavioral responses of evacuees. The effects of these countermeasures may then be tested with the model.

1.4 Comparison with Prior ETE Study

Table 1-3 presents a comparison of the present ETE study with the previous ETE study (KLD TR-492, dated June 2012. The 90^{th} percentile ETE for the full EPZ increases by as much as 1 hour and 35 minutes and as little as 40 minutes when compared with the previous study. The 100^{th} percentile ETE increased for the full EPZ by 45 minutes for nearly all scenarios. The major factor contributing to the differences between the ETE values obtained in this study and those of the previous study is primarily due to the increase in the time needed to mobilize residents who reside within the EPZ. Trip mobilization (also known as trip generation) rates for residents increased by 65 minutes from the previous study. Since congestion clears at 2 hours and 50 minutes after the ATE, mobilization time dictates the ETE (See Section 7.4). As such, this increase directly results in the increase in ETE.

Table 1-1. Stakeholder Interaction

Stakeholder	Nature of Stakeholder Interaction
Ameren Missouri	Attended kick-off meeting to define data requirements and set up contacts with local government agencies. Provided recent Callaway Energy Center data. Reviewed and approved all project assumptions. Engaged in the ETE development and were informed of the study results. Reviewed and approved report.
Callaway, Gasconade, Montgomery, and Osage County Emergency Management Departments (EMD)	Provided emergency plans, reviewed and approved special facility and transient data. Reviewed and approved all project assumptions. Informed of the study results. Reviewed and approved report.
Missouri State Emergency Management Department	Provided state emergency plans. Reviewed and approved all project assumptions. Informed of the study results. Reviewed and approved report.

Table 1-2. Highway Characteristics

- Number of lanes
- Lane width
- Shoulder type & width
- Interchange geometries
- Lane channelization & queuing capacity (including turn bays/lanes)
- Geometrics: curves, grades (>4%)
- Posted speed
- Actual free speed
- Abutting land use
- Control devices
- Intersection configuration (including roundabouts where applicable)
- Traffic signal type
- Unusual characteristics: Narrow bridges, sharp curves, poor pavement, flood warning signs, inadequate delineations, toll booths, etc.

Table 1-3. ETE Study Comparisons

Topic	Previous ETE Study	Current ETE Study
Resident Population Basis	ArcGIS Software using 2010 US Census blocks; area ratio method used. Population = 20,173 Vehicles = 10,929	ArcGIS Software using 2020 US Census blocks; area ratio method used. Population = 19,558 Vehicles = 9,063
Resident Population Vehicle Occupancy	2.40 persons/household, 1.35 evacuating vehicles/household yielding: 1.78 persons/vehicle.	2.79 persons/household, 1.55 evacuating vehicles/household yielding: 1.80 persons/vehicle.
Shadow Population	ArcGIS software using 2010 US Census blocks; area ratio method used. 20% Population = 1,340 20% Vehicles = 757	ArcGIS software using 2010 US Census blocks; area ratio method used. 20% Population = 1,312 20% Vehicles = 730
Employee Population	Data was provided by offsite agencies and supplemented by data gathered in phone calls to major employers. 1.09 employees per vehicle based on demographic survey results. Employees = 747 Vehicles = 687	Previous data was confirmed by the client. 1.09 employees per vehicle based on demographic survey results. Employees = 559 Vehicles = 513
Transit-Dependent Population	Estimates based upon U.S. Census data and the results of the demographic survey. A total of 342 people who do not have access to a vehicle, requiring 12 buses to evacuate. An additional 31 homebound access and/or functional needs persons need special transportation to evacuate (19 require a bus, 11 require a wheelchair-accessible vehicle, and 1 require an ambulance).	Estimates based upon U.S. Census data and the results of the demographic survey. A total of 37 people who do not have access to a vehicle, requiring 3 buses to evacuate. An additional 20 homebound access and/or functional needs persons need special transportation to evacuate (16 require a bus and 4 require an ambulance).
Transient Population	Transient estimates based upon information provided about transient attractions in EPZ, supplemented by observations of the facilities during the road survey and from aerial photography. Transients = 2,456 Transient Vehicles = 919	Transient estimates based upon information provided about transient attractions in EPZ, supplemented by observations of the facilities during the road survey and from aerial photography. Transients = 984 Transient Vehicles = 437

Topic	Previous ETE Study	Current ETE Study
Special Facilities Population	Special facility population based on information provided by each county within the EPZ. Medical Facilities: Current census = 17 Buses Required = 2 Wheelchair Bus Required = 0 Ambulances Required = 0 Correctional Facility: Current Census = 1,455	Special facility population based on information provided by each county within the EPZ. Population at Medical Facilities = 730 Population at Correctional Facilities = 1,455 Medical and correctional Facilities within the EPZ are advised to shelter in place.
School Population	School population based on information provided by each county within the EPZ. These estimates only include those at college/universities that need a bus. School enrollment = 5,703 Buses required = 117	School population based on information provided by each county within the EPZ. These estimates include college/universities. School enrollment = 7,849 Buses required = 108
Voluntary evacuation from within EPZ in areas outside region to be evacuated	20% of the population within the EPZ, but not within the Evacuation Region	20% of the population within the EPZ, but not within the Evacuation Region
Shadow Evacuation	20% of people outside of the EPZ within the Shadow Region	20% of people outside of the EPZ within the Shadow Region
Network Size	1,086 links; 918 nodes.	1,770 links; 1,558 nodes.
Roadway Geometric Data	Field surveys conducted in July, 2011. Roads and intersections are video archived and capacities are based on 2010 HCM.	Field surveys conducted in October, 2020. Roads and intersections are video archived and capacities are based on 2016 HCM.
School Evacuation	Direct evacuation to designated Reception Center.	Direct evacuation to designated Reception Center.
Ridesharing	50 percent of transit-dependent persons will evacuate with a neighbor or friend.	Based on the results of the demographic survey, 87% of transit-dependent persons will evacuate with a neighbor or friend.

Topic	Previous ETE Study	Current ETE Study
Trip Generation for Evacuation	Based on residential telephone survey of specific pre-trip mobilization activities: Residents with commuters returning leave between 40 and 220 minutes. Residents without commuters returning leave within 200 minutes. Employees and transients leave within 100 minutes. All times measured from the Advisory to Evacuate.	Based on demographic survey of specific pre-trip mobilization activities: Residents with commuters returning leave between 45 and 285 minutes. Residents without commuters returning leave within 225 minutes. Employees and transients leave within 105 minutes. All times measured from the Advisory to Evacuate.
Weather	Normal, Rain, or Snow. The capacity and free flow speed of all links in the network are reduced by 10% in the event of rain and 20% for snow.	Normal, Rain/Light Snow, or Heavy Snow. The free flow speed and capacity of all links in the network are reduced by 10% in the event of rain/light snow and 15% and 25% for heavy snow, respectively.
Modeling	DYNEV II System – Version 4.0.0.0	DYNEV II System – Version 4.0.22.0
Special Events	Construction of a new unit at the Callaway Plant site.	A refueling outage at the Callaway Energy Center.
Evacuation Cases	28 Regions (central sector wind direction and each adjacent sector technique used) and 14 Scenarios producing 392 unique cases.	44 Regions (central sector wind direction and each adjacent sector technique used) and 14 Scenarios producing 616 unique cases.
Evacuation Time Estimates Reporting	ETE reported for 90th and 100th percentile population. Results presented by Region and Scenario.	ETE reported for 90th and 100th percentile population. Results presented by Region and Scenario.
Evacuation Time Estimates for the entire EPZ, 90th percentile	Winter, Midweek, Midday, Good Weather: 2:05 Summer Weekend, Midday, Good Weather: 2:00	Winter, Midweek, Midday, Good Weather: 2:50 Summer Weekend, Midday, Good Weather: 2:55
Evacuation Time Estimates for the entire EPZ, 100th percentile	Winter, Midweek, Midday, Good Weather: 4:10 Summer Weekend, Midday, Good Weather: 4:10	Winter, Midweek, Midday, Good Weather: 4:55 Summer Weekend, Midday, Good Weather: 4:55

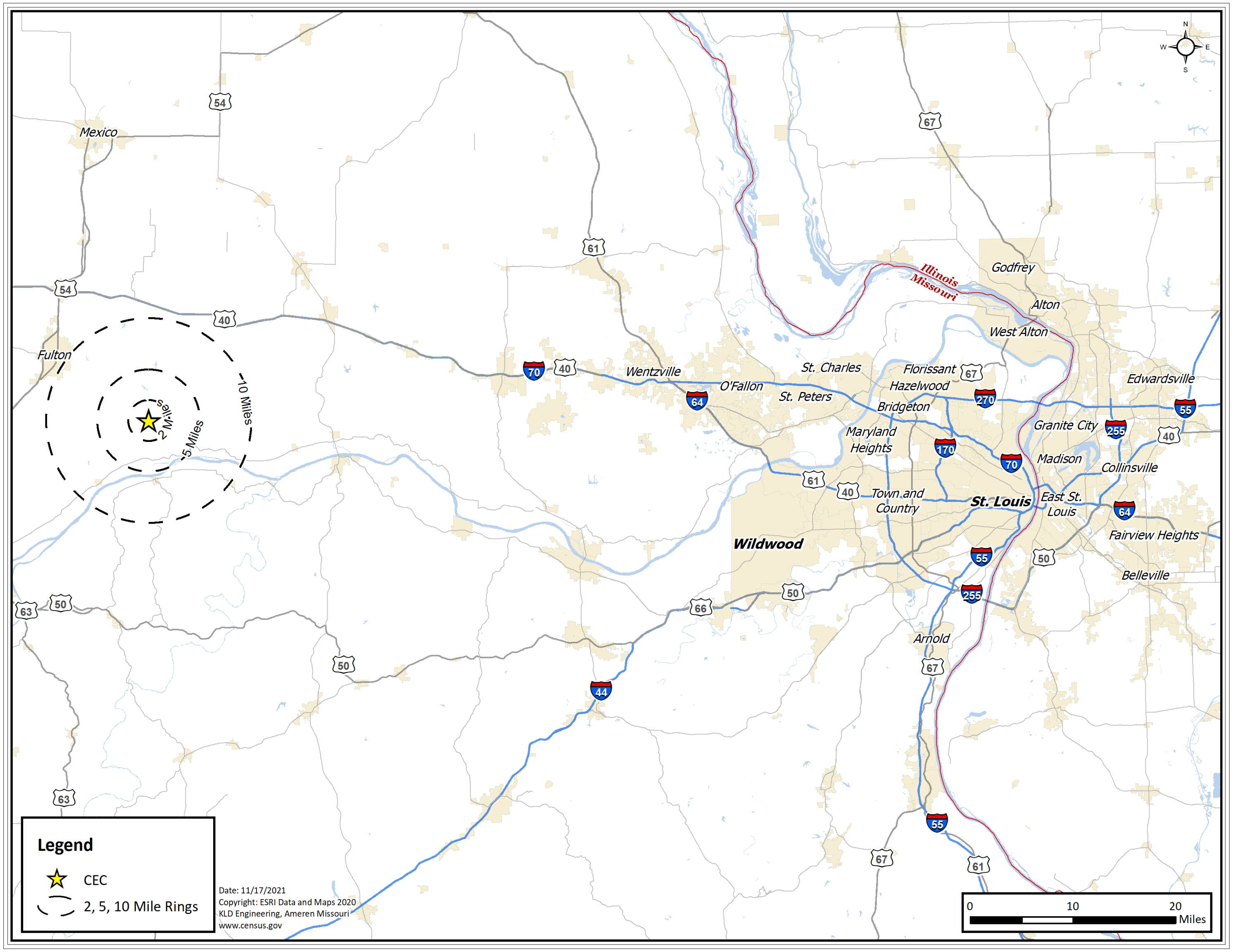

Figure 1-1. Callaway Energy Center Location

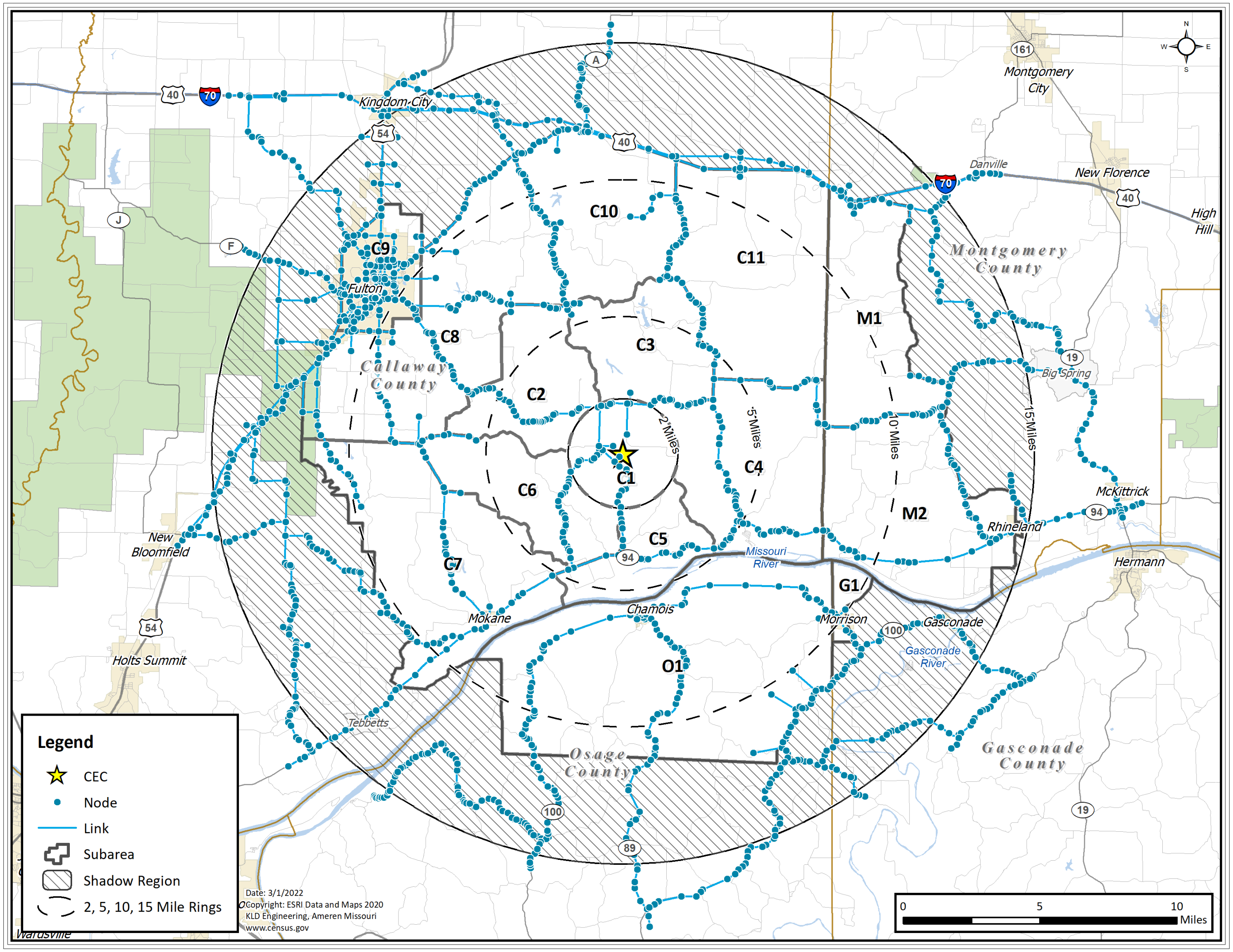

Figure 1-2. Callaway Energy Center Link-Node Analysis Network

2 STUDY ESTIMATES AND ASSUMPTIONS

This section presents the estimates and assumptions utilized in the development of the evacuation time estimates.

2.1 Data Estimate Assumptions

1. The permanent resident population are based on the 2020 U.S. Census population from the Census Bureau website[1]. (See Section 3.1.)
2. Estimates of employees who reside outside the Emergency Planning Zone (EPZ) and commute to work within the EPZ are based upon data provided by each county.
3. Population estimates at transient and special facilities are based on the data received from the counties within the EPZ and the previous ETE study, supplemented by internet searches where data was missing.
4. The relationship between permanent resident population and evacuating vehicles is based on the results of the demographic survey (see Appendix F). Values of 2.79 persons per household and 1.55 evacuating vehicles per household are used for the permanent resident population.
5. The average household size was used for vehicle occupancies at transient facilities wherein data was not provided.
6. Employee vehicle occupancies are based on the results of the demographic survey; 1.09 employees per vehicle is used in the study. (See Figure F-7).
7. The maximum bus speed assumed within the EPZ is 60 mph for buses and average posted speed limits on roadways within the EPZ.
8. Roadway capacity estimates are based on field surveys performed in October 2020 (verified by aerial imagery), and the application of the Highway Capacity Manual 2016.

2.2 Methodological Assumptions

1. The Planning Basis Assumption for the calculation of ETE is a rapidly escalating accident that requires evacuation, and includes the following[2] (as per NRC guidance):
    a. Advisory to Evacuate (ATE) is announced coincident with the siren notification.
    b. Mobilization of the general population will commence within 15 minutes after siren notification.

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[1] www.census.gov

[2] We emphasize that the adoption of this planning basis is not a representation that these events will occur within the indicated time frame. Rather, these assumptions are necessary in order to:
1. Establish a temporal framework for estimating the Trip Generation distribution in the format recommended in Section 2.13 of NUREG/CR-6863.
2. Identify temporal points of reference that uniquely define "Clear Time" and ETE.

It is likely that a longer time will elapse between the various stages of an emergency. See Section 5.1 for more detail.

c. ETE are measured relative to the ATE.

2. The center-point of the plant is located at the center of the containment building 38°45' 40.86" N, 91° 46' 50.88" W.
3. The DYNEV II[3] system is used to compute ETE in this study.
4. Evacuees will drive safely, travel radially away from the plant to the extent practicable given the highway network, and obey all control devices and traffic guides. All major evacuation routes are used in the analysis.
5. The existing EPZ and Subarea boundaries are used. See Figure 3-1.
6. The Shadow Region extends to 15 miles radially from the plant or approximately 5 miles radially from the EPZ boundary, as per NRC guidance. See Figure 7-2.
7. One hundred percent (100%) of the people within the impacted keyhole will evacuate. Twenty percent (20%) of the population within the Shadow Region and within Subareas of the EPZ not advised to evacuate will voluntarily evacuate, as shown in Figure 2-1, as per NRC guidance. Sensitivity studies explore the effect on ETE of increasing the percentage of voluntary evacuees in the Shadow Region (see Appendix M).
8. ETE are presented at the 90th and 100th percentiles, as well as in graphical and tabular format, as per NRC guidance. The percentile ETE is defined as the elapsed time from the Advisory to Evacuate issued to a specific Region of the EPZ, to the time that Region is clear of the indicated percentile of evacuees.
9. The ETE also includes consideration of "through" (External-External) trips during the time that such traffic is permitted to enter the evacuated Region. See Section 3.11.
10. To account for boundary conditions beyond the study area, this study assumes a 25% reduction in capacity on two-lane roads and multi-lane highways for roadways that have traffic signals downstream. The 25% reduction in capacity is based on the prevalence of actuated traffic signals in the study area and the fact that the evacuating traffic volume will be more significant than the competing traffic volume at any downstream signalized intersections, thereby warranting a more significant percentage (75% in this case) of the signal green time. There is no reduction in capacity for freeways due to boundary conditions.
11. This study does not assume that roadways are empty at the start of the first time period. Rather, there is a 30-minute initialization period (often referred to as "fill time in traffic simulation) wherein the traffic volumes from the first time period are loaded onto roadways in the study area. The amount of initialization/fill traffic that is on the roadways in the study area at the start of the first time period depends on the scenario and the region being evacuated. See Section 3.12.

[3] The models of the I-DYNEV System were recognized as state of the art by the Atomic Safety & Licensing Board (ASLB) in past hearings. (Sources: Atomic Safety & Licensing Board Hearings on Seabrook and Shoreham; Urbanik). The models have continuously been refined and extended since those hearings and were independently validated by a consultant retained by the NRC. The DYNEV II model incorporates the latest technology in traffic simulation and in dynamic traffic assignment.

2.3 Assumptions on Mobilization Times

1. Trip generation time (also known as mobilization time, or the time required by evacuees to prepare for the evacuation) are based upon the results of the demographic survey. It is assumed that stated events take place in sequence such that all preceding events must be completed before the current event can occur.
2. One hundred percent (100%) of the EPZ population can be notified within 45 minutes, in accordance with the 2019 Federal Emergency Management Agency (FEMA) Radiological Emergency Preparedness Program Manual.
3. Commuter percentages (and percentage of residents awaiting the return of a commuter) are based on the results of the demographic survey. According to the survey results, 70% of the households in the EPZ have at least 1 commuter (see Section F.3.1.); 60% of those households with commuters will await the return of a commuter before beginning their evacuation trip (see Section F.3.2.). Therefore, 42 percent (70% x 60% = 42%) of EPZ households will await the return of a commuter, prior to beginning their evacuation trip.

2.4 Transit Dependent Assumptions

1. The percentage of transit-dependent people who will rideshare with a neighbor or friend are based on the results of the demographic survey. According to the survey results, approximately 87% of the transit-dependent population will rideshare.
2. Transit vehicles are used to transport those without access to private vehicles:
    a. Schools and childcare centers
        i. If schools are in session, buses will evacuate students directly to the designated reception centers.
        ii. It is assumed that parents pick up children at childcare facilities prior to evacuation.
        iii. For the schools that area evacuated via buses, it is assumed no school children are picked up by their parents prior to the arrival of the buses.
        iv. Schoolchildren, if school is in session, are given priority in assigning transit vehicles.
    b. Medical and correctional facilities
        i. According to the emergency plans, all medical facilities and correctional facilities located within the 10-mile EPZ Shelter-in-Place according to the Callaway County/Fulton Radiological Emergency Response Plan dated February 2017.
    c. Transit-dependent permanent residents:
        i. Transit-dependent general population are evacuated to reception centers.
        ii. Access and/or functional needs population may require county assistance (ambulance, bus, or wheelchair transport) to evacuate. This is considered separately from the general population ETE, as per NRC guidance.

   iii. Households with 3 or more vehicles were assumed to have no need for transit vehicles.

  d. Analysis of the number of required round-trips ("waves") of evacuating transit vehicles is presented.
  e. Transport of transit-dependent evacuees from reception centers to congregate care centers is not considered in this study.

3. Transit vehicle capacities:
   a. School buses = 70 students per bus for primary schools and 50 students per bus for middle/high schools
   b. Ambulatory transit-dependent persons = 30 persons per bus
   c. Wheelchair buses = 15 wheelchair bound persons per bus
   d. Ambulances = 2 bedridden persons (includes advanced and basic life support)
4. Transit vehicles mobilization times:
   a. School buses will arrive at schools to be evacuated within 90 minutes of the ATE.
   b. Transit dependent buses are mobilized when approximately 90% of residents with no commuters have completed their mobilization at 150 minutes of the ATE. This mobilization time is assumed to be applicable to the access and/or functional needs population as well.
5. Transit Vehicle loading times:
   a. School buses are loaded in 15 minutes.
   b. Buses will require 1 minute of loading time per ambulatory passenger.
   c. Wheelchair transport vehicles require 5 minutes of loading time per passenger.
   d. Ambulances are loaded in 15 minutes per bedridden passenger.
6. It is assumed that drivers for all transit vehicles are available.

2.5 Traffic and Access Control Assumptions

1. Traffic Control Points (TCP) and Access Control Points (ACP) as defined in the approved county and state emergency plans are considered in the ETE analysis, as per NRC guidance. See Appendix G.
2. TCP and ACP are assumed to be staffed approximately 120 minutes after the ATE, as per NRC guidance. Earlier activation of ACP locations could delay returning commuters. It is assumed that no through traffic will enter the EPZ after this 120-minute time period.
3. It is assumed that all transit vehicles and other responders entering the EPZ to support the evacuation are unhindered by personnel manning TCPs and ACPs.

2.6 Scenarios and Regions

1. A total of 14 "Scenarios" representing different temporal variations (season, time of day, day of week) and weather conditions are considered. Scenarios to be considered are defined in Table 2-1:
    a. A refueling outage at Callaway Energy Center is considered as the special event (single or multi-day event that attracts a significant population into the EPZ; recommended by NRC guidance) for Scenario 13.
    b. As per NRC guidance, one of the top 5 highest volume roadways must be closed or one lane outbound on a freeway must be closed for a roadway impact scenario. This study considers the closure of one lane on I-70 in each direction outbound from the site for the roadway impact scenario – Scenario 14. For the westbound lane closure, one lane is closed from the intersection with Missouri A/Z (Exit 155) to the intersection with Missouri M (Exit 144). In the eastbound direction, one lane is closed from the intersection with Missouri A/Z (Exit 155) to the intersection with Missouri J/Rt 161 (Exit 170).
2. Two types of adverse weather scenarios are considered. Rain may occur for either winter or summer scenarios; heavy snow occurs in winter scenarios only. It is assumed that the rain or snow begins earlier or at about the same time the evacuation advisory is issued. No weather-related reduction in the number of transients who may be present in the EPZ is assumed. It is assumed that roads are passable and that the appropriate agencies are clearing/treating the roads as they would normally with ice and the roads are passable albeit at lower speeds and capacities.
3. Adverse weather scenarios affect roadway capacity and the free flow highway speeds. The capacity and free flow speed are reduced by 10% for rain/light snow, and range 10% to 25% for heavy snow. In accordance with Table 3-1 of Revision 1 to NUREG/CR-7002, this study assumes a 10% reduction in speed and capacity for rain/light snow and a speed and capacity reduction of 15% and 25%, respectively, for heavy snow.
4. It is also assumed that mobilization and loading times for transit vehicles are slightly longer in adverse weather. It is assumed that mobilization times are 10 minutes and 20 minutes longer in rain/light snow and heavy snow, respectively. It is assumed that loading times for school buses are 5 minutes and 10 minutes longer in rain/light snow and heavy snow, respectively. It is further assumed that loading times for other transit vehicles are 10 minutes and 20 minutes longer in rain/light snow and heavy snow, respectively. Refer to Table 2-2.

5. It is assumed for heavy snow scenarios that some evacuees will need additional time to clear their driveways and access the public roadway system. The distribution of time for this activity was gathered through a demographic survey of the public and takes up to 3 hours and 30 minutes. It is assumed that the time needed by evacuees to remove snow from their driveways is sufficient time for snow removal crews to mobilize and clear/treat the public roadway system.

6. It is assumed that employment is reduced slightly (4% reduction) in the summer for vacations.

7. Regions are defined by the underlying "keyhole" or circular configurations as specified in Section 1.4 of NUREG/CR-7002, Rev. 1. These Regions, as defined, display irregular boundaries reflecting the geography of the Subareas included within these underlying configurations. All 16 cardinal and intercardinal wind direction keyhole configurations are considered. Regions to be considered are defined in Table 6-1. It is assumed that everyone within the group of Subareas forming a Region that is issued an ATE will, in fact, respond and evacuate in general accord with the planned routes.

8. Due to the irregular shapes of the Subareas, there are instances where a small portion of a Subarea (a "sliver") is within the keyhole and the population within that small portion is low (less than 500 people or 10% of the Subarea population, whichever is less). Under those circumstances, the Subarea is not included in the Region so as to not evacuate large numbers of people outside of the keyhole for a small number of people that are actually in the keyhole, unless otherwise stated in the current PAR document.

9. Staged evacuation is considered as defined in NUREG/CR-7002, Rev. 1 – those people between 2 and 5 miles will shelter-in-place until 90% of the 2-mile region has evacuated, then they will evacuate. See Regions R34 through R44 in Table 6-1.

Table 2-1. Evacuation Scenario Definitions

Scenario	Season[4]	Day of Week	Time of Day	Weather	Special
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain/Light Snow	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain/Light Snow	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain/Light Snow	None
8	Winter	Midweek	Midday	Heavy Snow	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain/Light Snow	None
11	Winter	Weekend	Midday	Heavy Snow	None
12	Winter	Midweek, Weekend	Evening	Good	None
13	Winter	Midweek	Midday	Good	Special Event – Refueling Outage at Callaway Energy Center
14	Summer	Midweek	Midday	Good	Roadway Impact – Lane Closure on I-70 Outbound

[4] Winter means that school is in session, at normal enrollment levels (also applies to spring and autumn). Summer means that school is in session at summer school enrollment levels (lower than normal enrollment).

Table 2-2. Model Adjustment for Adverse Weather

Scenario	Highway Capacity*	Free Flow Speed*	Mobilization Time for General Population	Mobilization Time for Transit Vehicles	Loading Time for School Buses	Loading Time for Other Transit Vehicles
Rain/Light Snow	90%	90%	No Effect	10-minute increase	5-minute increase	10-minute increase
Heavy Snow	75%	85%	No Effect	20-minute increase	10-minute increase	20-minute increase
*Adverse weather capacity and speed values are given as a percentage of good weather conditions. Roads are assumed to be passable.						

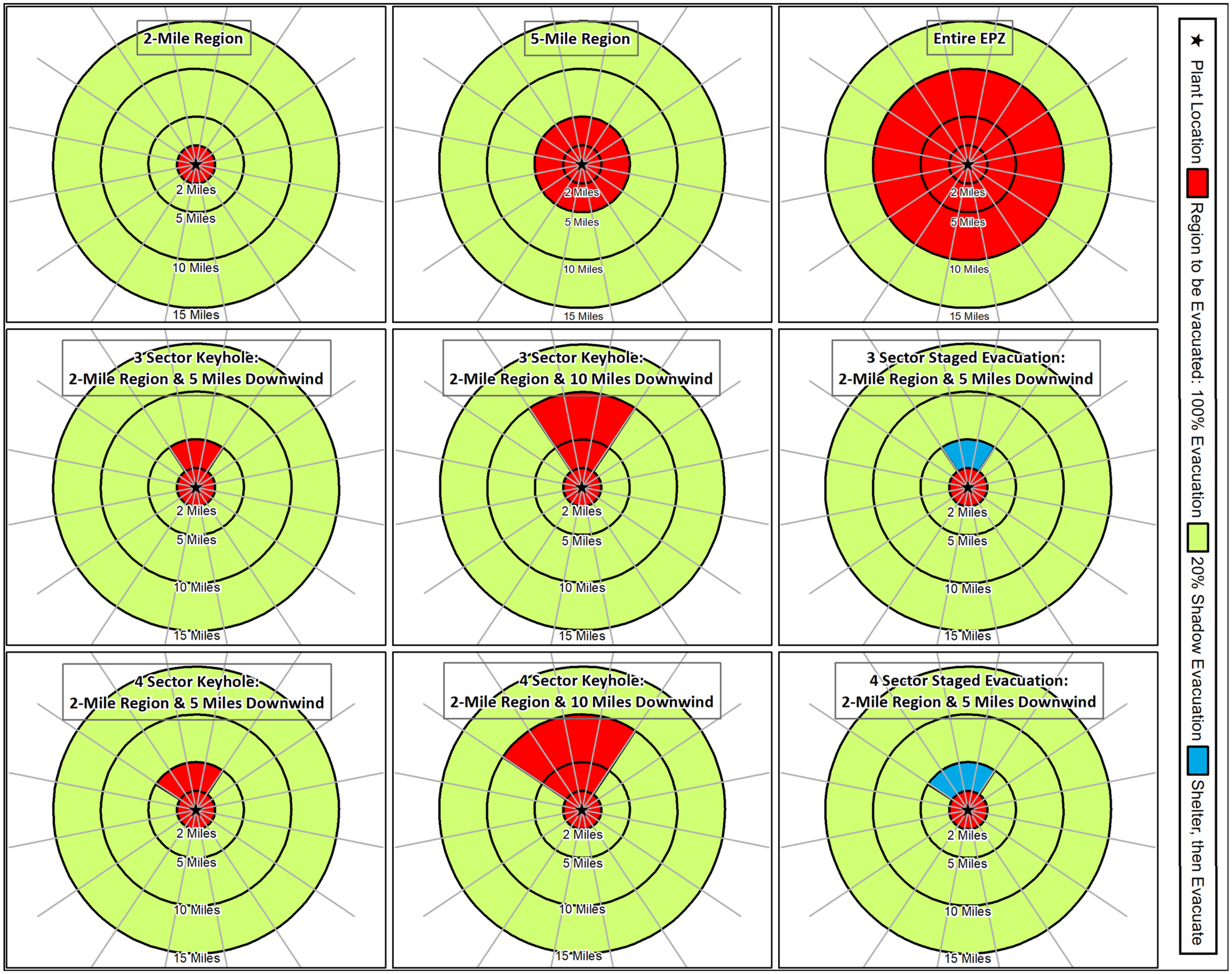


Figure 2-1. Voluntary Evacuation Methodology

3 DEMAND ESTIMATION

The estimates of demand, expressed in terms of people and vehicles, constitute a critical element in developing an evacuation plan. These estimates consist of three components:

1. An estimate of population within the EPZ, stratified into groups (e.g., resident, employee, transient, special facilities, etc.).
2. An estimate, for each population group, of mean occupancy per evacuating vehicle. This estimate is used to determine the number of evacuating vehicles.
3. An estimate of potential double-counting of vehicles.

Appendix E presents much of the source material for the population estimates. Our primary source of population data, the 2020 Census, is not adequate for directly estimating some transient groups.

Throughout the year, vacationers and tourists enter the EPZ. These non-residents may dwell within the EPZ for a short period (e.g., a few days or one or two weeks), or may enter and leave within one day. Estimates of the size of these population components must be obtained, so that the associated number of evacuating vehicles can be ascertained.

The potential for double-counting people and vehicles must be addressed. For example:

- A resident who works and shops within the EPZ could be counted as a resident, again as an employee and once again as a shopper.
- A visitor who stays at a hotel and spends time at a park, then goes shopping could be counted three times.

Furthermore, the number of vehicles at a location depends on time of day. For example, motel parking lots may be full at dawn and empty at noon. Similarly, parking lots at area parks, which are full at noon, may be almost empty at dawn. Estimating counts of vehicles by simply adding up the capacities of different types of parking facilities will tend to overestimate the number of transients and can lead to ETE that are too conservative.

Analysis of the population characteristics of the CEC EPZ indicates the need to identify three distinct groups:

- Permanent residents - people who are year-round residents of the EPZ.
- Transients - people who reside outside of the EPZ who enter the area for a specific purpose (shopping, recreation) and then leave the area.
- Employees - people who reside outside of the EPZ and commute to businesses within the EPZ on a daily basis.

Estimates of the population and number of evacuating vehicles for each of the population groups are presented for each Subarea and by polar coordinate representation (population rose). The CEC EPZ is subdivided into 15 Subareas. The Subareas comprising the EPZ are shown in Figure 3-1.

3.1 Permanent Residents

The primary source for estimating permanent population is the latest U.S. Census data with an availability date of September 16, 2021. The average household size (2.79 persons/household was obtained from the demographic survey – See Appendix F, Sub-section F.3.1). The number of evacuating vehicles per household (1.55 vehicles/household – See Appendix F, Sub-section F.3.2) was adapted from the demographic survey.

The permanent resident population is estimated by cutting the census block polygons by the Subarea and EPZ boundaries using GIS software. A ratio of the original area of each census block and the updated area (after cutting) is multiplied by the total block population to estimate the population within the EPZ. This methodology (referred to as the “area ratio method”) assumes that the population is evenly distributed across a census block. Table 3-1 provides permanent resident population within the EPZ, by Subarea, for 2010 and for 2020 (based on the methodology above). As indicated, the permanent resident population within the EPZ has decreased by -3.05% since the 2010 Census.

To estimate the number of vehicles, the year 2020 permanent resident population is divided by the average household size and multiplied by the average number of evacuating vehicles per household. Permanent resident population and vehicle estimates are presented in Table 3-2. Figure 3-2 and Figure 3-3 present the permanent resident population and permanent resident vehicle estimates by sector and distance from CEC. This population “rose” was constructed using GIS software. Note, the 2020 Census includes residents living in group quarters, such as skilled nursing facilities, group homes, prisons, college/university student housing, etc. These people are transit dependent (will not evacuate in personal vehicles) and are included in the special facility evacuation demand estimates. To avoid double counting vehicles, the vehicle estimates for these people have been removed. The resident vehicles in Table 3-2 and Figure 3-3 have been adjusted accordingly.

It can be argued that this estimate of permanent residents overstates, somewhat, the number of evacuating vehicles, especially during the summer. It is certainly reasonable to assert that some portion of the population would be on vacation during the summer and would travel elsewhere. A rough estimate of this reduction can be obtained as follows:

- Assume 50 percent of all households vacation for a period over the summer.
- Assume these vacations, in aggregate, are uniformly dispersed over 10 weeks, i.e. 10 percent of the population is on vacation during each two-week interval.
- Assume half of these vacationers leave the area.

On this basis, the permanent resident population would be reduced by 5 percent in the summer and by a lesser amount in the off-season. Given the uncertainty in this estimate, we elected to apply no reductions in permanent resident population for the summer scenarios to account for residents who may be out of the area.

3.1.1 Colleges and Universities

There are two higher education facilities in the Callaway EPZ: Westminster College and William Woods University. To estimate the demand for these facilities, it was assumed that all students without personal vehicles on campus would need to be provided transportation assistance from the county, and that all students with personal vehicles would evacuate with a ratio of one person per vehicle. For the previous study, the percentage of students without personal vehicles on campus was determined from the US News College and World Reports website[1]. Since then, the individual school websites have been updated and the percentage of students who have a car on campus have been removed. As such, the percentage of students without personal vehicles is 23% for Westminster College and 10% for William Woods University based on the data from the previous study. The enrollment data from National Application Center (NAC)[2] database indicate there are 760 full-time students at Westminster College and 1,737 full-time students at William Woods University. As a result, Westminster College has 175 (760 x 23%) students without personal vehicles and 585 (760 – 175) students with personal vehicles; William Woods University has 174 (1,737 x 10%) students without personal vehicles and 1,563 (1,737 – 174) students with personal vehicles. According to the demographic survey, approximately 87% of the transit-dependent people would rideshare with a neighbor or friend (see Appendix F, Sub-section F.3.1). As such, 152 (175 x 87%) students at Westminster College and 151 (174 x 87%) students at William Woods University would rideshare with a fellow classmate, leaving 23 (175 – 152, 174 – 151) students who would be evacuated by buses for each school. Using the capacity of 30 people per transit-dependent bus, the number of buses needed for each school is 1 (23 ÷ 30 = 1, rounded up) or 2 vehicles (1 bus equivalent to 2 passenger vehicles). In total, there are 2,148 (585 + 1,563) commuter vehicles and 2 transit-dependent buses for these two facilities.

3.2 Shadow Population

A portion of the population living outside the evacuation area extending to 15 miles radially from the CEC may elect to evacuate without having been instructed to do so. This area is called the Shadow Region. Based upon NUREG/CR-7002, Rev. 1 guidance, it is assumed that 20 percent of the permanent resident population, based on U.S. Census Bureau data, in the Shadow Region will elect to evacuate.

Shadow population characteristics (household size, evacuating vehicles per household, mobilization time) are assumed to be the same as that for the EPZ permanent resident population. Similar to the EPZ resident vehicle estimates, resident vehicles at group quarters have been removed from the shadow population vehicle demand in Table 3-3 and Figure 3-5.

3.3 Transient Population

Transient population groups are defined as those people (who are not permanent residents, nor commuting employees) who enter the EPZ for a specific purpose (shopping, recreation).

[1] https://www.usnews.com/best-colleges?int=top_nav_Colleges
[2] https://www.nationalapplicationcenter.com/,

Transients may spend less than one day or stay overnight at camping facilities, hotels and motels. Data from the previous ETE study was reviewed by the counties within the EPZ and confirmed to be still accurate. An addition, two new lodging facilities were identified within the study area. Data for the new lodging facilities were estimated based on the number of rooms. It is assumed that transients would travel as a family/household. As such, the average household size of 2.79 persons per household (see Section 3.1) was used for the new lodging facilities. The transient facilities within the CEC EPZ are summarized as follows:

- Campgrounds – 191 transients and 90 vehicles; an average of 2.12 transients per vehicle.
- Golf Courses – there is one golf course within the CEC EPZ. However, this facility was reported having local residents only. Therefore, no transients or vehicles were assigned to this facility to avoid double counting.
- Hunting/Fishing Areas – 72 transients and 56 vehicles; an average of 1.29 transients per vehicle.
- Parks and Other Recreational Areas – 510 transients and 187 vehicles; an average of 2.73 transients per vehicle.
- Lodging Facilities – 211 transients and 104 vehicles; an average of 2.03 transients per vehicle.

Appendix E summarizes the transient data that was estimated for the EPZ. Table E-4 presents the number of transients visiting recreational areas, while Table E-5 presents the number of transients at lodging facilities within the EPZ and select portions of the Shadow Region.

In total there are 984 transients evacuating in 437 vehicles (an average of 2.25 transients per vehicle) in the EPZ and select portions of the Shadow Region. Table 3-4 presents transient population and transient vehicle estimates by Subarea. Figure 3-6 and Figure 3-7 present these data by sector and distance from the plant.

3.4 Employees

Employees who work within the EPZ fall into two categories:

- Those who live and work in the EPZ
- Those who live outside of the EPZ and commute to jobs within the EPZ.

Those of the first category are already counted as part of the permanent resident population. To avoid double counting, we focus only on those employees commuting from outside the EPZ who will evacuate along with the permanent resident population.

The employment data from the previous study was reviewed by Ameren Missouri and by the counties within the EPZ. It was confirmed the data was still applicable. As per the NUREG/CR-7002, Rev. 1 guidance, employers with 200 or more employees working in a single shift are considered as major employers. As such, the employers with less than 200 employees (during the maximum shift) are not considered in this study. Table E-3 in Appendix E presents the major employers within the EPZ.

To estimate the evacuating employee vehicles, a vehicle occupancy of 1.09 employees per vehicle obtained from the demographic survey (See Appendix F, Sub-section F.3.1) was used for the major employers. Table 3-5 presents employee and vehicle estimates commuting into the EPZ by Subarea. Figure 3-8 and Figure 3-9 present these data by sector.

3.5 Medical Facilities

The capacity, current census and general information for each medical facility were provided by the county emergency management department and from the facilities themselves. According to the counties, all medical facilities and nursing homes within the EPZ shelter-in-place. Table 3-6 presents a list of medical facilities and their capacity.

3.6 School Population

Table 3-7 presents the school population and transportation requirements for the direct evacuation of all schools within the EPZ for the 2020-2021 school year (7,849 students, 108 buses). It should be noted that this table includes the total enrollment at colleges and universities within the EPZ which is also discussed in Section 3.1.1. This information was provided by the local county emergency management agencies. The column in Table 3-7 entitled “Buses Required” specifies the number of buses required for each school under the following set of assumptions and estimates:

- No students will be picked up by their parents prior to the arrival of the buses.
- While many high school students commute to school using private automobiles (as discussed in Section 2.4 of NUREG/CR-7002, Rev. 1), the estimate of buses required for school evacuation do not consider the use of these private vehicles.
- Bus capacity, expressed in students per bus, is set to 70 for primary schools and 50 for middle and high schools.
- Those staff members who do not accompany the students will evacuate in their private vehicles.
- No allowance is made for student absenteeism, typically 3 percent daily.

It is recommended that the counties in the EPZ implement a process to confirm individual school transportation needs prior to bus dispatch which may improve bus utilization. In this way, the number of buses dispatched to the schools will reflect the actual number needed. The need for buses would be reduced by any high school students who have evacuated using private automobiles (if permitted by school authorities). Those buses originally allocated to evacuate schoolchildren that are not needed due to children being picked up by their parents, can be gainfully assigned to service other facilities or those persons who do not have access to private vehicles or to ride-sharing.

School buses are represented as two vehicles in the ETE simulations due to their larger size and more sluggish operating characteristics.

3.7 Transit Dependent Population

The demographic survey (see Appendix F) results were used to estimate the portion of the population requiring transit service:

- Those persons in households that do not have a vehicle available.
- Those persons in households that do have vehicle(s) that would not be available at the time the evacuation is advised.

In the latter group, the vehicle(s) may be used by a commuter(s) who does not return (or is not expected to return) home to evacuate the household.

Table 3-8 presents estimates of transit-dependent people. Note:

- Estimates of persons requiring transit vehicles include schoolchildren. For those evacuation scenarios where children are at school when an evacuation is ordered, separate transportation is provided for the schoolchildren. The actual need for transit vehicles by residents is thereby less than the given estimates. However, estimates of transit vehicles are not reduced when schools are in session.
- It is reasonable and appropriate to consider that many transit-dependent persons will evacuate by ridesharing with neighbors, friends or family. For example, nearly 80 percent of those who evacuated from Mississauga, Ontario who did not use their own cars, shared a ride with neighbors or friends. Other documents report that approximately 70 percent of transit dependent persons were evacuated via ride sharing. **Based on the results of the demographic survey, approximately 87% of the transit-dependent population will rideshare.**

The estimated number of bus trips needed to service transit-dependent persons is based on an estimate of average bus occupancy of 30 persons at the conclusion of the bus run. Transit vehicle seating capacities typically equal or exceed 60 children (roughly equivalent to 40 adults). If transit vehicle evacuees are two thirds adults and one third children, then the number of "adult seats" taken by 30 persons is 20 + (2/3 x10) = 27. On this basis, the average load factor anticipated is (27/40) x 100 = 68 percent. Thus, if the actual demand for service exceeds the estimates of Table 3-8 by 50 percent, the demand for service can still be accommodated by the available bus seating capacity.

$$\left[20 + \left(\frac{2}{3} \times 10\right)\right] \div 40 \times 1.5 = 1.00$$

Table 3-8 indicates that transportation must be provided for 37 people. Therefore, a total of 2 buses are required from a capacity standpoint. Subareas with less than one transit-dependent person requiring transportation were ignored for this study. In order to service all transit-dependent people while minimizing evacuation time, **4 buses** are used in the ETE calculations, see section 8.1 for further discussion. These buses are represented as two vehicles in the ETE

simulations due to their larger size and more sluggish operating characteristics.

To illustrate this estimation procedure, we calculate the number of persons, P, requiring public transit or ride-share, and the number of buses, B, required for the CEC EPZ:

$$P = No. of\ HH \times \sum_{i=0}^{n} \{(\%\ HH\ with\ i\ vehicles) \times [(Average\ HH\ Size) - i]\} \times A^i C^i$$

Where,

A = Percent of households with commuters

C = Percent of households who will not await the return of a commuter

$$P = 7{,}010 \times [0.1200 \times (1.56 - 1) \times 0.70 \times 0.40 + 0.4280 \times (2.64 - 2) \times (0.70 \times 0.40)^2] = 282$$

$$B = (1 - 0.87 \times P) \div 30 = (0.13 \times 282) \div 30 = 2$$

These calculations are explained as follows:

- The total number of persons requiring public transit is the sum of such people in HH with no vehicles, or with 1 or 2 vehicles that are away from home.
- The approximate number of households is 7,010 (19,558 ÷2.79).
- No households (HH) indicated that they did not have access to a vehicle.
- The members of HH with 1 vehicle away (12.00%), who are at home, equal 0.56 (1.56-1). The number of HH where the commuter will not return home is equal to (7,010 x 0.12 x 0.70 x 0.40), as 70% of EPZ households have a commuter, 40% of which would not return home in the event of an emergency. The number of persons who will evacuate by public transit or ride-share is equal to the product of these two terms.
- The members of HH with 2 vehicles that are away (42.80%), who are at home, equal 0.64 (2.64 – 2). The number of HH where neither commuter will return home is equal to 7,010 x 0.4280 x $(0.70 \times 0.40)^2$. The number of persons who will evacuate by public transit or ride-share is equal to the product of these two terms (the last term is squared to represent the probability that neither commuter will return).
- Households with 3 or more vehicles are assumed to have no need for transit vehicles.

The estimate of transit-dependent population in

Table 3-8 exceeds the number of registered transit-dependent persons in the EPZ as provided by the counties. This is consistent with the findings of NUREG/CR-6953, Volume 2, in that a large majority of the transit-dependent population within the EPZs of U.S. nuclear plants does not register with their local emergency response agency.

3.8 Access and/or Functional Needs Population

The county emergency management agencies have a combined registration for transit-dependent and access and/or functional needs persons. Based on data provided by the counties, there are an estimated 20 access and/or functional needs people within EPZ who require transportation assistance to evacuate. Out of the 20 total access and/or functional needs persons there are 16 ambulatory persons and 4 bedridden persons. (See Table 3-9) Buses and wheelchair buses needed to evacuate the special needs population are represented as two vehicles in the ETE simulations due to their larger size and more sluggish operating characteristics.

3.9 Correctional Facilities

As detailed in Table E-9, there are two correctional facilities within the EPZ – The Fulton Reception and Diagnostic Center and the Callaway County Jail. As shown in the table, there are a total of 1,455 inmates at these facilities. Both of these facilities will shelter in place in the event of an evacuation, as per county plans (Callaway County/Fulton Radiological Emergency Response Plan, Section VI.F).

3.10 Special Event

Based on discussion with Ameren Missouri and the offsite agencies, the special event considered is a refueling outage at Callaway Energy Center – Scenario 13. Ameren Missouri estimates a refueling outage would bring 1,080 contractors from outside the EPZ. The employee vehicle occupancy rate of 1.09 employees per vehicle was used to estimate the number of additional vehicles (991) present for this event.

3.11 External Traffic

Vehicles will be traveling through the EPZ (external-external trips) at the time of an accident. After the Advisory to Evacuate (ATE) is announced, these through-travelers will also evacuate. These through vehicles are assumed to travel on the major routes traversing the EPZ – Interstate (I) - 70 and US Highway (US) – 54. It is assumed that this traffic will continue to enter the EPZ during the first 120 minutes following the ATE.

Average Annual Daily Traffic (AADT) data was obtained from Federal Highway Administration to estimate the number of vehicles per hour (vph) on the aforementioned routes. The AADT was multiplied by the K-Factor, which is the proportion of the AADT on a roadway segment or link during the design hour, resulting in the design hour volume (DHV). The design hour is usually the 30th highest hourly traffic volume of the year, measured in vph. The DHV is then multiplied

by the D-Factor, which is the proportion of the DHV occurring in the peak direction of travel (also known as the directional split). The resulting values are the directional design hourly volumes (DDHV) and are presented in Table 3-10, for each of the routes considered. The DDHV is then multiplied by 2 hours, since access control points (ACPs) are assumed to be activated at 120 minutes after the ATE, to estimate the total number of external vehicles loaded on the analysis network. As indicated, there are 7,256 vehicles entering the EPZ as external-external trips prior to the activation of the ACP and the diversion of this traffic. This number is reduced by 60% for evening scenarios (Scenarios 5 and 12).

3.12 Background Traffic

Section 5 discusses the time needed for the people in the EPZ to mobilize and begin their evacuation trips. As shown in Table 5-9 there are 14 time periods during which traffic is loaded on to roadways in the study area to model the mobilization time of people in the EPZ. Note, there is no traffic generated during the 15th time period, as this time period is intended to allow traffic that has already begun evacuating to clear the study area boundaries.

This study does not assume that roadways are empty at the start of Time Period 1. Rather, there is a 45-minute initialization time period (often referred to as “fill time” in traffic simulation) wherein the traffic volumes from Time Period 1 are loaded onto roadways in the study area. The amount of initialization/fill traffic that is on the roadways in the study area at the start of Time Period 1 depends on the scenario and the region being evacuated (see Section 6). There are 1,568 vehicles on the roadways in the study area at the end of fill time for an evacuation of the entire EPZ (Region R03) under Scenario 6 (winter, midweek, midday, good weather) conditions.

3.13 Summary of Demand

A summary of population and vehicle demand is summarized in Table 3-11 and Table 3-12, respectively. This summary includes all population groups described in this section. A total of 32,484 people and 20,371 vehicles are considered in this study.

Table 3-1. EPZ Permanent Resident Population

Subarea	2010 Population	2020 Population
C1	90	62
C2	363	333
C3	441	455
C4	264	249
C5	86	75
C6	492	496
C7	1,406	1,434
C8	2,493	2,331
C9	12,112	11,869
C10	544	454
C11	239	254
G1	107	86
M1	181	171
M2	496	483
O1	859	806
EPZ TOTAL:	**20,173**	**19,558**
EPZ Population Growth (2010-2020):		**-3.05%**

Table 3-2. Permanent Resident Population and Vehicles by Subarea

Subarea	2020 Population	Resident Vehicles
C1	62	36
C2	333	185
C3	455	252
C4	249	142
C5	75	42
C6	496	276
C7	1,434	781
C8	2,331	1,293
C9	11,869	4,802[3]
C10	454	247
C11	254	145
G1	86	48
M1	171	97
M2	483	268
O1	806	449
EPZ TOTAL:	**19,558**	**9,063**

[3] Modified to avoid double counting the vehicles at correctional and higher education facilities located in Subarea C9.

Table 3-3. Shadow Population and Vehicles by Sector

Sector	Population	Evacuating Vehicles
N	157	83
NNE	101	57
NE	148	82
ENE	139	77
E	89	52
ESE	228	126
SE	302	168
SSE	92	53
S	210	119
SSW	388	218
SW	402	227
WSW	538	300
W	661	370
WNW	1,754	974
NW	1,029	563
NNW	322	182
TOTAL:	6,560	3,651

Table 3-4. Summary of Transients and Transient Vehicles

Subarea	Transients	Transient Vehicles
C1	10	4
C2	151	76
C3	41	15
C4	2	2
C5	0	0
C6	10	4
C7	20	12
C8	500	183
C9	144	71
C10	4	2
C11	0	0
G1	0	0
M1	0	0
M2	5	5
O1	35	32
EPZ TOTAL:	922	406
Shadow Region[4]:	62	31
STUDY AREA TOTAL:	984	437

[4]A lodging facility in Callaway County is located in the Shadow Region. As per the county's request, this facility is included in the study due to the close proximity to the EPZ boundary. Figure 3-6 and Figure 3-7 display the transients and transient vehicles within the EPZ only, therefore, the total numbers shown in these two figures do not align with the study area total numbers in Table 3-4.

Table 3-5. Summary Employees and Employee Vehicles Commuting into the EPZ

Subarea	Employees	Employee Vehicles
C1	331	304
C2	0	0
C3	0	0
C4	0	0
C5	0	0
C6	0	0
C7	0	0
C8	0	0
C9	228	209
C10	0	0
C11	0	0
G1	0	0
M1	0	0
M2	0	0
O1	0	0
EPZ TOTAL:	**559**	**513**

Table 3-6. Medical Facilities Transit Demand

Subarea	Facility Name	Municipality	Capacity
CALLAWAY COUNTY, MO			
C7	Riverview Nursing Center	C7	60
C9	Ashbury Heights Independent Living	C9	12
C9	Bridgeway Assisted Living Care	C9	94
C9	Bristol Manor	C9	12
C9	Churchill Terrace	C9	44
C9	Fulton Manor Care Center	C9	52
C9	Fulton Medical Center	C9	39
C9	Fulton Nursing & Rehab	C9	100
C9	Fulton State Hospital	C9	281
C9	Kingdom Care Senior Living	C9	36
		Callaway County Subtotal:	*730*
		TOTAL:	**730**

Note: According to the Callaway RERP, dated February 2017, all medical facilities and nursing homes located within the 10-mile EPZ will shelter-in-place.

Table 3-7. School Population Demand Estimates

Subarea	School Name	Enrollment	Buses Required
CALLAWAY COUNTY, MO			
C7	South Callaway R-II Middle School	864	6
C7	South Callaway R-II High School		8
C7	South Callaway R-II Elementary School		4
C9	Bush Elementary School	370	6
C9	Missouri School for the Deaf	80	2
C9	Bartley Elementary School	282	5
C9	St Peter's Catholic School	128	2
C9	Fulton Middle School	580	12
C9	Kingdom Christian Academy	174	3
C9	Westminster College	760	1
C9	Rosa Parks Center	8	1
C9	William Woods University	1,737	1
C9	McIntire Elementary School	389	6
C9	Fulton High School	2,129	43
C10	Missouri Girls Town Foundation	50	1
	Callaway County Subtotal:	*7,551*	*101*
OSAGE COUNTY, MO			
O1	Chamois High School	79	2
O1	Osage County Chamois R-1 School District	219	5
	Lake County Subtotal:	*298*	*7*
	EPZ TOTAL:	**7,849**	**108**

Table 3-8. Transit-Dependent Population Estimates

2020 EPZ Population	Survey Average HH Size with Indicated No. of Vehicles			Estimated No. of Households	Survey Percent HH with Indicated No. of Vehicles			Survey Percent HH with Commuters	Survey Percent HH with Non-Returning Commuters	Total People Requiring Transport	Estimated Ridesharing Percentage	People Requiring Public Transit	Percent Population Requiring Public Transit
	0	1	2		0	1	2						
19,558	0.00	1.56	2.64	7,010	0.0%	12.0%	42.8%	70.00%	40.00%	282	87%	37	0.2%

Table 3-9. Access and/or Functional Needs Population Evacuation Time Estimates

Population Group	Population	Vehicles deployed
Ambulatory	16	4 buses
Bedridden	4	2 ambulances
Total:	**20**	**3 vehicles**

Table 3-10. CEC EPZ External Traffic

Upstream Node	Downstream Node	Road Name	Direction	AADT[5]	K-Factor[6]	D-Factor[9]	Hourly Volume	External Traffic
8005	5	I-70	Eastbound	27,758	0.107	0.5	1,485	2,970
8800	800	I-70	Westbound	27,758	0.107	0.5	1,485	2,970
8073	756	US 54	Northbound	11,348	0.116	0.5	329	658
8028	28	US 54	Southbound	11,348	0.116	0.5	329	658
							TOTAL	**7,256**

[5] Highway Performance Monitoring System (HPMS), Federal Highway Administration (FHWA), Washington, D.C., 2011.

[6] HCM 2016

Table 3-11. Summary of Population Demand

Subarea	Residents	Transit-Dependent	Transients	Employees	Special Facilities	Colleges and Universities	Schools	Shadow Population	External Traffic	Total
C1	62	0	10	331	0	0	0	0	0	403
C2	333	0	151	0	0	0	0	0	0	484
C3	455	0	41	0	0	0	0	0	0	496
C4	249	0	2	0	0	0	0	0	0	251
C5	75	0	0	0	0	0	0	0	0	75
C6	496	0	10	0	0	0	0	0	0	506
C7	1,434	3	20	0	60	0	864	0	0	2,381
C8	2,331	32	500	0	0	0	0	0	0	23,866
C9	11,869		144	228	2,125	2,497	4,140	0	0	
C10	454	0	4	0	0	0	50	0	0	508
C11	254	0	0	0	0	0	0	0	0	254
G1	86	0	0	0	0	0	0	0	0	86
M1	171	0	0	0	0	0	0	0	0	171
M2	483	0	5	0	0	0	0	0	0	488
O1	806	2	35	0	0	0	298	0	0	1,141
Shadow Region	0	0	62	0	0	0	0	1,312	0	1,374
TOTAL:	**19,558**	**37**	**984**	**559**	**2,185**	**2,497**	**5,352**	**1,312**	**0**	**32,484**

NOTE: Shadow Population has been reduced to 20%. Refer to Figure 2-1 for additional information.

NOTE: Special Facilities (medical and correctional facilities) are instructed to Shelter-in-Place during an evacuation.

NOTE: There is some inherent double counting in this table (specifically group quarters in the EPZ). This double counting is removed when computing the vehicular demand summarized in Table 3-12 which is what is used in the simulation of ETE.

Table 3-12. Summary of Vehicle Demand

Subarea	Residents	Transit-Dependent	Transients	Employees	Special Facilities	Colleges and Universities	Schools	Shadow Vehicles	External Traffic	Total
C1	36	0	4	304	0	0	0	0	0	334
C2	185	0	76	0	0	0	0	0	0	261
C3	252	0	15	0	0	0	0	0	0	267
C4	142	0	2	0	0	0	0	0	0	144
C5	42	0	0	0	0	0	0	0	0	42
C6	276	0	4	0	0	0	0	0	0	280
C7	781	2	12	0	0	0	36	0	0	831
C8	1,293	4	183	0	0	0	0	0	0	8,874
C9	4,802		71	209	0	2,148	164	0	0	
C10	247	0	2	0	0	0	2	0	0	251
C11	145	0	0	0	0	0	0	0	0	145
G1	48	0	0	0	0	0	0	0	0	48
M1	97	0	0	0	0	0	0	0	0	97
M2	268	0	5	0	0	0	0	0	0	273
O1	449	2	32	0	0	0	14	0	0	497
Shadow Region	0	0	31	0	0	0	0	730	7,256	8,017
TOTAL:	**9,063**	**8**	**437**	**513**	**0**	**2,148**	**216**	**730**	**7,256**	**20,371**

NOTE: Buses (including wheelchair buses) are represented as two passenger vehicles. Refer to Section 8 for additional information.

NOTE: Shadow Population has been reduced to 20%. Refer to Figure 2-1 for additional information.

NOTE: Special Facilities are instructed to Shelter-in-Place during an evacuation.

NOTE: Since the spatial distribution of the access and/or functional needs population is unknown, they are not included in this table.

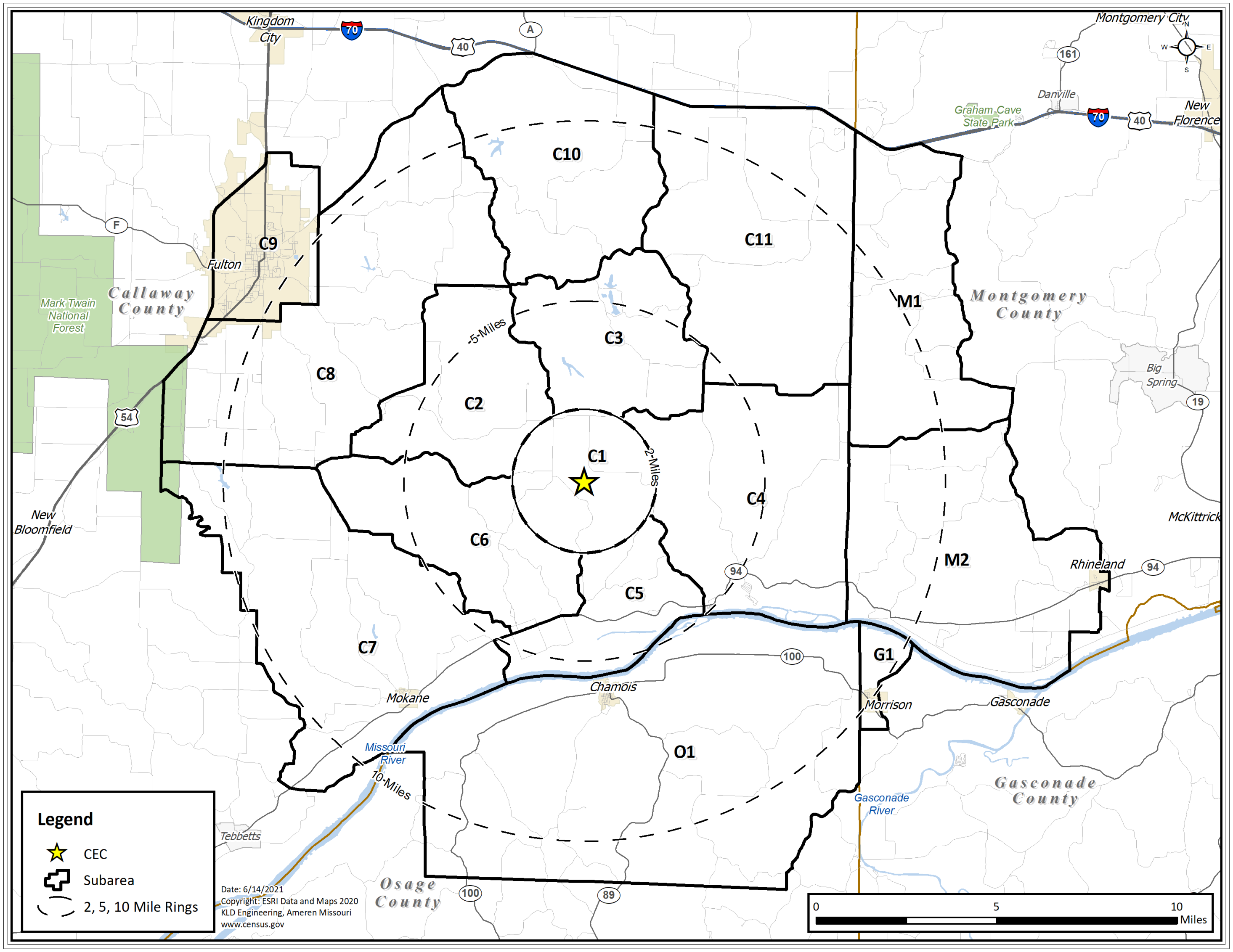
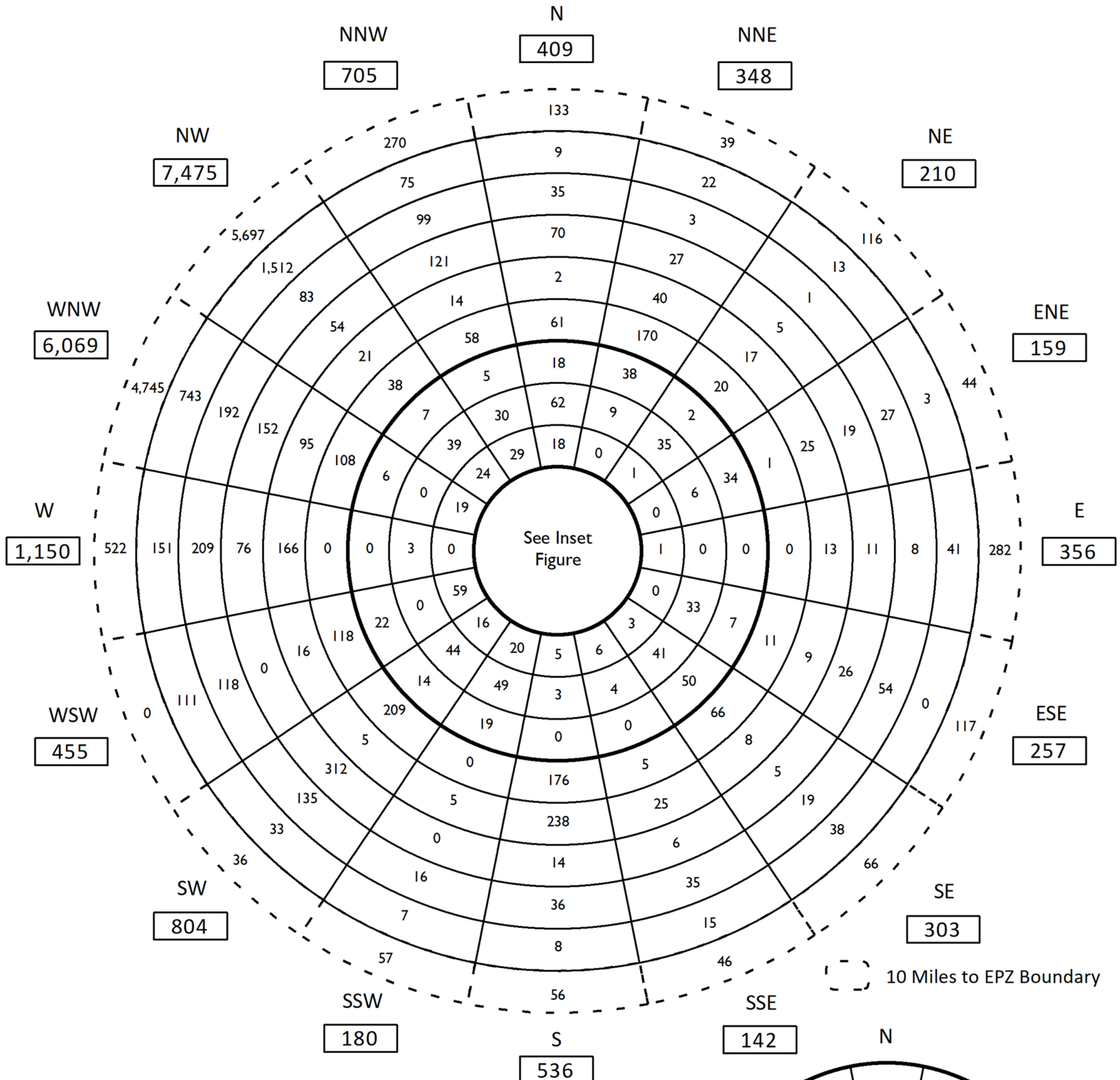


Figure 3-1. Subareas Comprising the CEC EPZ



2020 Permanent Resident Population

Miles	Subtotal by Ring	Cumulative Total
0 - 1	7	7
1 - 2	55	62
2 - 3	201	263
3 - 4	358	621
4 - 5	222	843
5 - 6	1,041	1,884
6 - 7	699	2,583
7 - 8	898	3,481
8 - 9	1,070	4,551
9 - 10	2,781	7,332
10 - EPZ	12,226	19,558
	Total:	19,558

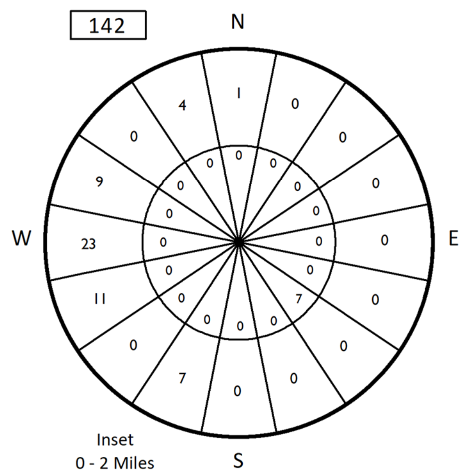
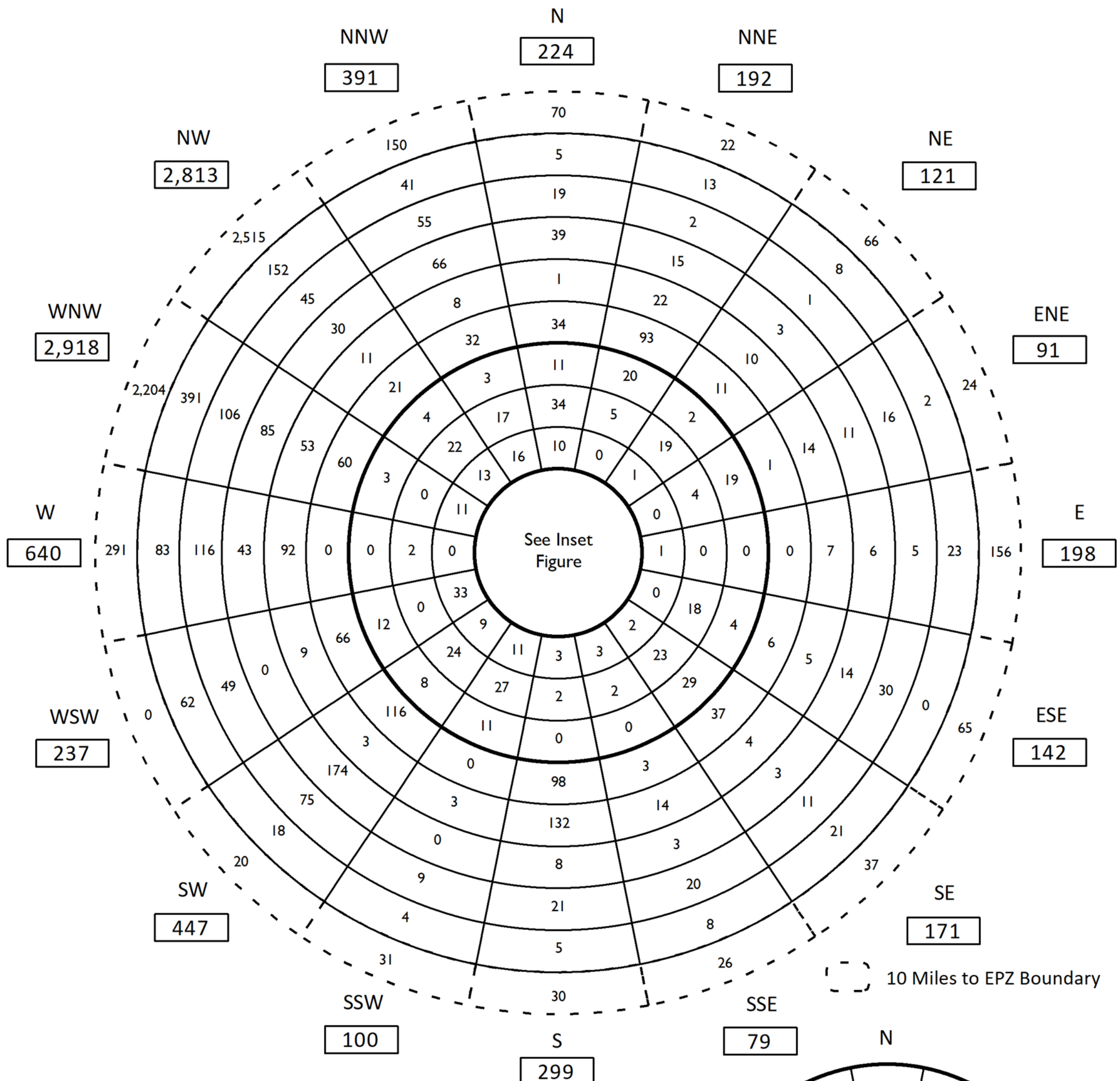


Figure 3-2. Permanent Resident Population by Sector



Resident Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	4	4
1 - 2	32	36
2 - 3	113	149
3 - 4	199	348
4 - 5	126	474
5 - 6	578	1,052
6 - 7	388	1,440
7 - 8	500	1,940
8 - 9	580	2,520
9 - 10	836	3,356
10 - EPZ	5,707	9,063
	Total:	9,063

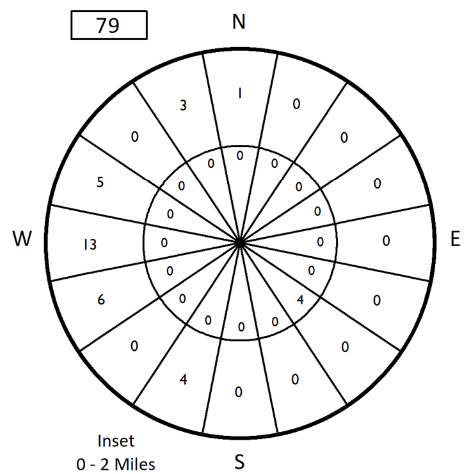
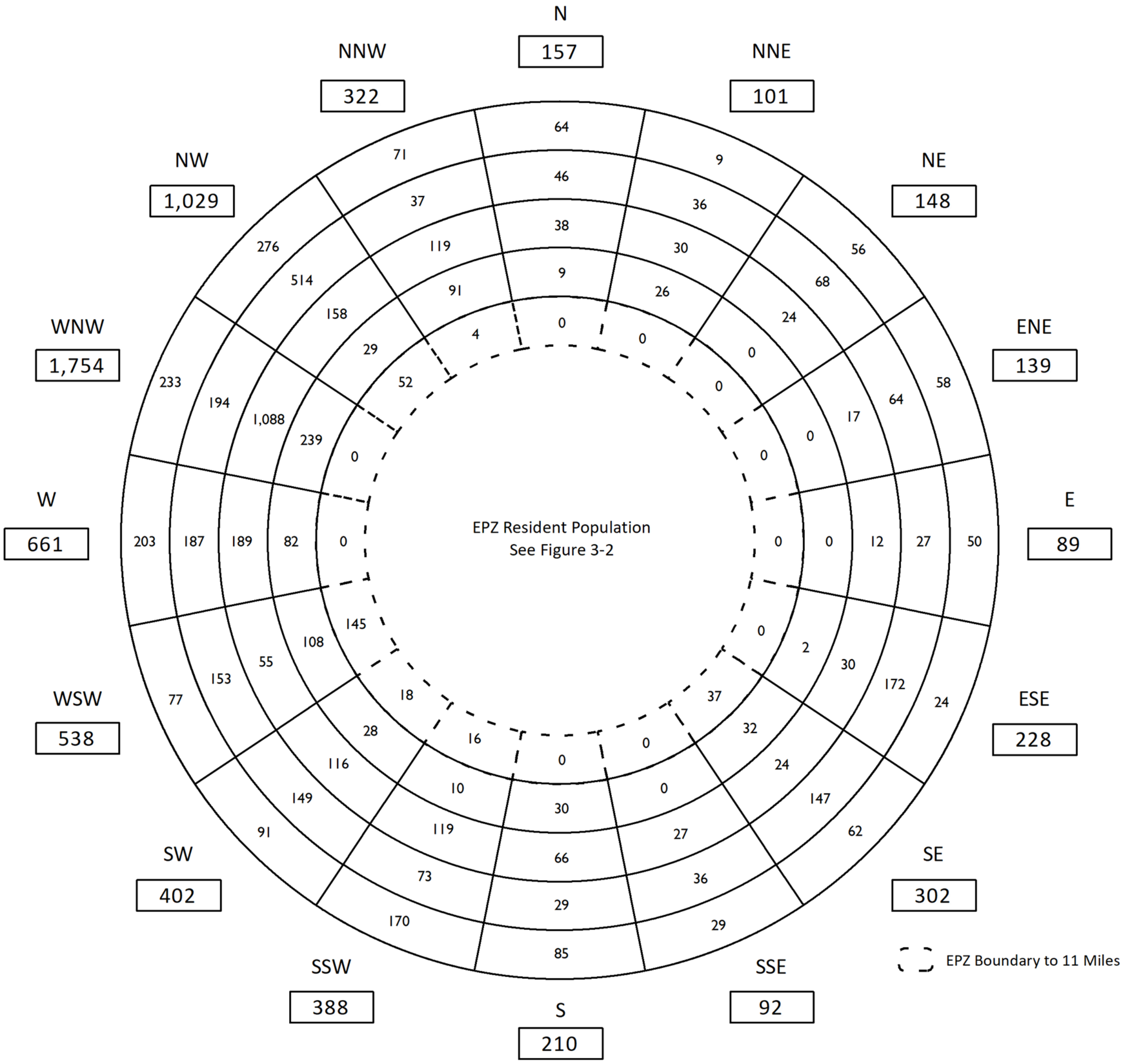


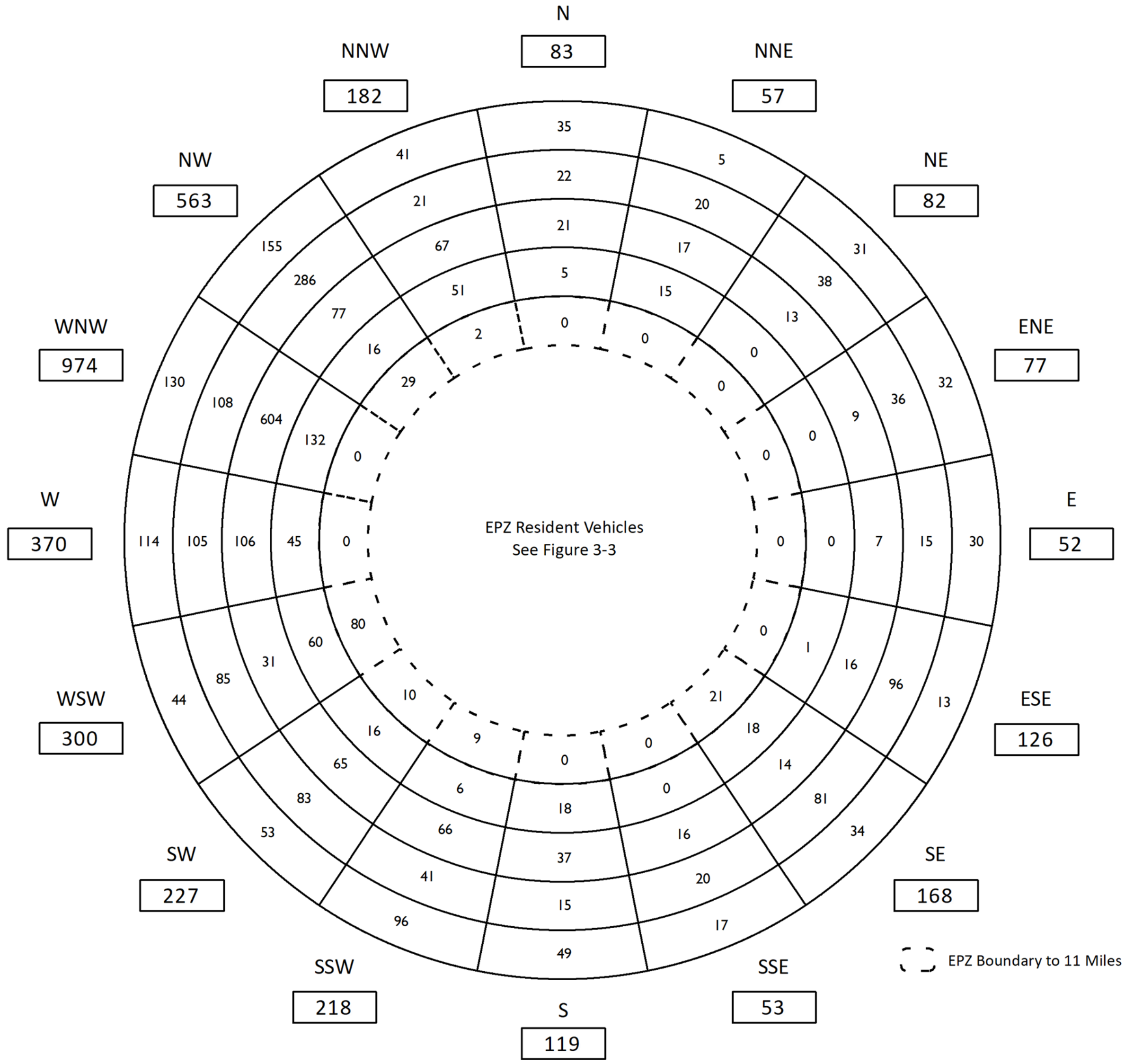
Figure 3-3. Permanent Resident Vehicles by Sector



2020 Shadow Population

Miles	Subtotal by Ring	Cumulative Total
EPZ - 11	272	272
11 - 12	686	958
12 - 13	2,112	3,070
13 - 14	1,932	5,002
14 - 15	1,558	6,560
	Total:	6,560

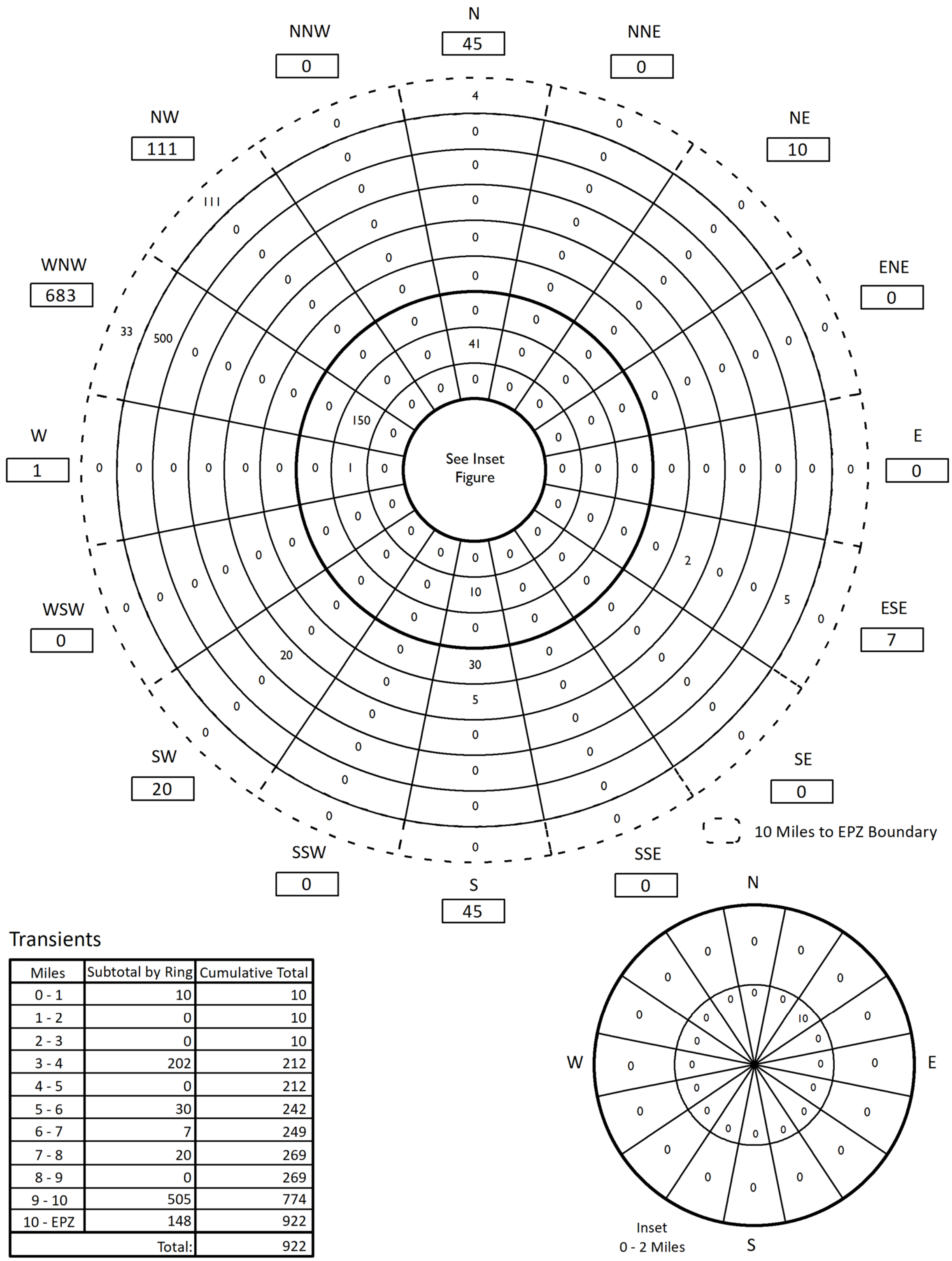
Figure 3-4. Shadow Population by Sector



Shadow Vehicles

Miles	Subtotal by Ring	Cumulative Total
EPZ - 11	151	151
11 - 12	383	534
12 - 13	1,166	1,700
13 - 14	1,072	2,772
14 - 15	879	3,651
	Total:	3,651

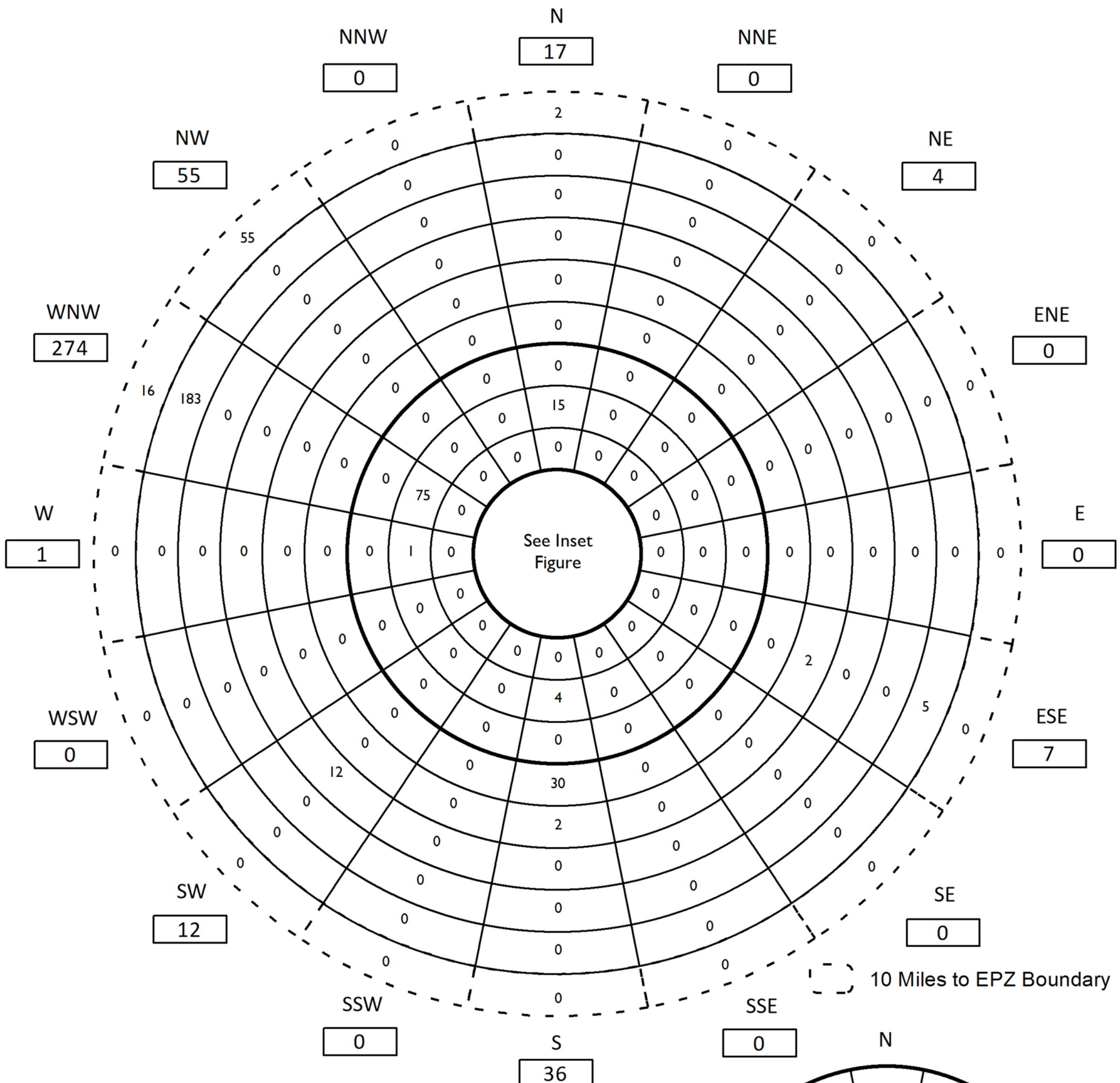
Figure 3-5. Shadow Vehicles by Sector



Transients

Miles	Subtotal by Ring	Cumulative Total
0 - 1	10	10
1 - 2	0	10
2 - 3	0	10
3 - 4	202	212
4 - 5	0	212
5 - 6	30	242
6 - 7	7	249
7 - 8	20	269
8 - 9	0	269
9 - 10	505	774
10 - EPZ	148	922
	Total:	922

Figure 3-6. Transient Population by Sector



Transient Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	4	4
1 - 2	0	4
2 - 3	0	4
3 - 4	95	99
4 - 5	0	99
5 - 6	30	129
6 - 7	4	133
7 - 8	12	145
8 - 9	0	145
9 - 10	188	333
10 - EPZ	73	406
	Total:	406

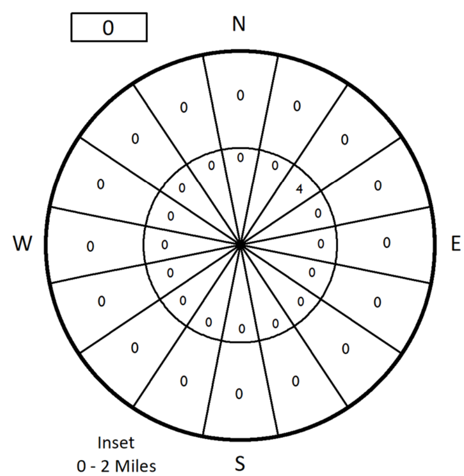
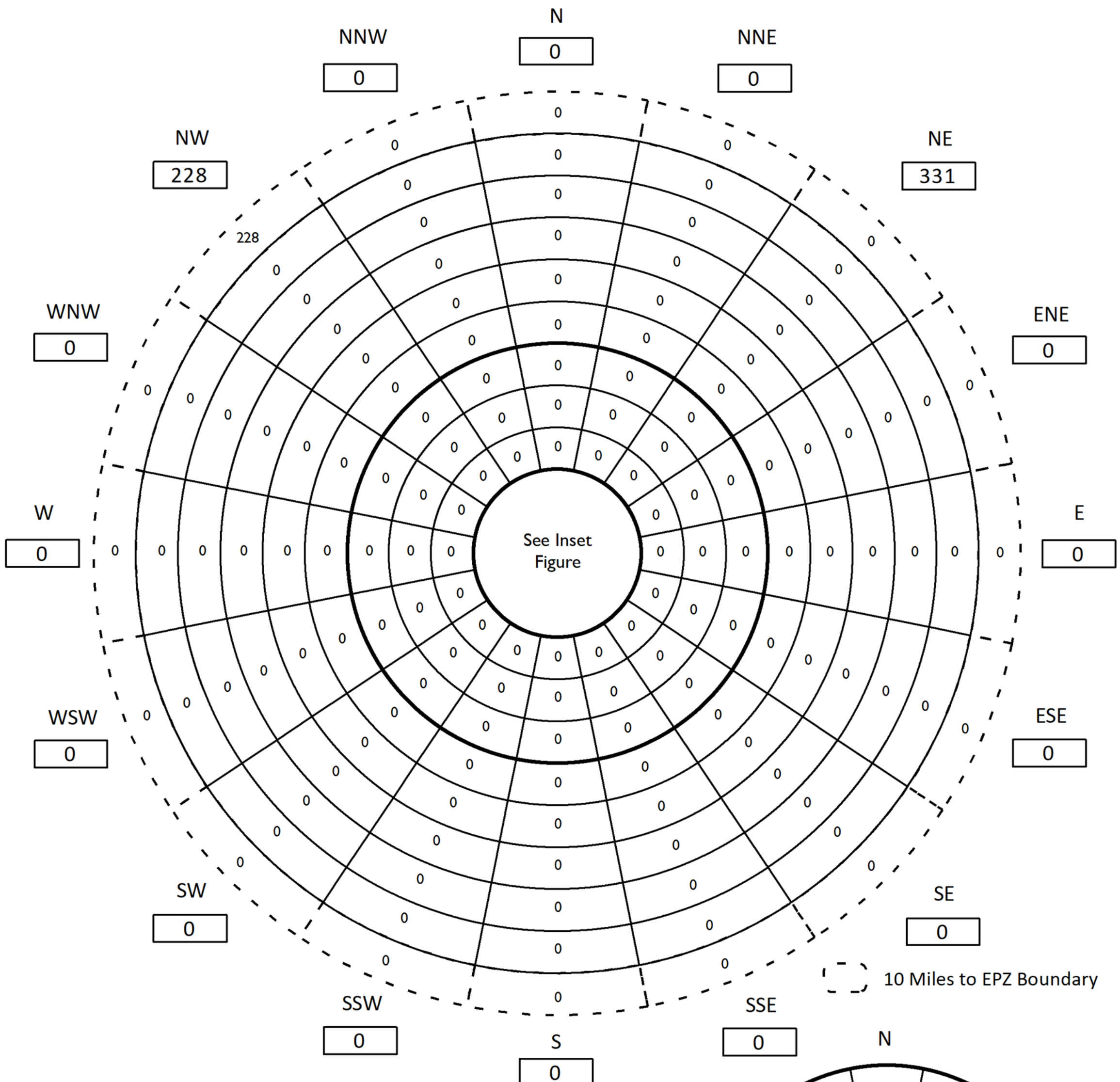


Figure 3-7. Transient Vehicles by Sector



Employees

Miles	Subtotal by Ring	Cumulative Total
0 - 1	331	331
1 - 2	0	331
2 - 3	0	331
3 - 4	0	331
4 - 5	0	331
5 - 6	0	331
6 - 7	0	331
7 - 8	0	331
8 - 9	0	331
9 - 10	0	331
10 - EPZ	228	559
	Total:	559

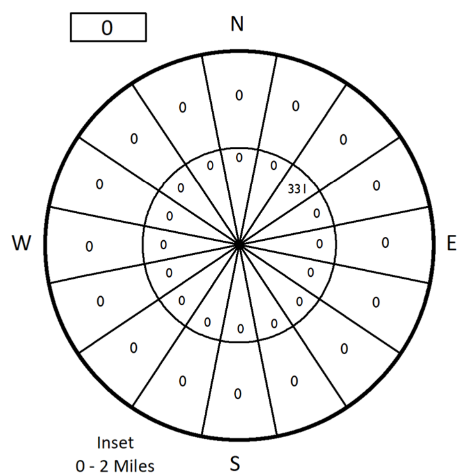
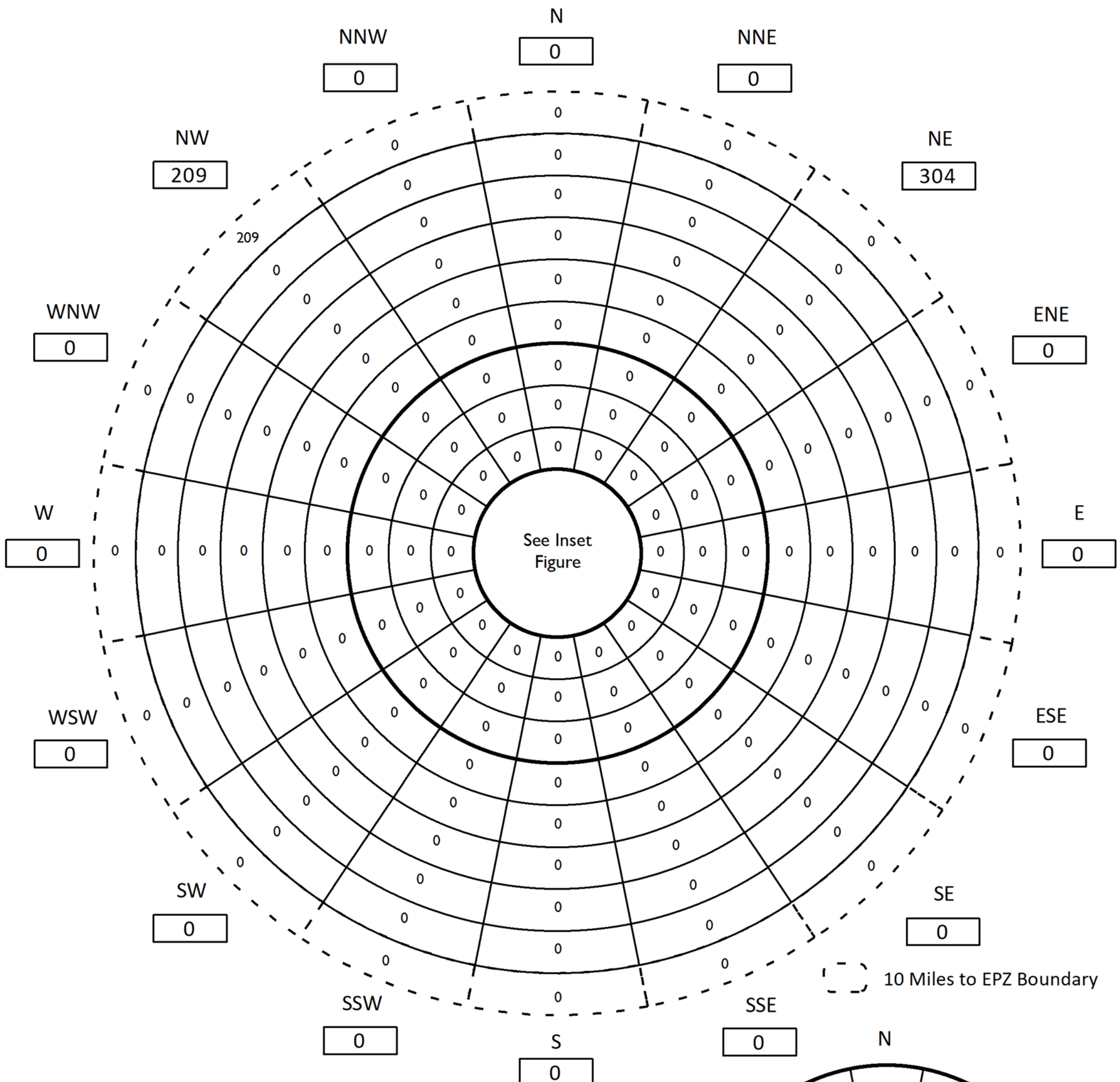


Figure 3-8. Employee Population by Sector



Employee Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	304	304
1 - 2	0	304
2 - 3	0	304
3 - 4	0	304
4 - 5	0	304
5 - 6	0	304
6 - 7	0	304
7 - 8	0	304
8 - 9	0	304
9 - 10	0	304
10 - EPZ	209	513
	Total:	513

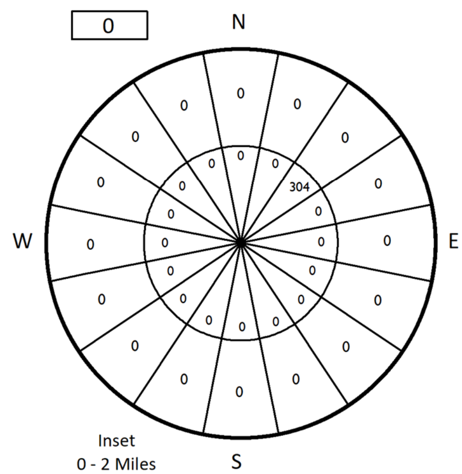


Figure 3-9. Employee Vehicles by Sector

4 ESTIMATION OF HIGHWAY CAPACITY

The ability of the road network to service vehicle demand is a major factor in determining how rapidly an evacuation can be completed. The capacity of a road is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane of roadway during a given time period under prevailing roadway, traffic and control conditions, as stated in the 2016 Highway Capacity Manual (HCM 2016).

In discussing capacity, different operating conditions have been assigned alphabetical designations, A through F, to reflect the range of traffic operational characteristics. These designations have been termed "Level of Service" (LOS). For example, LOS A connotes free-flow and high-speed operating conditions; LOS F represents a forced flow condition. LOS E describes traffic operating at or near capacity.

Another concept, closely associated with capacity, is “Service Volume”. Service volume (SV) is defined as “The maximum hourly rate at which vehicles, bicycles or persons reasonably can be expected to traverse a point or uniform section of a roadway during an hour under specific assumed conditions while maintaining a designated level of service.” This definition is similar to that for capacity. The major distinction is that values of SV vary from one LOS to another, while capacity is the SV at the upper bound of LOS E, only.

Thus, in simple terms, an SV is the maximum traffic that can travel on a road and still maintain a certain perceived level of quality to a driver based on the A, B, C, rating system (LOS). Any additional vehicles above the service SV would drop the rating to a lower letter grade.

This distinction is illustrated in Exhibit 12-7 of the HCM 2016. As indicated there, the SV varies with Free Flow Speed (FFS), and LOS. The SV is calculated by the DYNEV II simulation model, based on the specified link attributes, FFS, capacity, control device and traffic demand.

Other factors also influence capacity. These include, but are not limited to:

- Lane width
- Shoulder width
- Pavement condition
- Horizontal and vertical alignment (curvature and grade)
- Percent truck traffic
- Control device (and timing, if it is a signal)
- Weather conditions (rain, snow, fog, wind speed, ice)

These factors are considered during the road survey and in the capacity estimation process; some factors have greater influence on capacity than others. For example, lane and shoulder width have only a limited influence on Base Free Flow Speed (BFFS[1]) according to Exhibit 15-7 of the HCM 2016. Consequently, lane and shoulder widths at the narrowest points were observed during the road survey and these observations were recorded, but no detailed measurements of lane or shoulder width were taken. Horizontal and vertical alignment can

[1] A very rough estimate of BFFS might be taken as the posted speed limit plus 10 mph (HCM 2016 Page 15-15).

influence both FFS and capacity. The estimated FFS were measured using the survey vehicle's speedometer and observing local traffic, under free flow conditions. Capacity is estimated from the procedures of the HCM 2016. For example, HCM 2016 Exhibit 7-1(b) shows the sensitivity of SV at the upper bound of LOS D to grade (capacity is the SV at the upper bound of LOS E).

As discussed in Section 2.6 it is necessary to adjust capacity figures to represent the prevailing conditions during inclement weather. Based on limited empirical data, weather conditions such as rain reduce the values of free-flow speed and of highway capacity by approximately 10 percent. Over the last decade new studies have been made on the effects of rain on traffic capacity. These studies indicate a range of effects between 5 and 20 percent depending on wind speed and precipitation rates. As indicated in Section 2.6, we employ a reduction in free-flow speed and in highway capacity of a 10 percent for rain/light snow and a free-flow speed and capacity reduction of 15 percent and 25 percent, respectively, for heavy snow.

Since congestion arising from evacuation may be significant, estimates of roadway capacity must be determined with great care. Because of its importance, a brief discussion of the major factors that influence highway capacity is presented in this section.

Rural highways generally consist of: (1) one or more uniform sections with limited access (driveways, parking areas) characterized by "uninterrupted" flow; and (2) approaches to at-grade intersections where flow can be "interrupted" by a control device or by turning or crossing traffic at the intersection. Due to these differences, separate estimates of capacity must be made for each section. Often, the approach to the intersection is widened by the addition of one or more lanes (turn pockets or turn bays), to compensate for the lower capacity of the approach due to the factors there that can interrupt the flow of traffic. These additional lanes are recorded during the field survey and later entered as input to the DYNEV II system.

4.1 Capacity Estimations on Approaches to Intersections

At-grade intersections are apt to become the first bottleneck locations under local heavy traffic volume conditions. This characteristic reflects the need to allocate access time to the respective competing traffic streams by exerting some form of control. During evacuation, control at critical intersections will often be provided by traffic control personnel assigned for that purpose, whose directions may supersede traffic control devices. See Appendix G for more information.

The per-lane capacity of an approach to a signalized intersection can be expressed (simplistically) in the following form:

$$Q_{cap,m} = \left(\frac{3600}{h_m}\right) \times \left(\frac{G-L}{C}\right)_m = \left(\frac{3600}{h_m}\right) \times P_m$$

where:

$Q_{cap,m}$ = Capacity of a single lane of traffic on an approach, which executes movement, *m*, upon entering the intersection; vehicles per hour (vph)

h_m	=	Mean queue discharge headway of vehicles on this lane that are executing movement, *m*; seconds per vehicle
G	=	Mean duration of GREEN time servicing vehicles that are executing movement, *m*, for each signal cycle; seconds
L	=	Mean "lost time" for each signal phase servicing movement, *m*; seconds
C	=	Duration of each signal cycle; seconds
P_m	=	Proportion of GREEN time allocated for vehicles executing movement, *m*, from this lane. This value is specified as part of the control treatment.
m	=	The movement executed by vehicles after they enter the intersection: through, left-turn, right-turn, and diagonal.

The turn-movement-specific mean discharge headway h_m, depends in a complex way upon many factors: roadway geometrics, turn percentages, the extent of conflicting traffic streams, the control treatment, and others. A primary factor is the value of "saturation queue discharge headway", h_{sat}, which applies to through vehicles that are not impeded by other conflicting traffic streams. This value, itself, depends upon many factors including motorist behavior. Formally, we can write,

$$h_m = f_m(h_{sat}, F_1, F_2, \ldots)$$

where:

h_{sat}	=	Saturation discharge headway for through vehicles; seconds per vehicle
F_1, F_2	=	The various known factors influencing h_m
$f_m(\ )$	=	Complex function relating h_m to the known (or estimated) values of h_{sat}, F_1, F_2, …

The estimation of h_m for specified values of h_{sat}, F_1, F_2, ... is undertaken within the DYNEV II simulation model by a mathematical model[2]. The resulting values for h_m always satisfy the condition:

$$h_m \geq h_{sat}$$

That is, the turn-movement-specific discharge headways are always greater than, or equal to the saturation discharge headway for through vehicles. These headways (or its inverse equivalent, “saturation flow rate”), may be determined by observation or using the procedures of the HCM 2016.

The above discussion is necessarily brief given the scope of this ETE report and the complexity of the subject of intersection capacity. In fact, Chapters 19, 20 and 21 in the HCM 2016 address

[2] Lieberman, E., "Determining Lateral Deployment of Traffic on an Approach to an Intersection", McShane, W. & Lieberman, E., "Service Rates of Mixed Traffic on the far Left Lane of an Approach". Both papers appear in Transportation Research Record 772, 1980. Lieberman, E., Xin, W., “Macroscopic Traffic Modeling for Large-Scale Evacuation Planning”, presented at the TRB 2012 Annual Meeting, January 22-26, 2012

this topic. The factors, F_1, F_2, …, influencing saturation flow rate are identified in equation (19-8) of the HCM 2016.

The traffic signals within the EPZ and Shadow Region are modeled using representative phasing plans and phase durations obtained as part of the field data collection. Traffic responsive signal installations allow the proportion of green time allocated (P_m) for each approach to each intersection to be determined by the expected traffic volumes on each approach during evacuation circumstances. The amount of green time (G) allocated is subject to maximum and minimum phase duration constraints; 2 seconds of yellow time are indicated for each signal phase and 1 second of all-red time is assigned between signal phases, typically. If a signal is pre-timed, the yellow and all-red times observed during the road survey are used. A lost time (L) of 2.0 seconds is used for each signal phase in the analysis.

4.2 Capacity Estimation along Sections of Highway

The capacity of highway sections -- as distinct from approaches to intersections -- is a function of roadway geometrics, traffic composition (e.g. percent heavy trucks and buses in the traffic stream) and, of course, motorist behavior. There is a fundamental relationship which relates SV (i.e. the number of vehicles serviced within a uniform highway section in a given time period) to traffic density. The top curve in Figure 4-1 illustrates this relationship.

As indicated, there are two flow regimes: (1) Free Flow (left side of curve); and (2) Forced Flow (right side). In the Free Flow regime, the traffic demand is fully serviced; the SV increases as demand volume and density increase, until the SV attains its maximum value, which is the capacity of the highway section. As traffic demand and the resulting highway density increase beyond this "critical" value, the rate at which traffic can be serviced (i.e. the SV) can actually decline below capacity ("capacity drop"). Therefore, in order to realistically represent traffic performance during congested conditions (i.e. when demand exceeds capacity), it is necessary to estimate the SV, V_F, under congested conditions.

The value of V_F can be expressed as:

$$V_F = R \times Capacity$$

where:

R = Reduction factor which is less than unity

We have employed a value of R=0.90. The advisability of such a capacity reduction factor is based upon empirical studies that identified a fall-off in the service flow rate when congestion occurs at "bottlenecks" or "choke points" on a freeway system. Zhang and Levinson[3] describe a research program that collected data from a computer-based surveillance system (loop detectors) installed on the Interstate Highway System, at 27 active bottlenecks in the twin cities metro area in Minnesota over a 7-week period. When flow breakdown occurs, queues are formed which discharge at lower flow rates than the maximum capacity prior to observed

[3]Lei Zhang and David Levinson, "Some Properties of Flows at Freeway Bottlenecks," Transportation Research Record 1883, 2004.

breakdown. These queue discharge flow (QDF) rates vary from one location to the next and also vary by day of week and time of day based upon local circumstances. The cited reference presents a mean QDF of 2,016 passenger cars per hour per lane (pcphpl). This figure compares with the nominal capacity estimate of 2,250 pcphpl estimated for the ETE and indicated in Appendix K for freeway links. The ratio of these two numbers is 0.896 which translates into a capacity reduction factor of 0.90.

Since the principal objective of evacuation time estimate analyses is to develop a “realistic” estimate of evacuation times, use of the representative value for this capacity reduction factor (R=0.90) is justified. This factor is applied only when flow breaks down, as determined by the simulation model.

Rural roads, like freeways, are classified as “uninterrupted flow” facilities. (This is in contrast with urban street systems which have closely spaced signalized intersections and are classified as “interrupted flow” facilities.) As such, traffic flow along rural roads is subject to the same effects as freeways in the event traffic demand exceeds the nominal capacity, resulting in queuing and lower QDF rates. As a practical matter, rural roads rarely break down at locations away from intersections. Any breakdowns on rural roads are generally experienced at intersections where other model logic applies, or at lane drops which reduce capacity there. Therefore, the application of a factor of 0.90 is appropriate on rural roads, but rarely, if ever, activated.

The estimated value of capacity is based primarily upon the type of facility and on roadway geometrics. Sections of roadway with adverse geometrics are characterized by lower free-flow speeds and lane capacity. Exhibit 15-46 in the HCM 2016 was referenced to estimate saturation flow rates. The impact of narrow lanes and shoulders on free-flow speed and on capacity is not material, particularly when flow is predominantly in one direction as is the case during an evacuation.

The procedure used here was to estimate "section" capacity, V_E, based on observations made traveling over each section of the evacuation network, based on the posted speed limits and travel behavior of other motorists and by reference to the HCM 2016. The DYNEV II simulation model determines for each highway section, represented as a network link, whether its capacity would be limited by the "section-specific" SV, V_E, or by the intersection-specific capacity. For each link, the model selects the lower value of capacity.

4.3 Application to the Callaway Energy Center Study Area

As part of the development of the link-node analysis network for the study area, an estimate of roadway capacity is required. The source material for the capacity estimates presented herein is contained in:

2016 Highway Capacity Manual (HCM 2016)
Transportation Research Board
National Research Council
Washington, D.C.

The highway system in the study area consists primarily of three categories of roads and, of course, intersections:

- Two-Lane roads: Local, State
- Multilane Highways (at-grade)
- Freeways

Each of these classifications will be discussed below.

4.3.1 Two-Lane Roads

Ref: HCM 2016 Chapter 15

Two lane roads comprise the majority of highways within the EPZ. The per-lane capacity of a two-lane highway is estimated at 1,700 passenger cars per hour (pc/h). This estimate is essentially independent of the directional distribution of traffic volume except that, for extended distances, the two-way capacity will not exceed 3,200 pc/h. The HCM 2016 procedures then estimate LOS and Average Travel Speed. The DYNEV II simulation model accepts the specified value of capacity as input and computes average speed based on the time-varying demand: capacity relations.

Based on the field survey and on expected traffic operations associated with evacuation scenarios:

- Most sections of two-lane roads within the EPZ are classified as “Class I”, with "level terrain"; some are “rolling terrain”.
- “Class II” highways are mostly those within urban and suburban centers.

4.3.2 Multilane Highway

Ref: HCM 2016 Chapter 12

Exhibit 12-8 of the HCM 2016 presents a set of curves that indicate a per-lane capacity ranging from approximately 1,900 to 2,200 pc/h, for free-speeds of 45 to 60 mph, respectively. Based on observation, the multilane highways outside of urban areas within the EPZ, service traffic with free-speeds in this range. The actual time-varying speeds computed by the simulation model reflect the demand: capacity relationship and the impact of control at intersections. A conservative estimate of per-lane capacity of 1,900 pc/h is adopted for this study for multilane highways outside of urban areas, as shown in Appendix K.

4.3.3 Freeways

Ref: HCM 2016 Chapters 10, 12, 13, 14

Chapter 10 of the HCM 2016 describes a procedure for integrating the results obtained in Chapters 12, 13 and 14, which compute capacity and LOS for freeway components. Chapter 10

also presents a discussion of simulation models. The DYNEV II simulation model automatically performs this integration process.

Chapter 12 of the HCM 2016 presents procedures for estimating capacity and LOS for “Basic Freeway Segments". Exhibit 12-37 of the HCM 2016 presents capacity vs. free speed estimates, which are provided below.

Free Speed (mph):	55	60	65	70+
Per-Lane Capacity (pc/h):	2,250	2,300	2,350	2,400

The inputs to the simulation model are highway geometrics, free-speeds and capacity based on field observations. The simulation logic calculates actual time-varying speeds based on demand: capacity relationships. A conservative estimate of per-lane capacity of 2,250 pc/h is adopted for this study for freeways, as shown in Appendix K.

Chapter 13 of the HCM 2016 presents procedures for estimating capacity, speed, density and LOS for freeway weaving sections. The simulation model contains logic that relates speed to demand volume: capacity ratio. The value of capacity obtained from the computational procedures detailed in Chapter 12 depends on the "Type" and geometrics of the weaving segment and on the "Volume Ratio" (ratio of weaving volume to total volume).

Chapter 14 of the HCM 2016 presents procedures for estimating capacities of ramps and of "merge" areas. There are three significant factors to the determination of capacity of a ramp-freeway junction: The capacity of the freeway immediately downstream of an on-ramp or immediately upstream of an off-ramp; the capacity of the ramp roadway; and the maximum flow rate entering the ramp influence area. In most cases, the freeway capacity is the controlling factor. Values of this merge area capacity are presented in Exhibit 14-10 of the HCM 2016 and depend on the number of freeway lanes and on the freeway free speed. Ramp capacity is presented in Exhibit 14-12 and is a function of the ramp’s FFS. The DYNEV II simulation model logic simulates the merging operations of the ramp and freeway traffic in accord with the procedures in Chapter 14 of the HCM 2016. If congestion results from an excess of demand relative to capacity, then the model allocates service appropriately to the two entering traffic streams and produces LOS F conditions (The HCM 2016 does not address LOS F explicitly).

4.3.4 Intersections

Ref: HCM 2016 Chapters 19, 20, 21, 22

Procedures for estimating capacity and LOS for approaches to intersections are presented in Chapter 19 (signalized intersections), Chapters 20, 21 (un-signalized intersections) and Chapter 22 (roundabouts). The complexity of these computations is indicated by the aggregate length of these chapters. The DYNEV II simulation logic is likewise complex.

The simulation model explicitly models intersections: Stop/yield controlled intersections (both 2-way and all-way) and traffic signal controlled intersections. Where intersections are controlled by fixed time controllers, traffic signal timings are set to reflect average (non-evacuation) traffic conditions. Actuated traffic signal settings respond to the time-varying demands of evacuation traffic to adjust the relative capacities of the competing intersection approaches.

The model is also capable of modeling the presence of manned traffic control. At specific locations where it is advisable or where existing plans call for overriding existing traffic control to implement manned control, the model will use actuated signal timings that reflect the presence of traffic guides. At locations where a special traffic control strategy (continuous left-turns, contra-flow lanes) is used, the strategy is modeled explicitly. A list that includes the total number of intersections modeled that are unsignalized, signalized, or manned by response personnel is noted in Appendix K.

4.4 Simulation and Capacity Estimation

Chapter 6 of the HCM 2016 is entitled, "HCM and Alternative Analysis Tools." The chapter discusses the use of alternative tools such as simulation modeling to evaluate the operational performance of highway networks. Among the reasons cited in Chapter 6 to consider using simulation as an alternative analysis tool is:

> *"The system under study involves a group of different facilities or travel modes with mutual interactions invoking several HCM chapters. Alternative tools are able to analyze these facilities as a single system."*

This statement succinctly describes the analyses required to determine traffic operations across an area encompassing an EPZ operating under evacuation conditions. The model utilized for this study, DYNEV II, is further described in Appendix C. It is essential to recognize that simulation models do not replicate the methodology and procedures of the HCM 2016 – they replace these procedures by describing the complex interactions of traffic flow and computing Measures of Effectiveness (MOE) detailing the operational performance of traffic over time and by location. The DYNEV II simulation model includes some HCM 2016 procedures only for the purpose of estimating capacity.

All simulation models must be calibrated properly with field observations that quantify the performance parameters applicable to the analysis network. Two of the most important of these are: (1) FFS; and (2) saturation headway, h_{sat}. The first of these is estimated by direct observation during the road survey; the second is estimated using the concepts of the HCM 2016, as described earlier.

4.5 Boundary Conditions

As illustrated in Figure 1-2 and in Appendix K, the link-node analysis network used for this study is finite. The analysis network extends well beyond the 15-mile radial study area in some locations in order to model intersections with other major evacuation routes beyond the study area. However, the network does have an end at the destination (exit) nodes as discussed in Appendix C. Beyond these destination nodes, there may be signalized intersections or merge points that impact the capacity of the evacuation routes leaving the study area. As there are no signalized intersections leaving the study area, this study did not assume a reduction in capacity on two-lane roads (Section 4.3.1 above) and multilane highways (Section 4.3.2 above). There is also no reduction in capacity for freeways due to boundary conditions.

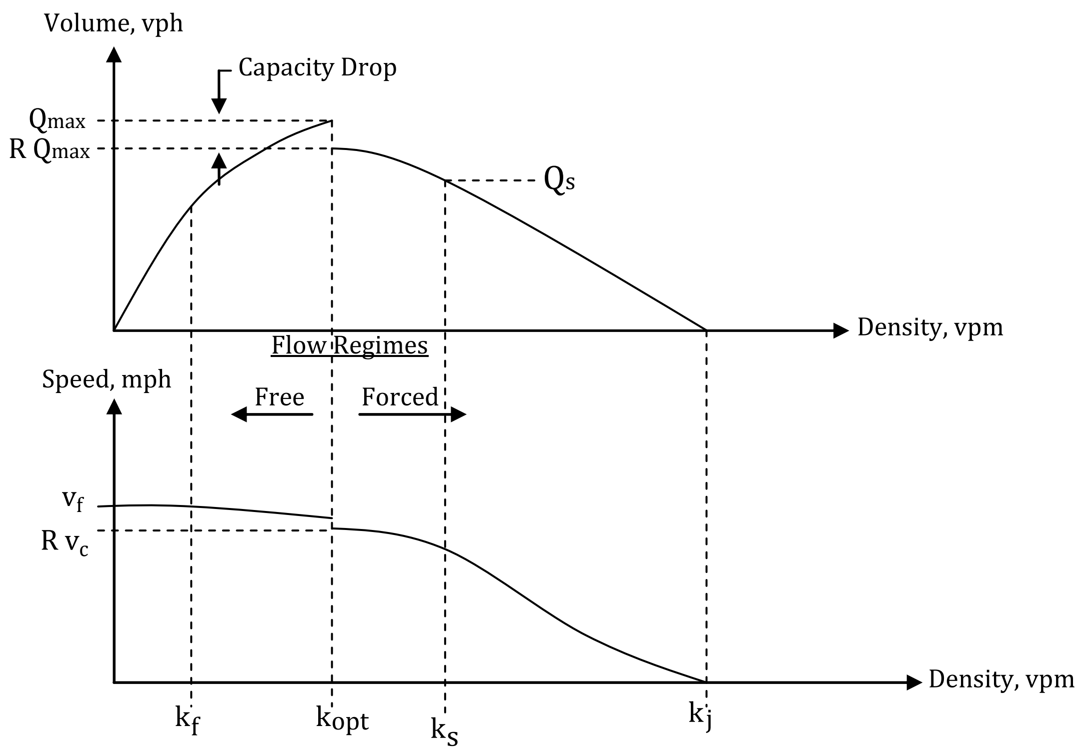


Figure 4-1. Fundamental Diagrams

5 ESTIMATION OF TRIP GENERATION TIME

Federal guidance (see NUREG CR-7002, Rev. 1) recommends that the Evacuation Time Estimate (ETE) study estimate the distributions of elapsed times associated with mobilization activities undertaken by the public to prepare for the evacuation trip. The elapsed time associated with each activity is represented as a statistical distribution reflecting differences between members of the public. The quantification of these activity-based distributions relies largely on the results of the demographic survey. We define the sum of these distributions of elapsed times as the Trip Generation Time Distribution.

5.1 Background

In general, an accident at a nuclear power plant is characterized by the following Emergency Classification Levels (see Section C of Part IV of Appendix E of 10 CFR 50 for details):

1. Unusual Event
2. Alert
3. Site Area Emergency
4. General Emergency

At each level, the Federal guidelines specify a set of Actions to be undertaken by the licensee, and by the state and local offsite agencies. As a Planning Basis, we will adopt a conservative posture, in accordance with Section 1.2 of NUREG/CR-7002, Rev. 1, that a rapidly escalating accident at the plant wherein evacuation is ordered promptly, and no early protective actions have been implemented will be considered in calculating the Trip Generation time. We will assume:

1. The Advisory to Evacuate (ATE) will be announced coincident with the siren notification.
2. Mobilization of the general population will commence within 10 minutes after the siren notification.
3. ETE are measured relative to the ATE.

We emphasize that the adoption of this planning basis is not a representation that these events will occur within the indicated time frame. Rather, these assumptions are necessary in order to:

1. Establish a temporal framework for estimating the Trip Generation distribution in the format recommended in Section 2.13 of NUREG/CR-6863.
2. Identify temporal points of reference that uniquely define "Clear Time" and ETE.

It is likely that a longer time will elapse between the various classes of an emergency.

For example, suppose one hour elapses from the siren alert to the ATE. In this case, it is reasonable to expect some degree of spontaneous evacuation by the public during this one-hour period. As a result, the population within the Emergency Planning Zone (EPZ) will be lower when the ATE is announced, than at the time of the siren alert. In addition, many will engage in preparation activities to evacuate, in anticipation that an Advisory will be broadcasted. Thus, the time needed to complete the mobilization activities and the number of people remaining to evacuate the EPZ after the ATE, will both be somewhat less than the estimates presented in this

report. Consequently, the ETE presented in this report are higher than the actual evacuation time, if this hypothetical situation were to take place.

The notification process consists of two events:

1. Transmitting information using the alert and notification systems (ANS) available within the EPZ (e.g. sirens, tone alerts, EAS broadcasts, loudspeakers and REVERSE911).
2. Receiving and correctly interpreting the information that is transmitted.

The population within the EPZ is dispersed over an area of approximately 420 square miles and is engaged in a wide variety of activities. It must be anticipated that some time will elapse between the transmission and receipt of the information advising the public of an accident.

The amount of elapsed time will vary from one individual to the next depending on where that person is, what that person is doing, and related factors. Furthermore, some persons who will be directly involved with the evacuation process may be outside the EPZ at the time the emergency is declared. These people may be commuters, shoppers and other travelers who reside within the EPZ and who will return to join the other household members upon receiving notification of an emergency.

As indicated in Section 2.13 of NUREG/CR-6863, the estimated elapsed times for the receipt of notification can be expressed as a distribution reflecting the different notification times for different people within, and outside, the EPZ. By using time distributions, it is also possible to distinguish between different population groups and different day-of-week and time-of-day scenarios, so that accurate ETE may be computed.

For example, people at home or at work within the EPZ will be notified by siren, and/or tone alert and/or radio (if available). Those well outside the EPZ will be notified by telephone, radio, TV and word-of-mouth, with potentially longer time lags. Furthermore, the spatial distribution of the EPZ population will differ with time of day - families will be united in the evenings but dispersed during the day. In this respect, weekends will differ from weekdays.

As indicated in Section 4.1 of NUREG/CR-7002, Rev. 1, the information required to compute trip generation times is typically obtained from a demographic survey of EPZ residents. Such a survey was conducted in support of this ETE study for this site. Appendix F discusses the survey sampling plan, number of completed surveys obtained, documents the survey instrument utilized, and provides the survey results. It is important to note that the shape and duration of the evacuation trip mobilization distribution is important at sites where traffic congestion is not expected to cause the evacuation time estimate to extend in time well beyond the trip generation period. The remaining discussion will focus on the application of the trip generation data obtained from the demographic survey to the development of the ETE documented in this report.

5.2 Fundamental Considerations

The environment leading up to the time that people begin their evacuation trips consists of a sequence of events and activities. Each event (other than the first) occurs at an instant in time and is the outcome of an activity.

Activities are undertaken over a period of time. Activities may be in "series" (i.e. to undertake an activity implies the completion of all preceding events) or may be in parallel (two or more activities may take place over the same period of time). Activities conducted in series are functionally dependent on the completion of prior activities; activities conducted in parallel are functionally independent of one another. The relevant events associated with the public's preparation for evacuation are:

Event Number	Event Description
1	Notification
2	Awareness of Situation
3	Depart Work
4	Arrive Home
5	Depart on Evacuation Trip

Associated with each sequence of events are one or more activities, as outlined in Table 5-1:

These relationships are shown graphically in Figure 5-1.

- An Event is a ‘state’ that exists at a point in time (e.g., depart work, arrive home)
- An Activity is a ‘process’ that takes place over some elapsed time (e.g., prepare to leave work, travel home)

As such, a completed Activity changes the ‘state’ of an individual (e.g. the activity, ‘travel home’ changes the state from ‘depart work’ to ‘arrive home’). Therefore, an Activity can be described as an ‘Event Sequence’; the elapsed times to perform an event sequence vary from one person to the next and are described as statistical distributions on the following pages.

An employee who lives outside the EPZ will follow sequence (c) of Figure 5-1. A household within the EPZ that has one or more commuters at work and will await their return before beginning the evacuation trip will follow the first sequence of Figure 5-1(a). A household within the EPZ that has no commuters at work, or that will not await the return of any commuters, will follow the second sequence of Figure 5-1(a), regardless of day of week or time of day.

Households with no commuters on weekends or in the evening/night-time, will follow the applicable sequence in Figure 5-1(b). Transients will always follow one of the sequences of Figure 5-1(b). Some transients away from their residence could elect to evacuate immediately without returning to the residence, as indicated in the second sequence.

It is seen from Figure 5-1, that the Trip Generation time (the total elapsed time from Event 1 to Event 5) depends on the scenario and will vary from one household to the next. Furthermore, Event 5 depends, in a complicated way, on the time distributions of all activities preceding that event. That is, to estimate the time distribution of Event 5, we must obtain estimates of the time distributions of all preceding events. For this study, we adopt the conservative posture that all activities will occur in sequence.

In some cases, assuming certain events occur strictly sequential (for instance, commuter returning home before beginning preparation to leave, or removing snow only after the preparation to leave) can result in rather *conservative* (that is, longer) estimates of mobilization times. It is reasonable to expect that at least some parts of these events will overlap for many households, but that assumption is not made in this study.

5.3 Estimated Time Distributions of Activities Preceding Event 5

The time distribution of an event is obtained by "summing" the time distributions of all prior contributing activities. (This "summing" process is quite different than an algebraic sum since it is performed on distributions – not scalar numbers).

Time Distribution No. 1, Notification Process: Activity 1 → 2

Federal regulations (10CFR50 Appendix E, Item IV.D.3) stipulate, "[t]he design objective of the prompt public alert and notification system shall be to have the capability to essentially complete the initial alerting and initiate notification of the public within the plume exposure pathway EPZ within about 15 minutes". Furthermore, FEMA REP Program Manual Section V Part B.1 Bullet 3 states that arrangements will be made to assure 100 percent coverage within 45 minutes of the population who may not have received the initial notification within the entire plume exposure EPZ.

Given the federal regulations and guidance, and the assumed presence of sirens within the EPZ, it is assumed that 87 percent of those within the EPZ will be aware of the accident within 30 minutes with the remainder notified within the following 15 minutes. The notification distribution is provided in Table 5-2. The distribution is plotted in Figure 5-2.

Distribution No. 2, Prepare to Leave Work: Activity 2 → 3

It is reasonable to expect that the vast majority of business enterprises within the EPZ will elect to shut down following notification and most employees would leave work quickly. Commuters, who work outside the EPZ could, in all probability, also leave quickly since facilities outside the EPZ would remain open and other personnel would remain. Personnel or farmers responsible for equipment/livestock would require additional time to secure their facility. The distribution of Activity 2 → 3 shown in Table 5-3 reflects data obtained by the demographic survey for employees working inside or outside of the EPZ who returns home prior to evacuating. This distribution is also applicable for residents to leave stores, restaurants, parks and other locations within the EPZ. This distribution is plotted in Figure 5-2.

<u>Distribution No. 3, Travel Home: Activity 3 → 4</u>

These data are provided directly by those households which responded to the demographic survey. This distribution is plotted in Figure 5-2 and listed in Table 5-4.

<u>Distribution No. 4, Prepare to Leave Home: Activity 2, 4 → 5</u>

These data are provided directly by those households which responded to the demographic survey. This distribution is plotted in Figure 5-2 and listed in Table 5-5.

<u>Distribution No. 5, Snow Clearance Time Distribution</u>

Inclement weather scenarios involving snowfall must address the time lags associated with snow clearance. It is assumed that snow equipment is mobilized and deployed during the snowfall to maintain passable roads. The general consensus is that the snow-plowing efforts are generally successful for all but the most extreme blizzards when the rate of snow accumulation exceeds that of snow clearance over a period of many hours.

Consequently, it is reasonable to assume that the highway system will remain passable – albeit at a lower capacity – under the vast majority of snow conditions. Nevertheless, for the vehicles to gain access to the highway system, it may be necessary for driveways and employee parking lots to be cleared to the extent needed to permit vehicles to gain access to the roadways. These clearance activities take time; this time must be incorporated into the trip generation time distributions. These data are provided by those households which responded to the demographic survey. This distribution is plotted in Figure 5-2 and listed in Table 5-6.

5.4 Calculation of Trip Generation Time Distribution

The time distributions for each of the mobilization activities presented herein must be combined to form the appropriate Trip Generation Distributions. As discussed above, this study assumes that the stated events take place in sequence such that all preceding events must be completed before the current event can occur. For example, if a household awaits the return of a commuter, the work-to-home trip (Activity 3 → 4) must precede Activity 4 → 5.

To calculate the time distribution of an event that is dependent on two sequential activities, it is necessary to “sum” the distributions associated with these prior activities. The distribution summing algorithm is applied repeatedly to form the required distribution. As an outcome of this procedure, new time distributions are formed; we assign “letter” designations to these intermediate distributions to describe the procedure. Table 5-7 presents the summing procedure to arrive at each designated distribution.

Table 5-8 presents a description of each of the final trip generation distributions achieved after the summing process is completed.

5.4.1 Statistical Outliers

As already mentioned, some portion of the survey respondents answer "decline to state" to some questions or choose to not respond to a question. The mobilization activity distributions are based upon actual responses. But, it is the nature of surveys that a few numeric responses are inconsistent with the overall pattern of results. An example would be a case in which for 500 responses, almost all of them estimate less than two hours for a given answer, but 3 say "four hours" and 4 say "six or more hours".

These "outliers" must be considered: are they valid responses, or so atypical that they should be dropped from the sample?

In assessing outliers, there are three alternatives to consider:

1) Some responses with very long times may be valid, but reflect the reality that the respondent really needs to be classified in a different population subgroup, based upon special needs;

2) Other responses may be unrealistic (6 hours to return home from commuting distance, or 2 days to prepare the home for departure);

3) Some high values are representative and plausible, and one must not cut them as part of the consideration of outliers.

The issue of course is how to make the decision that a given response or set of responses are to be considered "outliers" for the component mobilization activities, using a method that objectively quantifies the process.

There is considerable statistical literature on the identification and treatment of outliers singly or in groups, much of which assumes the data is normally distributed and some of which uses non-parametric methods to avoid that assumption. The literature cites that limited work has been done directly on outliers in sample survey responses.

In establishing the overall mobilization time/trip generation distributions, the following principles are used:

1) It is recognized that the overall trip generation distributions are conservative estimates, because they assume a household will do the mobilization activities sequentially, with no overlap of activities;
2) The individual mobilization activities (prepare to leave work, travel home, prepare home, clear snow) are reviewed for outliers, and then the overall trip generation distributions are created (see Figure 5-1, Table 5-7, Table 5-8);
3) Outliers can be eliminated either because the response reflects a special population (e.g. special needs, transit dependent) or lack of realism, because the purpose is to estimate trip generation patterns for personal vehicles;

4) To eliminate outliers,
    a) the mean and standard deviation of the specific activity are estimated from the responses,
    b) the median of the same data is estimated, with its position relative to the mean noted,
    c) the histogram of the data is inspected, and
    d) all values greater than 3 standard deviations are flagged for attention, taking special note of whether there are gaps (categories with zero entries) in the histogram display.

   In general, only flagged values more than 3 standard deviations from the mean are allowed to be considered outliers, with gaps in the histogram expected. The distribution for the time to prepare to leave work or college was truncated to 3.5 standard deviations as there were many respondents that indicated it would take up to an hour to complete this activity despite a gap in the histogram.

   When flagged values are classified as outliers and dropped, steps “a” to “d” are repeated.

5) As a practical matter, even with outliers eliminated by the above, the resultant histogram, viewed as a cumulative distribution, is not a normal distribution. A typical situation that results is shown in Figure 5-3.

6) In particular, the cumulative distribution differs from the normal distribution in two key aspects, both very important in loading a network to estimate evacuation times:
    - Most of the real data is to the left of the “normal” curve above, indicating that the network loads faster for the first 80-85% of the vehicles, potentially causing more (and earlier) congestion than otherwise modeled;
    - The last 10-15% of the real data “tails off” slower than the comparable “normal” curve, indicating that there is significant traffic still loading at later times.

   Because these two features are important to preserve, it is the histogram of the data that is used to describe the mobilization activities, not a “normal” curve fit to the data. One could consider other distributions, but using the shape of the *actual* data curve is unambiguous and preserves these important features;

7) With the mobilization activities each modeled according to Steps 1-6, including preserving the features cited in Step 6, the overall (or total) mobilization times are constructed.

This is done by using the data sets and distributions under different scenarios (e.g. commuter returning, no commuter returning, no snow or snow in each). In general, these are additive, using weighting based upon the probability distributions of each element; Figure 5-4 presents the combined trip generation distributions designated for each population group considered. These distributions are presented on the same time scale. (As discussed earlier, the use of strictly additive activities is a conservative approach, because it makes all activities sequential – preparation for departure follows the return of the commuter; snow clearance follows the preparation for departure, and so forth. In practice, it is reasonable that some of these activities

are done in parallel, at least to some extent – for instance, preparation to depart begins by a household member at home while the commuter is still on the road.)

The mobilization distributions that result are used in their tabular/graphical form as direct inputs to later computations that lead to the ETE.

The DYNEV II simulation model is designed to accept varying rates of vehicle trip generation for each origin centroid, expressed in the form of histograms. These histograms, which represent Distributions A, C, D, E and F, properly displaced with respect to one another, are tabulated in Table 5-9 (Distribution B, Arrive Home, omitted for clarity).

The final time period (15) is 600 minutes long. This time period is added to allow the analysis network to clear, in the event congestion persists beyond the trip generation period. Note that there are no trips generated during this final time period.

5.4.2 Staged Evacuation Trip Generation

As defined in NUREG/CR-7002, Rev. 1, staged evacuation consists of the following:

1. Subareas comprising the 2-Mile Region are advised to evacuate immediately
2. Subareas comprising regions extending from 2 to 5 miles downwind are advised to shelter in-place while the 2-Mile Region is cleared
3. As vehicles evacuate the 2-Mile Region, sheltered people from 2 to 5 miles downwind continue preparation for evacuation
4. The population sheltering in the 2 to 5-Mile Region are advised to begin evacuating when approximately 90% of those originally within the 2-Mile Region evacuate across the 2-Mile Region boundary
5. Non-compliance with the shelter recommendation is the same as the shadow evacuation percentage of 20%

<u>Assumptions</u>

1. The EPZ population in Subareas beyond 5 miles will shelter in place, with 20% non-compliance.
2. The population in the shadow region beyond the EPZ boundary, extending to approximately 15 miles radially from the plant, will react as they do for all non-staged evacuation scenarios. That is 20% of these households will elect to evacuate with no shelter delay.
3. The transient population will not be expected to stage their evacuation because of the limited sheltering options available to people who may be at parks, or at other venues. Also, notifying the transient population of a staged evacuation would prove difficult.
4. Employees will also be assumed to evacuate without first sheltering.

<u>Procedure</u>

1. Trip generation for population groups in the 2-Mile Region will be as computed based upon the results of the demographic survey and analysis.

2. Trip generation for the population subject to staged evacuation will be formulated as follows:
   a. Identify the 90th percentile evacuation time for the Subareas comprising the 2-Mile Region. This value, T_{Scen}^* is obtained from simulation results. It will become the time at which the region being sheltered will be told to evacuate for each scenario.
   b. The resultant trip generation curves for staging are then formed as follows:
      i. The non-shelter trip generation curve is followed until a maximum of 20% of the total trips are generated (to account for shelter non-compliance).
      ii. No additional trips are generated until time T_{Scen}^*
      iii. Following time T_{Scen}^*, the balance of trips are generated:
         1. by stepping up and then following the non-shelter trip generation curve (if T_{Scen}^* is $\leq$ max trip generation time) or
         2. by stepping up to 100% (if T_{Scen}^* is > max trip generation time)
   c. Note: This procedure implies that there may be different staged trip generation distributions for different scenarios. NUREG/CR-7002, Rev. 1 uses the statement “approximately 90th percentile” as the time to end staging and begin evacuating. The value of T_{Scen}^* is 1:30 for all weekday-midday scenarios (regardless of weather); T_{Scen}^* is 2:15 for weekend and evening scenarios, and 3:30 for weekend/evening-heavy snow scenarios. The reason for the time difference between weekday and weekend scenarios is that approximately 88% of the vehicles within the 2-Mile Region are those of the employees at the Callaway Energy Center. This population group mobilizes faster (100% have mobilized within 105 minutes) than the general population and will therefore evacuate in a shorter amount of time. While this has no impact on the 100th percentile evacuation time, the 90th percentile evacuation time during a weekday good weather scenario is almost an hour shorter than during a weekend good weather scenario when employee vehicles only account for 10% of all vehicles within the 2-Mile Region.

3. Staged trip generation distributions are created for the following population groups:
   a. Residents with returning commuters
   b. Residents without returning commuters
   c. Residents with returning commuters and snow conditions
   d. Residents without returning commuters and snow conditions

Figure 5-5 presents the staged trip generation distributions for both residents with and without returning commuters; the 90th percentile 2-mile evacuation time is 1 hour and 30 minutes for weekday scenarios, 2 hours and 15 minutes for weekend and evening scenarios in good weather and rain/light snow, and 3 hours and 30 minutes for weekend/evening-heavy snow

scenarios. At the 90th percentile evacuation time, approximately 20% of the population advised to shelter has nevertheless departed the area. These people do not comply with the shelter advisory. Also included on the plot are the trip generation distributions for these groups as applied to the regions advised to evacuate immediately.

Since the 90th percentile evacuation time occurs before the end of the trip generation time, after the sheltered region is advised to evacuate, the shelter trip generation distribution rises to meet the balance of the non-staged trip generation distribution. Following time T_{Scen}^*, the balance of staged evacuation trips that are ready to depart are released within 15 or 30 minutes. After T_{Scen}^*+15 (or +30), the remainder of evacuation trips are generated in accordance with the un-staged trip generation distribution.

Figure 5-5 and Table 5-10Table 5-1 provides the trip generation for staged evacuation.

5.4.3 Trip Generation for Waterways and Recreational Areas

The Special Notification of the Public Section of Appendix 1 of the State of Missouri Nuclear Power Plant Accident Plan (MoNAP) (dated December 2019) establishes the basic procedures and organizational responsibilities for the emergency alert and notification on the Missouri River and the Katy Trail State Park in addition to associated recreational sites, conservation areas, surrounding areas and other facilities within the 10-mile EPZ. Individuals located in these areas will be alerted by the public alert sirens, as well as instructional material posted at parking areas at state parks, conservation areas and public access points along the river to explain what to do if the fixed sirens were activated. As indicated in Table 5-2, this study assumes 100 percent notification in 45 minutes which is consistent with the FEMA REP Manual. Table 5-9 indicates that all transients will have mobilized within 1 hour and 45 minutes. It is assumed that this timeframe is sufficient time for boaters, campers, and other transients to return to their vehicles or lodging facilities and begin their evacuation trip.

Table 5-1. Event Sequence for Evacuation Activities

Event Sequence	Activity	Distribution
1 → 2	Receive Notification	1
2 → 3	Prepare to Leave Work	2
2,3 → 4	Travel Home	3
2,4 → 5	Prepare to Leave to Evacuate	4
N/A	Snow Clearance	5

Table 5-2. Time Distribution for Notifying the Public

Elapsed Time (Minutes)	Percent of Population Notified
0	0%
5	7%
10	13%
15	27%
20	47%
25	66%
30	87%
35	92%
40	97%
45	100%

Table 5-3. Time Distribution for Employees to Prepare to Leave Work

Elapsed Time (Minutes)	Cumulative Percent Employees Leaving work
0	0%
5	37%
10	57%
15	72%
20	78%
25	81%
30	89%
35	90%
40	92%
45	94%
50	97%
55	97%
60	100%

NOTE: The survey data was normalized to distribute the "Decline to State" response. That is, the sample was reduced in size to include only those households who responded to this question. The underlying assumption is that the distribution of this activity for the “Decline to State” responders, if the event takes place, would be the same as those responders who provided estimates.

Table 5-4. Time Distribution for Commuters to Travel Home

Elapsed Time (Minutes)	Cumulative Percent Returning Home
0	0
5	10%
10	28%
15	42%
20	58%
25	67%
30	79%
35	88%
40	92%
45	95%
50	99%
55	99%
60	100%

NOTE: The survey data was normalized to distribute the "Decline to State" response.

Table 5-5. Time Distribution for Population to Prepare to Evacuate

Elapsed Time (Minutes)	Cumulative Percent Ready to Evacuate
0	0%
15	5%
30	23%
45	35%
60	54%
75	69%
90	75%
105	78%
120	86%
135	95%
150	95%
165	96%
180	98%
195	100%

NOTE: The survey data was normalized to distribute the "Decline to State" response.

Table 5-6. Time Distribution for Population to Clear 6"-8" of Snow

Elapsed Time (Minutes)	Cumulative Percent Ready to Evacuate
0	22%
15	38%
30	47%
45	57%
60	71%
75	78%
90	82%
105	84%
120	87%
135	91%
150	93%
165	94%
180	98%
210	100%

NOTE: The survey data was normalized to distribute the "Decline to State" response.

Table 5-7. Mapping Distributions to Events

Apply "Summing" Algorithm To:	Distribution Obtained	Event Defined
Distributions 1 and 2	Distribution A	Event 3
Distributions A and 3	Distribution B	Event 4
Distributions B and 4	Distribution C	Event 5
Distributions 1 and 4	Distribution D	Event 5
Distributions C and 5	Distribution E	Event 5
Distributions D and 5	Distribution F	Event 5

Table 5-8. Description of the Distributions

Distribution	Description
A	Time distribution of commuters departing place of work (Event 3). Also applies to employees who work within the EPZ who live outside, and to Transients within the EPZ.
B	Time distribution of commuters arriving home (Event 4).
C	Time distribution of residents with commuters who return home, leaving home to begin the evacuation trip (Event 5).
D	Time distribution of residents without commuters returning home, leaving home to begin the evacuation trip (Event 5).
E	Time distribution of residents with commuters who return home, leaving home to begin the evacuation trip, after snow clearance activities (Event 5).
F	Time distribution of residents with no commuters returning home, leaving to begin the evacuation trip, after snow clearance activities (Event 5).

Table 5-9. Trip Generation Histograms for the EPZ Population for Un-staged Evacuation

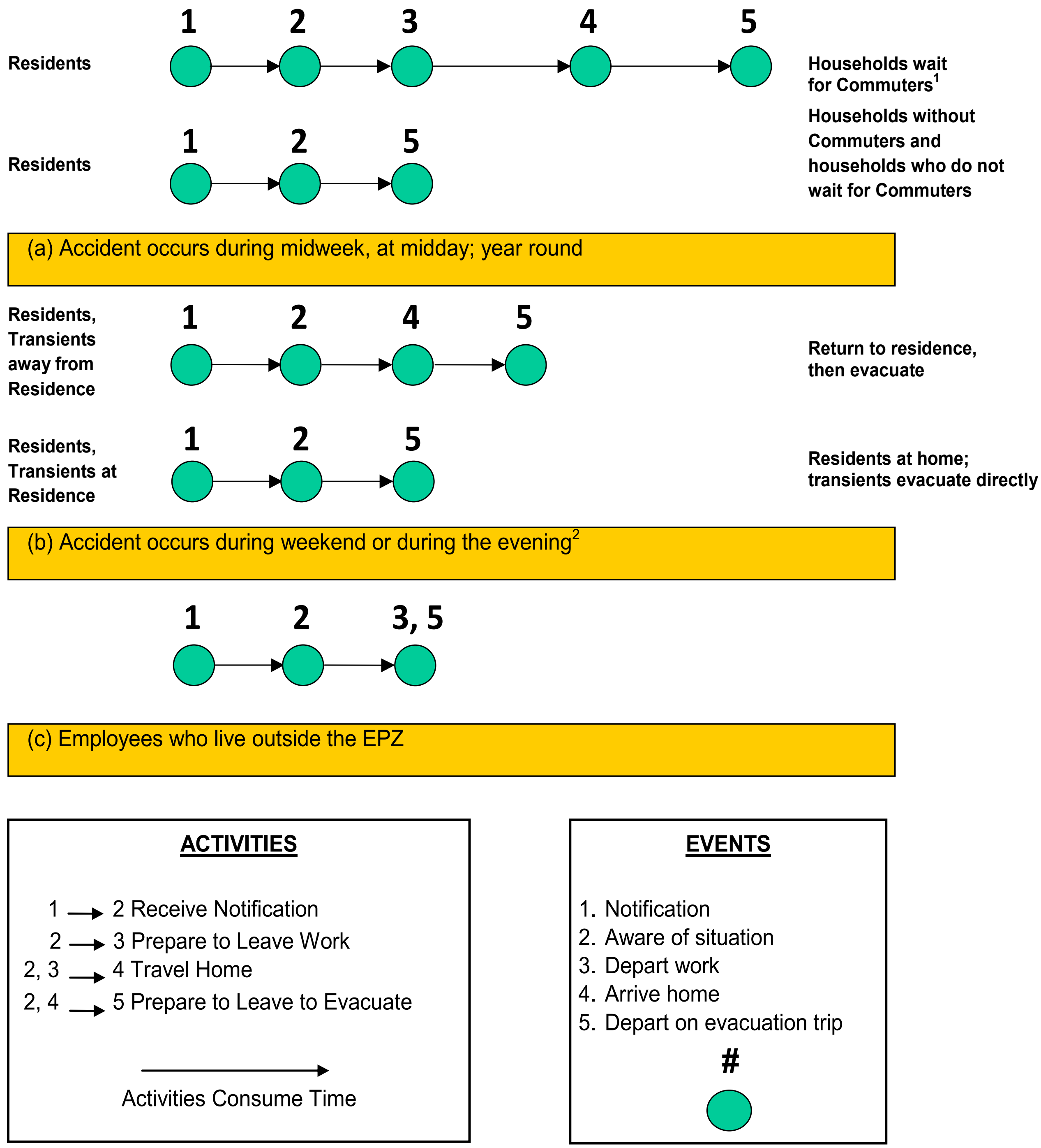
Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period					
		Employees (Distribution A)	Transients (Distribution A)	Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Residents With Commuters Snow (Distribution E)	Residents Without Commuters Snow (Distribution F)
1	15	6%	6%	0%	0%	0%	0%
2	15	33%	33%	0%	4%	0%	1%
3	15	36%	36%	1%	10%	0%	3%
4	15	15%	15%	3%	14%	1%	6%
5	15	6%	6%	8%	16%	3%	7%
6	15	3%	3%	11%	16%	4%	10%
7	15	1%	1%	14%	11%	7%	10%
8	30	0%	0%	25%	11%	17%	17%
9	30	0%	0%	17%	12%	17%	15%
10	30	0%	0%	11%	3%	15%	10%
11	30	0%	0%	6%	3%	12%	9%
12	60	0%	0%	4%	0%	15%	9%
13	60	0%	0%	0%	0%	7%	2%
14	60	0%	0%	0%	0%	2%	1%
15	600	0%	0%	0%	0%	0%	0%

NOTE: Shadow vehicles are loaded onto the analysis network (Figure 1-2) using Distributions C and E for good weather and snow, respectively. Special event vehicles are loaded using Distribution A

Table 5-10. Trip Generation Histograms for the EPZ Population for Staged Evacuation

Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period							
		Weekend/Evening				Weekday			
		Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Residents With Commuters-Snow (Distribution E)	Residents Without Commuters-Snow (Distribution F)	Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Residents With Commuters-Snow (Distribution E)	Residents Without Commuters-Snow (Distribution F)
1	15	0%	0%	0%	0%	0%	0%	0%	0%
2	15	0%	1%	0%	0%	0%	1%	0%	0%
3	15	0%	2%	0%	1%	0%	2%	0%	1%
4	15	1%	3%	0%	1%	1%	3%	0%	1%
5	15	1%	3%	1%	1%	1%	3%	1%	1%
6	15	3%	3%	1%	2%	3%	3%	1%	2%
7	15	2%	2%	1%	2%	32%	59%	13%	32%
8	30	5%	2%	3%	4%	25%	11%	17%	17%
9	30	67%	78%	4%	3%	17%	12%	17%	15%
10	30	11%	3%	3%	2%	11%	3%	15%	10%
11	30	6%	3%	63%	72%	6%	3%	12%	9%
12	60	4%	0%	15%	9%	4%	0%	15%	9%
13	60	0%	0%	7%	2%	0%	0%	7%	2%
14	60	0%	0%	2%	1%	0%	0%	2%	1%
15	600	0%	0%	0%	0%	0%	0%	0%	0%

NOTE: Trip Generation for Employees and Transients (see Table 5-9) is the same for Un-staged and Staged Evacuation.
NOTE: Trip Generation for Snow Distributions is referring to "heavy snow" weather conditions.



[1] Applies for evening and weekends also if commuters are at work.
[2] Applies throughout the year for transients.

Figure 5-1. Events and Activities Preceding the Evacuation Trip

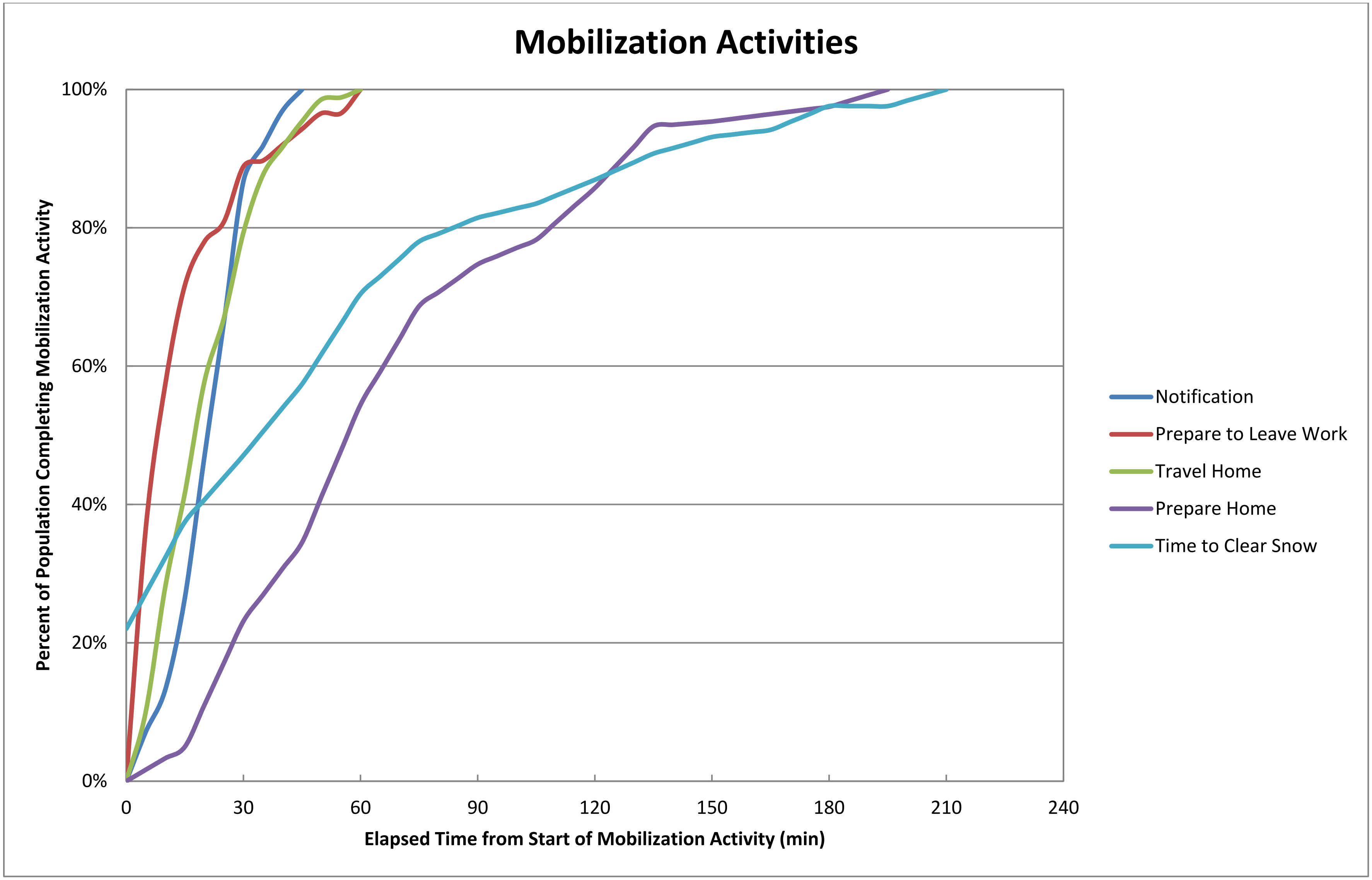


Figure 5-2. Time Distributions for Evacuation Mobilization Activities

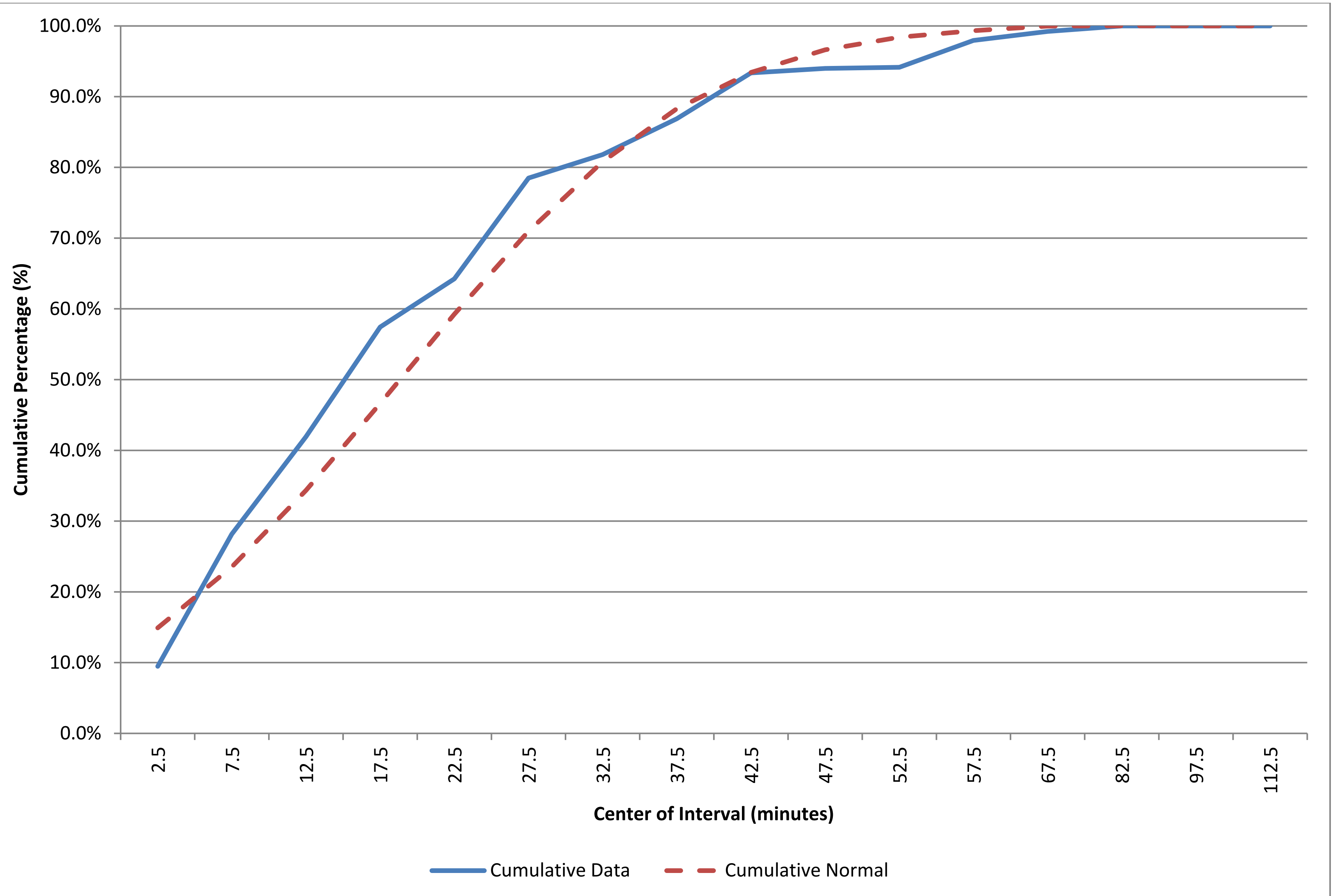


Figure 5-3. Comparison of Data Distribution and Normal Distribution

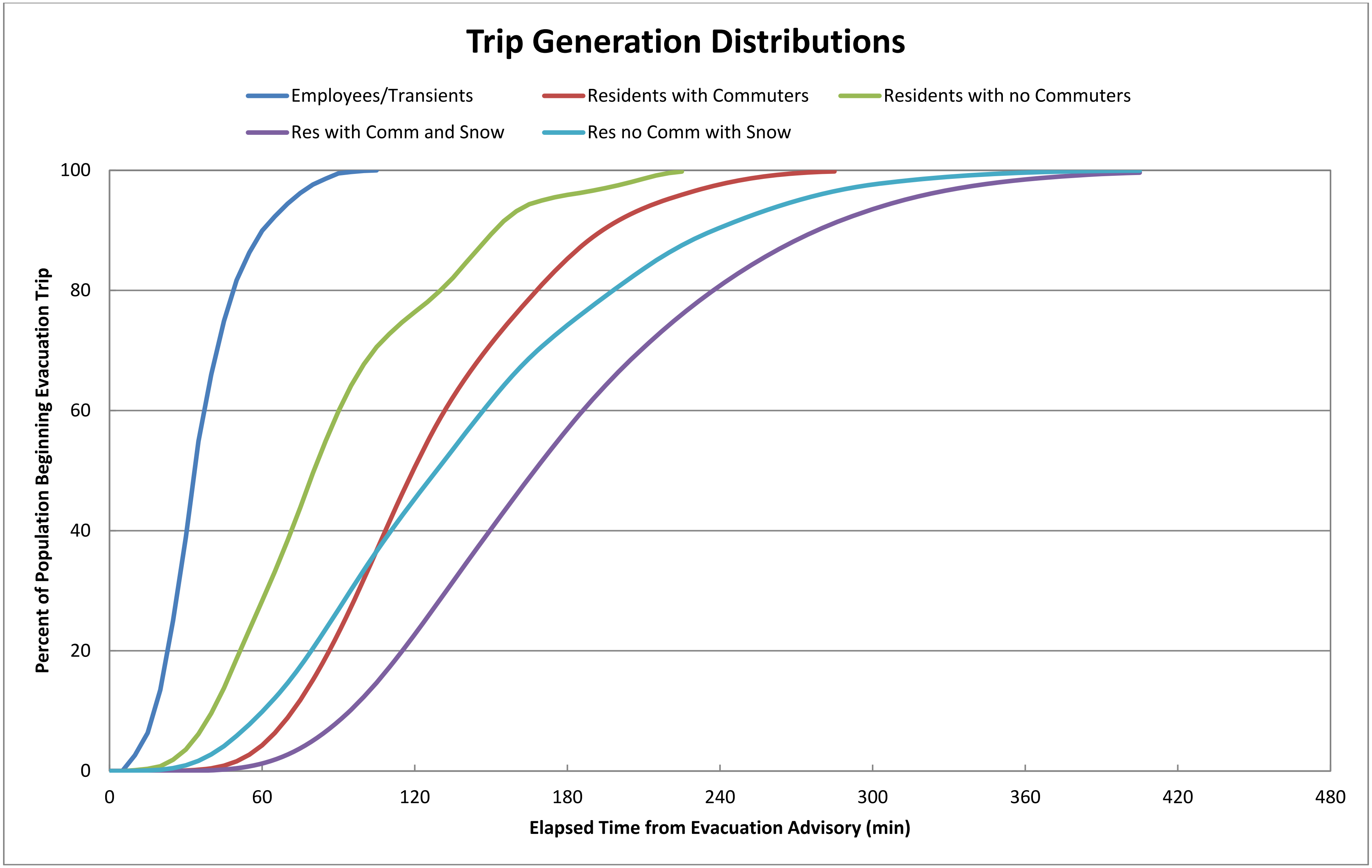


Figure 5-4. Comparison of Trip Generation Distributions

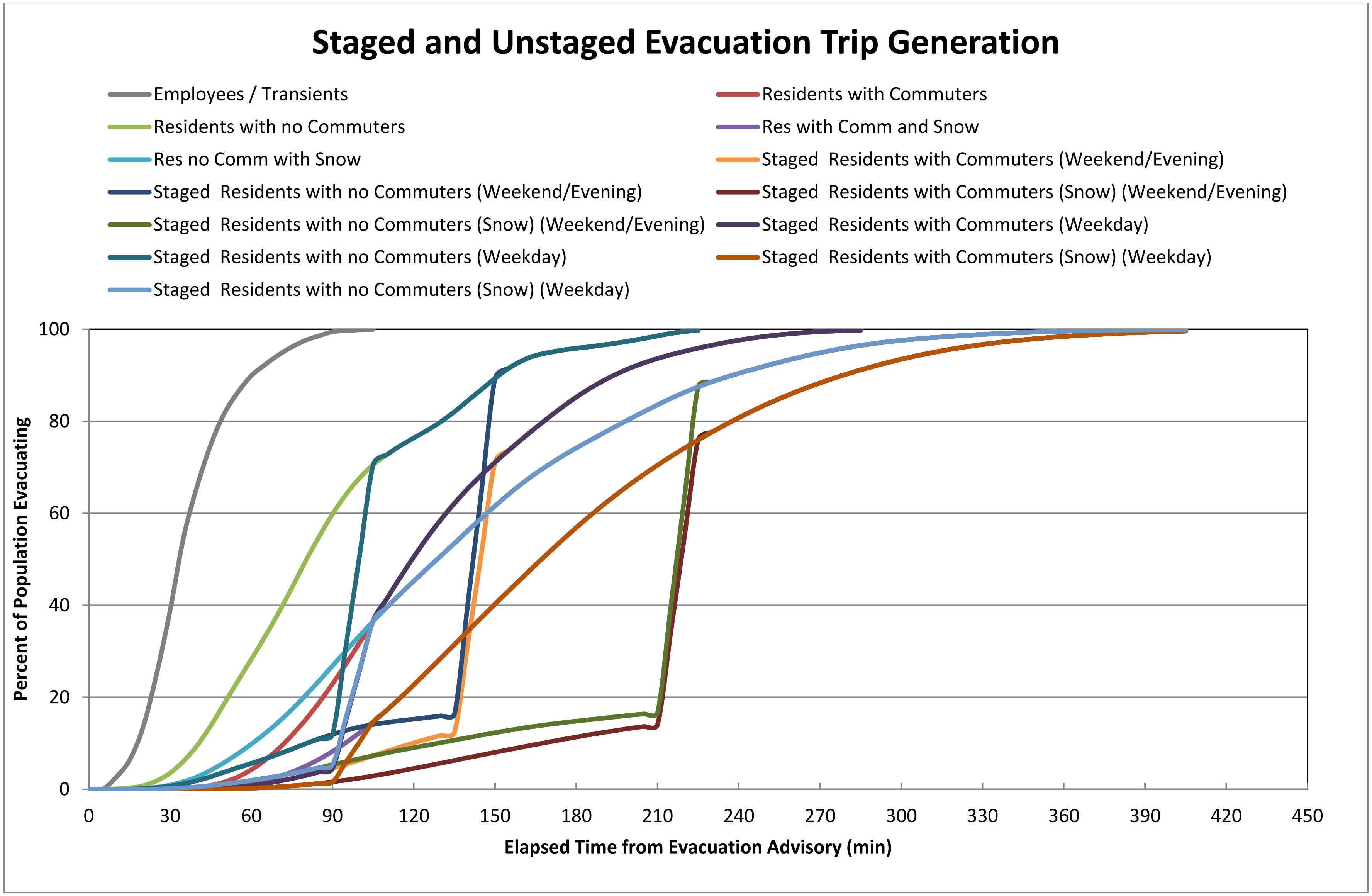


Figure 5-5. Comparison of Staged and Un-staged Trip Generation Distributions in the 2 to 5-Mile Region

6 EVACUATION CASES

An evacuation "case" defines a combination of Evacuation Region and Evacuation Scenario. The definitions of "Region" and "Scenario" are as follows:

Region A grouping of contiguous evacuating Subareas that forms either a "keyhole" sector-based area, or a circular area within the Emergency Planning Zone (EPZ), that must be evacuated in response to a radiological emergency.

Scenario A combination of circumstances, including time of day, day of week, season, and weather conditions. Scenarios define the number of people in each of the affected population groups and their respective mobilization time distributions.

A total of 44 Regions were identified which encompass all the groupings of Subareas considered. These Regions are defined in Table 6-1. The Subarea configurations are identified in Figure 6-1. Each 3-sector keyhole sector-based area consists of a central circle centered at the power plant, and three adjoining sectors, each with a central angle of 22.5 degrees, as per NUREG/CR-7002, Rev. 1 guidance. The central sector coincides with the wind direction. In addition, 4-sector keyholes – consisting of two sectors on either side of the central angle of the wind direction – are also considered to follow the current Protective Action Recommendation (PAR) strategy. These sectors extend to 5 miles from the plant (Regions R04 through R13) or to the EPZ boundary (Regions R14 through R33).

Regions R01, R02 and R03 represent evacuations of circular areas with radii of 2, 5 and 10 miles, respectively. Regions R34 through R44 are identical to Regions R02 and R04 through R13, respectively; however, those Subareas between 2 miles and 5 miles are staged until 90% of the 2-Mile Region (Region R01) has evacuated.

A total of 14 Scenarios were evaluated for all Regions. Thus, there are a total of 44 x 14 = 616 evacuation cases. Table 6-2 is a description of all Scenarios.

Each combination of Region and Scenario implies a specific population to be evacuated. The population group and the vehicle estimates presented in Section 3 and in Appendix E are peak values. These peak values are adjusted depending on the Scenario and Region being considered, using Scenario and Region-specific percentages, such that the population is considered for each evacuation case. The Scenario percentages are presented in Table 6-3, while the Region percentages are provided in Table H-1.

Table 6-4 presents the vehicle counts for each Scenario for an evacuation of Region R03 – the entire EPZ, based on the Scenario percentages in Table 6-3. The percentages presented in Table 6-3 were determined as follows:

The number of residents with commuters during the week (when workforce is at its peak) is equal to 42%, which is the product of 70% (the number of households with at least one commuter – see Figure F-6) and 60% (the number of households with a commuter that would await the return of the commuter prior to evacuating – see Figure F-11. See assumption 3 in Section 2.3. It is estimated for weekend and evening scenarios that 10% of those households

with returning commuters during the week (42%) will have a commuter at work during those time, or approximately 4% of households overall.

Employment is assumed to be at its peak (100%) during the winter, midweek, midday scenarios. Employment is reduced slightly (96%) for summer, midweek, midday scenarios. This is based on the estimation that 50% of the employees commuting into the EPZ will be on vacation for a week during the approximate 12 weeks of summer. It is further estimated that those taking vacation will be uniformly dispersed throughout the summer with approximately 4% of employees vacationing each week. It is assumed that only 10% of the employees are working in the evenings and during the weekends.

Transient activity is estimated to be at its peak (100%) during summer evenings and less (70%) during the day, due to a large number of facilities offering overnight accommodations (lodging facilities and campgrounds). Transient activity on summer weekends is estimated 95% since nearly all the facilities are open or operate on summer weekends. The recreational areas in the EPZ (shown in Appendix E, Table E-4) are predominantly outdoors and will be frequented more often during the summer than the winter. As a result, transient activity during winter weekends is estimated to be 55% and less during the week (45%). Due to the large number of lodging facilities and campgrounds, transient activity during the evenings in the winter are estimated to be slightly higher at 65%.

As noted in the shadow footnote to Table 6-3, the shadow percentages are computed using a base of 20% (see assumption 7 in Section 2.2); to include the employees within the Shadow Region who may choose to evacuate, the voluntary evacuation is multiplied by a scenario-specific proportion of employees to permanent residents in the Shadow Region. For example, using the values provided in

Table 6-4 for Scenario 1, the shadow percentage is computed as follows:

$$20\% \times \left(1 + \frac{492}{3{,}811 + 5{,}252}\right) = 21\%$$

One special event – a refueling outage at the Callaway Energy Center site – was considered as Scenario 13. Thus, the special event traffic is 100% evacuated for Scenario 13, and 0% for all other scenarios.

As discussed in Section 7, schools/colleges/universities are in session during the winter season, midweek, midday and 100% of buses/student vehicles will be needed under those circumstances. It is estimated that summer school enrollment is approximately 10% of enrollment during the regular school year for summer, midweek, midday scenarios. School is not in session during weekends and evenings, thus no buses for school children (or commuting student vehicles) are needed under those circumstances.

Transit buses for the transit-dependent population are set to 100% for all scenarios as it is assumed that the transit-dependent population is present in the EPZ for all scenarios.

External traffic is estimated to be 100% for all midday scenarios, while it is significantly less

(40%) during evening scenarios.

Table 6-1. Description of Evacuation Regions

Radial Regions																		
Region	Description:			Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R01	2-Mile Radius			X														
R02	5-Mile Radius			X	X	X	X	X	X									
R03	Full EPZ			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Evacuate 2-Mile Region and Downwind to 5 Miles																		
Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R04	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	X				X	X									
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	See Region R04														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)	See Region R04														
-	38 - 52	K, L, M	NE (3-Sector Keyhole)	See Region R04														
R05	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	X	X			X	X									
R06	60 - 75	L, M, N	ENE (3-Sector Keyhole)	X	X				X									
-	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	See Region R06														
-	83 - 97	M, N, P	E (3-Sector Keyhole)	See Region R06														
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)	See Region R06														
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)	See Region R06														

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R07	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	X	X	X			X									
R08	128 - 142	P, Q, R	SE (3-Sector Keyhole)	X	X	X												
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	**See Region R08**														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)															
-	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)															
-	173 - 187	R, A, B	S (3-Sector Keyhole)															
-	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)															
R09	195 - 210	A, B, C	SSW (3-Sector Keyhole)	X		X												
R10	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	X		X	X											
-	218 - 232	B, C, D	SW (3-Sector Keyhole)	**See Region R10**														
-	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)															
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)															
-	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)															
R11	263 - 277	D, E, F	W (3-Sector Keyhole)	X			X											

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R12	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	X			X	X										
-	285 - 300	E, F, G	WNW (3-Sector Keyhole)	See Region R12														
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)															
-	308 - 322	F, G, H	NW (3-Sector Keyhole)															
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)															
R13	330 - 345	G, H, J	NNW (3-Sector Keyhole)	X				X										
-	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	See Region R04														
-	353 - 7	H, J, K	N (3-Sector Keyhole)															
Evacuate 2-Mile Radius and Downwind to the EPZ Boundary																		
Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R14	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	X				X	X	X								X
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	See Region R14														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)															
-	38 - 52	K, L, M	NE (3-Sector Keyhole)															

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R15	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	X	X			X	X	X	X							X
R16	60 - 75	L, M, N	ENE (3-Sector Keyhole)	X	X				X	X	X							
R17	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	X	X				X	X	X	X						
-	83 - 97	M, N, P	E (3-Sector Keyhole)	**See Region R17**														
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)															
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)															
R18	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	X	X	X			X	X	X	X	X					
R19	128 - 142	P, Q, R	SE (3-Sector Keyhole)	X	X	X					X	X	X					
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	**See Region R19**														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)															
R20	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)	X	X	X					X	X	X	X				
R21	173 - 187	R, A, B	S (3-Sector Keyhole)	X	X	X					X		X	X				
R22	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)	X	X	X					X		X	X		X		
R23	195 - 210	A, B, C	SSW (3-Sector Keyhole)	X		X							X	X		X		
R24	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	X		X	X						X	X		X		
R25	218 - 232	B, C, D	SW (3-Sector Keyhole)	X		X	X							X		X		

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R26	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)	X		X	X							X		X	X	
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)	**See Region R26**														
R27	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)	X		X	X							X	X	X	X	
R28	263 - 277	D, E, F	W (3-Sector Keyhole)	X			X							X	X	X	X	
R29	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	X			X	X						X	X	X	X	X
R30	285 - 300	E, F, G	WNW (3-Sector Keyhole)	X			X	X							X		X	X
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)	**See Region R30**														
-	308 - 322	F, G, H	NW (3-Sector Keyhole)															
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)															
R31	330 - 345	G, H, J	NNW (3-Sector Keyhole)	X				X							X			X
R32	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	X				X	X						X			X
R33	353 - 7	H, J, K	N (3-Sector Keyhole)	X				X	X									X

Staged Evacuation - 2-Mile Radius Evacuates, then Evacuate Downwind to 5 Miles																		
Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R34	5-Mile Radius			X	X	X	X	X	X									
R35	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	X				X	X									
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	**See Region R35**														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)	**See Region R35**														
-	38 - 52	K, L, M	NE (3-Sector Keyhole)	**See Region R35**														
R36	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	X	X			X	X									
R37	60 - 75	L, M, N	ENE (3-Sector Keyhole)	X	X				X									
-	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	**See Region R37**														
-	83 - 97	M, N, P	E (3-Sector Keyhole)	**See Region R37**														
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)	**See Region R37**														
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)	**See Region R37**														
R38	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	X	X	X			X									

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R39	128 - 142	P, Q, R	SE (3-Sector Keyhole)	X	X	X												
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	**See Region R39**														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)															
-	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)															
-	173 - 187	R, A, B	S (3-Sector Keyhole)															
-	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)															
R40	195 - 210	A, B, C	SSW (3-Sector Keyhole)	X		X												
R41	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	X		X	X											
-	218 - 232	B, C, D	SW (3-Sector Keyhole)	**See Region R41**														
-	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)															
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)															
-	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)															
R42	263 - 277	D, E, F	W (3-Sector Keyhole)	X			X											

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R43	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	X			X	X										
-	285 - 300	E, F, G	WNW (3-Sector Keyhole)	**See Region R43**														
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)	**See Region R43**														
-	308 - 322	F, G, H	NW (3-Sector Keyhole)	**See Region R43**														
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)	**See Region R43**														
R44	330 - 345	G, H, J	NNW (3-Sector Keyhole)	X				X										
-	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	**See Region R35**														
-	353 - 7	H, J, K	N (3-Sector Keyhole)	**See Region R35**														
Subarea(s) Evacuate			Subarea(s) Shelter-in-Place								Shelter-in-Place until 90% ETE for R01, then Evacuate							

Table 6-2. Evacuation Scenario Definitions

Scenario	Season[1]	Day of Week	Time of Day	Weather	Special
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain/Light Snow	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain/Light Snow	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain/Light Snow	None
8	Winter	Midweek	Midday	Heavy Snow	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain/Light Snow	None
11	Winter	Weekend	Midday	Heavy Snow	None
12	Winter	Midweek, Weekend	Evening	Good	None
13	Winter	Midweek	Midday	Good	Special Event – Outage at the CEC
14	Summer	Midweek	Midday	Good	Roadway Impact – Lane Closure on I-70 Outbound in both directions

[1] Winter means that school is in session at normal enrollment levels (also applies to spring and autumn). Summer means that school is in session at summer school enrollment levels (lower than normal enrollment).

Table 6-3. Percent of Population Groups Evacuating for Various Scenarios

Scenario	Households With Returning Commuters	Households Without Returning Commuters	Employees	Transients	Shadow	Special Event	School Buses and Colleges/ Universities	Transit Buses	External Through Traffic
1	42%	58%	96%	70%	21%	0%	10%	100%	100%
2	42%	58%	96%	70%	21%	0%	10%	100%	100%
3	4%	96%	10%	95%	20%	0%	0%	100%	100%
4	4%	96%	10%	95%	20%	0%	0%	100%	100%
5	4%	96%	10%	100%	20%	0%	0%	100%	40%
6	42%	58%	100%	45%	21%	0%	100%	100%	100%
7	42%	58%	100%	45%	21%	0%	100%	100%	100%
8	42%	58%	100%	45%	21%	0%	100%	100%	100%
9	4%	96%	10%	55%	20%	0%	0%	100%	100%
10	4%	96%	10%	55%	20%	0%	0%	100%	100%
11	4%	96%	10%	55%	20%	0%	0%	100%	100%
12	4%	96%	10%	65%	20%	0%	0%	100%	40%
13	42%	58%	100%	45%	21%	100%	100%	100%	100%
14	42%	58%	96%	70%	21%	0%	10%	100%	100%

Resident Households with Commuters ....Households of EPZ residents who await the return of commuters prior to beginning the evacuation trip.
Resident Households with No Commuters ..Households of EPZ residents who do not have commuters or will not await the return of commuters prior to beginning the evacuation trip.
Employees..EPZ employees who live outside the EPZ
Transients ....People who are in the EPZ at the time of an accident for recreational or other (non-employment) purposes.
Shadow..Residents and employees in the Shadow Region (outside of the EPZ) who will spontaneously decide to relocate during the evacuation. The basis for the values shown is a 20% relocation of shadow residents along with a proportional percentage of shadow employees.
Special Event...Additional vehicles in the EPZ due to the identified special event.
School and Transit Buses ....Vehicle-equivalents present on the road during evacuation servicing schools and transit-dependent people (1 bus is equivalent to 2 passenger vehicles).
External Through Traffic ....Traffic passing through the EPZ on interstates/freeways and major arterial roads at the start of the evacuation. This traffic is stopped by access control approximately 2 hours after the evacuation begins.

Table 6-4. Vehicle Estimates by Scenario[2]

Scenario	Households With Returning Commuters	Households Without Returning Commuters	Employees	Transients	Shadow	Special Event	College and University Student Vehicles	School, College, and University Buses	Transit Buses	External Through Traffic	Total Scenario Vehicles
1	3,811	5,252	492	306	770	-	215	22	8	7,256	18,132
2	3,811	5,252	492	306	770	-	215	22	8	7,256	18,132
3	381	8,682	51	415	734	-	-	-	8	7,256	17,527
4	381	8,682	51	415	734	-	-	-	8	7,256	17,527
5	381	8,682	51	437	734	-	-	-	8	2,902	13,195
6	3,811	5,252	513	197	772	-	2,148	216	8	7,256	20,173
7	3,811	5,252	513	197	772	-	2,148	216	8	7,256	20,173
8	3,811	5,252	513	197	772	-	2,148	216	8	7,256	20,173
9	381	8,682	51	240	734	-	-	-	8	7,256	17,352
10	381	8,682	51	240	734	-	-	-	8	7,256	17,352
11	381	8,682	51	240	734	-	-	-	8	7,256	17,352
12	381	8,682	51	284	734	-	-	-	8	2,902	13,042
13	3,811	5,252	513	197	772	991	2,148	216	8	7,256	21,164
14	3,811	5,252	492	306	770	-	215	22	8	7,256	18,132

[2] Vehicle estimates are for an evacuation of the entire EPZ (Region R03)

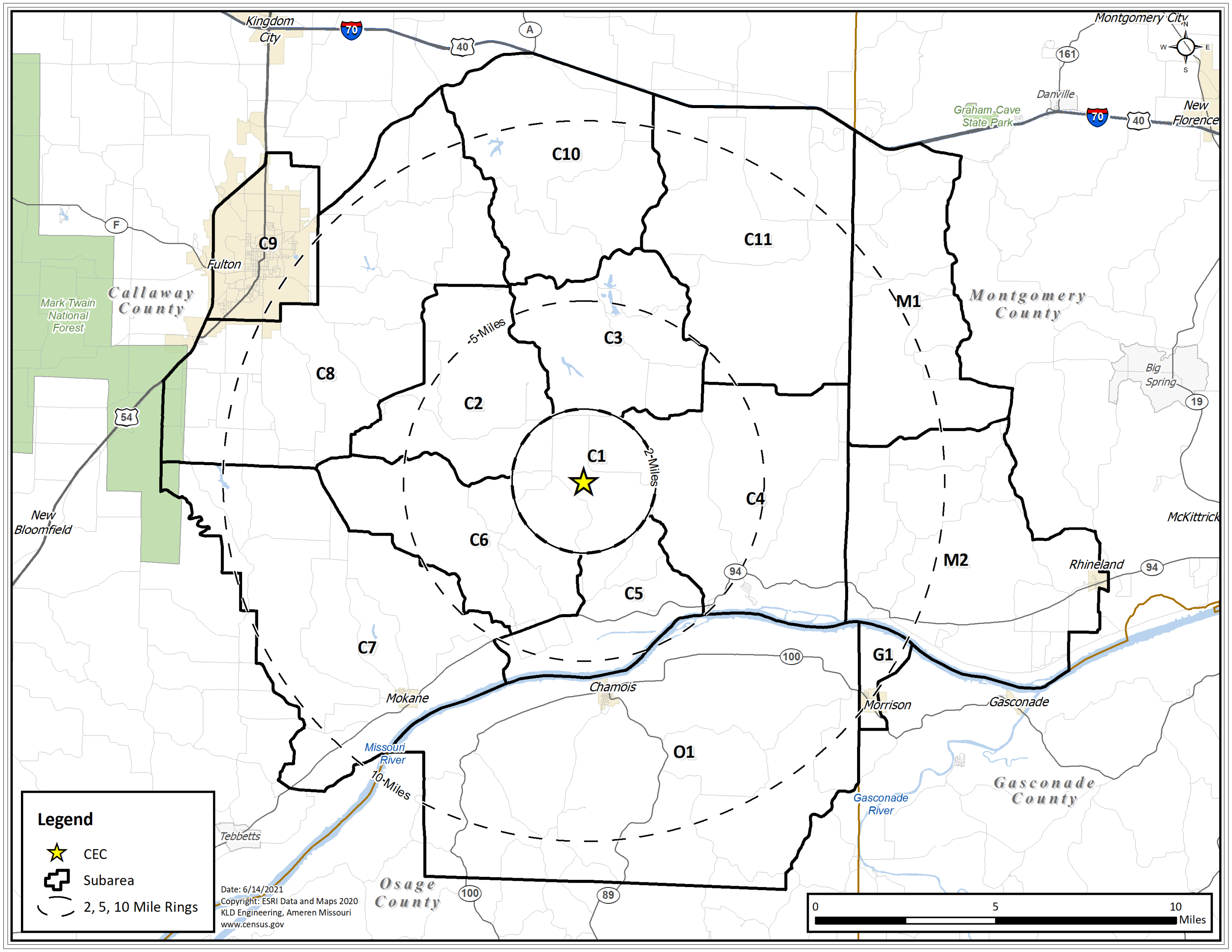


Figure 6-1. Subareas Comprising the Callaway Energy Center EPZ

7 GENERAL POPULATION EVACUATION TIME ESTIMATES (ETE)

This section presents the ETE results of the computer analyses using the DYNEV II System described in Appendices B, C and D. These results cover 44 regions within the Callaway Energy Center (CEC) Emergency Planning Zone (EPZ) and the 14 Evacuation Scenarios discussed in Section 6.

The ETE for all evacuation cases are presented in Table 7-1 and Table 7-2. These tables present the estimated times to clear the indicated population percentages from the evacuation regions for all evacuation scenarios. The ETE of the 2-Mile Region in both staged and un-staged regions are presented in Table 7-3 and Table 7-4. Table 7-5 defines the evacuation regions considered. The tabulated values of ETE are obtained from the DYNEV II System outputs which are generated at 5-minute intervals.

7.1 Voluntary Evacuation and Shadow Evacuation

"Voluntary evacuees" are people within the EPZ in subareas for which an Advisory to Evacuate (ATE) has not been issued, yet who elect to evacuate. "Shadow evacuation" is the voluntary outward movement of some people from the Shadow Region (outside the EPZ) for whom no protective action recommendation has been issued. Both voluntary and shadow evacuations are assumed to take place over the same time frame as the evacuation from within the impacted evacuation region.

The ETE for the CEC EPZ addresses the issue of voluntary evacuees in the manner shown in Figure 7-1. Within the EPZ, 20 percent of permanent residents located in subareas outside of the evacuation region who are not advised to evacuate, are assumed to elect to evacuate. Similarly, it is assumed that 20 percent of those permanent residents in the shadow region will choose to leave the area.

Figure 7-2 presents the area identified as the Shadow Region. This region extends radially from the CEC to cover a region between the EPZ boundary and approximately 15 miles. The population and number of evacuating vehicles in the shadow region were estimated using the same methodology that was used for permanent residents within the EPZ (see Section 3.1). As discussed in Section 3.2, it is estimated that a total of 6,560 people reside in the Shadow Region; 20 percent of them would evacuate. See Table 6-4 for the number of evacuating vehicles from the Shadow Region.

Traffic generated within this Shadow Region including external-external traffic (see Section 3.11), traveling away from the plant location, has the potential for impeding evacuating vehicles from within the evacuation region. All ETE calculations include this shadow traffic movement.

7.2 Staged Evacuation

As defined in NUREG/CR-7002, Rev. 1, staged evacuation consists of the following:

1. Subareas comprising the 2-Mile Region are advised to evacuate immediately.

2. Subareas comprising regions extending from 2 to 5 miles downwind are advised to shelter in-place while the 2-Mile Region is cleared.
3. As vehicles evacuate the 2-Mile Region, people from 2 to 5 miles downwind continue preparation for evacuation while they shelter.
4. The population sheltering in the 2 to 5-Mile Region is advised to evacuate when approximately 90% of the 2-Mile Region evacuating traffic crosses the 2-Mile Region boundary.
5. The population in the 5-to-10-mile region (to the EPZ boundary) shelters in place.
6. Non-compliance with the shelter recommendation is the same as the shadow evacuation percentage of 20%.

See Section 5.4.2 for additional information on staged evacuation.

7.3 Patterns of Traffic Congestion during Evacuation

Figure 7-3 through Figure 7-7 illustrate the patterns of traffic congestion that arise for the case when the entire EPZ (Region R03) is advised to evacuate during the winter, midweek, midday period under good weather conditions (Scenario 6).

Traffic congestion, as the term is used here, is defined as Level of Service (LOS) F. LOS F is defined as follows (HCM 2016, page 5-5):

> The HCM uses LOS F to define operations that have either broken down (i.e., demand exceeds capacity) or have reached a point that most users would consider unsatisfactory, as described by a specified service measure value (or combination of service measure values). However, analysts may be interested in knowing just how bad the LOS F condition is, particularly for planning applications where different alternatives may be compared. Several measures are available for describing individually, or in combination, the severity of a LOS F condition:
>
> - *Demand-to-capacity ratios* describe the extent to which demand exceeds capacity during the analysis period (e.g., by 1%, 15%);
> - *Duration of LOS F* describes how long the condition persists (e.g., 15 min, 1 h, 3 h); and
> - *Spatial extent measures* describe the areas affected by LOS F conditions. They include measures such as the back of queue and the identification of the specific intersection approaches or system elements experiencing LOS F conditions.

All highway "links" which experience LOS F are delineated in these figures by a thick red line; all others are lightly indicated.

At 30 minutes after the ATE, slight congestion can be seen along State Route O as employees evacuate CEC towards Fulton as seen in Figure 7-3. W 12th Street in Fulton exhibits LOS F conditions due to students evacuating from Williams Wood University. W 12th Street intersects

Westminster Ave at a stop sign. The low capacity (about 900 vehicles per hour) of the stop sign causes a queue of vehicles leaving the campus generating congestion. Similarly, W7th Street exhibits LOS D conditions due to the students evacuating from Westminster College. Again, W 7th Street intersects Westminster Ave at a stop sign. Slight congestion (LOS B or better) has developed in other parts of Fulton – along Westminster Ave, Missouri F, and US-54 Business. As shown in the figure, congestion does not back up into the 2-mile region (Subarea C1). At this time, approximately 11 percent of evacuees have mobilized, and approximately 6 percent of vehicles have successfully evacuated the EPZ.

Figure 7-4 displays the patterns of congestion at 1 hour after the ATE. It can be seen that at this time congestion primarily only exists in Fulton (Subarea C9). In Fulton, W 12th Street continues to exhibit LOS F conditions as students from William Woods University continue to evacuate. Similar to 30 minutes prior, many major evacuation routes in Fulton experience slight congestion (LOS C or better). At this time, the 5-mile region is clear of congestion, approximately 34 percent of evacuees have mobilized, and approximately 23 percent of vehicles have successfully evacuated the EPZ.

Congestion peaks in Fulton at 1 hour and 30 minutes after the ATE as seen in Figure 7-5. W 12th Street still exhibits LOS F conditions, and now Westminster Ave exhibits LOS E conditions as the students mix with more evacuating residents and attempt to access US-54. The ramps that give access to US-54 are a single lane and have limited capacity to process the demand that is trying to access US-54. As such traffic builds along Westminster Ave and congestion develops. In addition, Missouri F exhibits LOS E and F leaving Fulton (mostly in the Shadow Region) as vehicles attempt to access US-54, but again are limited to the capacity of the on ramps. Some vehicles choose to remain on Missouri F and travel toward Columbia. In the shadow region, slight congestion exists along I-70 and US-54. At this time, approximately 58 percent of evacuees have mobilized, and approximately 47 percent of vehicles have successfully evacuated the EPZ.

Congestion from Williams Wood University clears at 2 hours and 30 minutes after the ATE as shown in Figure **7**-**6**. Nearly all congestion within the EPZ has dissipated. The last remnants of congestion are along Martin Luther King Junior Boulevard/Missouri F both in the EPZ and Shadow Region. At this time, approximately 85 percent of evacuees have mobilized, and approximately 84 percent of vehicles have successfully evacuated the EPZ.

The study area is completely clear of congestion at 2 hours and 50 minutes after the ATE as shown in Figure 7-7. At this time, approximately 92 percent of evacuees have mobilized, and approximately 91 percent of vehicles have successfully evacuated the EPZ. Vehicles are still present in the network for another 2 hours and 5 minutes after the ATE due to the mobilization time. The remaining vehicles are not enough to cause congestion such that roadways in the study area experience any LOS lower than LOS A for the remainder of the evacuation.

7.4 Evacuation Rates

Evacuation is a continuous process, as implied by Figure 7-8 through Figure 7-21. These figures display the rate at which traffic flows out of the indicated areas for the case of an evacuation of

the full EPZ (Region R03) under the indicated conditions. One figure is presented for each scenario considered.

As indicated in Figure 7-8 through Figure 7-21, there is typically a long "tail" to these distributions. Vehicles begin to evacuate an area slowly at first, as people respond to the ATE at different rates. Then traffic demand builds rapidly (slopes of curves increase). When the system becomes congested, traffic exits the EPZ at rates somewhat below capacity until some evacuation routes have cleared. As more routes clear, the aggregate rate of egress slows since many vehicles have already left the EPZ. Towards the end of the process, there are few evacuation routes to service the remaining demand.

The decline in aggregate flow rate, towards the end of the process, is characterized by these curves flattening and gradually becoming horizontal. Ideally, it would be desirable to fully saturate all evacuation routes equally so that all will service traffic near capacity levels, and all will clear at the same time. For this ideal situation, all curves would retain the same slope until the end – thus minimizing evacuation time. In reality, this ideal is generally unattainable reflecting the spatial variation in population density, mobilization rates and in highway capacity over the EPZ.

7.5 ETE Results

Table 7-1 through Table 7-2 present the ETE values for all 44 Evacuation Regions and all 14 Evacuation Scenarios. Table 7-3 through Table 7-4 present the ETE values for 2-Mile Region for both staged and un-staged keyhole regions downwind to 5 miles. They are organized as follows:

Table	Contents
7-1	ETE represents the elapsed time required for 90 percent of the population within a Region, to evacuate from that Region. All Scenarios are considered, as well as Staged Evacuation scenarios.
7-2	ETE represents the elapsed time required for 100 percent of the population within a Region, to evacuate from that Region. All Scenarios are considered, as well as Staged Evacuation scenarios.
7-3	ETE represents the elapsed time required for 90 percent of the population within the 2-Mile Region, to evacuate from that Region with both Concurrent and Staged Evacuations.
7-4	ETE represents the elapsed time required for 100 percent of the population within the 2-Mile Region, to evacuate from that Region with both Concurrent and Staged Evacuations.

The animation snapshots described in Section 7.3, reflect the ETE statistics for the concurrent (un-staged) evacuation scenarios and regions, which are displayed in Figure 7-3 through Figure 7-7. Most of the congestion is located in Subarea C9, which is beyond the 5-mile area, and is reflected in the ETE statistics:

- The 90th percentile ETE for the 2-Mile Region (R01) generally ranges from 1:25 (hours:minutes) to 2:15 (longer during heavy snow scenarios).
- The 90th percentile ETE for the 5-Mile Region (R02) generally ranges from 2:20 to 2:45 (longer during heavy snow scenarios).
- The 90th percentile ETE for the full EPZ (R03) generally ranges from 2:40 to 2:55 (longer during heavy snow scenarios).
- The 100th percentile ETE for all Regions and Scenarios mirror the trip generation times. This fact implies that the congestion within the EPZ dissipates prior to the end of mobilization, as displayed in Figure 7-7 and discussed in Section 7.3.

Comparison of Scenarios 6 and 13 in Table 7-1 indicates that the Special Event – a refueling outage at the Callaway Energy Center – has little impact on the ETE for the 90th percentile ETE. The additional 991 vehicles at the CEC increases congestion slightly on roadways surrounding the CEC, but congestion quickly dissipates as vehicles are dispersed throughout the network. For most regions, the 90th percentile ETE for Scenario 13 is slightly shorter than Scenario 6 because the added vehicles in Scenario 13 mobilize at a faster rate than the general population, bringing down the overall average 90th percentile ETE.

The Special Event scenario occurs during good weather as this is the most probable weather condition throughout the year. Any ETE increases for rain/light snow or heavy snow can be estimated by comparing effects between Scenarios 6, 7, and 8 and applying any differences to Scenario 13. Note that there is no significant time increase for rain/light snow and about 1 hour and 25 minute increase for heavy snow at the 90th percentile.

Comparison of Scenarios 1 and 14 in Table 7-1 and Table 7-2 indicates that the roadway closure – one lane on I-70 – does not significantly impact ETE because there is no significant congestion on the mainline of I-70. However, the ramps to I-70, especially US-54, do experience congestion. Thus, the mainline is under-utilized and removing a lane does not impact ETE.

7.6 Staged Evacuation Results

Table 7-3 and Table 7-4 present a comparison of the ETE compiled for the concurrent (un-staged) and staged evacuation studies. Note that Regions R34 through R44 are the same geographic areas as Regions R02 and R04 through R13, respectively.

The objective of a staged evacuation strategy is worthy of consideration, one must show that the ETE for the 2-Mile Region can be reduced (30 minutes or 25%, whichever is less) without significantly affecting the region between 2 miles and 5 miles. In all cases, as shown in Table 7-3 and Table 7-4, the ETE for the 2-Mile Region is unchanged when a staged evacuation is implemented. The reason for this is that there is no significant congestion in the 5-mile area. Staging the evacuation to attempt to reduce congestion within the 5-mile area provides no benefits to evacuees from within the 2-Mile Region.

To determine the effect of staged evacuation on residents beyond the 2-mile region, the ETE for Regions R02 and R04 through R13 are compared to Regions R34 through R44, respectively, in Table 7-1 and Table 7-2. A comparison of ETE between these similar regions reveals that

staging increases the 90th percentile ETE for those in the 2 to 5-mile area by at most 15 minutes (see Table 7-1). This extending of ETE is due to the delay in beginning the evacuation trip, experienced by those who shelter, plus the effect of the trip-generation "spike" (significant volume of traffic beginning the evacuation trip at the same time) that follows their eventual ATE, in creating congestion within the EPZ area beyond 2 miles.

In summary, staging evacuation provides no benefit to evacuees within 2 miles of the CEC, and adversely impacts many evacuees located beyond 2 miles from the CEC. Based on the guidance in NUREG-0654, Supplement 3, this analysis would result in staged evacuation not being implemented for this site.

7.7 Guidance on Using ETE Tables

The user first determines the percentile of population for which the ETE is sought (The NRC guidance calls for the 90th percentile). The applicable value of ETE within the chosen table may then be identified using the following procedure:

1. Identify the applicable **Scenario**:
   - Season
     - Summer
     - Winter (also Autumn and Spring)
   - Day of Week
     - Midweek
     - Weekend
   - Time of Day
     - Midday
     - Evening
   - Weather Condition
     - Good Weather
     - Rain/Light Snow
     - Heavy Snow
   - Special Event
     - A Refueling Outage at the Callaway Energy Center
   - Roadway Impact
     - A single lane closed on I-70 eastbound (east of the CEC) and I-70 westbound (west of the CEC), as explained in Section 2.6.
   - Evacuation Staging
     - No, Staged Evacuation is not considered
     - Yes, Staged Evacuation is considered

While these Scenarios are designed, in aggregate, to represent conditions throughout the year, some further clarification is warranted:

- The conditions of a summer evening (either midweek or weekend) and rain/light snow are not explicitly identified in the Tables. For these conditions, Scenarios (2) and (4) apply.

- The conditions of a winter evening (either midweek or weekend) and rain/light snow are not explicitly identified in the Tables. For these conditions, Scenarios (7) and (10) for rain/light snow apply.
- The conditions of a winter evening (either midweek or weekend) and heavy snow are not explicitly identified in the Tables. For these conditions, Scenarios (8) and (11) for heavy snow apply.
- The seasons are defined as follows:
  - Summer assumes public school is in session at summer enrollment levels (lower than normal enrollment).
  - Winter (includes Spring and Autumn) considers that public schools are in session at normal enrollment levels.
- Time of Day: Midday implies the time over which most commuters are at work or are travelling to/from work.

2. With the desired percentile ETE and Scenario identified, now identify the **Evacuation Region**:
   - Determine the projected azimuth direction of the plume (coincident with the wind direction). This direction is expressed in terms of compass orientation: from the N, NNE, NE, etc.
   - Determine the distance that the Evacuation Region will extend from the nuclear power plant. The applicable distances and their associated candidate Regions are given below:
     - 2 Miles (Region R01)
     - To 5 Miles (Region R02, R04 through R13)
     - to EPZ Boundary (Regions R03, R14 through R33)
   - Enter Table 7-5 and identify the applicable group of candidate Regions based on the distance that the selected Region extends from the CEC. Select the Evacuation Region identifier in that row, based on the azimuth direction of the plume, from the first column of the Table.
3. Determine the **ETE Table** based on the **percentile** selected. Then, for the **Scenario** identified in Step 1 and the **Evacuation Region** identified in Step 2, proceed as follows:
   - The columns of Table 7-1 are labeled with the Scenario numbers. Identify the proper column in the selected Table using the Scenario number defined in Step 1.
   - Identify the row in this table that provides ETE values for the Region identified in Step 2.
   - The unique data cell defined by the column and row so determined contains the desired value of ETE expressed in Hours:Minutes.

<u>Example</u>

It is desired to identify the ETE for the following conditions:

- Sunday, August 10th at 10:00 PM.
- It is raining.
- Wind direction is from the southwest (SW).
- Wind speed is such that the distance to be evacuated is judged to be a 2-mile radius

and downwind to 10 miles (to EPZ boundary) with a 3-sector keyhole.

- The desired ETE is that value needed to evacuate 90 percent of the population from within the impacted Region.
- A staged evacuation is not desired.

Table 7-1 is applicable because the 90th percentile ETE is desired. Proceed as follows:

1. Identify the Scenario as summer, weekend, evening and raining. Entering Table 7-1, it is seen that there is no match for these descriptors. However, the clarification given above assigns this combination of circumstances to Scenario 4.
2. Enter Table 7-5 and locate the Region described as “Evacuate 2-Mile Radius and Downwind to the EPZ Boundary” for wind direction from the SW with a 3-sector keyhole and read Region R25 in the first column of that row.
3. Enter Table 7-1 to locate the data cell containing the value of ETE for Scenario 4 and Region R25. This data cell is in column (4) and in the row for Region R25; it contains the ETE value of 2:45.

Table 7-1. Time to Clear the Indicated Area of *__90__* Percent of the Affected Population

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Midday		Midday		Evening	Midday			Midday			Evening	Midday	Midday
Region	Good Weather	Rain/Light Snow	Good Weather	Rain/Light Snow	Good Weather	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R02	2:45	2:45	2:35	2:35	2:35	2:45	2:45	4:00	2:40	2:40	4:00	2:35	2:20	2:45
R03	2:55	2:55	2:40	2:40	2:40	2:50	2:50	4:10	2:40	2:40	4:05	2:40	2:45	2:55
2-Mile Region and Keyhole to 5 Miles														
R04	2:35	2:35	2:35	2:35	2:35	2:35	2:35	3:40	2:35	2:35	3:55	2:35	1:45	2:35
R05	2:35	2:40	2:35	2:35	2:35	2:40	2:40	3:50	2:35	2:35	3:55	2:35	2:00	2:35
R06	2:35	2:35	2:35	2:35	2:35	2:35	2:35	3:50	2:35	2:35	3:55	2:35	1:55	2:35
R07	2:40	2:40	2:35	2:35	2:35	2:40	2:40	4:00	2:35	2:35	4:00	2:35	2:10	2:40
R08	2:35	2:35	2:35	2:35	2:30	2:35	2:35	3:45	2:35	2:35	3:55	2:35	1:55	2:35
R09	2:25	2:25	2:35	2:35	2:35	2:25	2:25	3:35	2:35	2:35	3:55	2:35	1:35	2:25
R10	2:35	2:35	2:35	2:35	2:35	2:35	2:35	3:50	2:35	2:40	4:00	2:35	1:50	2:35
R11	2:20	2:20	2:35	2:35	2:35	2:15	2:15	3:25	2:35	2:35	3:50	2:35	1:35	2:20
R12	2:25	2:25	2:35	2:35	2:35	2:25	2:25	3:30	2:35	2:35	3:55	2:35	1:35	2:25
R13	1:45	1:50	2:25	2:25	2:25	1:45	1:45	2:35	2:25	2:25	3:40	2:25	1:30	1:45
2-Mile Region and Keyhole to EPZ Boundary														
R14	2:50	2:55	2:40	2:40	2:40	2:50	2:50	4:10	2:40	2:40	4:00	2:40	2:35	2:50
R15	2:55	2:55	2:40	2:40	2:40	2:55	2:55	4:20	2:40	2:40	4:00	2:40	2:45	2:55
R16	2:50	2:55	2:40	2:40	2:40	2:50	2:50	4:15	2:40	2:40	4:05	2:40	2:40	2:50
R17	2:55	2:55	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:05	2:40	2:45	2:55
R18	2:55	2:55	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:05	2:40	2:45	2:55
R19	2:55	2:55	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:05	2:40	2:40	2:55
R20	2:55	2:55	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:05	2:40	2:40	2:55
R21	2:50	2:50	2:40	2:40	2:40	2:50	2:50	4:15	2:40	2:40	4:00	2:40	2:40	2:50
R22	2:50	2:50	2:40	2:40	2:40	2:50	2:50	4:15	2:40	2:40	4:00	2:40	2:40	2:50
R23	2:45	2:45	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:00	2:40	2:15	2:45
R24	2:45	2:45	2:40	2:40	2:40	2:45	2:45	4:05	2:40	2:40	4:00	2:40	2:20	2:45
R25	2:45	2:45	2:40	2:45	2:40	2:45	2:45	4:00	2:40	2:45	4:00	2:40	2:15	2:45
R26	2:50	2:50	2:45	2:45	2:45	2:50	2:50	4:10	2:45	2:45	4:05	2:45	2:25	2:50
R27	2:50	2:50	2:45	2:45	2:45	2:50	2:50	4:10	2:45	2:45	4:05	2:45	2:25	2:50
R28	2:45	2:45	2:40	2:45	2:40	2:45	2:45	4:05	2:40	2:45	4:00	2:40	2:15	2:45
R29	2:50	2:50	2:40	2:45	2:40	2:50	2:50	4:10	2:40	2:45	4:00	2:40	2:30	2:50
R30	2:50	2:50	2:40	2:45	2:40	2:50	2:50	4:05	2:40	2:45	4:00	2:40	2:25	2:50
R31	2:45	2:45	2:40	2:40	2:40	2:45	2:45	3:50	2:40	2:40	3:55	2:40	2:00	2:45
R32	2:45	2:45	2:40	2:40	2:40	2:45	2:45	4:00	2:40	2:40	4:00	2:40	2:20	2:45
R33	2:45	2:45	2:40	2:40	2:40	2:45	2:45	4:00	2:40	2:40	3:55	2:40	2:15	2:45

Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R34	2:45	2:45	2:50	2:50	2:50	2:45	2:45	4:05	2:50	2:50	4:00	2:50	2:20	2:45
R35	2:35	2:35	2:45	2:45	2:45	2:35	2:35	3:40	2:45	2:45	3:55	2:45	1:50	2:35
R36	2:40	2:40	2:45	2:45	2:45	2:40	2:40	3:50	2:45	2:45	3:55	2:45	2:00	2:40
R37	2:35	2:35	2:45	2:45	2:45	2:35	2:35	3:50	2:45	2:45	3:55	2:45	1:55	2:35
R38	2:40	2:40	2:45	2:45	2:45	2:40	2:40	4:00	2:45	2:45	4:00	2:45	2:10	2:40
R39	2:35	2:35	2:45	2:45	2:45	2:35	2:35	3:45	2:45	2:45	3:55	2:45	1:55	2:35
R40	2:25	2:25	2:45	2:45	2:45	2:25	2:25	3:35	2:45	2:45	3:55	2:45	1:45	2:25
R41	2:35	2:35	2:50	2:50	2:50	2:35	2:35	3:50	2:50	2:50	4:00	2:50	1:55	2:35
R42	2:20	2:20	2:50	2:50	2:50	2:20	2:20	3:25	2:50	2:50	3:55	2:50	1:40	2:20
R43	2:25	2:25	2:50	2:50	2:50	2:25	2:25	3:30	2:50	2:50	3:55	2:50	1:45	2:25
R44	1:50	1:50	2:40	2:40	2:40	1:50	1:50	2:40	2:40	2:40	3:50	2:40	1:30	1:50

Table 7-2. Time to Clear the Indicated Area of *100* Percent of the Affected Population

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Midday	Midday
	Good Weather	Rain/Light Snow	Good Weather	Rain/Light Snow	Good Weather	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R02	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R03	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
2-Mile Region and Keyhole to 5 Miles														
R04	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R05	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R06	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R07	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R08	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R09	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R10	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R11	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R12	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R13	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
2-Mile Region and Keyhole to EPZ Boundary														
R14	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R15	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R16	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R17	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R18	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R19	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R20	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R21	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R22	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R23	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R24	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R25	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R26	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R27	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R28	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R29	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R30	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R31	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R32	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55
R33	4:55	4:55	4:55	4:55	4:55	4:55	4:55	6:55	4:55	4:55	6:55	4:55	4:55	4:55

Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R34	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R35	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R36	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R37	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R38	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R39	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R40	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R41	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R42	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R43	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50
R44	4:50	4:50	4:50	4:50	4:50	4:50	4:50	6:50	4:50	4:50	6:50	4:50	4:50	4:50

Table 7-3. Time to Clear *90* Percent of the 2-Mile Region within the Indicated Region

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain/Light Snow	Good Weather	Rain/Light Snow	Good Weather	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region and 5-Mile Region														
R01	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R02	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
Unstaged Evacuation - 2-Mile Region and Keyhole to 5-Miles														
R04	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R05	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R06	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R07	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R08	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R09	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R10	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R11	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R12	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R13	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
Staged Evacuation - 2-Mile Region and Keyhole to 5-Miles														
R34	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R35	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R36	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R37	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R38	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R39	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R40	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R41	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R42	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R43	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25
R44	1:25	1:25	2:15	2:15	2:10	1:25	1:25	1:40	2:15	2:15	3:30	2:15	1:30	1:25

Table 7-4. Time to Clear *100* Percent of the 2-Mile Region within the Indicated Region

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain/Light Snow	Good Weather	Rain/Light Snow	Good Weather	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Rain/Light Snow	Heavy Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region and 5-Mile Region														
R01	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R02	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
Unstaged Evacuation - 2-Mile Region and Keyhole to 5-Miles														
R04	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R05	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R06	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R07	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R08	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R09	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R10	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R11	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R12	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R13	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
Staged Evacuation - 2-Mile Region and Keyhole to 5-Miles														
R34	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R35	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R36	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R37	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R38	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R39	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R40	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R41	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R42	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R43	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45
R44	4:45	4:45	4:45	4:45	4:45	4:45	4:45	6:45	4:45	4:45	6:45	4:45	4:45	4:45

Table 7-5. Description of Evacuation Regions

Radial Regions																
Region	Description:	Subarea														
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R01	2-Mile Radius	X														
R02	5-Mile Radius	X	X	X	X	X	X									
R03	Full EPZ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Evacuate 2-Mile Region and Downwind to 5 Miles																		
Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R04	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	X				X	X									
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	See Region R04														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)	See Region R04														
-	38 - 52	K, L, M	NE (3-Sector Keyhole)	See Region R04														
R05	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	X	X			X	X									
R06	60 - 75	L, M, N	ENE (3-Sector Keyhole)	X	X				X									
-	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	See Region R06														
-	83 - 97	M, N, P	E (3-Sector Keyhole)	See Region R06														
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)	See Region R06														
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)	See Region R06														

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R07	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	X	X	X			X									
R08	128 - 142	P, Q, R	SE (3-Sector Keyhole)	X	X	X												
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	**See Region R08**														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)	**See Region R08**														
-	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)	**See Region R08**														
-	173 - 187	R, A, B	S (3-Sector Keyhole)	**See Region R08**														
-	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)	**See Region R08**														
R09	195 - 210	A, B, C	SSW (3-Sector Keyhole)	X		X												
R10	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	X		X	X											
-	218 - 232	B, C, D	SW (3-Sector Keyhole)	**See Region R10**														
-	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)	**See Region R10**														
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)	**See Region R10**														
-	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)	**See Region R10**														
R11	263 - 277	D, E, F	W (3-Sector Keyhole)	X			X											

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R12	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	X			X	X										
-	285 - 300	E, F, G	WNW (3-Sector Keyhole)	**See Region R12**														
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)	**See Region R12**														
-	308 - 322	F, G, H	NW (3-Sector Keyhole)	**See Region R12**														
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)	**See Region R12**														
R13	330 - 345	G, H, J	NNW (3-Sector Keyhole)	X				X										
-	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	**See Region R04**														
-	353 - 7	H, J, K	N (3-Sector Keyhole)	**See Region R04**														
Evacuate 2-Mile Radius and Downwind to the EPZ Boundary																		
Region	**Wind Direction From: (Degrees)**	**Sectors:**	**Cardinal Compass Equivalent:**	**Subarea**														
				C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**G1**	**M1**	**M2**	**O1**
R14	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	X				X	X	X								X
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	**See Region R14**														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)	**See Region R14**														
-	38 - 52	K, L, M	NE (3-Sector Keyhole)	**See Region R14**														

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R15	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	X	X			X	X	X	X							X
R16	60 - 75	L, M, N	ENE (3-Sector Keyhole)	X	X				X	X	X							
R17	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	X	X				X	X	X	X						
-	83 - 97	M, N, P	E (3-Sector Keyhole)	**See Region R17**														
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)															
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)															
R18	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	X	X	X			X	X	X	X	X					
R19	128 - 142	P, Q, R	SE (3-Sector Keyhole)	X	X	X					X	X	X					
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	**See Region R19**														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)															
R20	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)	X	X	X					X	X	X	X				
R21	173 - 187	R, A, B	S (3-Sector Keyhole)	X	X	X					X		X	X				
R22	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)	X	X	X					X		X	X		X		
R23	195 - 210	A, B, C	SSW (3-Sector Keyhole)	X		X							X	X		X		
R24	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	X		X	X						X	X		X		
R25	218 - 232	B, C, D	SW (3-Sector Keyhole)	X		X	X							X		X		

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R26	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)	X		X	X							X		X	X	
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)	**See Region R26**														
R27	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)	X		X	X							X	X	X	X	
R28	263 - 277	D, E, F	W (3-Sector Keyhole)	X			X							X	X	X	X	
R29	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	X			X	X						X	X	X	X	X
R30	285 - 300	E, F, G	WNW (3-Sector Keyhole)	X			X	X							X		X	X
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)	**See Region R30**														
-	308 - 322	F, G, H	NW (3-Sector Keyhole)															
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)															
R31	330 - 345	G, H, J	NNW (3-Sector Keyhole)	X				X							X			X
R32	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	X				X	X						X			X
R33	353 - 7	H, J, K	N (3-Sector Keyhole)	X				X	X									X

Staged Evacuation - 2-Mile Radius Evacuates, then Evacuate Downwind to 5 Miles																		
Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R34	5-Mile Radius			X	X	X	X	X	X									
R35	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	X				X	X									
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	See Region R35														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)	See Region R35														
-	38 - 52	K, L, M	NE (3-Sector Keyhole)	See Region R35														
R36	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	X	X			X	X									
R37	60 - 75	L, M, N	ENE (3-Sector Keyhole)	X	X				X									
-	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	See Region R37														
-	83 - 97	M, N, P	E (3-Sector Keyhole)	See Region R37														
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)	See Region R37														
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)	See Region R37														
R38	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	X	X	X			X									

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R39	128 - 142	P, Q, R	SE (3-Sector Keyhole)	X	X	X												
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	See Region R39														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)	See Region R39														
-	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)	See Region R39														
-	173 - 187	R, A, B	S (3-Sector Keyhole)	See Region R39														
-	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)	See Region R39														
R40	195 - 210	A, B, C	SSW (3-Sector Keyhole)	X		X												
R41	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	X		X	X											
-	218 - 232	B, C, D	SW (3-Sector Keyhole)	See Region R41														
-	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)	See Region R41														
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)	See Region R41														
-	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)	See Region R41														
R42	263 - 277	D, E, F	W (3-Sector Keyhole)	X			X											

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R43	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	X			X	X										
-	285 - 300	E, F, G	WNW (3-Sector Keyhole)	**See Region R43**														
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)	**See Region R43**														
-	308 - 322	F, G, H	NW (3-Sector Keyhole)	**See Region R43**														
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)	**See Region R43**														
R44	330 - 345	G, H, J	NNW (3-Sector Keyhole)	X				X										
-	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	**See Region R35**														
-	353 - 7	H, J, K	N (3-Sector Keyhole)	**See Region R35**														

Subarea(s) Evacuate	Subarea(s) Shelter-in-Place	Shelter-in-Place until 90% ETE for R01, then Evacuate

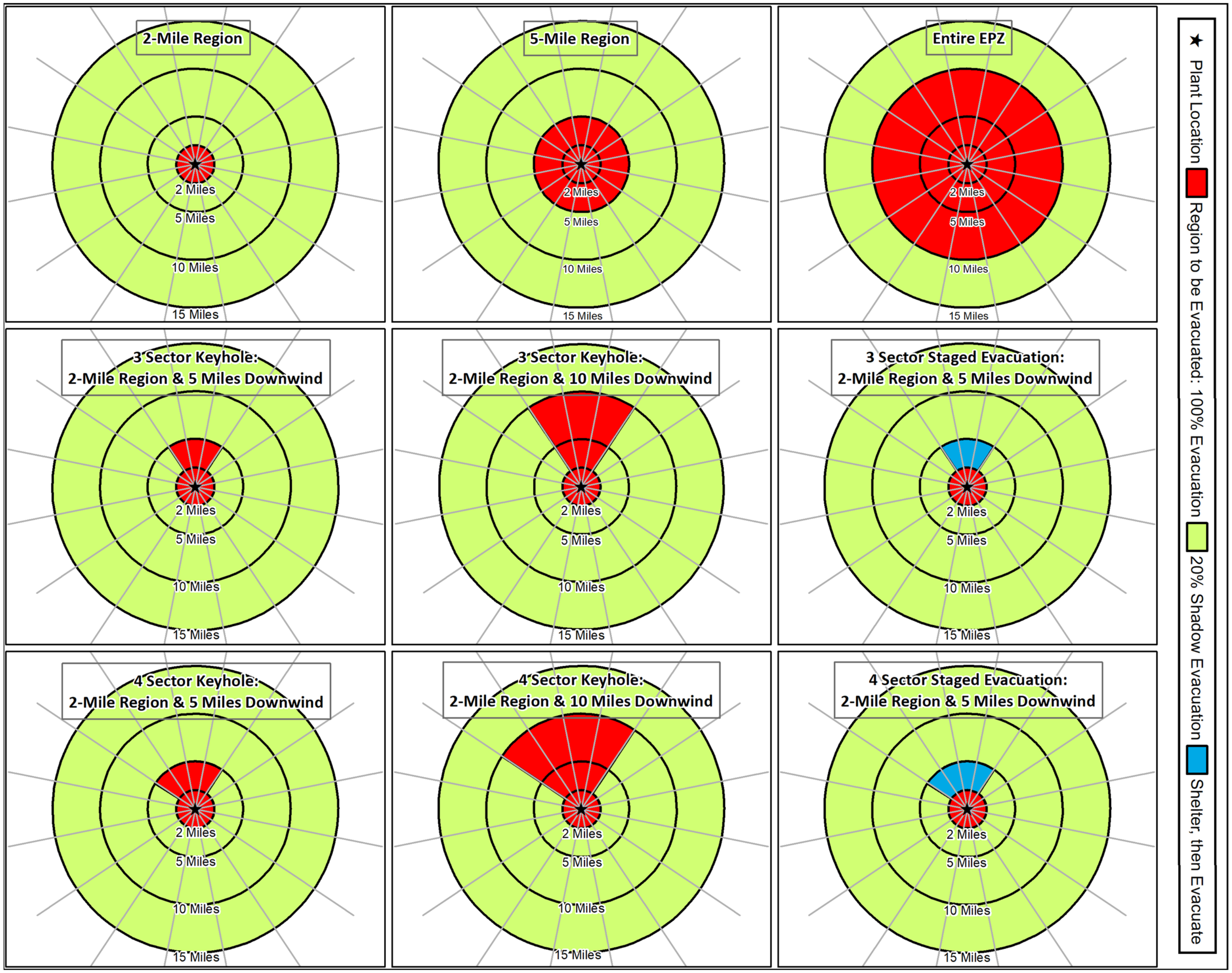


Figure 7-1. Voluntary Evacuation Methodology

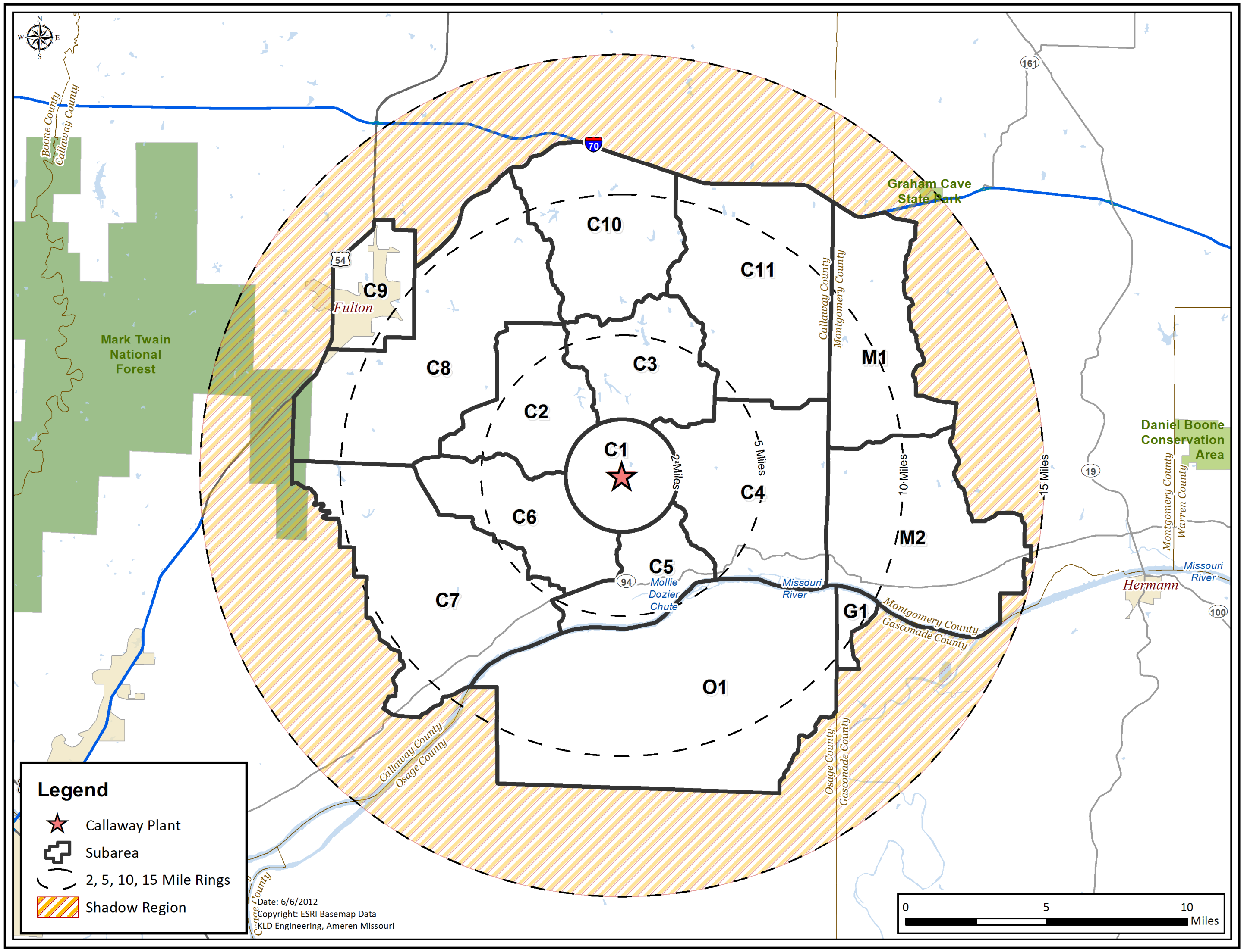


Figure 7-2. Callaway Energy Center Shadow Region

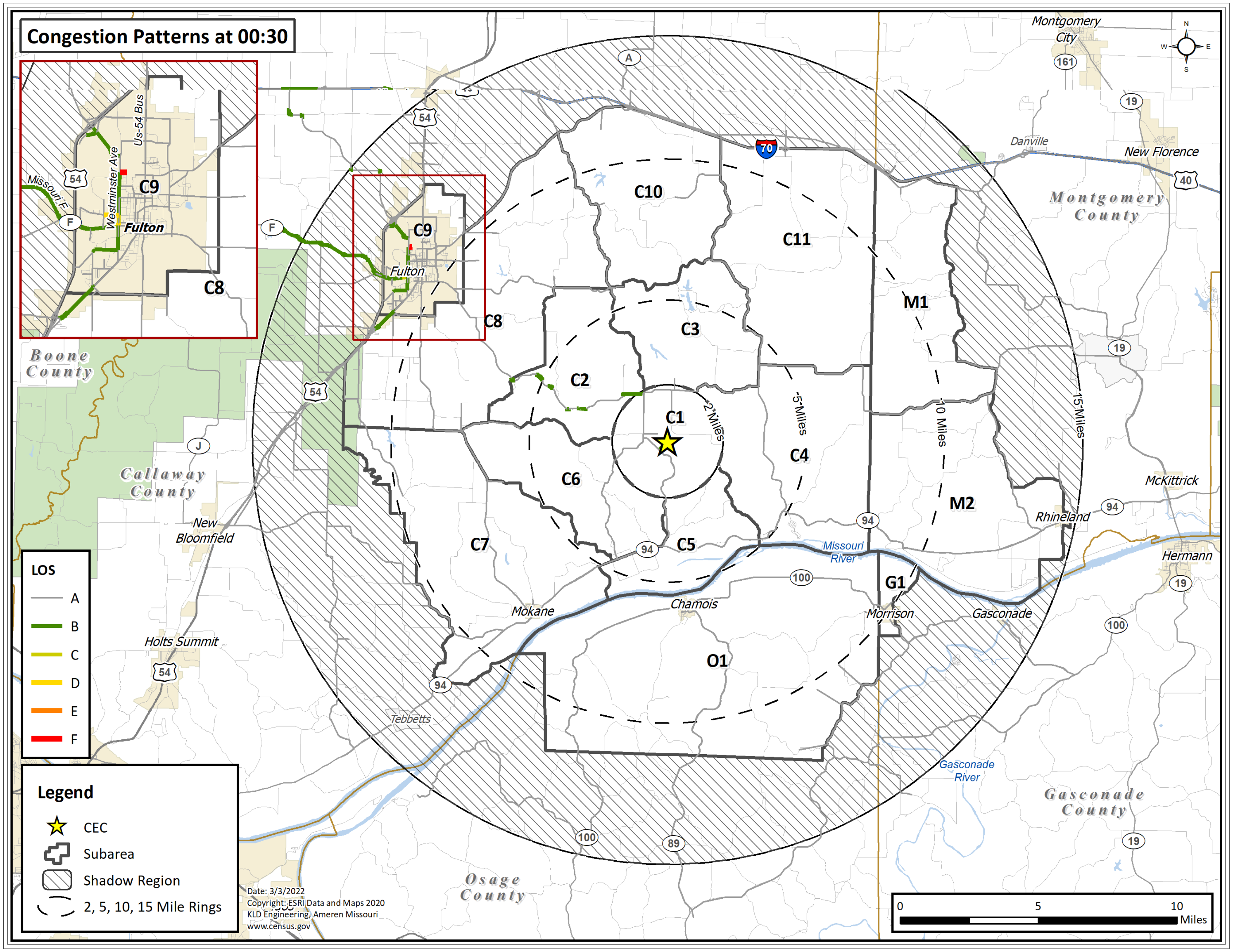


Figure 7-3. Congestion Patterns at 30 Minutes after the ATE

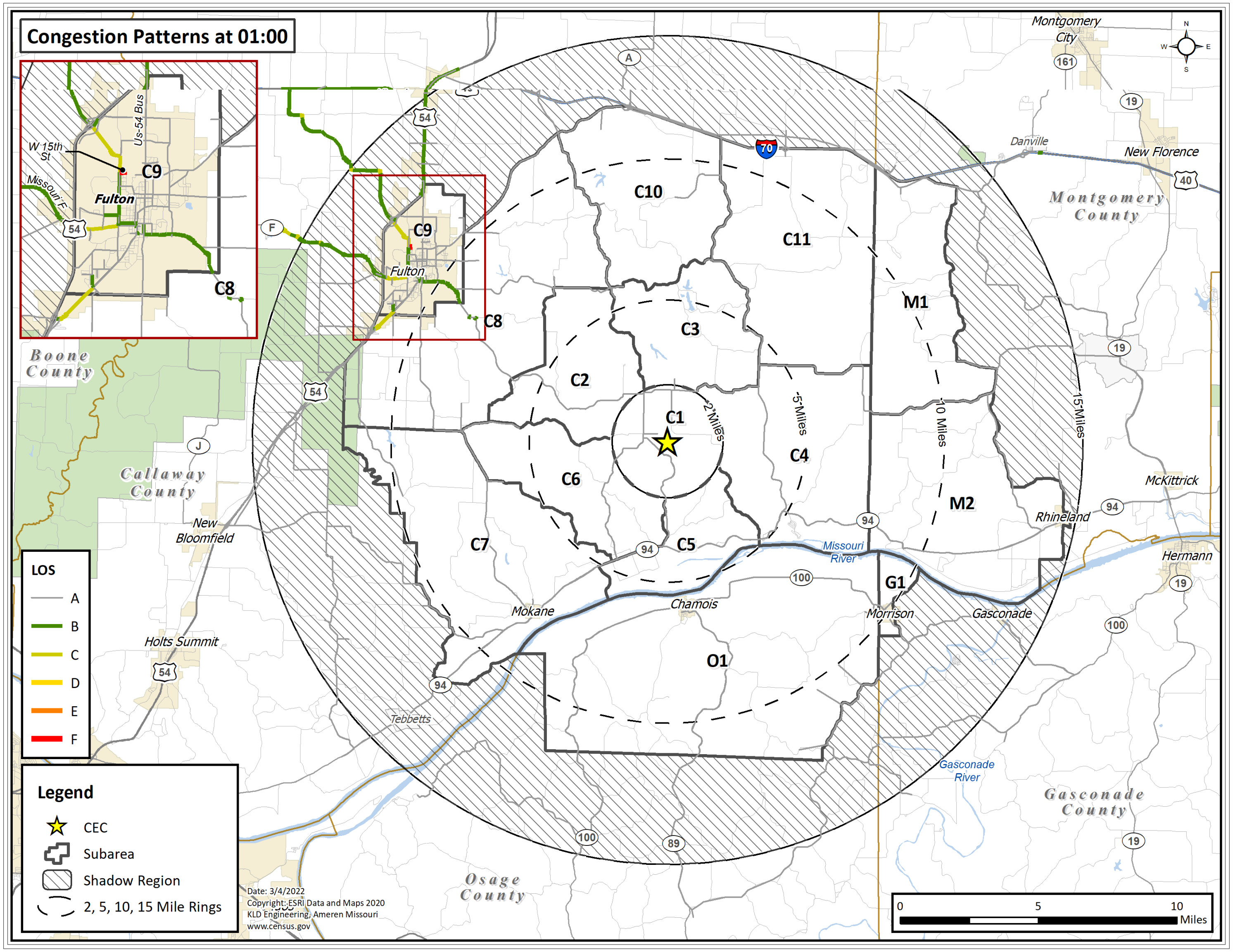


Figure 7-4. Congestion Patterns at 1 Hour after the ATE

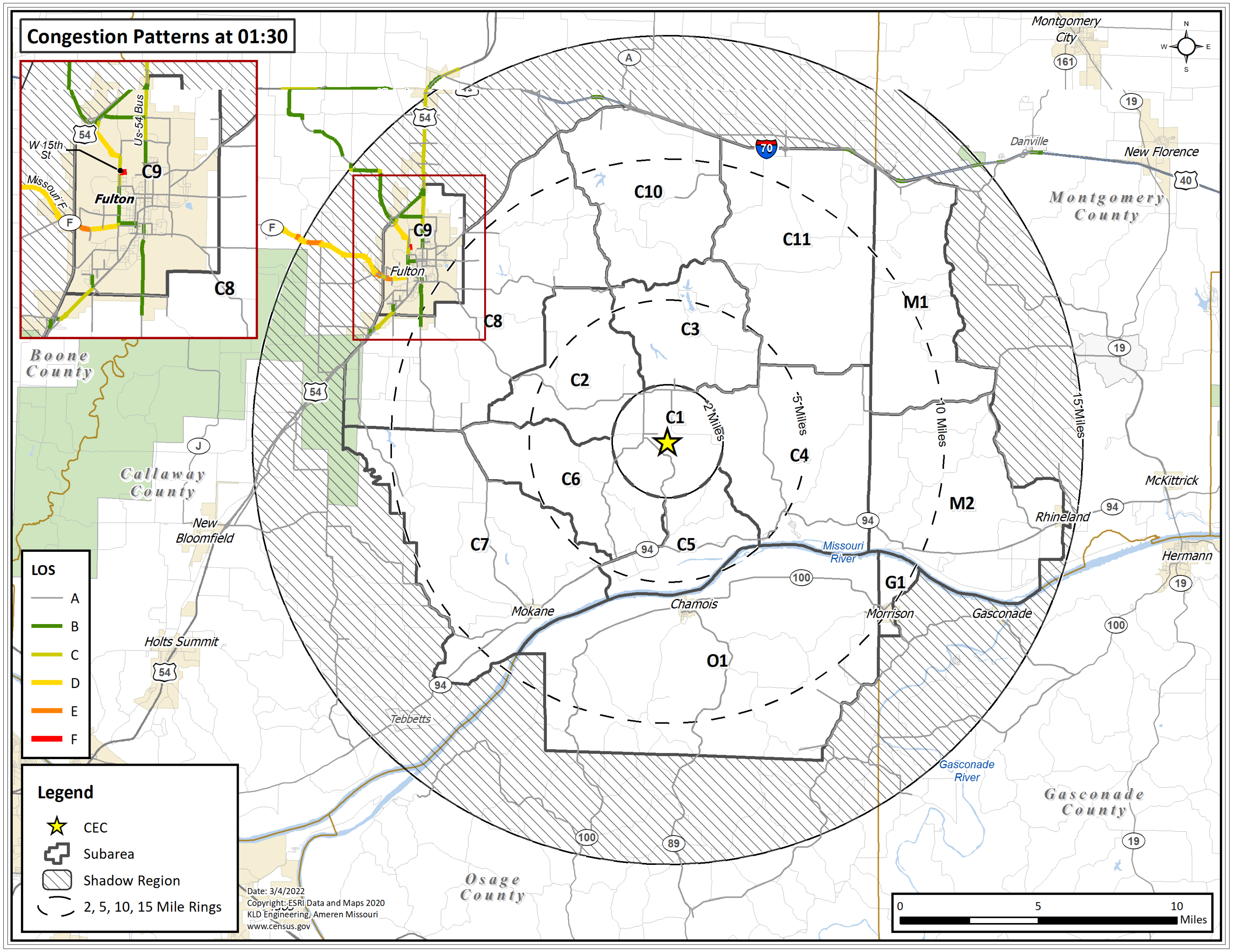


Figure 7-5. Congestion Patterns at 1 Hour and 30 Minutes after the ATE

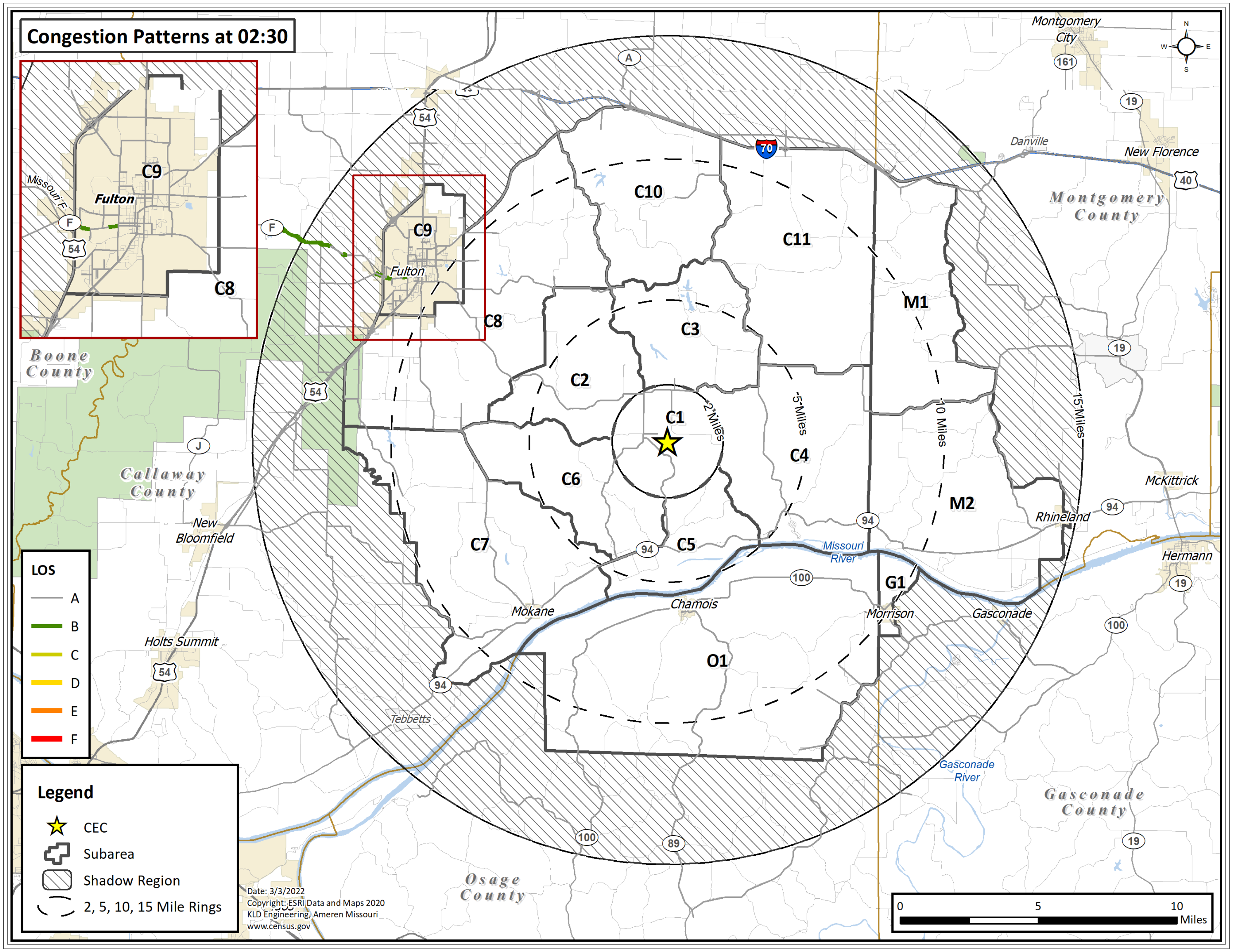


Figure 7-6. Congestion Patterns at 2 Hours and 30 Minutes after the ATE

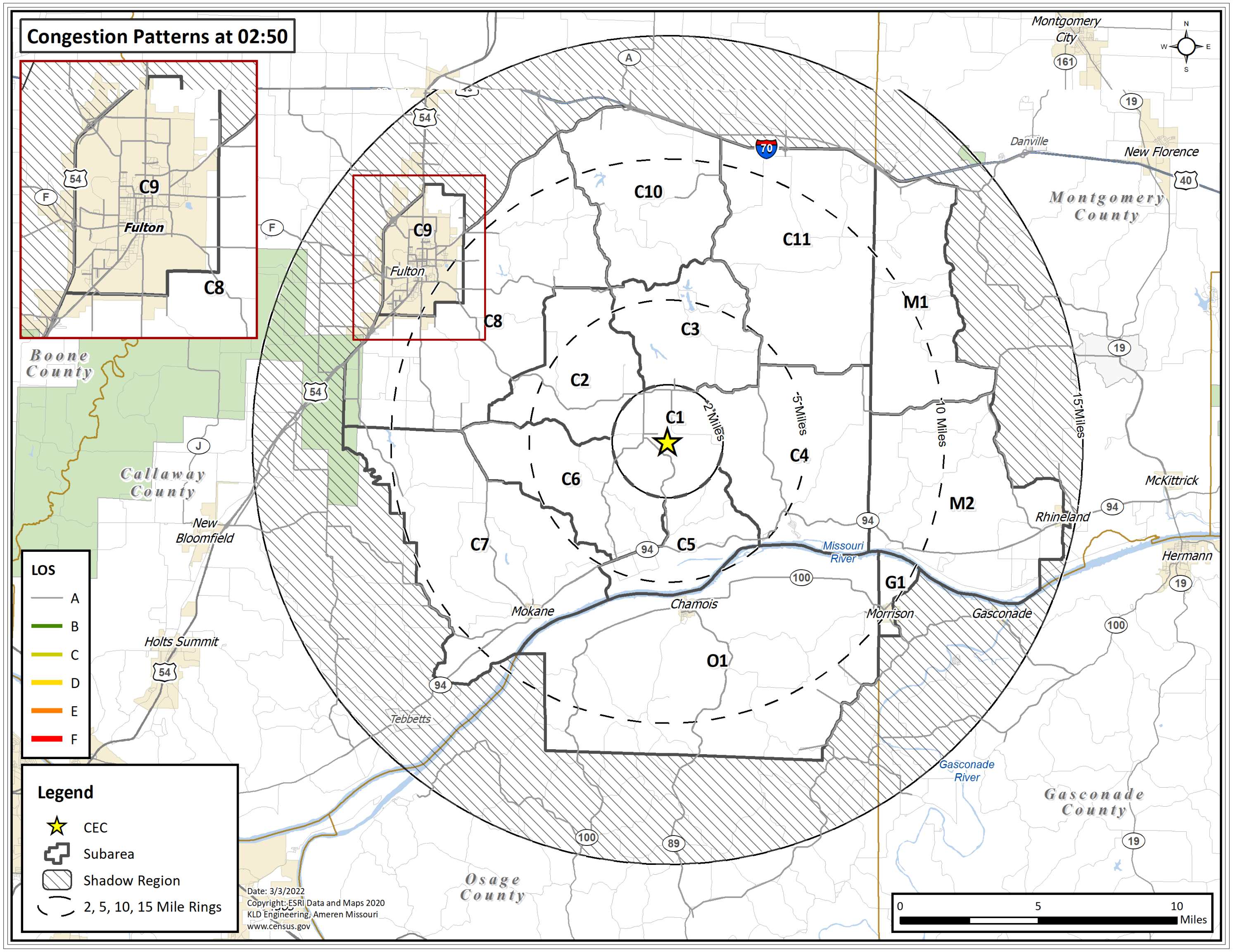


Figure 7-7. Congestion Patterns at 2 Hours and 50 Minutes after the ATE

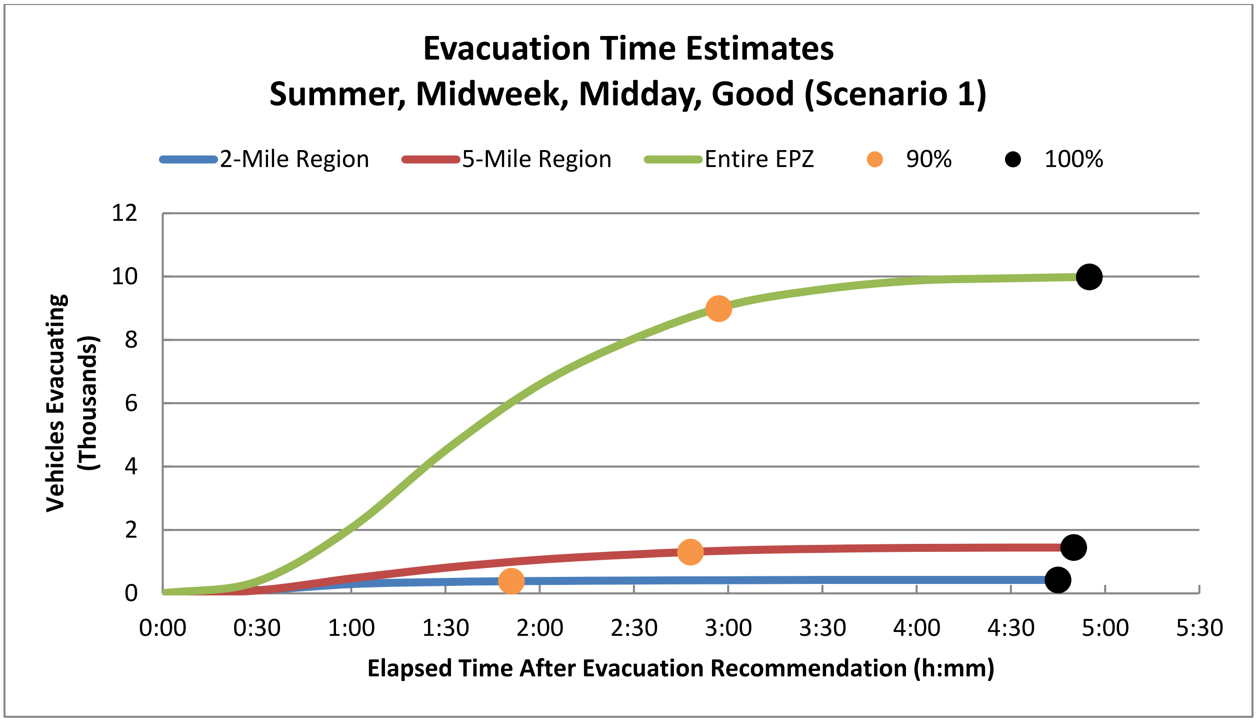


Figure 7-8. Evacuation Time Estimates – Scenario 1 for Region R03

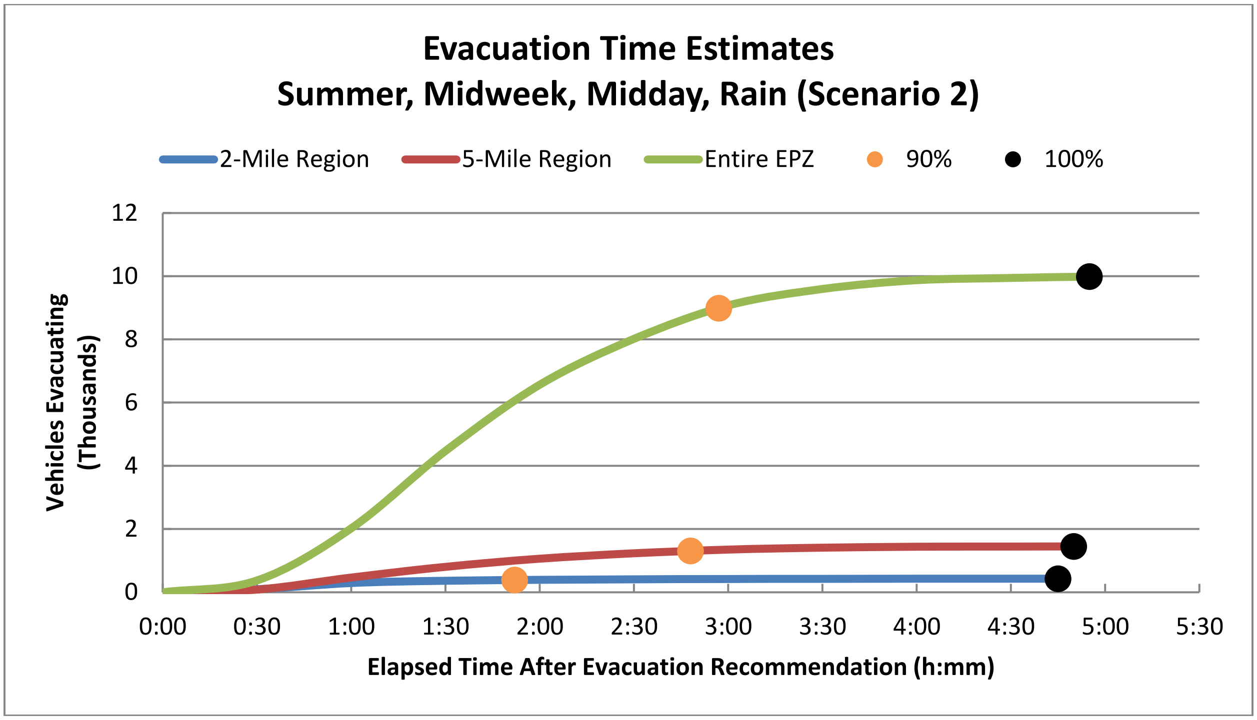


Figure 7-9**. Evacuation Time Estimates – Scenario 2 for Region R03**

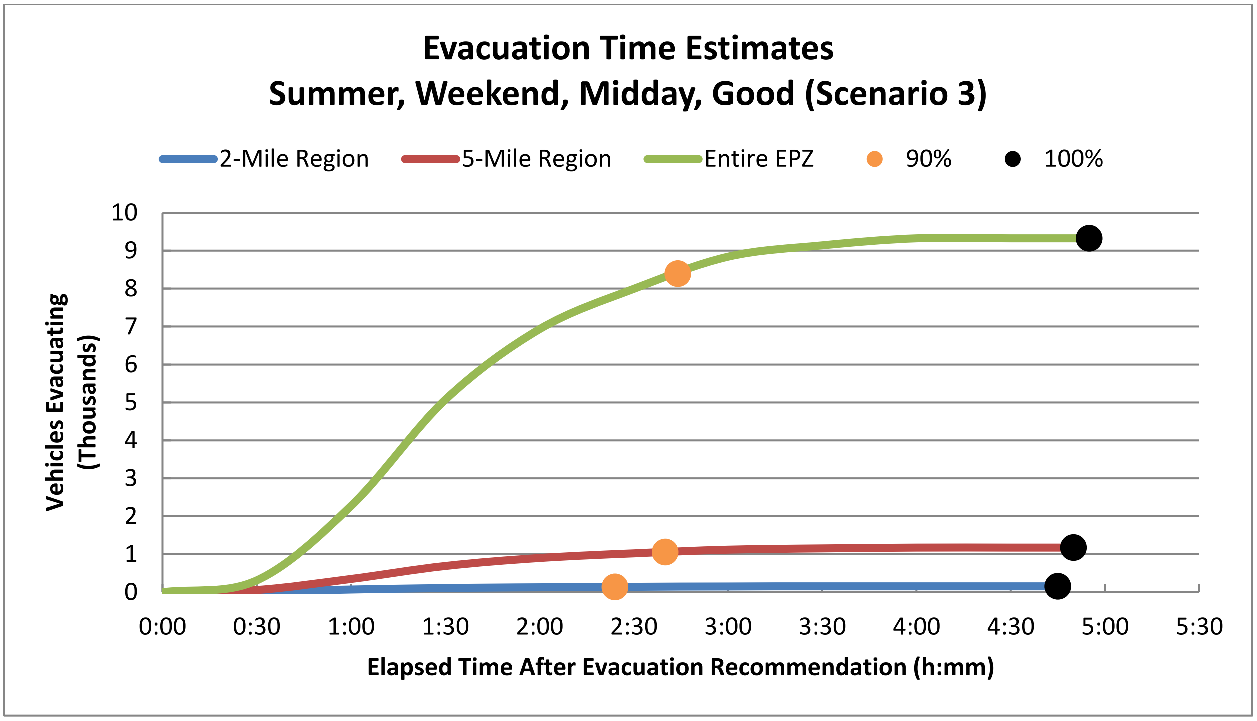


Figure 7-10. Evacuation Time Estimates – Scenario 3 for Region R03

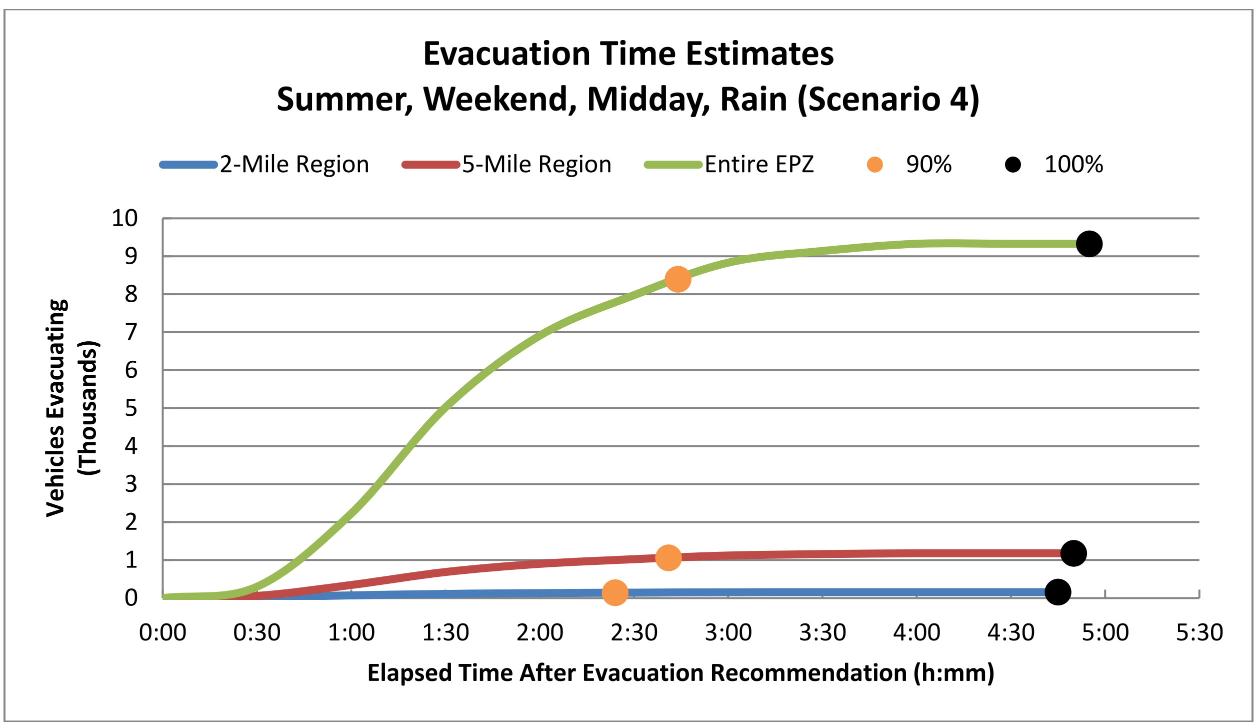


Figure 7-11. Evacuation Time Estimates – Scenario 4 for Region R03

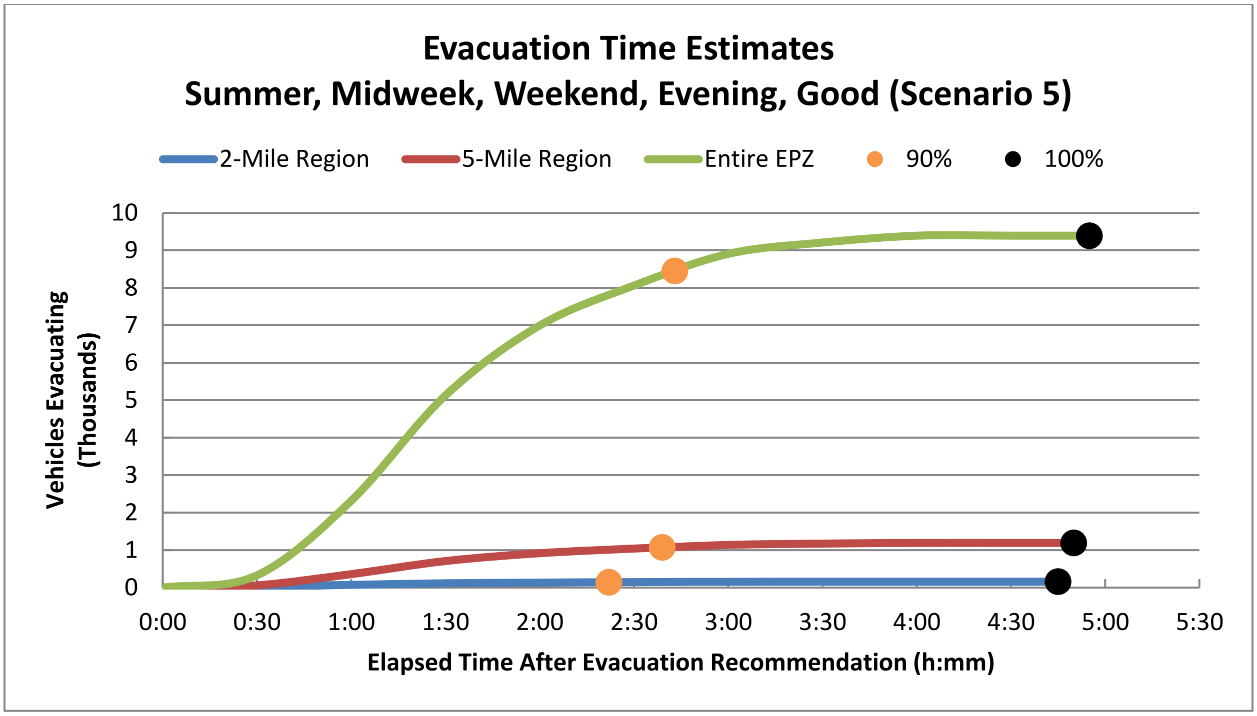


Figure 7-12. Evacuation Time Estimates – Scenario 5 for Region R03

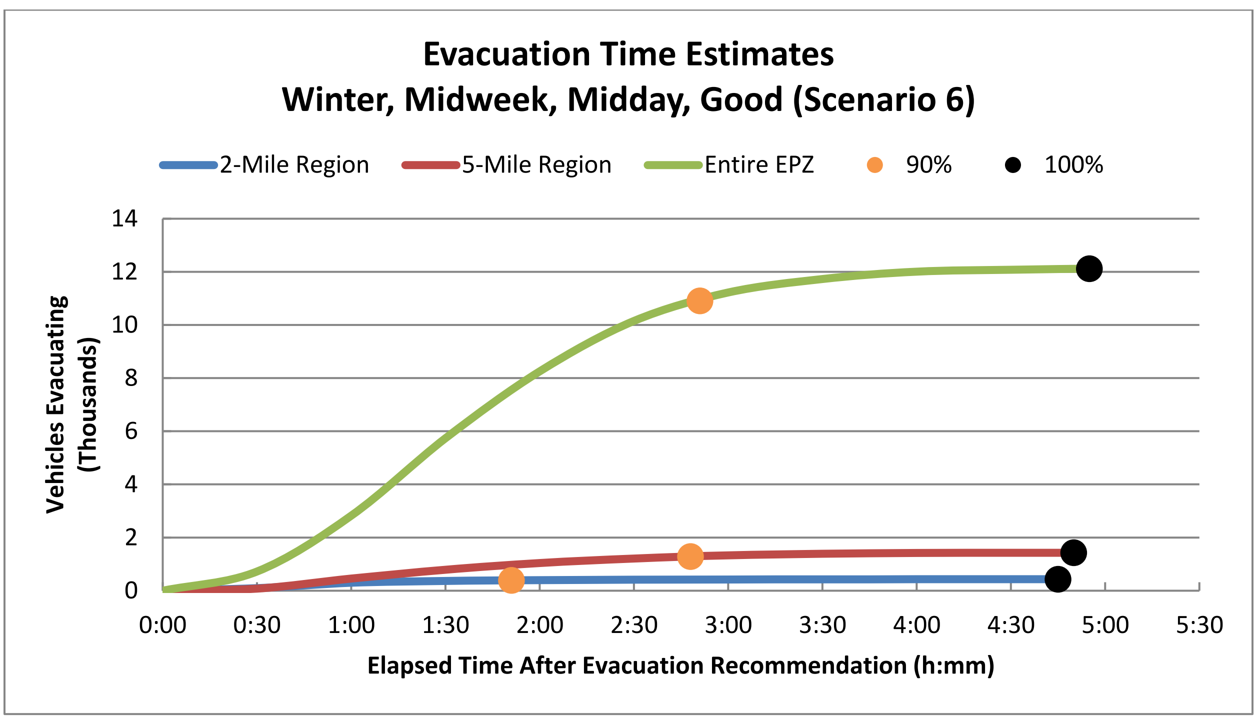


Figure 7-13. Evacuation Time Estimates – Scenario 6 for Region R03

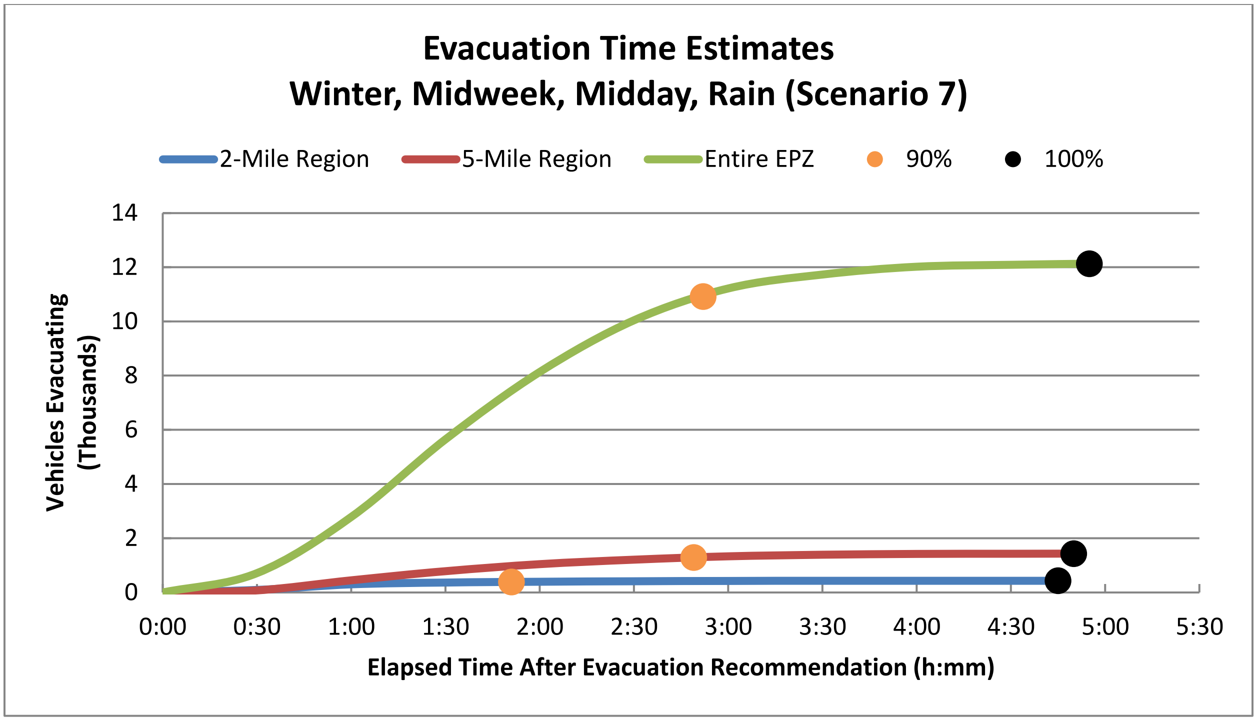


Figure 7-14. Evacuation Time Estimates – Scenario 7 for Region R03

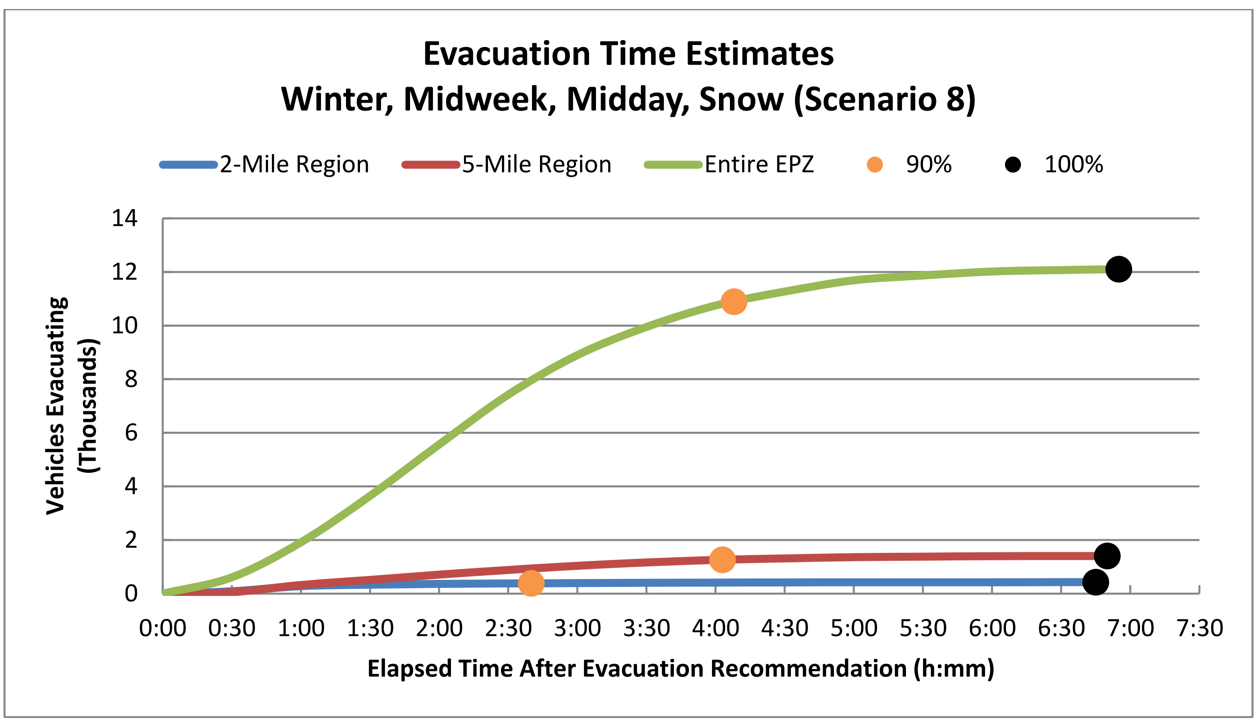


Figure 7-15. Evacuation Time Estimates – Scenario 8 for Region R03

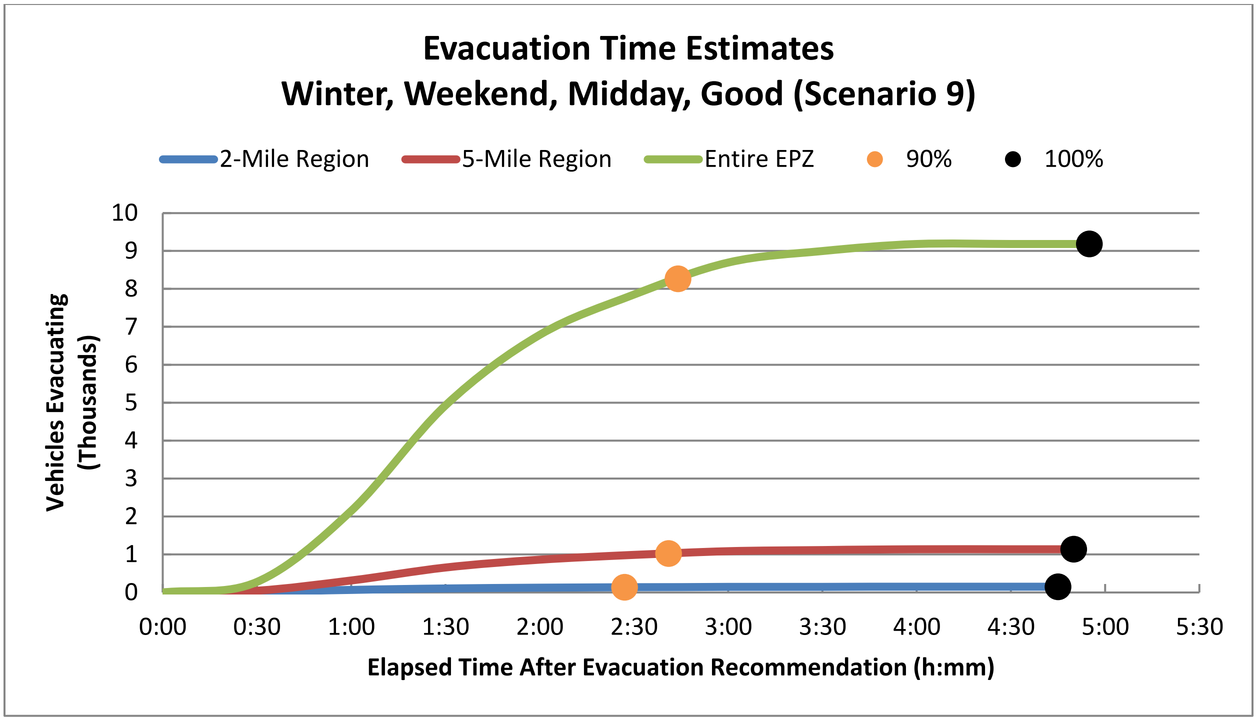


Figure 7-16. Evacuation Time Estimates – Scenario 9 for Region R03

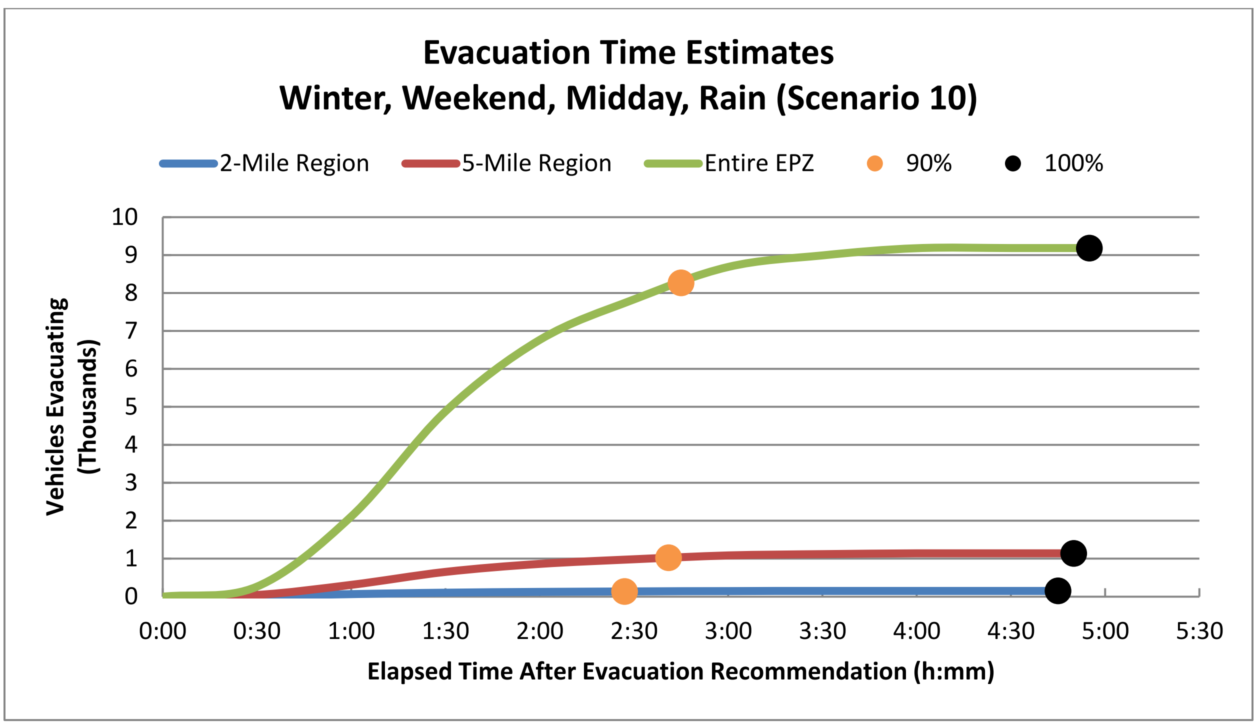


Figure 7-17. Evacuation Time Estimates – Scenario 10 for Region R03

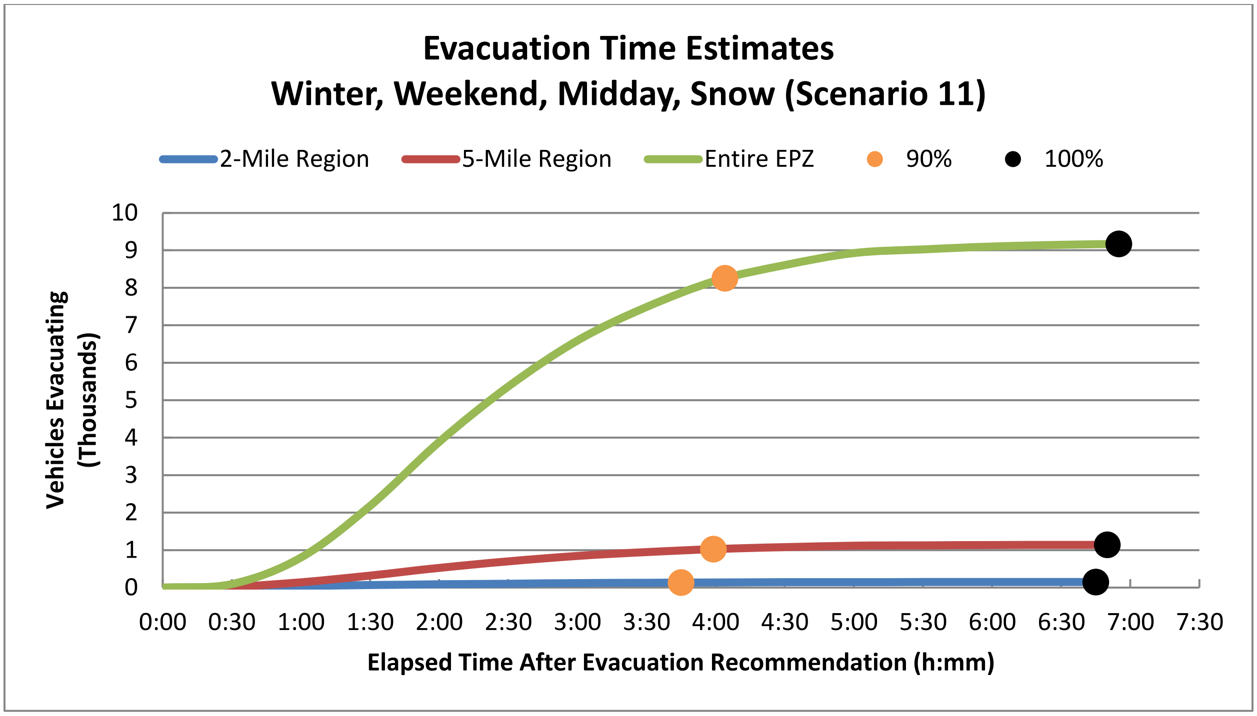


Figure 7-18. Evacuation Time Estimates – Scenario 11 for Region R03

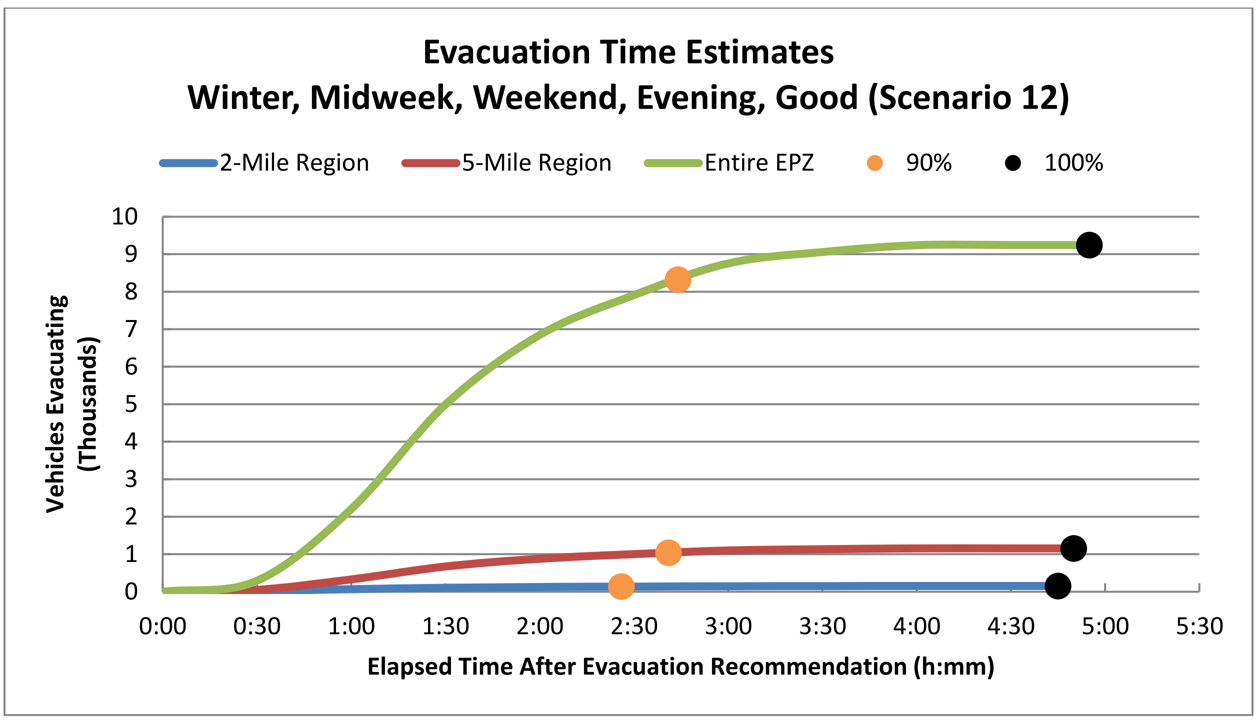


Figure 7-19. Evacuation Time Estimates – Scenario 12 for Region R03

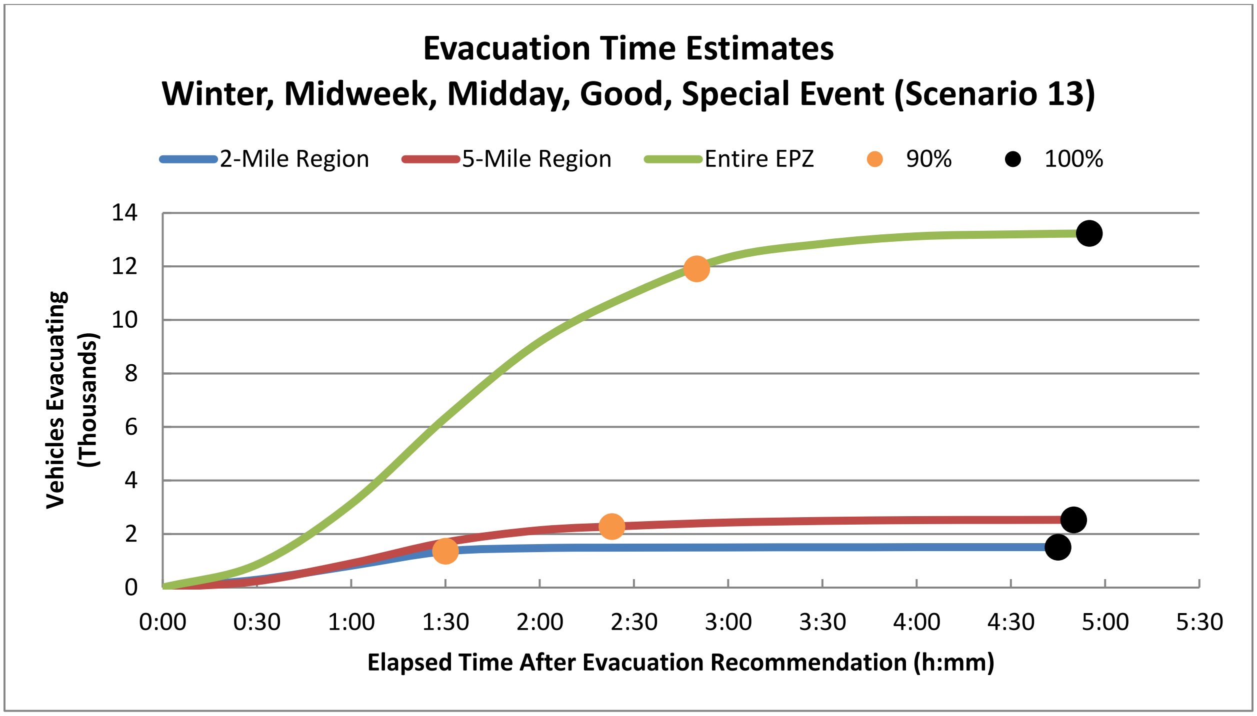


Figure 7-20. Evacuation Time Estimates – Scenario 13 for Region R03

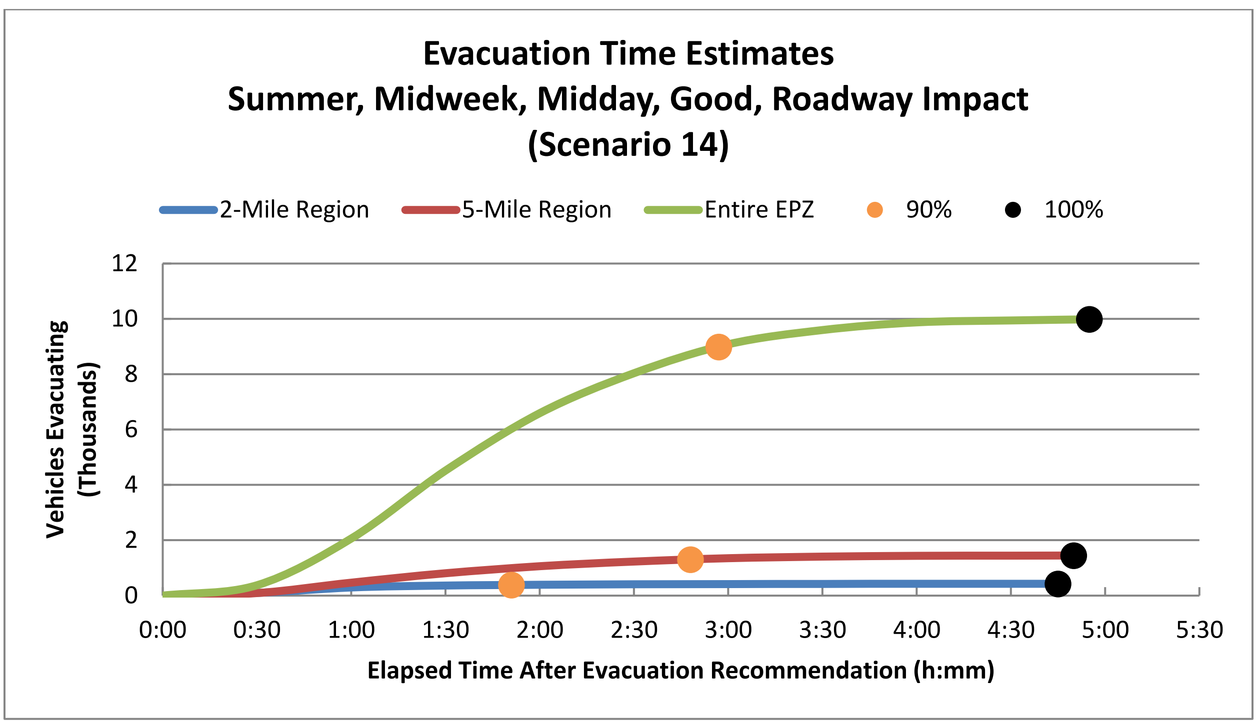


Figure 7-21. Evacuation Time Estimates – Scenario 14 for Region R03

8 TRANSIT-DEPENDENT AND SCHOOL EVACUATION TIME ESTIMATES

This section details the analyses applied and the results obtained in the form of Evacuation Time Estimates (ETE) for transit vehicles (buses, wheelchair buses and ambulances). The demand for transit service reflects the needs of three population groups: (1) residents with no vehicles available; (2) residents of special facilities such as schools; and (3) access and/or functional needs population.

These transit vehicles mix with the general evacuating traffic that is comprised mostly of "passenger cars" (pc's). The presence of each bus in the evacuating traffic stream is represented within the modeling paradigm described in Appendix D as equivalent to two pc's. This equivalence factor represents the longer size and more sluggish operating characteristics of a transit vehicle, relative to those of a pc. An ambulance is treated as one pc.

Transit vehicles must be mobilized in preparation for their respective evacuation missions. Specifically:

- Bus drivers must be alerted
- They must travel to the bus depot
- They must be briefed there and assigned to a route or facility

These activities consume time. Based on discussion with offsite agencies, it is estimated that bus mobilization time for schools will average approximately 90 minutes extending from the Advisory to Evacuate (ATE), to the time when buses first arrive at the facility to be evacuated. It is assumed transit dependent buses and access and/or functional needs vehicles are mobilized when about 90% of the residents with no commuters have completed their mobilization activities at 150 minutes after the ATE, as discussed in item 4b of Section 2.4.

During this mobilization period, other mobilization activities are taking place. One of these is the action taken by parents, neighbors, relatives and friends to pick up children from school prior to the arrival of buses, so that they may join their families. Virtually all studies of evacuations have concluded that this "bonding" process of uniting families is universally prevalent during emergencies and should be anticipated in the planning process. The current public information disseminated to residents of the Callaway Energy Center (CEC) Emergency Planning Zone (EPZ) indicates that each school has its own evacuation plan and covers where children will go if their school is in an evacuation area. Emergency Alert System (EAS) stations will give information about school actions.

As discussed in Section 2, this study assumes a fast-breaking general emergency. This report provides estimates of buses under the assumption that no children will be picked up by their parents (in accordance with NUREG/CR-7002, Rev. 1) to present an upper bound estimate of buses required. Picking up children at school could add to traffic congestion at the schools, delaying the departure of the buses evacuating schoolchildren, which may have to return in a subsequent "wave" to the EPZ to evacuate the transit-dependent population.

Based on the emergency plans provided by the offsite agencies, children at day-care centers should be picked up by parents or guardians. It is assumed that the time to perform this activity is included in the trip generation times discussed in Section 5.

The procedure for computing transit-dependent ETE is to:

- Estimate demand for transit service (discussed in Section 3)
- Estimate time to perform all transit functions
- Estimate route travel times to the EPZ boundary and to the reception centers

Figure 8-1 presents the chronology of events relevant to transit operations. The elapsed time for each activity will now be discussed with reference to Figure 8-1.

8.1 ETEs for Schools and Transit Dependent People

The EPZ bus resources are assigned to evacuating schoolchildren (if schools are in session at the time of the ATE) as the first priority in the event of an emergency. In the event that the allocation of buses dispatched from the depots to the various facilities and to the bus routes is somewhat "inefficient", or if there is a shortfall of available drivers, then there may be a need for some buses to return to the EPZ from the reception center after completing their first evacuation trip, to complete a "second wave" of providing transportation service to evacuees. The number of available transportation resources were provided by the offsite agencies. Table 8-1 summarizes the capacity of transportation resources. Also included in the table is the transportation resource capacity needed to evacuate schools, transit-dependent population, and access and/or functional needs (discussed below in Section 8.2). There are no transportation resources needed for medical and correction facilities as they will shelter-in-place (discussed in Section 2.4). There are sufficient bus resources available to evacuate the schoolchildren and transit-dependent population in the EPZ in a single wave. Furthermore, if the impacted Evacuation Region is other than R03 (the entire EPZ), then there will likely be ample transit resources relative to demand in the impacted Region.

When school evacuation needs are satisfied, subsequent assignments of buses to service the transit-dependent should be sensitive to their mobilization time. Clearly, the buses should be dispatched after people have completed their mobilization activities and are in a position to board the buses when they arrive along the transit routes.

Evacuation of Schools

Activity: Mobilize Drivers (A→B→C)

Mobilization time is the elapsed time from the ATE until the time the buses arrive at the school to be evacuated. As previously stated, it is assumed that for a rapidly escalating radiological emergency with no observable indication before the fact, drivers would require 90 minutes to be contacted, to travel to the depot, be briefed, and to travel to the schools. Mobilization time is slightly longer in adverse weather – 100 minutes in rain/light snow and 110 minutes in heavy snow conditions.

Activity: Board Passengers (C→D)

As discussed in Section 2.6, a loading time of 15 minutes for good weather (20 minutes for rain/light snow and 25 minutes for heavy snow) for school buses is used.

Activity: Travel to EPZ Boundary (D→E)

The buses servicing the schools are ready to begin their evacuation trips at 105 minutes after the ATE – 90 minutes mobilization time plus 15 minutes loading time – in good weather. The UNITES software discussed in Section 1.3 was used to define bus routes along the most likely path from a school being evacuated to the EPZ boundary, traveling toward the appropriate reception center. This is done in UNITES by interactively selecting the series of nodes from the school to the EPZ boundary. Each bus route is given an identification number and is written to the DYNEV II input stream. DYNEV computes the route length and outputs the average speed for each 5-minute interval, for each bus route. The specified bus routes are documented in Section 10 in Table 10-2 (refer to the maps of the link-node analysis network in Appendix K for node locations). Data provided by DYNEV during the appropriate timeframe depending on the mobilization and loading times (i.e., 100 to 105 minutes after the ATE for good weather) were used to compute the average speed for each route, as follows:

$$Average\ Speed\ \left(\frac{mi.}{hr}\right) = \left[\frac{\sum_{i-1}^{n} length\ of\ link\ i\ (mi)}{\sum_{i-1}^{n} Delay\ on\ link\ i\ (min.) + \dfrac{length\ of\ link\ i\ (mi.)}{current\ speed\ on\ link\ i\ \left(\frac{mi.}{hr.}\right)} \times \dfrac{60\ min.}{1\ hr.}}\right] \times \frac{60\ min.}{1\ hr.}$$

The average speed computed (using this methodology) for the buses servicing each of the schools in the EPZ is shown in Table 8-2 through Table 8-4. To comply with state bus speed regulations, the computed speeds are restricted to 60 mph, 55 mph, and 45 mph for good weather, rain/light snow and heavy snow, respectively. The travel time to the EPZ boundary was computed for each bus using the computed average speed and the distance to the EPZ boundary along the most likely route out of the EPZ. The travel time from the EPZ boundary to the Reception Center was computed assuming an average speed of 60 mph, 55 mph, and 45 mph for good weather, rain/light snow and heavy snow, respectively.

Table 8-2 (good weather), Table 8-3 (rain/light snow) and Table 8-4 (heavy snow) present the following ETEs (rounded up to the nearest 5 minutes) for schools in the EPZ:

(1) The elapsed time from the ATE until the bus exits the EPZ; and
(2) The elapsed time until the bus reaches the School Reception Center.

The evacuation time out of the EPZ can be computed as the sum of times associated with Activities A→B→C, C→D, and D→E (For example: 90 min. + 15 + 2 = 1:50 rounded to the nearest 5 minutes for Bartley Elementary School in good weather). The average ETE for schools are 55 minutes less than the 90th percentile ETE for Region R03 for the general population during Scenario 6 conditions (2:50 –1:55 = 0:55) in good weather.

The evacuation time to the School Reception Center is determined by adding the time associated with Activity E→F (discussed below), to this EPZ evacuation time.

<u>Activity: Travel to Reception Centers (E→F)</u>

The distances from the EPZ boundary to the reception centers are measured using geographic information system (GIS) software along the most likely route from the EPZ exit point to the reception center. The reception centers are mapped in Figure 10-3. For a single-wave evacuation, this travel time outside the EPZ does not contribute to the ETE. Assumed bus speeds of 60 mph, 55 mph, and 45 mph for good weather, rain/light snow, and heavy snow, respectively, are applied for this activity for buses servicing the schools in the EPZ.

<u>Evacuation of Transit Dependent People (Residents without access to a vehicle)</u>

<u>Activity: Mobilize Drivers (A→B→C)</u>

Mobilization time is the elapsed time from the ATE until the time the buses arrive at their designated route. The buses dispatched from the depots to service the transit-dependent evacuees will be scheduled so that they arrive at their respective routes after their passengers have completed their mobilization. As shown in Figure 5-4 (Residents with no Commuters), 90 percent of the evacuees will complete their mobilization when the buses begin their routes at approximately 150 minutes after the ATE. The residents taking longer to mobilize are assumed to rideshare with a friend or neighbor. Mobilization time is slightly longer in adverse weather – 160 minutes in rain/light snow and 170 minutes in heavy snow conditions.

A detailed computation of the transit dependent people is discussed in Section 3.7. The total number of transit dependent people per Subarea was determined using a weighted distribution based on population. Subareas that were determined to have less than one transit-dependent person were ignored and no transit bus routes were assigned. It was estimated that the four Subareas with the highest population (C7, C8, C9 & O1) are the only Subareas that required transit-dependent buses. The bus routes utilized in this study were designed by KLD to service the most populated Subareas. These routes are described in Table 10-1 and mapped in Figure 10-2. Those buses servicing the transit-dependent evacuees will first travel along their pick-up routes, then proceed out of the EPZ. It is assumed that residents will walk to the nearest major roadway and flag down a passing bus, and that they can arrive at the roadway within the 150-minute bus mobilization time (good weather).

The ETEs for transit trips were developed using both good weather and adverse weather conditions. Each route has one bus that departs at 150 minutes after the ATE. Table 8-5 (good weather), Table 8-6 (rain/light snow) and Table 8-7 (heavy snow) show the ETE breakdown for each step in the transit-dependent evacuation process.

Activity: Board Passengers (C→D)

For multiple stops along a pick-up route (transit-dependent bus routes) estimation of travel time must allow for the delay associated with stopping and starting at each pick-up point. The time, t, required for a bus to decelerate at a rate, “a”, expressed in ft/sec/sec, from a speed, “v”, expressed in ft/sec, to a stop, is t = v/a. Assuming the same acceleration rate and final speed following the stop yields a total time, T, to service boarding passengers:

$$T = t + B + t = B + 2t = B + \frac{2v}{a},$$

Where B = Dwell time to service passengers. The total distance, “s” in feet, travelled during the deceleration and acceleration activities is: s = v^2/a. If the bus had not stopped to service passengers, but had continued to travel at speed, v, then its travel time over the distance, s, would be: s/v = v/a. Then the total delay (i.e. pickup time, P) to service passengers is:

$$P = T - \frac{v}{a} = B + \frac{v}{a}$$

Assigning reasonable estimates:

- B = 50 seconds: a generous value for a single passenger, carrying personal items, to board per stop
- v = 25 miles per hour (mph) = 37 feet/second (ft/sec)
- a = 4 ft/sec/sec, a moderate average rate

Then, P ≈ 1 minute per stop. Allowing 30 minutes pick-up time per bus run implies 30 stops per run, for good weather. It is assumed that bus acceleration and speed will be less in rain/light snow resulting in 40 minutes of pick-up time per bus and 50 minutes in heavy snow.

Activity: Travel to EPZ Boundary (D→E)

The travel distance along the respective pick-up routes within the EPZ is estimated using the UNITES software. Bus travel times within the EPZ are computed using average speeds computed by DYNEV, using the aforementioned methodology that was used for school evacuation, where they are restricted to 60 mph, 55 mph, and 45 mph for good weather, rain/light snow and heavy snow, respectively.

Table 8-5 through Table 8-7 present the transit-dependent population ETE for each bus route calculated using the above procedures for good weather, rain/light snow and heavy snow, respectively.

For example, the ETE for the Bus Route 3 is computed as 150 + 12 + 30 = 3:15 for good weather (rounded to nearest 5 minutes). Here, 12 minutes is the time to travel 9.1 miles at 44.8 mph, the average speed output by the model for this route at 150 minutes.

Activity: Travel to Reception Centers (E→F)

The distances from the EPZ boundary to the reception centers are measured using geographic information system (GIS) software along the most likely route from the EPZ exit point to the reception center. The reception centers are mapped in Figure 10-3. For a single-wave evacuation, this travel time outside the EPZ does not contribute to the ETE. Assumed bus

speeds of 60 mph, 55 mph, and 45 mph for good weather, rain/light snow, and heavy snow, respectively, will be applied for this activity for buses servicing the transit-dependent population.

The average ETE for a single-wave evacuation of transit-dependent population exceed the ETE for the general population at the 90th percentile.

The relocation of transit-dependent evacuees from the reception centers to congregate care centers, if the counties decide to do so, is not considered in this study.

8.2 ETE for Access and/or Functional Needs Population

Table 8-8 summarizes the ETE for access and/or functional needs population. The table is categorized by type of vehicle required and then broken down by weather condition. The table takes into consideration the deployment of multiple vehicles (not filled to capacity) to reduce the number of stops per vehicle. Due to the limitations on driving for access and/or functional needs persons, it assumed they will be picked up from their homes. Furthermore, it is conservatively assumed that ambulatory access and/or functional needs households are spaced 3 miles apart and bedridden households are spaced 5 miles apart. Bus speeds approximate 20 mph between households and ambulance speeds approximate 30 mph in good weather (10% slower in rain/light snow, 20% slower in heavy snow). Similar to transit dependent evacuees, mobilization times of 150 minutes were used (160 minutes for rain/light snow, and 170 minutes for heavy snow). Loading times of 1 minute per person are assumed for ambulatory people and 15 minutes per person are assumed for bedridden people. For buses evacuating ambulatory access and/or functional needs, the last household is assumed to be 5 miles from the EPZ boundary, and the network-wide average speed, capped at 60 mph (55 mph for rain/light snow and 45 mph for heavy snow), is used to compute travel time after the last pickup. ETE is computed by summing mobilization time, loading time at first household, travel to subsequent households, loading time at subsequent households, and travel time to EPZ boundary. All ETE are rounded up to the nearest 5 minutes.

For example, assuming no more than one access and/or functional need person per HH implies that 16 households need to be serviced. While only 1 bus is needed from a capacity perspective, if 4 buses are deployed to service these special needs HH, then each would require 4 stops maximum. For example, the ETE for access and/or functional needs ambulatory people in good weather is computed as follows :

1. Assume 4 buses are deployed, each with about 4 stops, to service a total of 16 HH.
2. The ETE is calculated as follows:
    a. Buses arrive at the first pickup location: 2:30
    b. Load HH members at first pickup: 1 minute
    c. Travel to subsequent pickup locations: 4 @ 9 minutes (3 miles at 20 mph) = 27 minutes
    d. Load HH members at subsequent pickup locations: 3 @ 1 minutes = 3 minutes
    e. Travel to EPZ boundary: 5 miles @ 53 mph (network wide average speed at 3 hours after the ATE) = 6 minutes

ETE: 2:30 + 1 + 27 + 3 + 6 = 3:10

It is estimated that 2 ambulances will be needed to evacuate the 4 homebound bed-ridden person within the EPZ. As discussed above, there are 19 ambulances available within the EPZ and only 2 are required to evacuate the bedridden access and/or functional needs population within the EPZ (see Table 8-1).

For example, the ETE for access and/or functional needs bedridden people in good weather is computed as follows:

3. Ambulance arrives at first household: 150 minutes
4. Loading time at first household: 15 minutes
5. Ambulance travels to second household: 5 miles @ 30 mph = 10 minutes
6. Loading time at second household: 15 minutes
7. Travel time to EPZ boundary: 5 miles @ 53 mph (network wide average speed at 3 hours and 10 minutes after the ATE) = 6 minutes

ETE: 150 + 15 + 10 + 15 + 6 = 3:20 (rounded up to the nearest 5 minutes).

The average ETE for a single wave evacuation of the access and/or functional needs population exceeds the general population ETE at the 90th percentile for an evacuation of the entire EPZ (Region R03), during Scenario 6 conditions.

8.3 Medical and Correctional Facilities

As discussed in Section 2.4, all medical facilities and correctional facilities located within the 10-mile EPZ will shelter-in-place according to county emergency plans.

Table 8-1. Summary of Transportation Resources

Transportation Resource	Drivers	Buses	Vans	Wheelchair Buses	Wheelchair Vans	Ambulances
Resources Available						
Callaway County Ambulance District (Fulton)	6	0	0	0	0	6
Fulton School District	34	33	0	1	0	0
Holts Summit (Callaway Ambulance District)	2	0	0	0	0	2
Joe Zimmer, Chamois (Osage R-1 Schools)	4	4	0	0	0	0
Montgomery County	7	0	0	0	3	4
North Callaway R-I Schools	20	20	0	0	0	0
Osage R-I School District (Chamois)	2	1	1	0	0	0
R-I School District (Hermann)	12	12	0	0	0	0
Riverview Nursing Center (Mokane)	1	0	0	0	1	0
Rudroff Bus Company (Linn)	36	36	0	0	0	0
SERVE (Fulton)	11	9	0	0	2	0
South Callaway R-II School District (Mokane)	19	17	0	2	0	0
Swartz Bus Co. (Gasconade/Montgomery)	23	23	0	0	0	0
University of Missouri Hospital	7	0	0	0	0	7
William Woods University (Fulton)	7	4	3	0	0	0
TOTAL:	**191**	**159**	**4**	**3**	**6**	**19**
Resources Needed						
Medical Facilities (Table 3-6):		Shelter-in-Place				
Schools (Table 3-7):		108	0	0	0	0
Homebound Access and/or Functional Needs (Table 3-9):		4	0	0	0	2
Correctional Facilities (Section 3.9):		Shelter-in-Place				
Transit-Dependent Population (Table 10-1):		3	0	0	0	0
TOTAL TRANSPORTATION NEEDS:		**115**	**0**	**0**	**0**	**2**

Table 8-2. School Evacuation Time Estimates - Good Weather

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETA to R.C. (hr:min)
CALLAWAY COUNTY SCHOOLS									
Bartley Elementary School	90	15	1.5	37.4	2	**1:50**	22.6	23	**2:15**
Bush Elementary School	90	15	2.4	29.1	5	**1:50**	22.6	23	**2:15**
Fulton High School	90	15	1.6	45.6	2	**1:50**	26.1	26	**2:20**
Fulton Middle School	90	15	2.1	36.2	3	**1:50**	22.6	23	**2:15**
Kingdom Christian Academy	90	15	2.1	33.2	4	**1:50**	22.6	23	**2:15**
McIntire Elementary School	90	15	1.0	45.3	1	**1:50**	22.6	23	**2:15**
Missouri School for the Deaf	90	15	1.7	29.0	4	**1:50**	22.6	23	**2:15**
South Callaway R-II Elementary School	90	15	6.0	52.8	7	**1:55**	17.7	18	**2:15**
South Callaway R-II Middle School	90	15	6.0	52.8	7	**1:55**	17.7	18	**2:15**
South Callaway R-II High School	90	15	6.0	52.8	7	**1:55**	17.7	18	**2:15**
St. Peter's Catholic School	90	15	3.0	34.7	5	**1:50**	26.1	26	**2:20**
Westminster College	90	15	1.1	45.3	1	**1:50**	22.6	23	**2:15**
William Woods University	90	15	3.0	39.4	5	**1:50**	26.1	26	**2:20**
OSAGE COUNTY SCHOOLS									
Chamois High School	90	15	9.1	47.9	11	**2:00**	24.8	25	**2:25**
Osage County Chamois R-1 School District	90	15	9.1	47.9	11	**2:00**	24.8	25	**2:25**
					Maximum for EPZ:	**2:00**		**Maximum:**	**2:25**
					Average for EPZ:	**1:55**		**Average:**	**2:20**

Table 8-3. School Evacuation Time Estimates – Rain/Light Snow

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETA to R.C. (hr:min)
CALLAWAY COUNTY SCHOOLS									
Bartley Elementary School	100	20	1.5	34.2	3	**2:05**	22.6	25	**2:30**
Bush Elementary School	100	20	2.4	23.9	6	**2:10**	22.6	25	**2:35**
Fulton High School	100	20	1.0	41.6	1	**2:05**	22.6	25	**2:30**
Fulton Middle School	100	20	2.1	32.3	4	**2:05**	22.6	25	**2:30**
Kingdom Christian Academy	100	20	2.1	24.9	5	**2:05**	22.6	25	**2:30**
McIntire Elementary School	100	20	3.0	39.1	5	**2:05**	26.1	28	**2:35**
Missouri School for the Deaf	100	20	1.7	21.7	5	**2:05**	22.6	25	**2:30**
South Callaway R-II Elementary School	100	20	6.0	48.1	7	**2:10**	17.7	19	**2:30**
South Callaway R-II Middle School	100	20	6.0	48.1	7	**2:10**	17.7	19	**2:30**
South Callaway R-II High School	100	20	6.0	48.1	7	**2:10**	17.7	19	**2:30**
St. Peter's Catholic School	100	20	3.0	32.2	6	**2:10**	26.1	28	**2:40**
Westminster College	100	20	1.1	39.1	2	**2:05**	22.6	25	**2:30**
William Woods University	100	20	3.0	35.0	5	**2:05**	26.1	28	**2:35**
OSAGE COUNTY SCHOOLS									
Chamois High School	100	20	9.1	43.4	13	**2:15**	24.8	27	**2:45**
Osage County Chamois R-1 School District	100	20	9.1	43.4	13	**2:15**	24.8	27	**2:45**
					Maximum for EPZ:	**2:15**		**Maximum:**	**2:45**
					Average for EPZ:	**2:10**		**Average:**	**2:35**

Table 8-4. School Evacuation Time Estimates – Heavy Snow

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETA to R.C. (hr:min)
CALLAWAY COUNTY SCHOOLS									
Bartley Elementary School	110	25	1.5	32.5	3	**2:20**	22.6	30	**2:50**
Bush Elementary School	110	25	2.4	23.7	6	**2:25**	22.6	30	**2:55**
Fulton High School	110	25	1.0	39.0	2	**2:20**	22.6	30	**2:50**
Fulton Middle School	110	25	2.1	30.8	4	**2:20**	22.6	30	**2:50**
Kingdom Christian Academy	110	25	2.1	26.3	5	**2:20**	22.6	30	**2:50**
McIntire Elementary School	110	25	3.0	32.9	5	**2:20**	26.1	35	**2:55**
Missouri School for the Deaf	110	25	1.7	22.8	4	**2:20**	22.6	30	**2:50**
South Callaway R-II Elementary School	110	25	6.0	43.6	8	**2:25**	17.7	24	**2:50**
South Callaway R-II Middle School	110	25	6.0	43.6	8	**2:25**	17.7	24	**2:50**
South Callaway R-II High School	110	25	6.0	43.6	8	**2:25**	17.7	24	**2:50**
St. Peter's Catholic School	110	25	3.0	30.6	6	**2:25**	26.1	35	**3:00**
Westminster College	110	25	1.1	33.3	2	**2:20**	22.6	30	**2:50**
William Woods University	110	25	3.0	33.4	5	**2:20**	26.1	35	**2:55**
OSAGE COUNTY SCHOOLS									
Chamois High School	110	25	9.1	41.0	13	**2:30**	24.8	33	**3:05**
Osage County Chamois R-1 School District	110	25	9.1	41.0	13	**2:30**	24.8	33	**3:05**
					Maximum for EPZ:	**2:30**		**Maximum:**	**3:05**
					Average for EPZ:	**2:25**		**Average:**	**2:55**

Table 8-5. Transit-Dependent Evacuation Time Estimates - Good Weather

Bus Route Number	Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	ETA to R.C. (hr:min)
1	150	6.0	55.3	7	30	**3:10**	17.7	18	**3:30**
2	150	11.2	36.8	18	30	**3:20**	26.1	26	**3:50**
3	150	9.1	44.8	12	30	**3:15**	24.8	25	**3:40**
					Maximum ETE:	**3:20**		**Maximum ETE:**	**3:50**
					Average ETE:	**3:15**		**Average ETE:**	**3:40**

Table 8-6. Transit-Dependent Evacuation Time Estimates – Rain/Light Snow

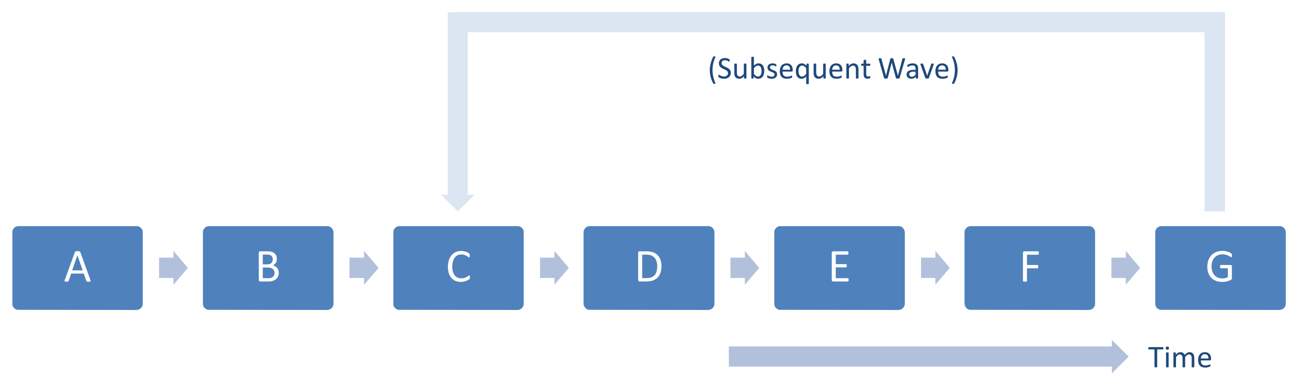
Bus Route Number	Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	ETA to R.C. (hr:min)
1	160	6.0	50.0	7	40	**3:30**	17.7	19	**3:50**
2	160	11.2	33.7	20	40	**3:40**	26.1	28	**4:10**
3	160	9.1	40.3	14	40	**3:35**	24.8	27	**4:05**
					Maximum ETE:	**3:40**		**Maximum ETE:**	**4:10**
					Average ETE:	**3:35**		**Average ETE:**	**4:05**

Table 8-7. Transit Dependent Evacuation Time Estimates – Heavy Snow

Bus Route Number	Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	ETA to R.C. (hr:min)
1	170	6.0	45.0	8	50	**3:50**	17.7	24	**4:15**
2	170	11.2	31.9	21	50	**4:05**	26.1	35	**4:40**
3	170	9.1	38.2	14	50	**3:55**	24.8	33	**4:30**
					Maximum ETE:	**4:05**		**Maximum ETE:**	**4:40**
					Average ETE:	**4:00**		**Average ETE:**	**4:30**

Table 8-8. Access and/or Functional Needs Evacuation Time Estimates

Vehicle Type	People Requiring Vehicle	Vehicles deployed	Stops	Weather Conditions	Mobilization Time (min)	Loading Time at 1st Stop (min)	Travel to Subsequent Stops (min)	Total Loading Time at Subsequent Stops (min)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
Buses	16	4	4	Good	150	1	27	3	6	**3:10**
				Rain	160		30		6	**3:20**
				Snow	170		33		7	**3:35**
Ambulances	4	2	2	Good	150	15	10	15	6	**3:20**
				Rain	160		11		6	**3:30**
				Snow	170		13		7	**3:40**
									Maximum ETE:	**3:40**
									Average ETE:	**3:25**



Event	
A	Advisory to Evacuate
B	Bus Dispatched from Depot
C	Bus Arrives at Facility/Pick-up Route
D	Bus Departs for Reception Center
E	Bus Exits Region
F	Bus Arrives at Reception Center/Host Facility
Activity	
A→B	Driver Mobilization
B→C	Travel to Facility or to Pick-up Route
C→D	Passengers Board the Bus
D→E	Bus Travels Towards Region Boundary
E→F	Bus Travels Towards Reception Center Outside the EPZ

Figure 8-1. Chronology of Transit Evacuation Operations

9 TRAFFIC MANAGEMENT STRATEGY

This section discusses the suggested Traffic Management Plan (TMP) that is designed to expedite the movement of evacuating traffic. The resources required to implement the TMP include:

- Personnel with the capabilities of performing the planned control functions of traffic guides (preferably, not necessarily, law enforcement officers).
- The Manual of Uniform Traffic Control Devices (MUTCD) published by the Federal Highway Administration (FHWA) of the U.S.D.O.T. provides guidance for Traffic Control Devices to assist these personnel in the performance of their tasks. All state and most county transportation agencies have access to the MUTCD, which is available on-line: http://mutcd.fhwa.dot.gov which provides access to the official PDF version.
- A written plan that defines all Access Control Points (ACP) and Traffic Control Point (TCP) locations, provides necessary details and is documented in a format that is readily understood by those assigned to perform traffic control.

The functions to be performed in the field are:

1. <u>Facilitate</u> evacuating traffic movements that safely expedite travel out of the EPZ.
2. <u>Discourage</u> traffic movements that move evacuating vehicles in a direction which takes them significantly closer to the power plant, or which interferes with the efficient flow of other evacuees.

We employ the terms "facilitate" and "discourage" rather than "enforce" and "prohibit" to indicate the need for flexibility in performing the traffic control function. There are always legitimate reasons for a driver to prefer direction other than that indicated. For example:

- A driver may be traveling home from work or from another location, to join other family members prior to evacuating.
- An evacuating driver may be travelling to pick up a relative, or other evacuees.
- The driver may be an emergency worker entering the area being evacuated to perform an important emergency service.

The implementation of a TMP <u>must</u> also be flexible enough for the application of sound judgment by the traffic guide.

The TMP is the outcome of the following process:

1. The existing mandatory TCPs and ACPs identified by the offsite response organizations in their existing emergency plans serve as the basis of the traffic management plan, as per NUREG/CR-7002, Rev 1. The ETE analysis treated all controlled intersections that are existing TCP or ACP locations in the offsite agency plans as being controlled by actuated signals. Appendix K identifies the number of intersections that were modeled as TCPs.
2. Evacuation simulations were run using DYNEV II to predict traffic congestion during evacuation (see Section 7.3 and Figure 7-3 through Figure 7-7). These simulations help to identify the best routing and critical intersections that experience pronounced

congestion during evacuation. Any critical intersections that would benefit from traffic or access control which are not already identified in the existing offsite plans are examined. No additional TCPs or ACPs were identified as part of this study

3. Prioritization of TCPs and ACPs. Application of traffic and access control at some TCPs and ACPs will have a more pronounced influence on expediting traffic movements than at other TCPs and ACPs. For example, TCPs controlling traffic originating from areas in close proximity to the power plant could have a more beneficial effect on minimizing potential exposure to radioactivity than those TCPs located far from the power plant. Key locations for manual traffic control (MTC) were analyzed and their impact to ETE was quantified, as per NUREG/CR-7002, Rev. 1. See Appendix G for more detail.

Appendix G documents the existing TMP and its use in the study using the process enumerated above.

9.1 Assumptions

- The ETE calculations documented in Section 7 and 8 assume that the traffic management plan is implemented during evacuation.
- The ETE calculations reflect the assumptions that all "external-external" trips are interdicted and diverted after 2 hours have elapsed from the Advisory to Evacuate (ATE).
- All transit vehicles and other responders entering the EPZ to support the evacuation are assumed to be unhindered by personal manning TCPs and ACPs.
- Study assumptions 1 and 2 in Section 2.5 discuss TCP and ACP operations.

9.2 Additional Considerations

The use of Intelligent Transportation Systems (ITS) technologies can reduce the manpower and equipment needs, while still facilitating the evacuation process. Dynamic Message Signs (DMS) can be placed within the EPZ to provide information to travelers regarding traffic conditions, route selection, and reception/care center information. DMS placed outside of the EPZ will warn motorists to avoid using routes that may conflict with the flow of evacuees away from the power plant. Highway Advisory Radio (HAR) can be used to broadcast information to evacuees during egress through their vehicles stereo systems. Automated Travel Information Systems (ATIS) can also be used to provide evacuees with information. Internet websites can provide traffic and evacuation route information before the evacuee begins their trip, while the on-board navigation systems (GPS units) and smartphones can be used to provide information during evacuation trip.

These are only some examples of how ITS technologies can benefit the evacuation process. Considerations should be given that ITS technologies can be used to facilitate the evacuation process, and any additional signage placed should consider evacuation needs.

10 EVACUATION ROUTES AND RECEPTION CENTERS

10.1 Evacuation Routes

Evacuation routes are comprised of two distinct components:

- Routing from a Subarea being evacuated to the boundary of the Evacuation Region and thence out of the Emergency Planning Zone (EPZ).
- Routing of transit-dependent evacuees from the EPZ boundary to reception/care centers.

Evacuees will select routes within the EPZ in such a way as to minimize their exposure to risk. This expectation is met by the DYNEV II model routing traffic away from the location of the plant, to the extent practicable. The DTRAD model satisfies this behavior by routing traffic so as to balance traffic demand relative to the available highway capacity to the extent possible. See Appendices B through D for further discussion. The major evacuation routes for the EPZ are presented in Figure 10-1. These routes will be used by the general population evacuating in private vehicles, and by the school and transit-dependent population evacuating in buses. Transit-dependent evacuees and school buses will be routed to reception centers. General population may evacuate to either a reception center or some alternate destination (e.g., lodging facility, relative's home, campground) outside the EPZ.

The routing of transit-dependent evacuees from the EPZ boundary to reception centers is designed to minimize the amount of travel outside the EPZ, from the points where these routes cross the EPZ boundary. The three bus routes shown graphically in Figure 10-2 and described in Table 10-1 have been identified to service the transit-dependent evacuees throughout the entire EPZ. These routes were designed by KLD to service the major routes through the Subareas with the largest population and then proceed to the nearest reception center. It is assumed that residents will walk to and congregate at the nearest major road to be picked up.

The specified bus routes for all the transit-dependent population are documented in Table 10-2 (refer to the maps of the link-node analysis network in Appendix K for node locations). Representative routes were developed for all schools within the EPZ. It is assumed that all school evacuees will be taken to their appropriate reception center. School evacuees will subsequently be picked up by parents or guardians. Transit-dependent evacuees are transported to the nearest reception center for each county. This study does not consider the transport of evacuees from reception centers to alternate care centers or congregate care centers if the counties do make the decision to relocate evacuees.

10.2 Reception Centers

Figure 10-3 presents a map showing the general population reception centers for evacuees. Transit-dependent evacuees are transported to the nearest reception center for each county.

Table 10-3 presents a list of the reception centers for each school in the EPZ. It is assumed that all school evacuees will be taken to the appropriate reception center and will be subsequently picked up by parents or guardians.

Table 10-1. Summary of Transit-Dependent Bus Routes

Route	No. of Buses	Route Description	Length (mi.)
1	1	Servicing communities in Subarea C7	6.0
2	1	Servicing communities in Subarea C8 & C9	11.2
3	1	Servicing communities in Subarea O1	9.1

Table 10-2. Bus Route Descriptions

Bus Route Number	Description	Nodes Traversed from Route Start to EPZ Boundary
7	Bartley Elementary School	402, 403, 404, 405, 963, 66, 441, 65, 64, 67
6	Bush Elementary School	780, 982, 779, 776, 865, 387, 388, 813, 394, 395, 396, 397, 398, 58, 57, 56, 59
4	Fulton High School	399, 400, 48, 40, 45
11	Fulton Middle School	779, 776, 386, 809, 399, 400, 48, 40, 45
10	Kingdom Christian Academy	388, 813, 394, 395, 396, 397, 398, 58, 57, 56, 59
5	McIntire Elementary School	397, 398, 58, 57, 56, 59
1	Osage County Chamois R-1 School District	938, 618, 788, 551, 550, 1411, 549, 548, 1410, 547, 1409, 1408, 546, 545, 544, 1407, 1406, 543, 542, 1405, 541, 540, 1404, 1403, 539, 538, 537, 536, 535, 534, 1614, 1402, 1401, 533, 1400, 532, 1399, 531
3	School for the Deaf	863, 815, 813, 394, 395, 396, 397, 398, 58, 57, 56, 59
2	South Callaway Schools	428, 1236, 429, 430, 431, 185, 1220, 186, 187, 188, 189, 190, 197, 191, 192
8	St. Peter Catholic School	780, 1616, 384, 1019, 385, 386, 809, 399, 400, 48, 40, 45
12	Westminster College	397, 398, 58, 57, 56, 59
9	William Woods University	810, 386, 809, 399, 400, 48, 40, 45
23	Transit Dependent Bus Route #1 – Subarea C7	422, 1242, 423, 1241, 1240, 424, 425, 1239, 426, 1237, 1238, 427, 428, 1236, 429, 430, 431, 185, 1220, 186, 187, 188, 189, 190, 197, 191
19	Transit Dependent Bus Route #2 – Subareas C8 + C9	369, 1176, 370, 371, 1175, 1174, 372, 1173, 1172, 373, 1171, 374, 375, 376, 1170, 1169, 377, 1168, 378, 379, 1167, 232, 1269, 393, 392, 1274, 1275, 391, 390, 815, 387, 865, 776, 386, 809, 399, 400, 48, 40, 45
22	Transit Dependent Bus Route #3 – Subarea O1	617, 678, 618, 788, 551, 1506, 552, 1507, 1508, 553, 911, 554, 555, 556, 557, 910, 558, 559, 1423, 1424, 560, 1425, 561, 1426, 562, 1427, 1428, 1429, 563, 1431, 564, 1430, 565

Table 10-3. School Reception Centers

School	Reception Center
Bartley Elementary School	Lincoln University
Osage County Chamois R-1 School District	
South Callaway R-II Elementary School	
South Callaway R-II High School	
South Callaway R-II Middle School	
Bush Elementary School	University of Missouri
Chamois High School	
Fulton High School	
Fulton Middle School	
Kingdom Christian Academy	
McIntire Elementary School	
Missouri Girls Town Foundation	
Missouri School for the Deaf	
Rosa Parks Center	
St Peter's Catholic School	
Westminster College	
William Woods University	

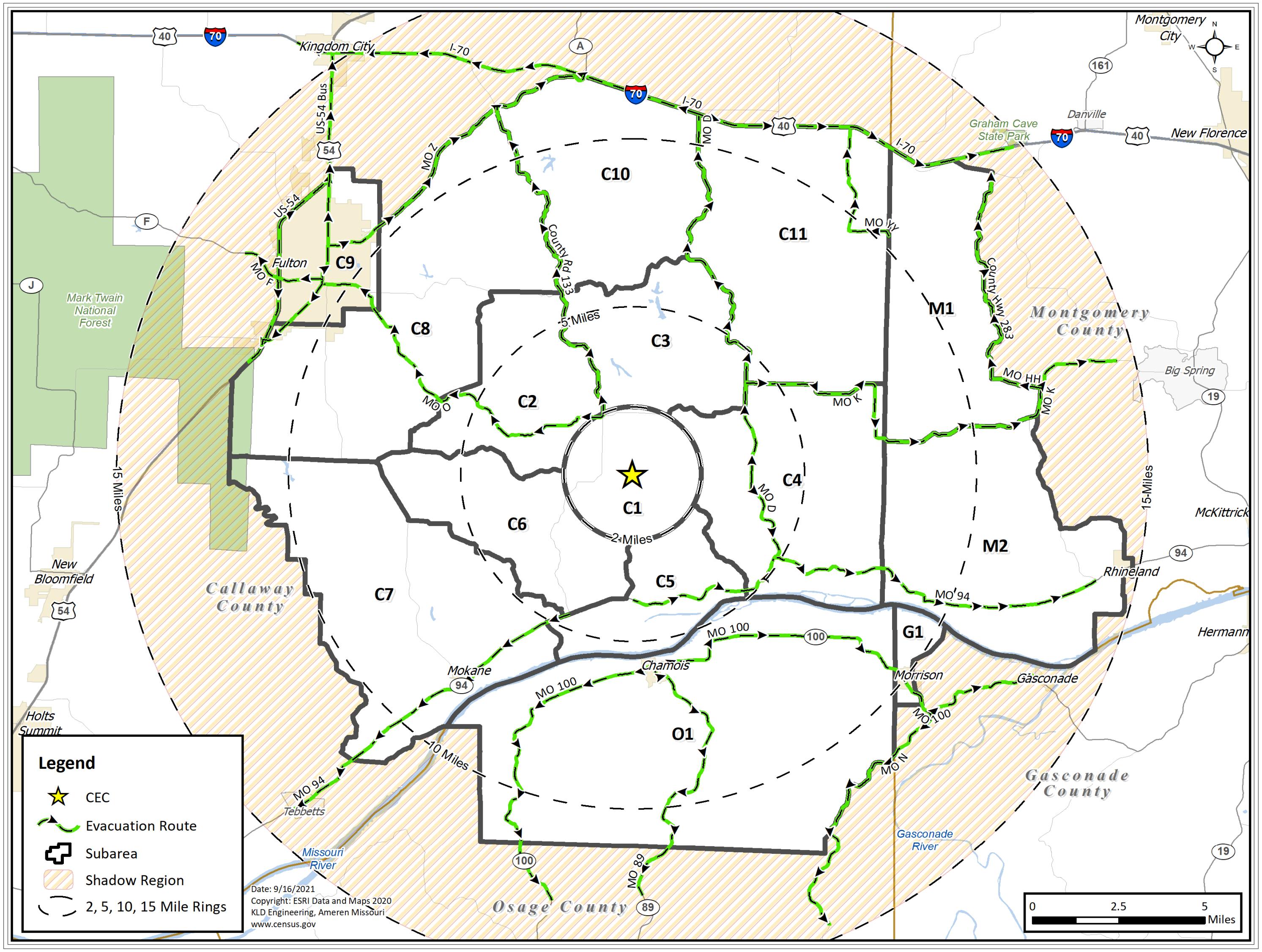


Figure 10-1. Evacuation Route Map

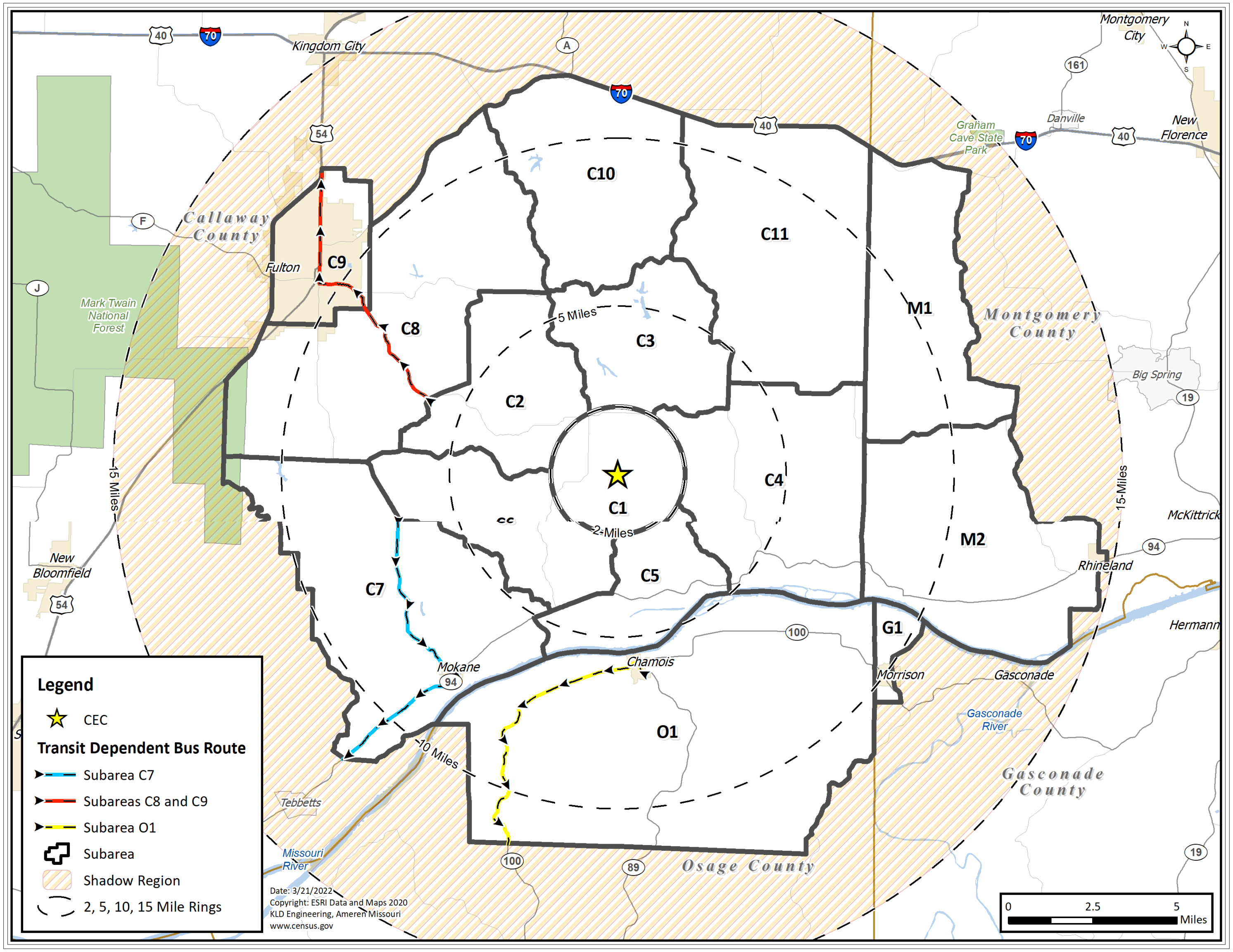


Figure 10-2. Transit-Dependent Bus Routes

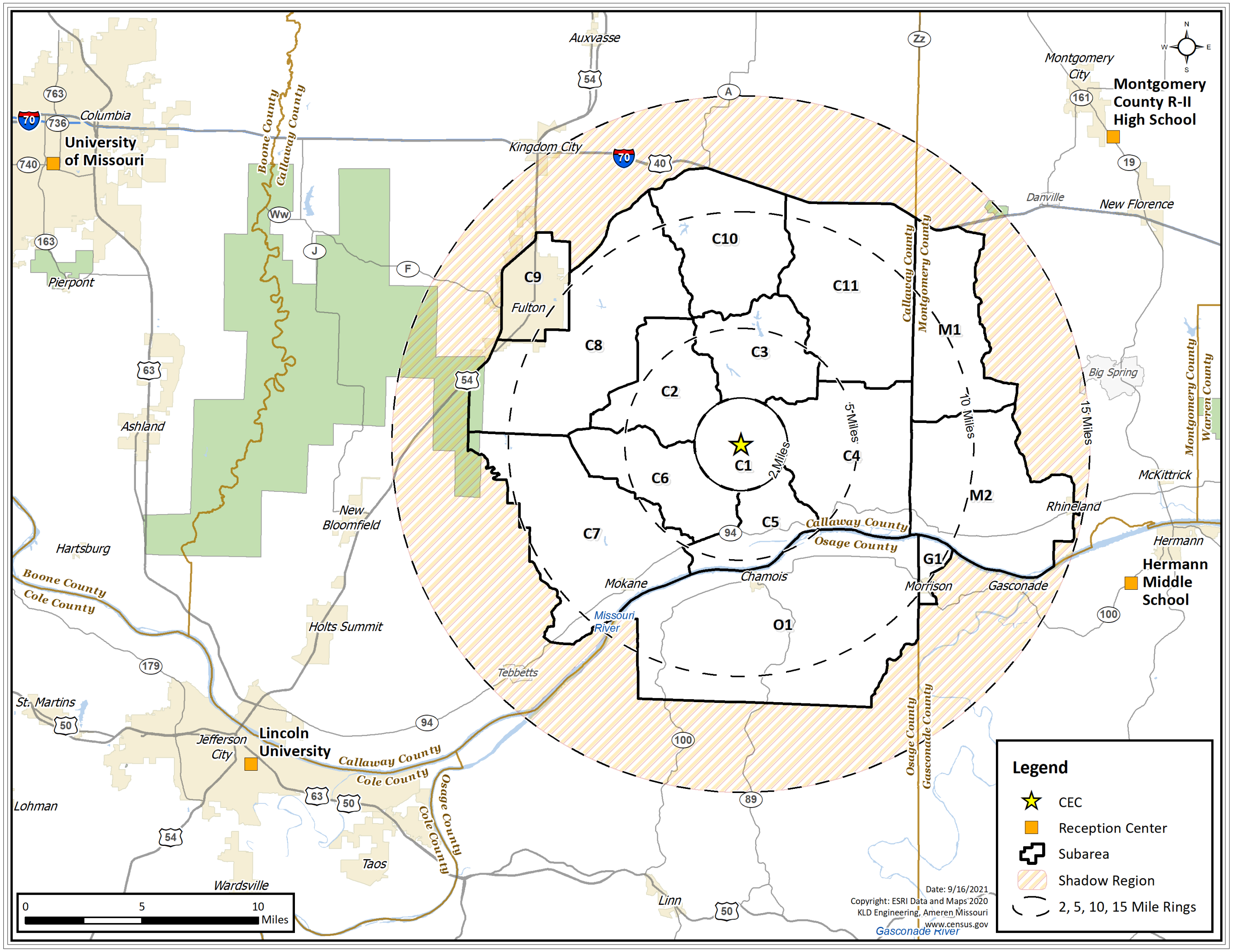


Figure 10-3. CEC Reception Centers

APPENDIX A

Glossary of Traffic Engineering Terms

A. GLOSSARY OF TRAFFIC ENGINEERING TERMS

Table A-1. Glossary of Traffic Engineering Terms

Term	Definition
Analysis Network	A graphical representation of the geometric topology of a physical roadway system, which is comprised of directional links and nodes.
Link	A network link represents a specific, one-directional section of roadway. A link has both physical (length, number of lanes, topology, etc.) and operational (turn movement percentages, service rate, free-flow speed) characteristics.
Measures of Effectiveness	Statistics describing traffic operations on a roadway network.
Node	A network node generally represents an intersection of network links. A node has control characteristics, i.e., the allocation of service time to each approach link.
Origin	A location attached to a network link, within the EPZ or Shadow Region, where trips are generated at a specified rate in vehicles per hour (vph). These trips enter the roadway system to travel to their respective destinations.
Prevailing Roadway and Traffic Conditions	Relates to the physical features of the roadway, the nature (e.g., composition) of traffic on the roadway and the ambient conditions (weather, visibility, pavement conditions, etc.).
Service Rate	Maximum rate at which vehicles, executing a specific turn maneuver, can be discharged from a section of roadway at the prevailing conditions, expressed in vehicles per second (vps) or vph.
Service Volume	Maximum number of vehicles which can pass over a section of roadway in one direction during a specified time period with operating conditions at a specified Level of Service (The Service Volume at the upper bound of Level of Service, E, equals Capacity). Service Volume is usually expressed as vph.
Signal Cycle Length	The total elapsed time to display all signal indications, in sequence. The cycle length is expressed in seconds.
Signal Interval	A single combination of signal indications. The interval duration is expressed in seconds. A signal phase is comprised of a sequence of signal intervals, usually green, yellow, red.

Term	Definition
Signal Phase	A set of signal indications (and intervals) which services a particular combination of traffic movements on selected approaches to the intersection. The phase duration is expressed in seconds.
Traffic (Trip) Assignment	A process of assigning traffic to paths of travel in such a way as to satisfy all trip objectives (i.e., the desire of each vehicle to travel from a specified origin in the network to a specified destination) and to optimize some stated objective or combination of objectives. In general, the objective is stated in terms of minimizing a generalized "cost". For example, "cost" may be expressed in terms of travel time.
Traffic Density	The number of vehicles that occupy one lane of a roadway section of specified length at a point in time, expressed as vehicles per mile (vpm).
Traffic (Trip) Distribution	A process for determining the destinations of all traffic generated at the origins. The result often takes the form of a Trip Table, which is a matrix of origin-destination traffic volumes.
Traffic Simulation	A computer model designed to replicate the real-world operation of vehicles on a roadway network, so as to provide statistics describing traffic performance. These statistics are called Measures of Effectiveness.
Traffic Volume	The number of vehicles that pass over a section of roadway in one direction, expressed in vph. Where applicable, traffic volume may be stratified by turn movement.
Travel Mode	Distinguishes between private auto, bus, rail, pedestrian and air travel modes.
Trip Table or Origin-Destination Matrix	A rectangular matrix or table, whose entries contain the number of trips generated at each specified origin, during a specified time period, that are attracted to (and travel toward) each of its specified destinations. These values are expressed in vph or in vehicles.
Turning Capacity	The capacity associated with that component of the traffic stream which executes a specified turn maneuver from an approach at an intersection.

APPENDIX B

DTRAD: Dynamic Traffic Assignment and Distribution Model

B. DYNAMIC TRAFFIC ASSIGNMENT AND DISTRIBUTION MODEL

This section describes the integrated dynamic trip assignment and distribution model named DTRAD (Dynamic Traffic Assignment and Distribution) that is expressly designed for use in analyzing evacuation scenarios. DTRAD employs logit-based path-choice principles and is one of the models of the DYNEV II System. The DTRAD module implements path-based *Dynamic Traffic Assignment* (DTA) so that time dependent Origin-Destination (OD) trips are "assigned" to routes over the network based on prevailing traffic conditions.

To apply the DYNEV II System, the analyst must specify the highway network, link capacity information, the time-varying volume of traffic generated at all origin centroids and, optionally, a set of accessible candidate destination nodes on the periphery of the EPZ for selected origins. DTRAD calculates the optimal dynamic trip distribution (i.e., trip destinations) and the optimal dynamic trip assignment (i.e., trip routing) of the traffic generated at each origin node traveling to its set of candidate destination nodes, so as to minimize evacuee travel "cost."

Overview of Integrated Distribution and Assignment Model

The underlying premise is that the selection of destinations and routes is intrinsically coupled in an evacuation scenario. That is, people in vehicles seek to travel out of an area of potential risk as rapidly as possible by selecting the "best" routes. The model is designed to identify these "best" routes in a manner that realistically distributes vehicles from origins to destinations and routes them over the highway network, in a consistent and optimal manner, reflecting evacuee behavior.

For each origin, a set of "candidate destination nodes" is selected by the software logic and by the analyst to reflect the desire by evacuees to travel away from the power plant and to access major highways. The specific destination nodes within this set that are selected by travelers and the selection of the connecting paths of travel, are both determined by DTRAD. This determination is made by a logit-based path choice model in DTRAD, so as to minimize the trip "cost", as discussed later.

The traffic loading on the network and the consequent operational traffic environment of the network (density, speed, throughput on each link) vary over time as the evacuation takes place. The DTRAD model, which is interfaced with the DYNEV simulation model, executes a succession of "sessions" wherein it computes the optimal routing and selection of destination nodes for the conditions that exist at that time.

Interfacing the DYNEV Simulation Model with DTRAD

The DYNEV II system reflects NRC guidance that evacuees will seek to travel in a general direction away from the location of the hazardous event. An algorithm was developed to support the DTRAD model in dynamically varying the Trip Table (O-D matrix) over time from one DTRAD session to the next. Another algorithm executes a "mapping" from the specified "geometric" network (link-node analysis network) that represents the physical highway system, to a "path" network that represents the vehicle [turn] movements. DTRAD computations are performed on the "path" network: DYNEV simulation model, on the "geometric" network.

DTRAD Description

DTRAD is the DTA module for the DYNEV II System.

When the road network under study is large, multiple routing options are usually available between trip origins and destinations. The problem of loading traffic demands and propagating them over the network links is called Network Loading and is addressed by DYNEV II using macroscopic traffic simulation modeling. Traffic assignment deals with computing the distribution of the traffic over the road network for given O-D demands and is a model of the route choice of the drivers. Travel demand changes significantly over time, and the road network may have time dependent characteristics, e.g., time-varying signal timing or reduced road capacity because of lane closure, or traffic congestion. To consider these time dependencies, DTA procedures are required.

The DTRAD DTA module represents the dynamic route choice behavior of drivers, using the specification of dynamic origin-destination matrices as flow input. Drivers choose their routes through the network based on the travel cost they experience (as determined by the simulation model). This allows traffic to be distributed over the network according to the time-dependent conditions. The modeling principles of DTRAD include:

- It is assumed that drivers not only select the best route (i.e., lowest cost path) but some also select less attractive routes. The algorithm implemented by DTRAD archives several "efficient" routes for each O-D pair from which the drivers choose.
- The choice of one route out of a set of possible routes is an outcome of "discrete choice modeling". Given a set of routes and their generalized costs, the percentages of drivers that choose each route is computed. The most prevalent model for discrete choice modeling is the logit model. DTRAD uses a variant of Path-Size-Logit model (PSL). PSL overcomes the drawback of the traditional multinomial logit model by incorporating an additional deterministic path size correction term to address path overlapping in the random utility expression.
- DTRAD executes the traffic assignment (TA) algorithm on an abstract network representation called "the path network" which is built from the actual physical link-node analysis network. This execution continues until a stable situation is reached: the volumes and travel times on the edges of the path network do not change significantly from one iteration to the next. The criteria for this convergence are defined by the user.
- Travel "cost" plays a crucial role in route choice. In DTRAD, path cost is a linear summation of the generalized cost of each link that comprises the path. The generalized cost for a link, a, is expressed as

  $$c_a = \alpha t_a + \beta l_a + \gamma s_a ,$$

  where c_a is the generalized cost for link a, and α, β, and γ are cost coefficients for link travel time, distance, and supplemental cost, respectively. Distance and supplemental costs are defined as invariant properties of the network model, while travel time is a dynamic property dictated by prevailing traffic conditions. The DYNEV simulation model

computes travel times on all edges in the network and DTRAD uses that information to constantly update the costs of paths. The route choice decision model in the next simulation iteration uses these updated values to adjust the route choice behavior. This way, traffic demands are dynamically re-assigned based on time dependent conditions. The interaction between the DTRAD traffic assignment and DYNEV II simulation models is depicted in Figure B-1. Each round of interaction is called a Traffic Assignment Session (TA session). A TA session is composed of multiple iterations, marked as loop B in the figure.

- The supplemental cost is based on the "survival distribution" (a variation of the exponential distribution).The Inverse Survival Function is a "cost" term in DTRAD to represent the potential risk of travel toward the plant:

  $s_a = - \beta \ln (p), 0 \le p \le l ; \beta > 0$

  $p = \frac{d_n}{d_0}$

  d_n = Distance of node, n, from the plant
  d_0 =Distance from the plant where there is zero risk
  β = Scaling factor

The value of d_o = 15 miles, the outer distance of the EPZ. Note that the supplemental cost, s_a, of link, a, is (high, low), if its downstream node, n, is (near, far from) the power plant.

Network Equilibrium

In 1952, John Wardrop wrote:

> *Under equilibrium conditions traffic arranges itself in congested networks in such a way that no individual trip-maker can reduce his path costs by switching routes.*

The above statement describes the "User Equilibrium" definition, also called the "Selfish Driver Equilibrium". It is a hypothesis that represents a [hopeful] condition that evolves over time as drivers search out alternative routes to identify those routes that minimize their respective "costs". It has been found that this "equilibrium" objective to minimize costs is largely realized by most drivers who routinely take the same trip over the same network at the same time (i.e., commuters). Effectively, such drivers "learn" which routes are best for them over time. Thus, the traffic environment "settles down" to a near-equilibrium state.

Clearly, since an emergency evacuation is a sudden, unique event, it does not constitute a long-term learning experience which can achieve an equilibrium state. Consequently, DTRAD was not designed as an equilibrium solution, but to represent drivers in a new and unfamiliar situation, who respond in a flexible manner to real-time information (either broadcast or observed) in such a way as to minimize their respective costs of travel.

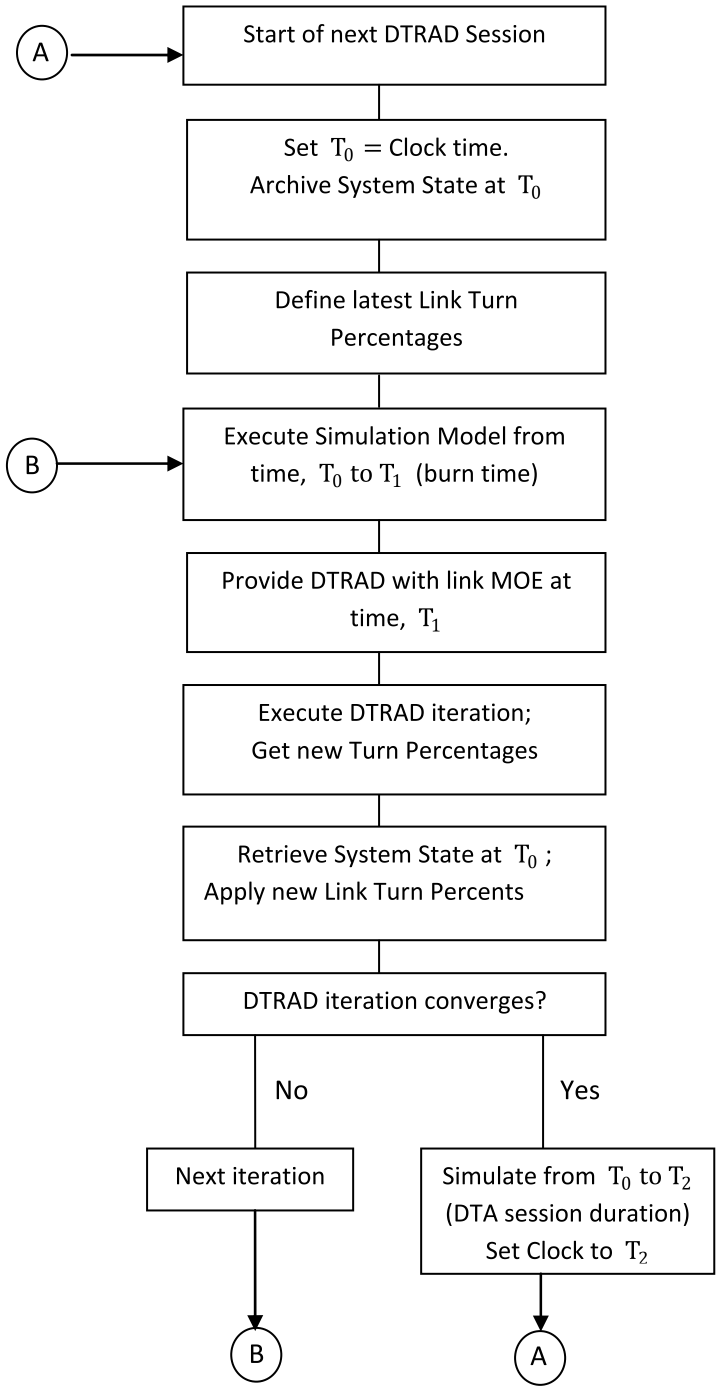


Figure B-1. Flow Diagram of Simulation-DTRAD Interface

APPENDIX C

DYNEV Traffic Simulation Model

C. DYNEV TRAFFIC SIMULATION MODEL

The DYNEV traffic simulation model is a *macroscopic* model that describes the operations of traffic flow in terms of aggregate variables: vehicles, flow rate, mean speed, volume, density, queue length, *on each link*, for each turn movement, during each Time Interval (simulation time step). The model generates trips from "sources" and from Entry Links and introduces them onto the analysis network at rates specified by the analyst based on the mobilization time distributions. The model simulates the movements of all vehicles on all network links over time until the network is empty. At intervals, the model outputs Measures of Effectiveness (MOE) such as those listed in Table C-1.

Model Features Include:

- Explicit consideration is taken of the variation in density over the time step; an iterative procedure is employed to calculate an average density over the simulation time step for the purpose of computing a mean speed for moving vehicles.
- Multiple turn movements can be serviced on one link; a separate algorithm is used to estimate the number of (fractional) lanes assigned to the vehicles performing each turn movement, based, in part, on the turn percentages provided by the Dynamic Traffic Assignment and Distribution (DTRAD) model.
- At any point in time, traffic flow on a link is subdivided into two classifications: queued and moving vehicles. The number of vehicles in each classification is computed. Vehicle spillback, stratified by turn movement for each network link, is explicitly considered and quantified. The propagation of stopping waves from link to link is computed within each time step of the simulation. There is no "vertical stacking" of queues on a link.
- Any link can accommodate "source flow" from zones via side streets and parking facilities that are not explicitly represented. This flow represents the evacuating trips that are generated at the source.
- The relation between the number of vehicles occupying the link and its storage capacity is monitored every time step for every link and for every turn movement. If the available storage capacity on a link is exceeded by the demand for service, then the simulator applies a "metering" rate to the entering traffic from both the upstream feeders and source node to ensure that the available storage capacity is not exceeded.
- A "path network" that represents the specified traffic movements from each network link is constructed by the model; this path network is utilized by the DTRAD model.
- A two-way interface with DTRAD: (1) provides link travel times; (2) receives data that translates into link turn percentages.
- Provides MOE to animation software, Evacuation Animator (EVAN)
- Calculates ETE statistics

All traffic simulation models are data-intensive. Table C-2 outlines the necessary input data elements.

To provide an efficient framework for defining these specifications, the physical highway environment is represented as a network. The unidirectional links of the network represent

roadway sections: rural, multi-lane, urban streets or freeways. The nodes of the network generally represent intersections or points along a section where a geometric property changes (e.g. a lane drop, change in grade or free flow speed).

Figure C-1 is an example of a small network representation. The freeway is defined by the sequence of links, (20,21), (21,22), and (22,23). Links (8001, 19) and (3, 8011) are Entry and Exit links, respectively. An arterial extends from node 3 to node 19 and is partially subsumed within a grid network. Note that links (21,22) and (17,19) are grade-separated.

C.1 Methodology

C.1.1 The Fundamental Diagram

It is necessary to define the fundamental diagram describing flow-density and speed-density relationships. Rather than "settling for" a triangular representation, a more realistic representation that includes a "capacity drop", (I-R)$Q_{max,}$ at the critical density when flow conditions enter the forced flow regime, is developed and calibrated for each link. This representation, shown in Figure C-2, asserts a constant free speed up to a density, k_f, and then a linear reduction in speed in the range, $k_f \leq k \leq k_c = 45$ vpm, the density at capacity. In the flow-density plane, a quadratic relationship is prescribed in the range, $k_c < k \leq k_s = 95$ vpm which roughly represents the "stop-and-go" condition of severe congestion. The value of flow rate, Q_s, corresponding to k_s, is approximated at $0.7\ RQ_{max}$. A linear relationship between k_s and k_j completes the diagram shown in Figure C-2. Table C-3 is a glossary of terms.

The fundamental diagram is applied to <u>moving</u> traffic on every link. The specified calibration values for each link are: (1) Free speed, v_f; (2) Capacity, Q_{max}; (3) Critical density, $k_c = 45$ vpm; (4) Capacity Drop Factor, R = 0.9 ; (5) Jam density, k_j. Then, $v_c = \frac{Q_{max}}{k_c}$, $k_f = k_c - \frac{(V_f - V_c)\ k_c^2}{Q_{max}}$. Setting $\bar{k} = k - k_c$, then $Q = RQ_{max} - \frac{RQ_{max}}{8333}\ \bar{k}^2$ for $0 \leq \bar{k} \leq \bar{k}_s = 50$. It can be shown that $Q = \left(0.98 - 0.0056\ \bar{k}\right) RQ_{max}$ for $\bar{k}_s \leq \bar{k} \leq \bar{k}_j$, where $\bar{k}_s = 50$ and $\bar{k}_j = 175$.

C.1.2 The Simulation Model

The simulation model solves a sequence of "unit problems". Each unit problem computes the movement of traffic on a link, for each specified turn movement, over a specified time interval (TI) which serves as the simulation time step for all links. Figure C-3 is a representation of the unit problem in the time-distance plane. Table C-3 is a glossary of terms that are referenced in the following description of the unit problem procedure.

The formulation and the associated logic presented below are designed to solve the unit problem for each sweep over the network (discussed below), for each turn movement serviced on each link that comprises the evacuation network, and for each TI over the duration of the evacuation.

$\text{Given} = Q_b, M_b, L, TI, E_0, LN, {}^{G}/_{C}, h, L_v, R_0, L_c, E, M$

$\text{Compute} = O, Q_e, M_e$

Define $O = O_Q + O_M + O_E$; $E = E_1 + E_2$

1. For the first sweep, s = 1, of this TI, get initial estimates of mean density, k_0 , the R – factor, R_0 and entering traffic, E_0 , using the values computed for the final sweep of the prior TI. For each subsequent sweep, $s > 1$, calculate $E = \sum_i P_i \; O_i + S$ where P_i , O_i are the relevant turn percentages from feeder link, i , and its total outflow (possibly metered) over this TI; S is the total source flow (possibly metered) during the current TI.
   Set iteration counter, n = 0, $k = k_0$, and $E = E_0$.

2. Calculate $v(k)$ such that $k \leq 130$ using the analytical representations of the fundamental diagram.
   Calculate $\text{Cap} = \frac{Q_{max}(TI)}{3600} \left({}^{G}/_{C}\right) LN$, in vehicles, this value may be reduced due to metering
   Set $R = 1.0$ if ${}^{G}/_{C} < 1$ or if $k \leq k_c$; Set $R = 0.9$ only if ${}^{G}/_{C} = 1$ and $k > k_c$
   Calculate queue length, $L_b = Q_b \frac{L_v}{LN}$

3. Calculate $t_1 = TI - \frac{L}{V}$. If $t_1 < 0$, set $t_1 = E_1 = O_E = 0$; Else, $E_1 = E \frac{t_1}{TI}$.

4. Then $E_2 = E - E_1$; $t_2 = TI - t_1$

5. If $Q_b \geq \text{Cap}$, then
   $O_Q = \text{Cap}$, $O_M = O_E = 0$
   If $t_1 > 0$, then
   $Q'_e = Q_b + M_b + E_1 - \text{Cap}$
   Else
   $Q'_e = Q_b - \text{Cap}$
   End if
   Calculate Q_e and M_e using Algorithm A (below)

6. Else $(Q_b < \text{Cap})$
   $O_Q = Q_b$, $\text{RCap} = \text{Cap} - O_Q$

7. If $M_b \leq \text{RCap}$, then

8. If $t_1 > 0$, $O_M = M_b$, $O_E = \min\left(\text{RCap} - M_b, \frac{t_1 \, \text{Cap}}{TI}\right) \geq 0$
   $Q'_e = E_1 - O_E$
   If $Q'_e > 0$, then
   Calculate Q_e , M_e with Algorithm A
   Else
   $Q_e = 0$, $M_e = E_2$
   End if

Else $(t_1 = 0)$

$$O_M = \left(\frac{v(TI) - L_b}{L - L_b}\right) M_b \text{ and } O_E = 0$$

$$M_e = M_b - O_M + E\ ;\ Q_e = 0$$

End if

9. Else $(M_b > RCap)$

$O_E = 0$

If $t_1 > 0$, then

$O_M = RCap\ , Q'_e = M_b - O_M + E_1$

Calculate Q_e and M_e using Algorithm A

10. Else $(t_1 = 0)$

$$M_d = \left[\left(\frac{v(TI) - L_b}{L - L_b}\right) M_b\right]$$

If $M_d > RCap$, *then*

$O_M = RCap$

$Q'_e = M_d - O_M$

Apply Algorithm A to calculate Q_e and M_e

Else

$O_M = M_d$

$M_e = M_b - O_M + E$ and $Q_e = 0$

End if

End if

End if

End if

11. Calculate a new estimate of average density, $\bar{k}_n = \frac{1}{4}[k_b + 2\ k_m + k_e]$,

where k_b = density at the beginning of the TI

k_e = density at the end of the TI

k_m = density at the mid-point of the TI

All values of density apply only to the moving vehicles.

If $\left|\bar{k}_n - \bar{k}_{n-1}\right| > \in$ and $n < N$

where $N = \max$ number of iterations, and ϵ is a convergence criterion, then

12. set $n = n + 1$, and return to step 2 to perform iteration, n, using $k = \bar{k}_n$.

End if

Computation of unit problem is now complete. Check for excessive inflow causing spillback.

13. If $Q_e + M_e > \frac{(L-W)\,LN}{L_v}$, then

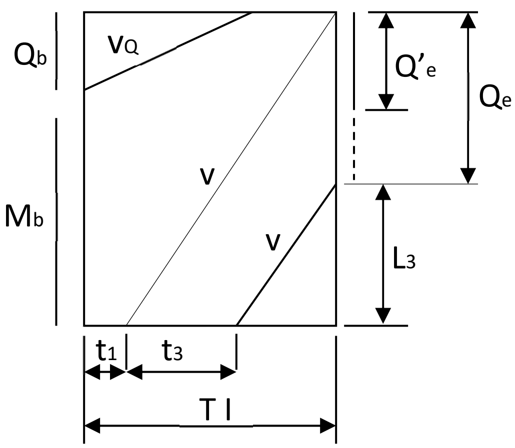
The number of excess vehicles that cause spillback is: $SB = Q_e + M_e - \frac{(L-W)\cdot LN}{L_v}$, where W is the width of the upstream intersection. To prevent spillback, meter the outflow from the feeder approaches and from the source flow, S, during this TI by the amount, SB. That is, set

$$M = 1 - \frac{SB}{(E+S)} \geq 0 \text{, where M is the metering factor (over all movements).}$$

This metering factor is assigned appropriately to all feeder links and to the source flow, to be applied during the next network sweep, discussed later.

Algorithm A

This analysis addresses the flow environment over a TI during which moving vehicles can join a standing or discharging queue. For the case shown, $Q_b \leq Cap$, with $t_1 > 0$ and a queue of length, Q'_e, formed by that portion of M_b and E that reaches the stop-bar within the TI, but could not discharge due to inadequate capacity. That is, $Q_b + M_b + E_1 > Cap$. This queue length, $Q'_e = Q_b + M_b + E_1 - Cap$ can be extended to Q_e by traffic entering the approach during the current TI, traveling at speed, v, and reaching the rear of the queue within the TI. A portion of the entering vehicles, $E_3 = E\,\frac{t_3}{TI}$, will likely join the queue. This analysis calculates t_3, Q_e and M_e for the input values of L, TI, v, E, t, L_v, LN, Q'_e.



When $t_1 > 0$ and $Q_b \leq Cap$:

Define: $L'_e = Q'_e\,\frac{L_v}{LN}$. From the sketch, $L_3 = v(TI - t_1 - t_3) = L - (Q'_e + E_3)\frac{L_v}{LN}$.

Substituting $E_3 = \frac{t_3}{TI}\,E$ yields: $-vt_3 + \frac{t_3}{TI}\,E\,\frac{L_v}{LN} = L - v(TI - t_1) - L'_e$. Recognizing that the first two terms on the right hand side cancel, solve for t_3 to obtain:

$$t_3 = \frac{L'_e}{\left[v - \frac{E}{TI}\,\frac{L_v}{LN}\right]} \qquad \text{such that} \quad 0 \leq t_3 \leq TI - t_1$$

If the denominator, $\left[v - \frac{E}{TI}\,\frac{L_v}{LN}\right] \leq 0$, set $t_3 = TI - t_1$.

$$\text{Then, } Q_e = Q'_e + E\,\frac{t_3}{TI} \quad , \qquad M_e = E\left(1 - \frac{t_1 + t_3}{TI}\right)$$

The complete Algorithm A considers all flow scenarios; space limitation precludes its

inclusion, here.

C.1.3 Lane Assignment

The “unit problem” is solved for each turn movement on each link. Therefore, it is necessary to calculate a value, LN_x, of allocated lanes for each movement, x. If in fact all lanes are specified by, say, arrows painted on the pavement, either as full lanes or as lanes within a turn bay, then the problem is fully defined. If however there remain un-channelized lanes on a link, then an analysis is undertaken to subdivide the number of these physical lanes into turn movement specific virtual lanes, LN_x.

C.2 Implementation

C.2.1 Computational Procedure

The computational procedure for this model is shown in the form of a flow diagram as Figure C-4. As discussed earlier, the simulation model processes traffic flow for each link independently over TI that the analyst specifies; it is usually 60 seconds or longer. The first step is to execute an algorithm to define the sequence in which the network links are processed so that as many links as possible are processed after their feeder links are processed, within the same network sweep. Since a general network will have many closed loops, it is not possible to guarantee that every link processed will have all of its feeder links processed earlier.

The processing then continues as a succession of time steps of duration, TI, until the simulation is completed. Within each time step, the processing performs a series of “sweeps” over all network links; this is necessary to ensure that the traffic flow is synchronous over the entire network. Specifically, the sweep ensures continuity of flow among all the network links; in the context of this model, this means that the values of E, M, and S are all defined for each link such that they represent the synchronous movement of traffic from each link to all of its outbound links. These sweeps also serve to compute the metering rates that control spillback.

Within each sweep, processing solves the “unit problem” for each turn movement on each link. With the turn movement percentages for each link provided by the DTRAD model, an algorithm allocates the number of lanes to each movement serviced on each link. The timing at a signal, if any, applied at the downstream end of the link, is expressed as a G/C ratio, the signal timing needed to define this ratio is an input requirement for the model. The model also has the capability of representing, with macroscopic fidelity, the actions of actuated signals responding to the time-varying competing demands on the approaches to the intersection.

The solution of the unit problem yields the values of the number of vehicles, O, that discharge from the link over the time interval and the number of vehicles that remain on the link at the end of the time interval as stratified by queued and moving vehicles: Q_e and M_e. The procedure considers each movement separately (multi-piping). After all network links are processed for a given network sweep, the updated consistent values of entering flows, E; metering rates, M; and source flows, S are defined so as to satisfy the “no spillback” condition. The procedure then performs the unit problem solutions for all network links during the

following sweep.

Experience has shown that the system converges (i.e. the values of E, M and S "settle down" for all network links) in just two sweeps if the network is entirely under-saturated or in four sweeps in the presence of extensive congestion with link spillback. (The initial sweep over each link uses the final values of E and M, of the prior TI). At the completion of the final sweep for a TI, the procedure computes and stores all measures of effectiveness for each link and turn movement for output purposes. It then prepares for the following time interval by defining the values of $\mathrm{Q_b}$ and $\mathrm{M_b}$ for the start of the next TI as being those values of $\mathrm{Q_e}$ and $\mathrm{M_e}$ at the end of the prior TI. In this manner, the simulation model processes the traffic flow over time until the end of the run. Note that there is no space-discretization other than the specification of network links.

C.2.2 Interfacing with Dynamic Traffic Assignment (DTRAD)

The **DYNEV II** system reflects NRC guidance that evacuees will seek to travel in a general direction away from the location of the hazardous event. Thus, an algorithm was developed to identify an appropriate set of destination nodes for each origin based on its location and on the expected direction of travel. This algorithm also supports the DTRAD model in dynamically varying the Trip Table (O-D matrix) over time from one DTRAD session to the next.

Figure B-1 depicts the interaction of the simulation model with the DTRAD model in the **DYNEV II** system. As indicated, **DYNEV II** performs a succession of DTRAD "sessions"; each such session computes the turn link percentages for each link that remain constant for the session duration, $[\mathrm{T_0}, \mathrm{T_2}]$, specified by the analyst. The end product is the assignment of traffic volumes from each origin to paths connecting it with its destinations in such a way as to minimize the network-wide cost function. The output of the DTRAD model is a set of updated link turn percentages which represent this assignment of traffic.

As indicated in Figure B-1, the simulation model supports the DTRAD session by providing it with operational link MOE that are needed by the path choice model and included in the DTRAD cost function. These MOE represent the operational state of the network at a time, $\mathrm{T_1} \leq \mathrm{T_2}$, which lies within the session duration, $[\mathrm{T_0}, \mathrm{T_2}]$. This "burn time", $\mathrm{T_1} - \mathrm{T_0}$, is selected by the analyst. For each DTRAD iteration, the simulation model computes the change in network operations over this burn time using the latest set of link turn percentages computed by the DTRAD model. Upon convergence of the DTRAD iterative procedure, the simulation model accepts the latest turn percentages provided by the Dynamic Traffic Assignment (DTA) model, returns to the origin time, $\mathrm{T_0}$, and executes until it arrives at the end of the DTRAD session duration at time, $\mathrm{T_2}$. At this time the next DTA session is launched and the whole process repeats until the end of the **DYNEV II** run.

Additional details are presented in Appendix B.

Table C-1. Selected Measures of Effectiveness Output by DYNEV II

Measure	Units	Applies To
Vehicles Discharged	Vehicles	Link, Network, Exit Link
Speed	Miles/Hours (mph)	Link, Network
Density	Vehicles/Mile/Lane	Link
Level of Service	LOS	Link
Content	Vehicles	Network
Travel Time	Vehicle-hours	Network
Evacuated Vehicles	Vehicles	Network, Exit Link
Trip Travel Time	Vehicle-minutes/trip	Network
Capacity Utilization	Percent	Exit Link
Attraction	Percent of total evacuating vehicles	Exit Link
Max Queue	Vehicles	Node, Approach
Time of Max Queue	Hours:minutes	Node, Approach
Route Statistics	Length (mi); Mean Speed (mph); Travel Time (min)	Route
Mean Travel Time	Minutes	Evacuation Trips; Network

Table C-2. Input Requirements for the DYNEV II Model

HIGHWAY NETWORK

- Links defined by upstream and downstream node numbers
- Link lengths
- Number of lanes (up to 9) and channelization
- Turn bays (1 to 3 lanes)
- Destination (exit) nodes
- Network topology defined in terms of downstream nodes for each receiving link
- Node Coordinates (X,Y)
- Nuclear Power Plant Coordinates (X,Y)

GENERATED TRAFFIC VOLUMES

- On all entry links and source nodes (origins), by Time Period

TRAFFIC CONTROL SPECIFICATIONS

- Traffic signals: link-specific, turn movement specific
- Signal control treated as fixed time or actuated
- Location of traffic control points (these are represented as actuated signals)
- Stop and Yield signs
- Right-turn-on-red (RTOR)
- Route diversion specifications
- Turn restrictions
- Lane control (e.g. lane closure, movement-specific)

DRIVER’S AND OPERATIONAL CHARACTERISTICS

- Driver’s (vehicle-specific) response mechanisms: free-flow speed, discharge headway
- Bus route designation.

DYNAMIC TRAFFIC ASSIGNMENT

- Candidate destination nodes for each origin (optional)
- Duration of DTA sessions
- Duration of simulation “burn time”
- Desired number of destination nodes per origin

INCIDENTS

- Identify and Schedule of closed lanes
- Identify and Schedule of closed links

Table C-3. Glossary

Cap	The maximum number of vehicles, of a particular movement, that can discharge from a link within a time interval.
E	The number of vehicles, of a particular movement, that enter the link over the time interval. The portion, E_{TI}, can reach the stop-bar within the TI.
G/C	The green time: cycle time ratio that services the vehicles of a particular turn movement on a link.
h	The mean queue discharge headway, seconds.
k	Density in vehicles per lane per mile.
$\bar{k}$	The average density of <u>moving</u> vehicles of a particular movement over a TI, on a link.
L	The length of the link in feet.
L_b , L_e	The queue length in feet of a particular movement, at the [beginning, end] of a time interval.
LN	The number of lanes, expressed as a floating point number, allocated to service a particular movement on a link.
L_v	The mean effective length of a queued vehicle including the vehicle spacing, feet.
M	Metering factor (Multiplier): 1.
M_b , M_e	The number of moving vehicles on the link, of a particular movement, that are moving at the [beginning, end] of the time interval. These vehicles are assumed to be of equal spacing, over the length of link upstream of the queue.
O	The total number of vehicles of a particular movement that are discharged from a link over a time interval.
O_Q , O_M , O_E	The components of the vehicles of a particular movement that are discharged from a link within a time interval: vehicles that were Queued at the beginning of the TI; vehicles that were Moving within the link at the beginning of the TI; vehicles that Entered the link during the TI.
P_x	The percentage, expressed as a fraction, of the total flow on the link that executes a particular turn movement, x.

Q_b , Q_e	The number of queued vehicles on the link, of a particular turn movement, at the [beginning, end] of the time interval.
Q_{max}	The maximum flow rate that can be serviced by a link for a particular movement in the absence of a control device. It is specified by the analyst as an estimate of link capacity, based upon a field survey, with reference to the HCM 2016.
R	The factor that is applied to the capacity of a link to represent the "capacity drop" when the flow condition moves into the forced flow regime. The lower capacity at that point is equal to RQ_{max} .
RCap	The remaining capacity available to service vehicles of a particular movement after that queue has been completely serviced, within a time interval, expressed as vehicles.
S_x	Service rate for movement x, vehicles per hour (vph).
t_1	Vehicles of a particular turn movement that enter a link over the first t_1 seconds of a time interval, can reach the stop-bar (in the absence of a queue down-stream) within the same time interval.
TI	The time interval, in seconds, which is used as the simulation time step.
v	The mean speed of travel, in feet per second (fps) or miles per hour (mph), of moving vehicles on the link.
v_Q	The mean speed of the last vehicle in a queue that discharges from the link within the TI. This speed differs from the mean speed of moving vehicles, v.
W	The width of the intersection in feet. This is the difference between the link length which extends from stop-bar to stop-bar and the block length.

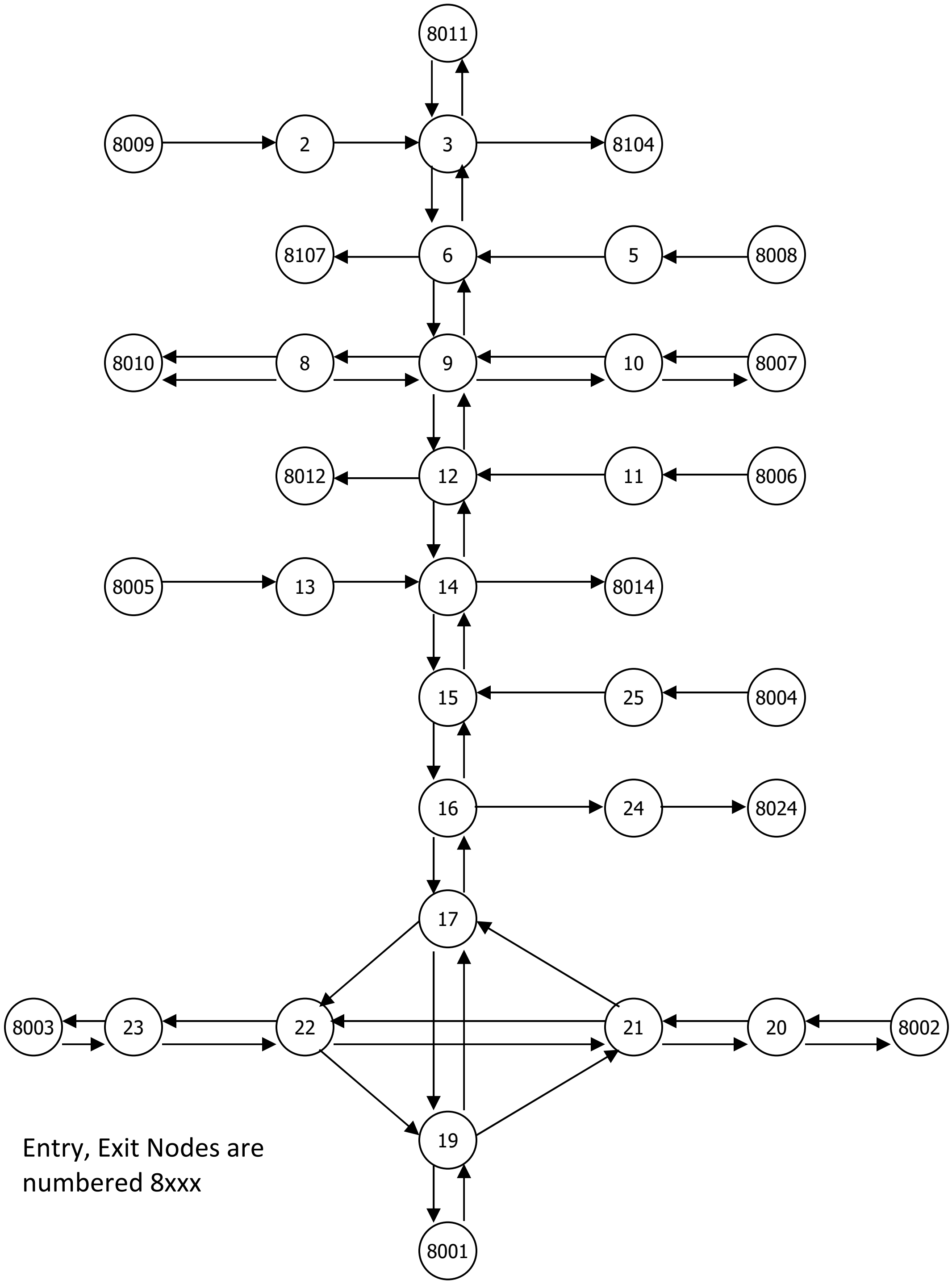


Figure C-1. Representative Analysis Network

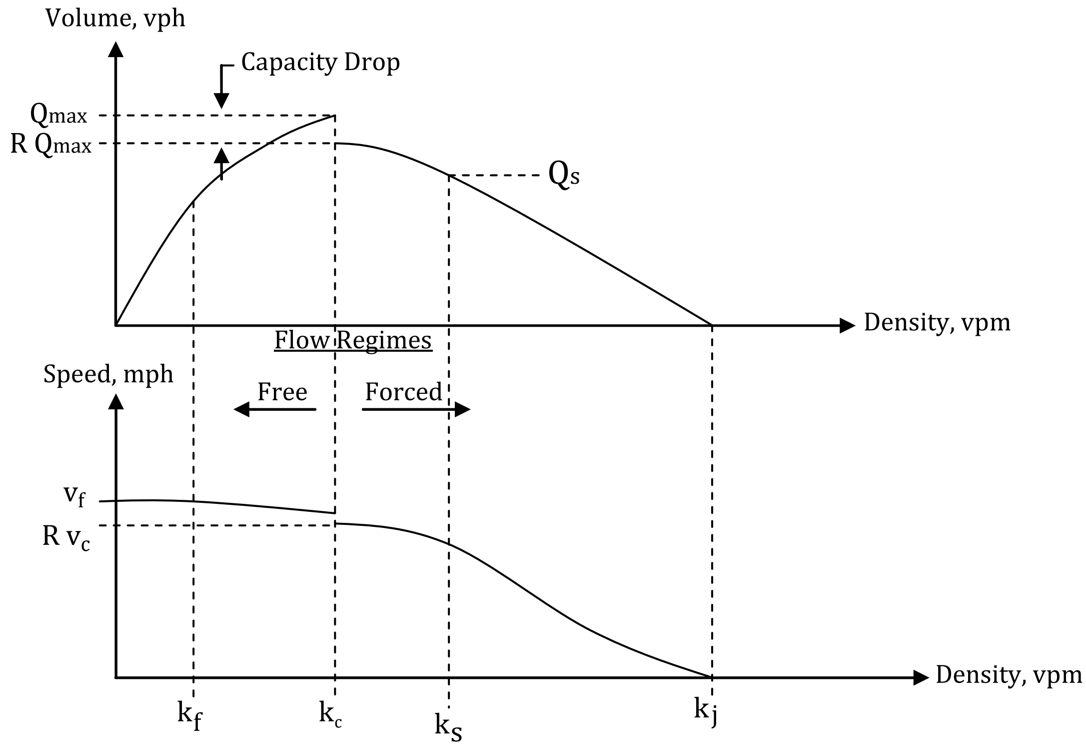


Figure C-2. Fundamental Diagrams

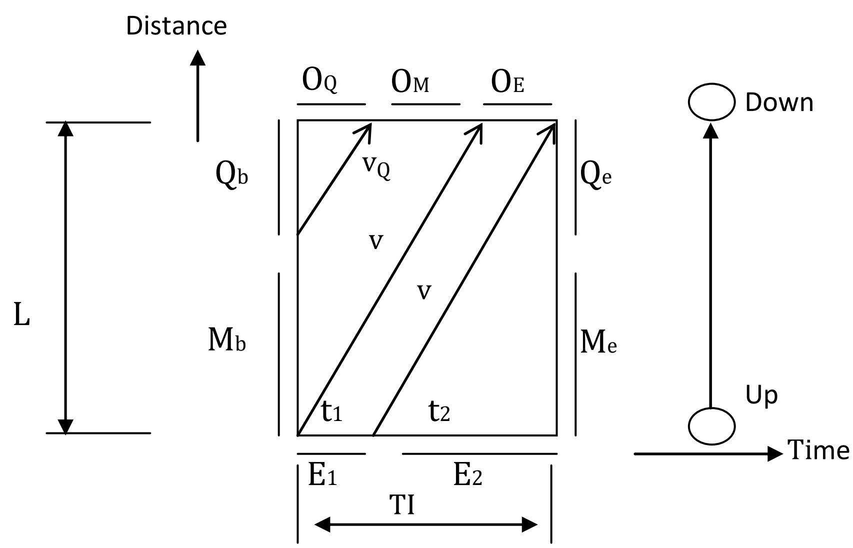


Figure C-3. A UNIT Problem Configuration with t_1 > 0

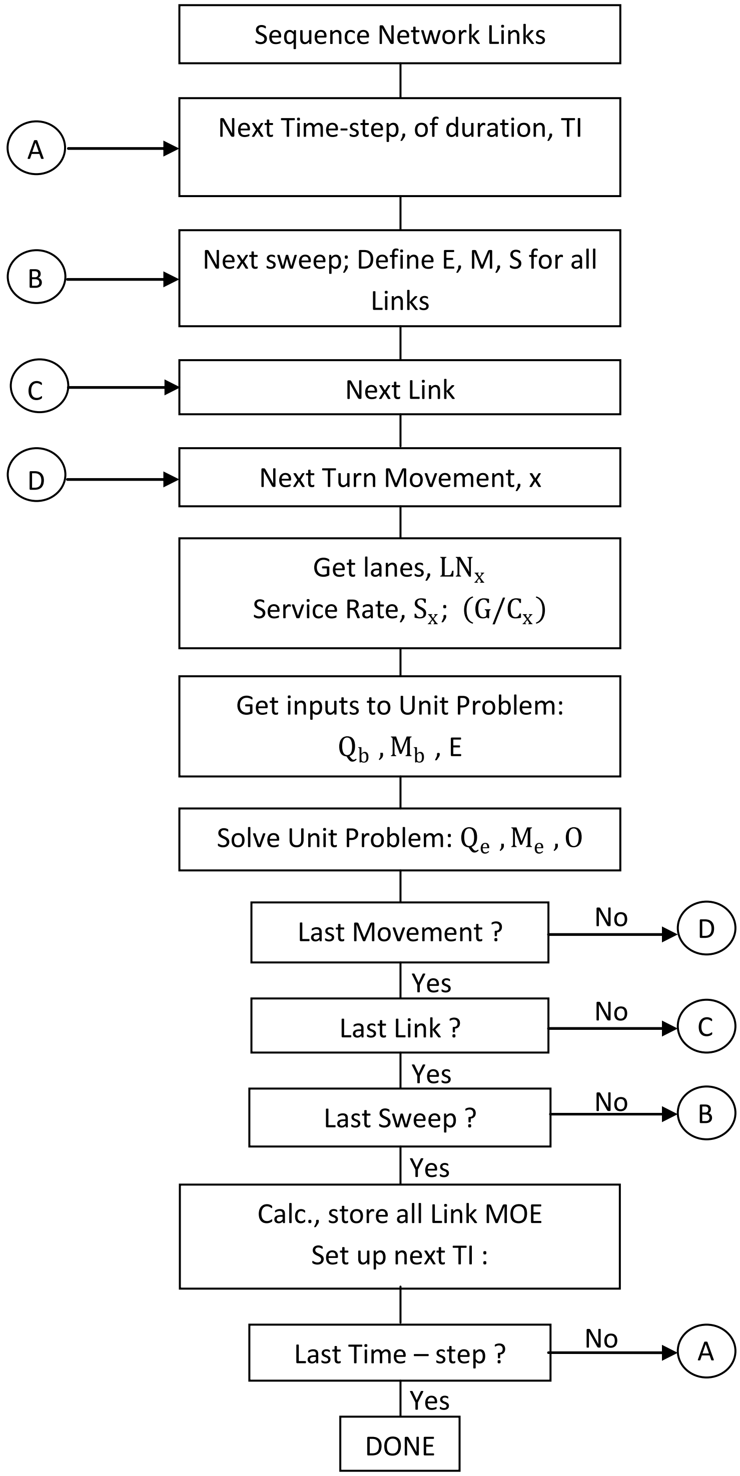


Figure C-4. Flow of Simulation Processing (See Glossary: Table C-3)

APPENDIX D

Detailed Description of Study Procedure

D. DETAILED DESCRIPTION OF STUDY PROCEDURE

This appendix describes the activities that were performed to compute Evacuation Time Estimate (ETE). The individual steps of this effort are represented as a flow diagram in Figure D-1. Each numbered step in the description that follows corresponds to the numbered element in the flow diagram.

Step 1

The first activity was to obtain Emergency Planning Zone (EPZ) boundary information and create a geographical information system (GIS) base map. The base map extends beyond the Shadow Region which extends approximately 15 miles (radially) from the power plant location. The base map incorporates the local roadway topology, a suitable topographic background and the EPZ boundary.

Step 2

2020 Census block information was obtained in GIS format. This information was used to estimate the permanent resident population within the EPZ and Shadow Region and to define the spatial distribution and demographic characteristics of the population within the study area. Data for employees, transients, schools, and other facilities were obtained from the county emergency management departments, supplemented by internet searches and data from the previous ETE study where new data could not be obtained.

Step 3

A kickoff meeting was conducted with project stakeholders. The purpose of the kickoff meeting was to present an overview of the work effort, identify key agency personnel, and indicate the data requirements for the study. Specific requests for information were also presented. Unique features of the study area were discussed to identify the local concerns that should be addressed by the ETE study.

Step 4

Next, a physical survey of the roadway system in the study area was conducted to determine the geometric properties of the highway sections, the channelization of lanes on each section of roadway, whether there are any turn restrictions or special treatment of traffic at intersections, the type and functioning of traffic control devices, gathering signal timings for pre-timed traffic signals (if any exist within the study area) and to make the necessary observations needed to estimate realistic values of roadway capacity. Roadway characteristics were also verified using aerial imagery.

Step 5

A demographic survey of households within the EPZ was conducted to identify household dynamics, trip generation characteristics, and evacuation-related demographic information of the EPZ population for this study. This information was used to determine important study factors including the average number of evacuating vehicles used by each household, and the time required to perform pre-evacuation mobilization activities.

Step 6

A computerized representation of the physical roadway system, called a link-node analysis network, was developed using the most recent UNITES software (see Section 1.3) developed by KLD. Once the geometry of the network was completed, the network was calibrated using the information gathered during the road survey (Step 4) and information obtained from aerial imagery. Estimates of highway capacity for each link and other link-specific characteristics were introduced to the network description. Traffic signal timings were input accordingly. The link-node analysis network was imported into a GIS map. The 2020 Census data were overlaid in the map, and origin centroids where trips would be generated during the evacuation process were assigned to appropriate links.

Step 7

The EPZ is subdivided into 15 Subareas. Based on wind direction and speed, Regions (groupings of Subarea) that may be advised to evacuate, were developed.

The need for evacuation can occur over a range of time-of-day, day-of-week, seasonal and weather-related conditions. Scenarios were developed to capture the variation in evacuation demand, highway capacity and mobilization time, for different time of day, day of the week, time of year, and weather conditions.

Step 8

The input stream for the DYNEV II system, which integrates the dynamic traffic assignment and distribution model, DTRAD, with the evacuation simulation model, was created for a prototype evacuation case – the evacuation of the entire EPZ for a representative scenario.

Step 9

After creating this input stream, the DYNEV II System was executed on the prototype evacuation case to compute evacuating traffic routing patterns consistent with the appropriate NRC guidelines. DYNEV II contains an extensive suite of data diagnostics which check the completeness and consistency of the input data specified. The analyst reviews all warning and error messages produced by the model and then corrects the database to create an input stream that properly executes to completion.

The model assigns destinations to all origin centroids consistent with a (general) radial evacuation of the EPZ and Shadow Region. The analyst may optionally supplement and/or replace these model-assigned destinations, based on professional judgment, after studying the topology of the analysis highway network. The model produces link and network-wide measures of effectiveness as well as estimates of evacuation time.

Step 10

The results generated by the prototype evacuation case are critically examined. The examination includes observing the animated graphics (using the EVAN software – see Section 1.3) and reviewing the statistics output by the model. This is a labor-intensive activity, requiring

the direct participation of skilled engineers who possess the necessary practical experience to interpret the results and to determine the causes of any problems reflected in the results.

Essentially, the approach is to identify those bottlenecks in the network that represent locations where congested conditions are pronounced and to identify the cause of this congestion. This cause can take many forms, either as excess demand due to high rates of trip generation, improper routing, a shortfall of capacity, or as a quantitative flaw in the way the physical system was represented in the input stream. This examination leads to one of two conclusions:

- The results are satisfactory; or
- The input stream must be modified accordingly.

This decision requires, of course, the application of the user's judgment and experience based upon the results obtained in previous applications of the model and a comparison of the results of the latest prototype evacuation case iteration with the previous ones. If the results are satisfactory in the opinion of the user, then the process continues with Step 13. Otherwise, proceed to Step 11.

Step 11

There are many "treatments" available to the user in resolving apparent problems. These treatments range from decisions to reroute the traffic by assigning additional evacuation destinations for one or more sources, imposing turn restrictions where they can produce significant improvements in capacity, changing the control treatment at critical intersections so as to provide improved service for one or more movements, adding routes (which are paved and traversable) that were not previously modelled but may assist in an evacuation and increase the available roadway network capacity, or in prescribing specific treatments for channelizing the flow so as to expedite the movement of traffic along major roadway systems. Such "treatments" take the form of modifications to the original prototype evacuation case input stream. All treatments are designed to improve the representation of evacuation behavior.

Step 12

As noted above, the changes to the input stream must be implemented to reflect the modifications undertaken in Step 11. At the completion of this activity, the process returns to Step 9 where the DYNEV II System is again executed.

Step 13

Evacuation of transit-dependent evacuees and schools are included in the evacuation analysis. Fixed routing for transit buses, school buses, ambulatory buses, wheelchair buses, and ambulances, are introduced into the final prototype evacuation case data set. DYNEV II generates route-specific speeds over time for use in the estimation of evacuation times for the transit dependent population and schools.

Step 14

The prototype evacuation case was used as the basis for generating all region and scenario-specific evacuation cases to be simulated. This process was automated through the UNITES user interface. For each specific case, the population to be evacuated, the trip generation distributions, the highway capacity and speeds, and other factors are adjusted to produce a customized case-specific data set.

Step 15

All evacuation cases are executed using the DYNEV II System to compute ETE. Once results are available, quality control procedures are used to assure the results were consistent, dynamic routing is reasonable, and traffic congestion/bottlenecks are addressed properly.

Step 16

Once vehicular evacuation results are accepted, average travel speeds for transit and school routes are used to compute evacuation time estimates for transit-dependent permanent residents and schools.

Step 17

The simulation results are analyzed, tabulated and graphed. The results are then documented, as required by NUREG/CR-7002, Rev. 1.

Step 18

Following the completion of documentation activities, the ETE criteria checklist (see Appendix N) is completed. An appropriate report reference is provided for each criterion provided in the checklist.

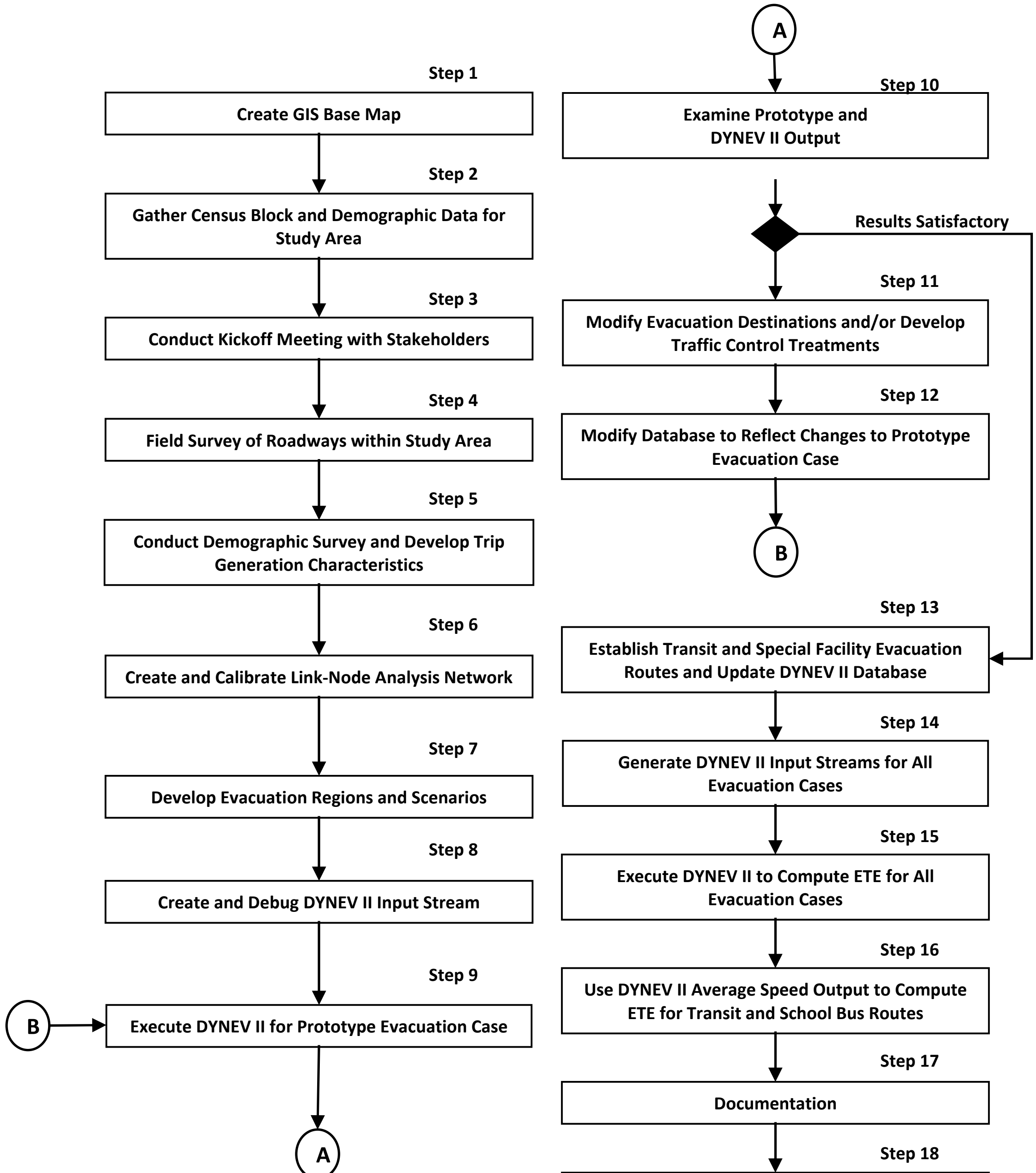


Figure D-1. Flow Diagram of Activities

APPENDIX E

Special Facility Data

E. SPECIAL FACILITY DATA

The following tables list population information, as of November 2021, for special facilities, transient attractions, and major employers that are located within the Callaway Energy Center EPZ. Special facilities are defined as schools, colleges/universities, hospitals, other medical care facilities, and correctional facilities. Transient population data is included in the tables for recreational areas (parks, campgrounds, hunting/fishing areas) and lodging facilities. Each table is grouped by county. The location of the facility is defined by its straight-line distance (miles) and direction (magnetic bearing) from the center point of the plant. Maps of each school, college/university, medical facility, major employer, recreational facility, lodging facility, and correctional facility are also provided.

Table E-1. Schools and Colleges/Universities within the EPZ

Subarea	Distance (miles)	Dire-ction	School Name	Street Address	Municipality	Enroll-ment
			CALLAWAY COUNTY			
C7	7.8	SW	South Callaway R-II Middle School	10135 State Rd C	Mokane	864
C7	7.9	SW	South Callaway R-II High School	10135 State Rd C	Mokane	
C7	7.9	SW	South Callaway R-II Elementary School	10135 State Rd C	Mokane	
C9	10.5	NW	Bush Elementary School	908 Wood St	Fulton	370
C9	10.5	NW	Missouri School for the Deaf	505 E 5th St	Fulton	80
C9	10.7	WNW	Bartley Elementary School	603 S Business 54	Fulton	282
C9	10.8	NW	St Peter's Catholic School	700 State Rd Z	Fulton	128
C9	10.9	NW	Fulton Middle School	403 E 10th St	Fulton	580
C9	11.2	WNW	Kingdom Christian Academy	605 Old Jefferson City Rd	Fulton	174
C9	11.3	WNW	Westminster College	501 Westminster Ave	Fulton	760
C9	11.3	NW	Rosa Parks Center	211 W 12th St	Fulton	8
C9	11.4	NW	William Woods University	One University Ave	Fulton	223
C9	11.4	WNW	McIntire Elementary School	706 Hickman Ave	Fulton	1,737
C9	11.7	NW	Fulton High School	1 Hornet Dr	Fulton	2,129
C10	11.8	N	Missouri Girls Town Foundation	8548 Jade Rd	Fulton	50
					Callaway County Subtotal:	*7,551*
			OSAGE COUNTY			
O1	6.2	S	Chamois High School	614 Poplar St	Chamois	79
O1	6.2	S	Osage County Chamois R-1 School District	614 S Poplar St	Chamois	219
					Osage County Subtotal:	*298*
					EPZ TOTAL:	**7,849**

Table E-2. Medical Facilities within the EPZ

Subarea	Distance (miles)	Dire-ction	Facility Name	Street Address	Municipality	Capacity	Ambul-atory Patients	Wheel-chair Patients	Bed-ridden Patients
CALLAWAY COUNTY									
C7	7.8	SW	Riverview Nursing Center	10303 State Rd C	Mokane	60	Shelter in Place		
C9	10.3	NW	Fulton State Hospital	600 E 5th St	Fulton	281	Shelter in Place		
C9	10.9	NW	Kingdom Care Senior Living	811 Center St	Fulton	36	Shelter in Place		
C9	11.1	WNW	Ashbury Heights Independent Living	704 W Chestnut St	Fulton	12	Shelter in Place		
C9	11.1	NW	Bridgeway Assisted Living Care	828 Jefferson St	Fulton	94	Shelter in Place		
C9	11.2	NW	Fulton Nursing & Rehab	1510 N Bluff St	Fulton	100	Shelter in Place		
C9	11.2	WNW	Bristol Manor	750 Sign Painter Rd	Fulton	12	Shelter in Place		
C9	11.3	NW	Fulton Manor Care Center	520 Manor Dr	Fulton	52	Shelter in Place		
C9	11.4	WNW	Fulton Medical Center	10 S Hospital Dr	Fulton	39	Shelter in Place		
C9	11.5	WNW	Churchill Terrace	120 Hospital Dr	Fulton	44	Shelter in Place		
Callaway County Subtotal:						*730*	*0*	*0*	*0*
EPZ TOTAL:						**730**	**0**	**0**	**0**

Table E-3. Major Employers within the EPZ

Subarea	Distance (miles)	Dire-ction	Facility Name	Street Address	Municipality	Employees (Max Shift)	% Employees Commuting into the EPZ	Employees Commuting into the EPZ	Employee Vehicles Commuting into the EPZ
CALLAWAY COUNTY									
C1	-	-	Callaway Nuclear Plant	County Rd 459	Callaway	770	43%	331	304
C9	12.4	NW	Dollar General	1990 North Bluff St	Fulton	350	65%	228	209
Callaway County Subtotal:						*1,120*	*-*	*559*	*513*
EPZ TOTAL:						**1,120**	**-**	**559**	**513**

Table E-4. Recreational Areas within the EPZ

Subarea	Distance (miles)	Dire-ction	Facility Name	Street Address	Municipality	Facility Type	Transients	Vehicles
CALLAWAY COUNTY								
C1	0.9	NE	Reform Conservation Area	-	Portland	Hunting/Fishing	10	4
C2	3.0	WNW	Harmony Hills Youth Camp	8033 State Rd O	Fulton	Campground	150	75
C2	3.1	W	Hams Prairie Access	County Rd 449	Auxvasse	Hunting/Fishing	1	1
C3	3.3	N	Wildwood Lot Owners Association	7233 Wildwood Estates Dr	Steedman	Campground	41	15
C4	6.8	ESE	Tate Island CA	-	Portland	Hunting/Fishing	2	2
C6	3.7	S	KATY Trail	Route 94	Portland	Park	10	4
C7	7.9	SW	High Hopes Hunting Sports Club	440 Fulton Rd	Mokane	Hunting	20	12
C8	9.2	WNW	Kingdom of Callaway County Fair	7217 State Rd C	Fulton	Other	500	183
C9	10.6	NW	Fulton Country Club[1]	701 E 10th St	Fulton	Golf Course	Local residents only	
C10	10.4	N	Moores Mill Access	County Rd 139	Calwood	Hunting/Fishing	4	2
						Callaway County Subtotal:	*738*	*298*
MONTGOMERY COUNTY								
M2	9.5	ESE	Grand Bluffs CA	Bluffton Rd	Fulton	Hunting/Fishing	5	5
						Montgomery County Subtotal:	*5*	*5*
OSAGE COUNTY								
O1	5.6	S	Chamois Access	Highway 100	Chamois	Hunting/Fishing	30	30
						Osage County Subtotal:	*30*	*30*
						EPZ TOTAL:	**773**	**333**

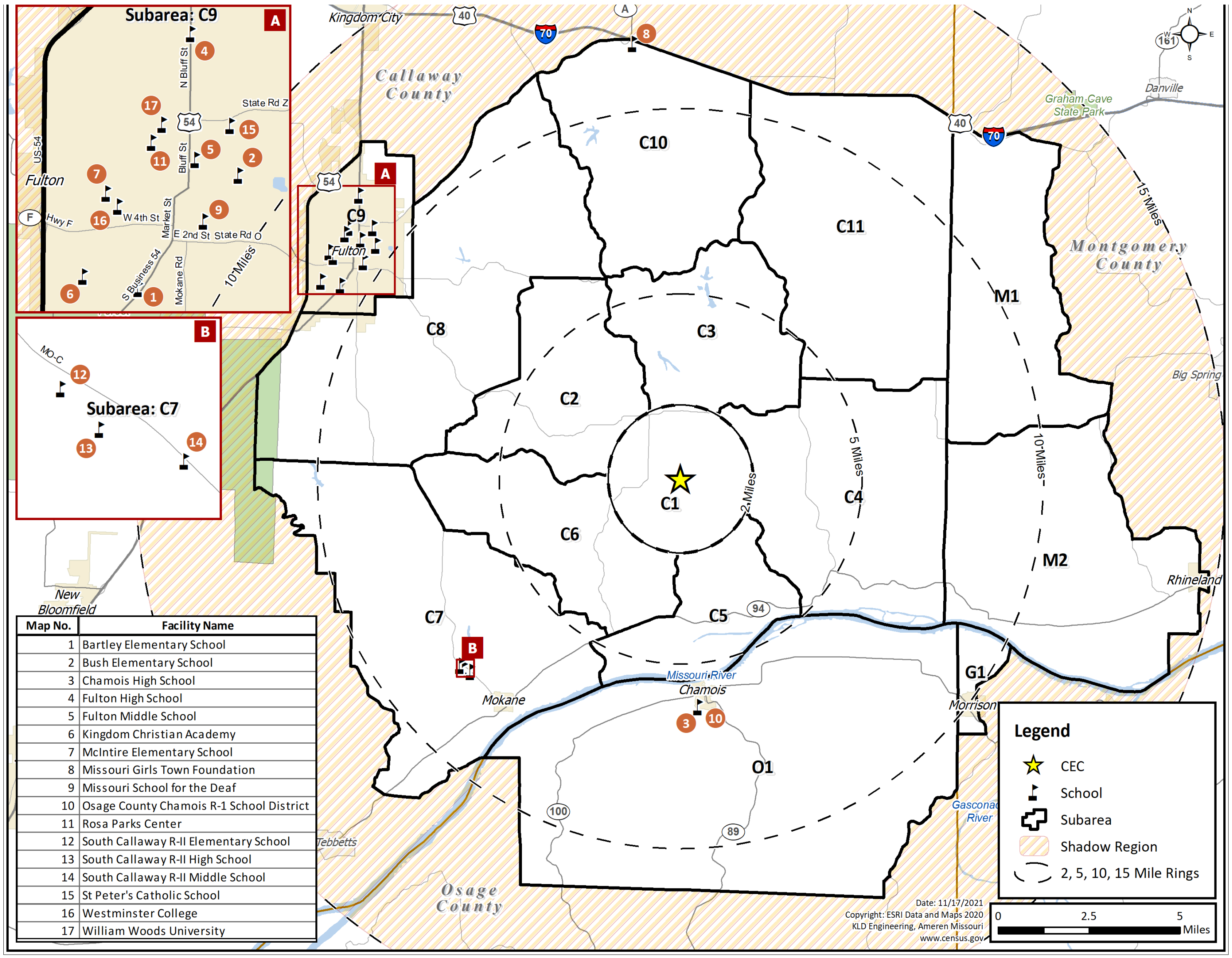
[1] Fulton Country Club was reported having all local residents, resulting in no transients or transient vehicles.

Table E-5. Lodging Facilities within the EPZ

Subarea	Distance (miles)	Dire-ction	Facility Name	Street Address	Municipality	Transients	Vehicles
CALLAWAY COUNTY							
C9	10.8	WNW	Travelier Motel	600 South Business 54	Fulton	10	5
C9	11.1	WNW	Loganberry Inn	310 West Seventh St	Fulton	4	2
C9	11.8	WNW	Westwoods Motel	422 Gaylord Dr	Fulton	19	9
C9	12.5	NW	Baymont Inn and Suites Fulton Hotel	2205 Cardinal Dr	Fulton	111	55
S.R.	12.0	WNW	Country Hearth Inn	556 Amerihost Dr	Fulton	62	31
					Callaway County Subtotal:	*206*	*102*
OSAGE COUNTY							
O1	6.1	S	Old School on the Hill Bed & Breakfast	402 S Main St	Chamois	5	2
					Osage County Subtotal:	*5*	*2*
					EPZ TOTAL:	**211**	**104**

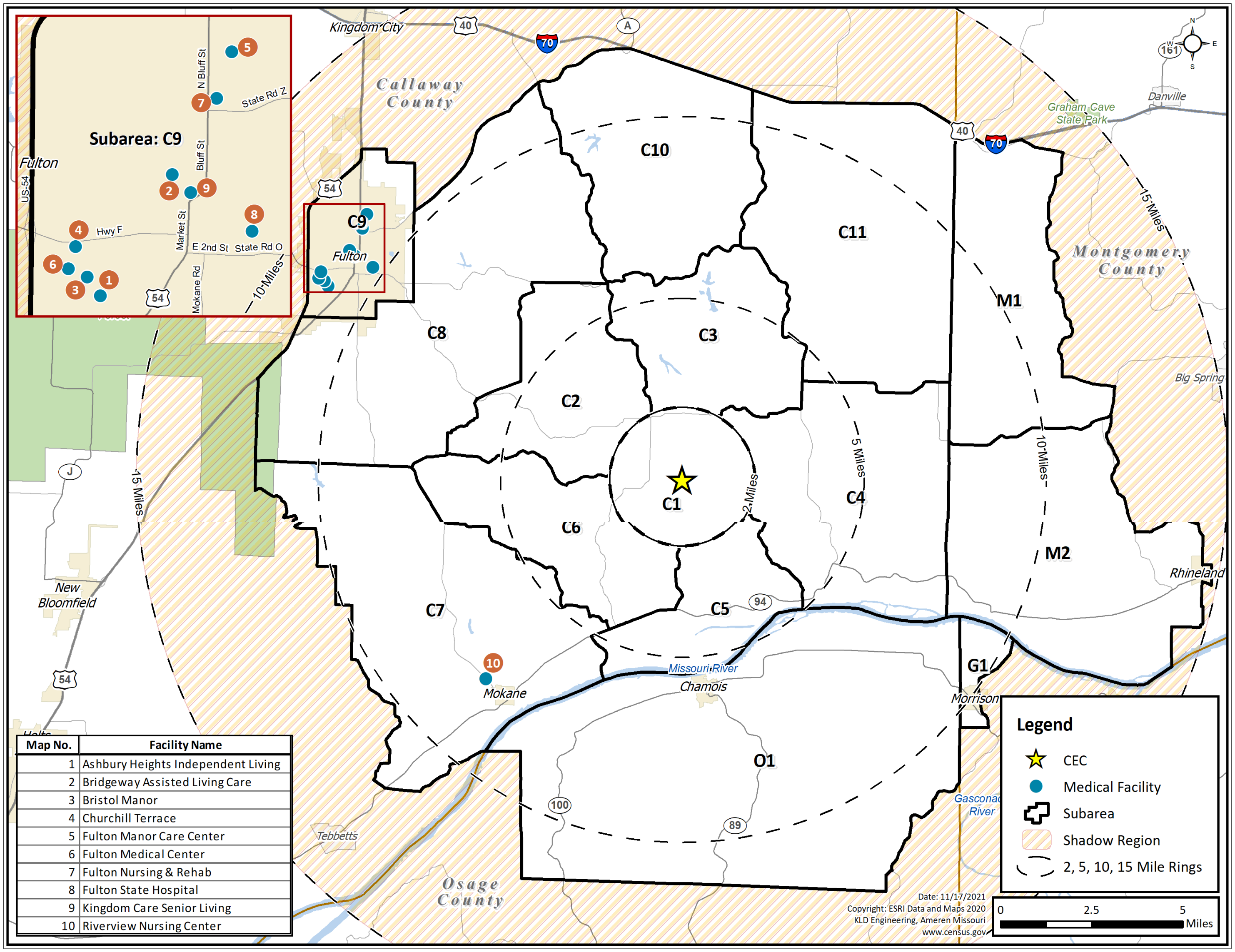
Table E-6. Correctional Facilities within the EPZ

Subarea	Distance (miles)	Dire-ction	Facility Name	Street Address	Municipality	Cap-acity
CALLAWAY COUNTY						
C9	9.6	NW	Fulton Reception and Diagnostic Center	1393 Highway O	Fulton	1,346
C9	9.8	NW	Callaway County Jail	1201 Missouri O	Fulton	109
					Callaway County Subtotal:	*1,455*
					EPZ TOTAL:	**1,455**



Map No.	Facility Name
1	Bartley Elementary School
2	Bush Elementary School
3	Chamois High School
4	Fulton High School
5	Fulton Middle School
6	Kingdom Christian Academy
7	McIntire Elementary School
8	Missouri Girls Town Foundation
9	Missouri School for the Deaf
10	Osage County Chamois R-1 School District
11	Rosa Parks Center
12	South Callaway R-II Elementary School
13	South Callaway R-II High School
14	South Callaway R-II Middle School
15	St Peter's Catholic School
16	Westminster College
17	William Woods University

Figure E-1. Schools and Colleges/Universities within the EPZ



Map No.	Facility Name
1	Ashbury Heights Independent Living
2	Bridgeway Assisted Living Care
3	Bristol Manor
4	Churchill Terrace
5	Fulton Manor Care Center
6	Fulton Medical Center
7	Fulton Nursing & Rehab
8	Fulton State Hospital
9	Kingdom Care Senior Living
10	Riverview Nursing Center

Figure E-2. Medical Facilities within the EPZ

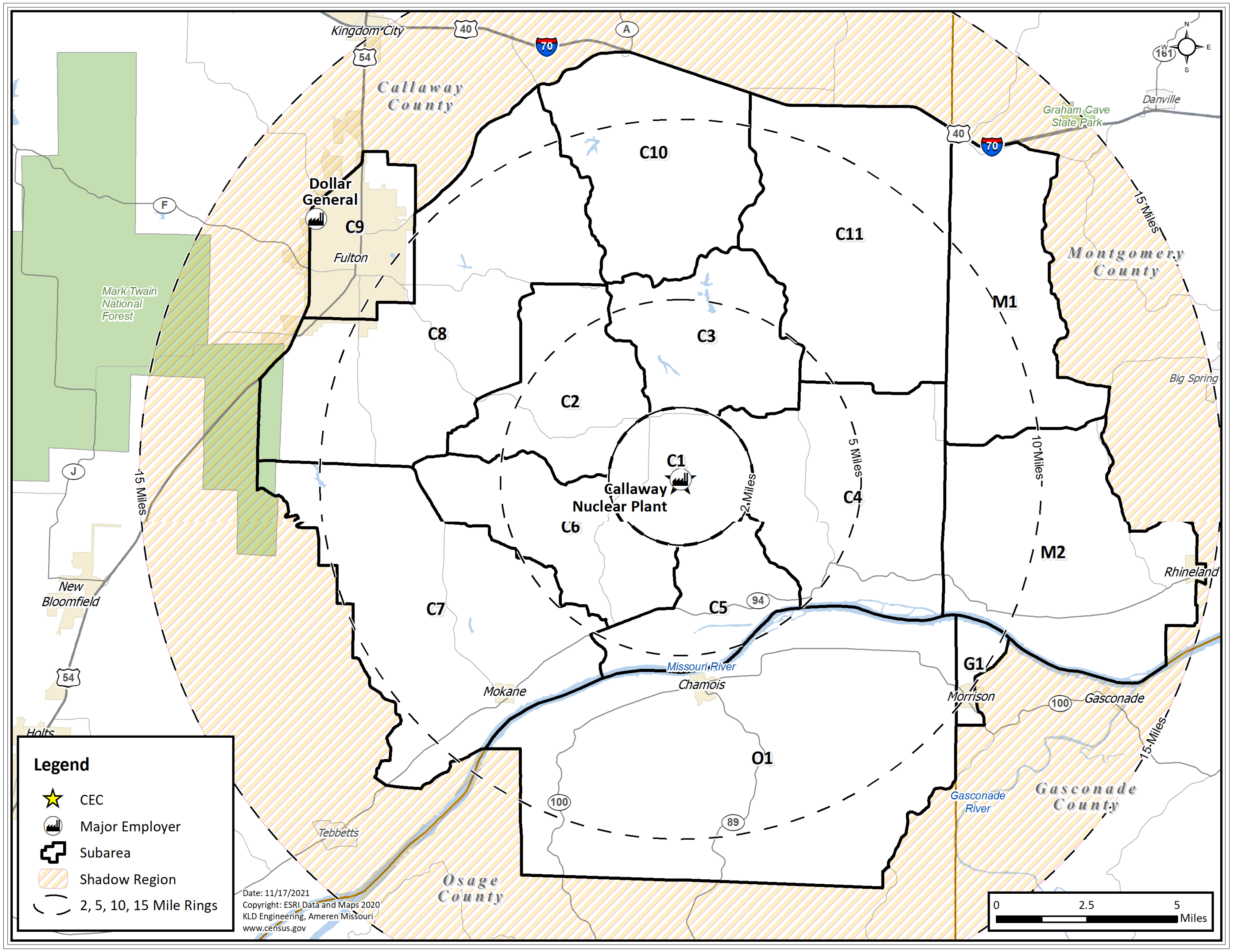
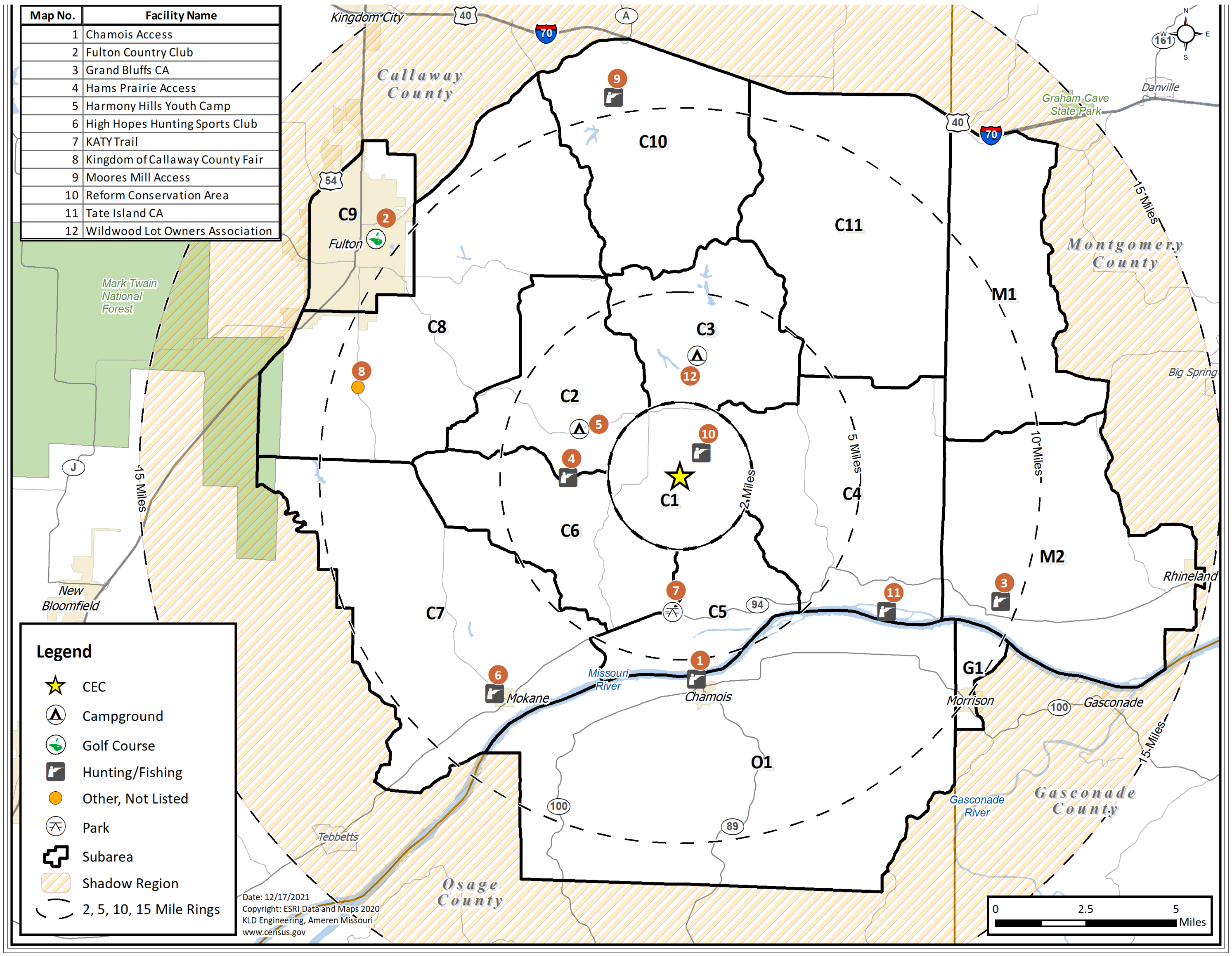
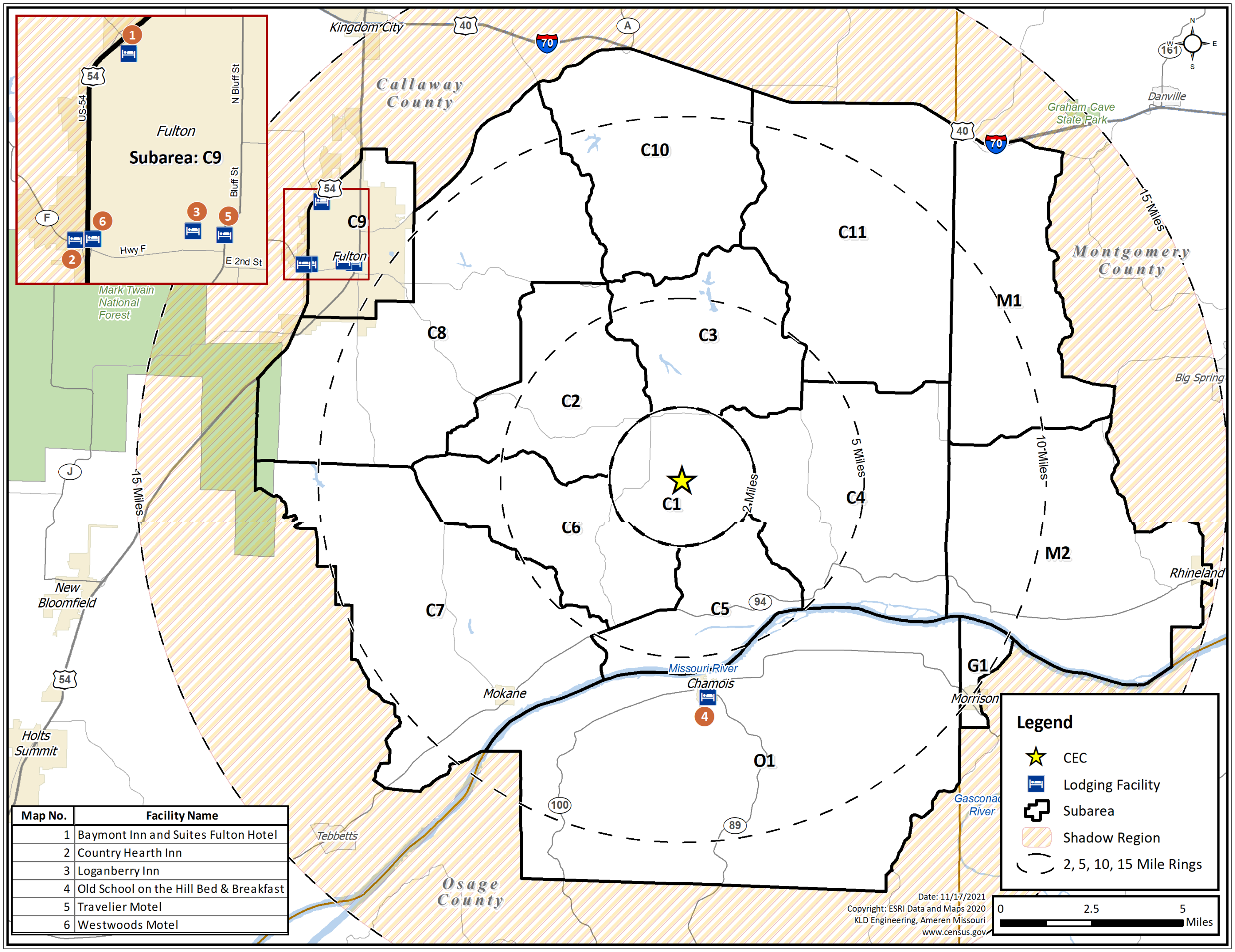


Figure E-3. Major Employers within the EPZ



Map No.	Facility Name
1	Chamois Access
2	Fulton Country Club
3	Grand Bluffs CA
4	Hams Prairie Access
5	Harmony Hills Youth Camp
6	High Hopes Hunting Sports Club
7	KATY Trail
8	Kingdom of Callaway County Fair
9	Moores Mill Access
10	Reform Conservation Area
11	Tate Island CA
12	Wildwood Lot Owners Association

Figure E-4. Recreational Areas within the EPZ



Map No.	Facility Name
1	Baymont Inn and Suites Fulton Hotel
2	Country Hearth Inn
3	Loganberry Inn
4	Old School on the Hill Bed & Breakfast
5	Travelier Motel
6	Westwoods Motel

Figure E-5. Lodging Facilities within the EPZ

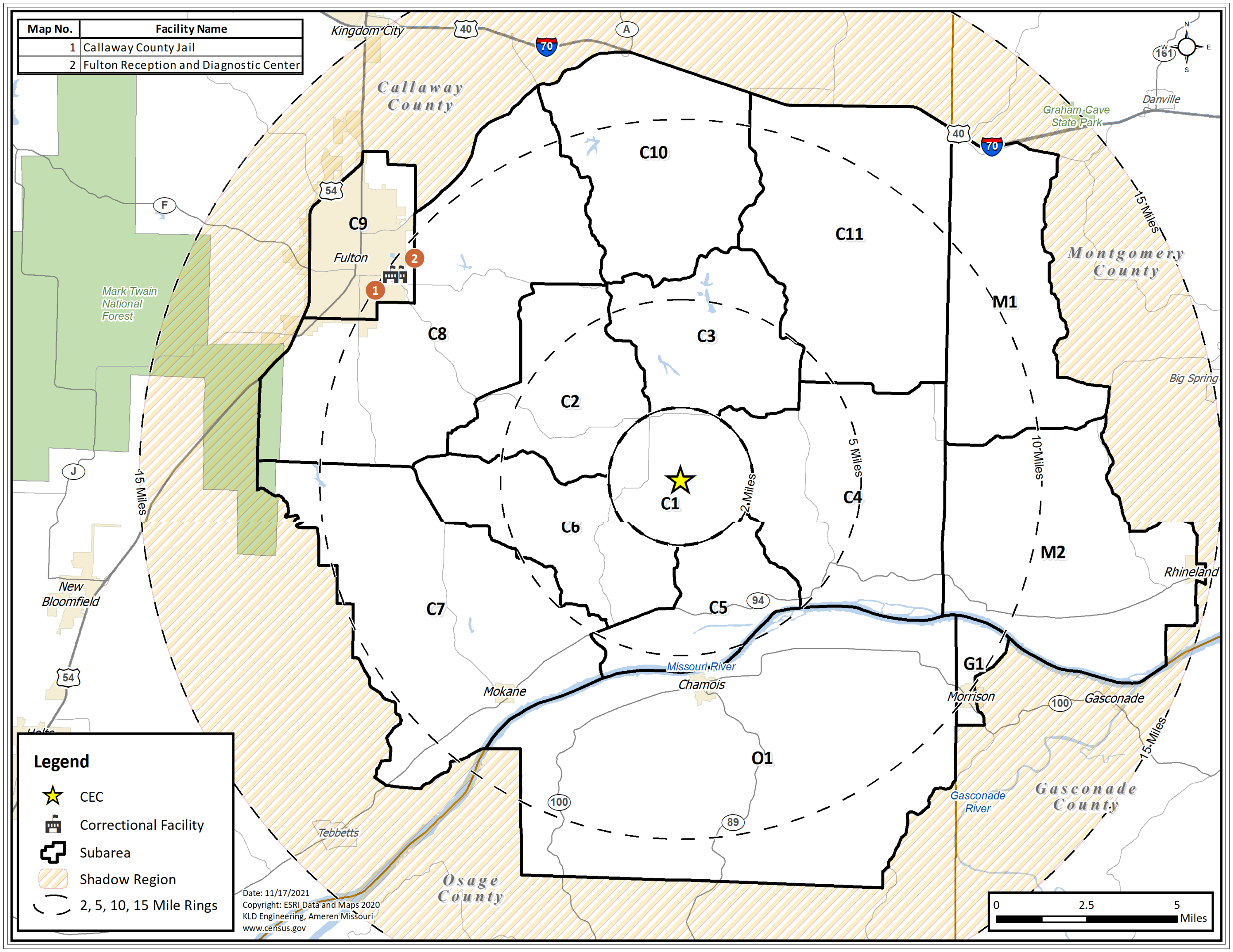


Figure E-6. Correctional Facilities within the EPZ

APPENDIX F

Demographic Survey

F. DEMOGRAPHIC SURVEY

F.1 Introduction

The development of evacuation time estimates (ETE) for the Callaway Energy Center (CEC) Emergency Planning Zone (EPZ) requires the identification of travel patterns, car ownership and household size of the population within the EPZ. Demographic information can be obtained from Census data; however, the use of this data has several limitations when applied to emergency planning. First, the Census data do not encompass the range of information needed to identify the time required for preliminary activities (mobilization) that must be undertaken prior to evacuating the area. Secondly, Census data do not contain attitudinal responses needed from the population of the EPZ and consequently may not accurately represent the anticipated behavioral characteristics of the evacuating populace.

These concerns are addressed by conducting a demographic survey of a representative sample of the EPZ population. The survey is designed to elicit information from the public concerning family demographics and estimates of response times to well defined events. The design of the survey includes a limited number of questions of the form “What would you do if …?” and other questions regarding activities with which the respondent is familiar (“How long does it take you to…?”)

F.2 Survey Instrument and Sampling Plan

Attachment A presents the final survey instrument used in this study. A draft of the instrument was submitted to stakeholders for comment. Comments were received and the survey instrument was modified accordingly, prior to conducting the survey.

Following the completion of the instrument, a sampling plan was developed. Since the demographic survey discussed herein was performed in 2020 and the 2020 Census data had not been released, 2010 Census data was used to develop the sampling plan.

The sample must be drawn from the EPZ population. Consequently, a list of zip codes in the EPZ was developed using GIS software. This list is shown in Table F-1. Along with each zip code, an estimate of the population and number of households in each area was determined by overlaying 2010 Census data and the EPZ boundary, again using GIS software. The proportional percentage of desired completed survey interviews for each area was identified, as shown in Table F-1. Note that the average household size computed in Table F-1 was an estimate for sampling purposes and was not used in the ETE study. A sample size of 304 **completed** survey forms was obtained and yielded results with a sampling error of ±5.5% at the 95% confidence level. The number of samples obtained from each zip code is also shown in Table F-1.

F.3 Survey Results

The results of the survey fall into two categories. First, the household demographics of the area can be identified. Demographic information includes such factors as household size, automobile ownership, and automobile availability. The distributions of the time to perform certain pre-evacuation activities are the second category of survey results. These data are processed to develop the trip generation distributions used in the evacuation modeling effort, as discussed in Section 5.

A review of the survey instrument reveals that several questions have a "don't know" (DK) or "refused" entry for a response. It is accepted practice in conducting surveys of this type to accept the answers of a respondent who offers a DK response for a few questions or who refuses to answer a few questions. To address the issue of occasional DK/refused responses from a large sample, the practice is to assume that the distribution of these responses is the same as the underlying distribution of the positive responses. In effect, the DK/refused responses are ignored, and the distributions are based upon the positive data that is acquired.

F.3.1 Household Demographic Results

Household Size

Figure F-1 presents the distribution of household size within the EPZ, based on the responses to the demographic survey. The average household contains 2.79 people. The estimated household size (2.87 persons) used to determine the survey sample (Table F-1) was drawn from the 2010 Census data. According to the 2020 Census data, the average household size is 2.78 people per household, which is in good agreement with the results of the demographic survey and falls within the margin of error of the survey.

Automobile Ownership

The average number of vehicles available per household in the EPZ is 2.65. The distribution of automobile ownership is presented in Figure F-2. Figure F-3 and Figure F-4 present the vehicle availability by household size. It should be noted that all households, according to the survey, have access to at least one vehicle.

Ridesharing

Approximately 87% of the households surveyed responded that they would share a ride with a neighbor, relative, or friend if a car was not available to them when advised to evacuate in the event of an emergency, as shown in Figure F-5.

Commuters

Figure F-6 presents the distribution of the number of commuters in each household. Commuters are defined as household members who travel to work or college on a daily basis. The data shows an average of 1.19 commuters per household in the EPZ, and 70 percent of households have at least one commuter.

Commuter Travel Modes

Figure F-7 presents the mode of travel that commuters use on a daily basis. The vast majority of commuters use their private automobiles to travel to work. The data shows an average of 1.09 employees per vehicle, assuming 2 people per vehicle – on average – for carpools.

Impact of COVID-19 on Commuters

Figure F-8 presents the distribution of the number of commuters in each household that were temporarily impacted by the COVID-19 pandemic. The data shows an average of 0.66 commuters per household were impacted. Sixty one percent of households indicated that no one in their household had a work and/or school commute that was temporarily impacted by the COVID-19 pandemic; 23% indicated one commuter was impacted; 9% indicated two were impacted; 3% indicated 3 were impacted and 4% indicated 4 or more commuters were impacted. Since the majority of respondents indicated no commuters were impacted, the results for the time distribution of commuters (time to prepare to leave work/college and time to travel home from work/college) were used as is in this study.

Functional or Transportation Needs

Figure F-9 presents the distribution of the number of individuals with functional or transportation need. The survey results show that approximately 10.5 percent of households have functional or transportation needs. Of those with functional or transportation need, 47% require a bus, 19% require a medical bus/van, 9% require a wheelchair accessible van, 3% require an ambulance, and 22% indicated that they would need other accommodations.

F.3.2 Evacuation Response

Several questions were asked to gauge the population's response to an emergency. These are now discussed:

"How many of the vehicles would your household use during an evacuation?" The response is shown in Figure F-10. On average, evacuating households would use 1.55 vehicles.

"Would your family await the return of other family members prior to evacuating the area?" Of the survey participants who responded, 60 percent said they would await the return of other family members before evacuating and 40 percent indicated that they would not await the return of other family members, as shown in Figure F-11.

"If you had a household pet, would you take your pet with you if you were asked to evacuate the area?" Based on responses from the survey, 79 percent of households have a family pet/animal; 21 percent said they do not. Of the 79 percent of households with pets/animals, 89 percent of them indicated that they would take their pets with them during an evacuation. The remaining 11% said they would leave their pets/animals at home. Of the households that would evacuate with their pets, 98 percent indicated that they have sufficient room in their vehicle to evacuate with their pet(s)/animal(s).

"What type of pet(s) and/or animal(s) do you have?" Based on responses from the survey, 82 percent of households have a household pet (dog, cat, bird, reptile, or fish), 14% of households have farm animals (horse, chicken, goat, pig, etc.), and 4 percent have other small pets/animals.

"Emergency officials advise you to take shelter at home in an emergency. Would you?" This question is designed to elicit information regarding compliance with instructions to shelter in place. The results, as shown in Figure F-12, indicate that 90 percent of households who are advised to shelter in place would do so; the remaining 10 percent would choose to evacuate the area. Note the baseline ETE study assumes 20 percent of households will not comply with the shelter advisory, as per Section 2.5.2 of NUREG/CR-7002, Revision 1. Thus, the data obtained through the survey is less than the federal guidance recommendation. A sensitivity study was conducted to estimate the impact of shadow evacuation non-compliance of shelter advisory on ETE – see Table M-2 in Appendix M.

"Emergency officials advise you to take shelter at home now in an emergency and possibly evacuate later while people in other areas are advised to evacuate now. Would you?" This question is designed to elicit information specifically related to the possibility of a staged evacuation. That is, asking a population to shelter in place now and then to evacuate after a specified period of time. As shown in Figure F-13, results indicate that 71 percent of households would follow instructions and delay the start of evacuation until so advised, while the balance of 29 percent would choose to begin evacuating immediately.

"Emergency officials advise you to evacuate due to an emergency. Where would you evacuate to?" This question is designed to elicit information regarding the destination of evacuees in case of an evacuation. As shown in Figure F-14, fifty one percent of households indicated that they would evacuate to a friend or relatives' home, 6% to a reception center, 9% to a hotel, motel or campground, 8% to a second or seasonal home, 1% of people indicated they would not evacuate, and the remaining 25% answered other/don't know to this question.

F.3.3 Time Distribution Results

The survey asked several questions about the amount of time it takes to perform certain pre-evacuation activities. These activities involve actions taken by residents during the course of their day-to-day lives. Thus, the answers fall within the realm of the responder's experience.

The mobilization distributions provided below are the result of having applied the analysis described in Section 5.4.1 on the component activities of the mobilization.

"How long does it take the commuter to complete preparation for leaving work?" Figure F-15 presents the cumulative distribution; in all cases, the activity is completed by about 60 minutes. Approximately 80 percent can leave within 25 minutes.

"How long would it take the commuter to travel home?" Figure F-16 presents the work to home travel time for the EPZ. Nearly 80 percent of commuters can arrive home within about 30 minutes of leaving work; all within 60 minutes.

"How long would it take the family to pack clothing, secure the house, and load the car?" Figure F-17 presents the time required to prepare for leaving on an evacuation trip. In many ways this activity mimics a family's preparation for a short holiday or weekend away from home. Hence, the responses represent the experience of the responder in performing similar activities.

The distribution shown in Figure F-17 has a long "tail." About 75 percent of households can be ready to leave home within 90 minutes; the remaining households require up to an additional hour and 45 minutes.

"How long would it take you to clear 6 to 8 inches of snow from your driveway?" During adverse, snowy weather conditions, an additional activity must be performed before residents can depart on the evacuation trip. Although snow scenarios assume that the roads and highways have been plowed and are passable (albeit at lower speeds and capacities), it may be necessary to clear a private driveway prior to leaving the home so that the vehicle can access the street. Figure F-18 presents the time distribution for removing 6 to 8 inches of snow from a driveway. The time distribution for clearing the driveway has a long tail; about 70 percent of driveways are passable within 60 minutes. The last driveway is cleared three hours and 30 minutes after the start of this activity. Note that those respondents (22%) who answered that they would not take time to clear their driveway were assumed to be ready immediately at the start of this activity. Essentially, they would drive through the snow on the driveway to access the roadway and begin their evacuation trip.

Table F-1. Callaway Energy Center Demographic Survey Sampling Plan

Zip Code	EPZ Population within EPZ (2010)	EPZ Households within Zip Code (2010)	Required Sample	Samples Obtained
63361	181	84	5	8
63388	579	250	14	16
65016	4	2	0	1
65024	831	338	18	13
65041	28	10	1	0
65059	867	326	18	23
65061	131	55	3	1
65067	379	162	9	13
65069	597	258	14	3
65077	641	242	13	20
65080	32	11	1	2
65251	15,843	5,250	282	202
65262	137	38	2	2
Total	**20,173**	**7,026**	**380**	**304**
Average Household Size:		**2.87**		

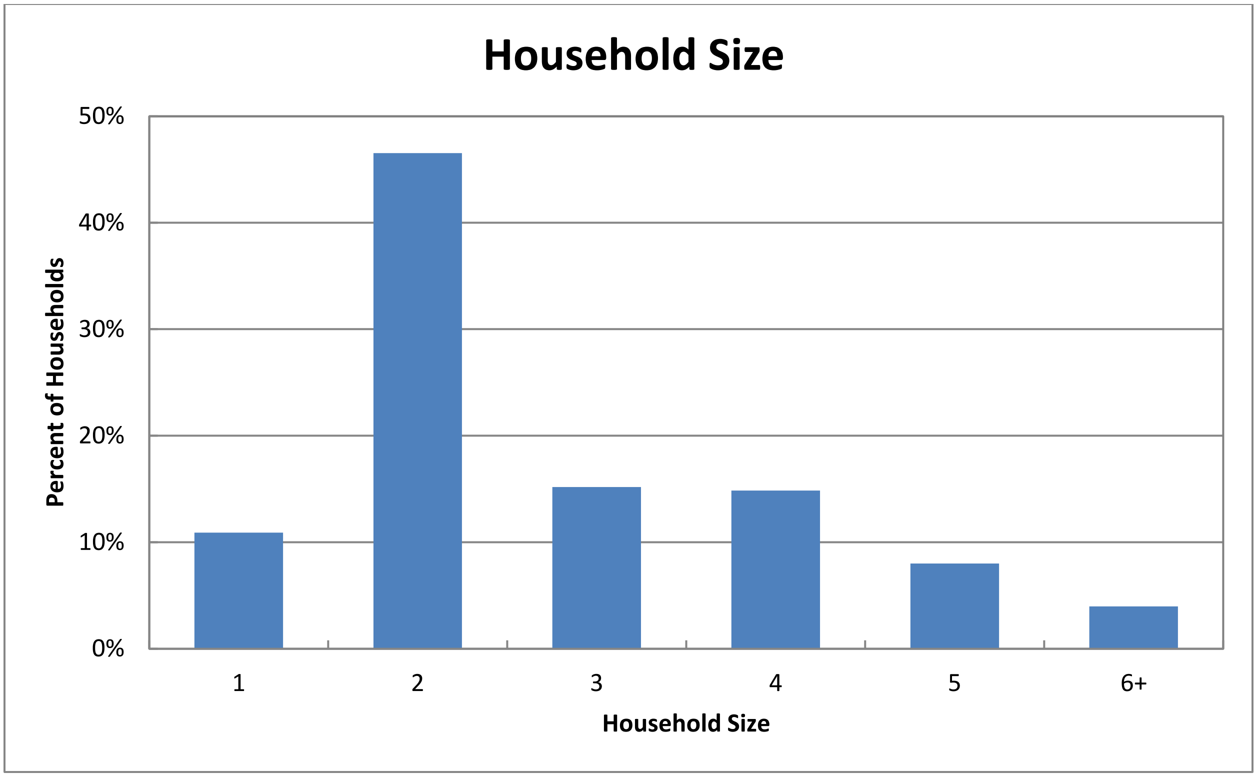


Figure F-1. Household Size in the EPZ

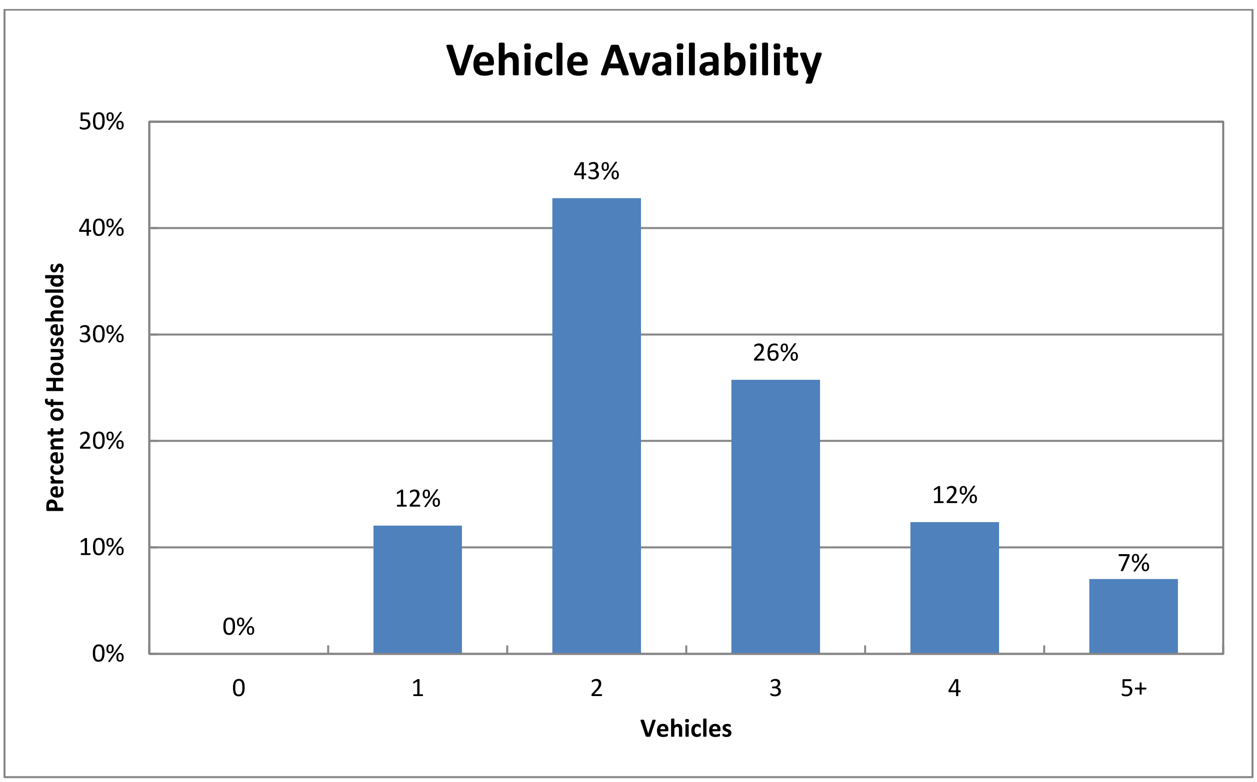


Figure F-2. Vehicle Availability

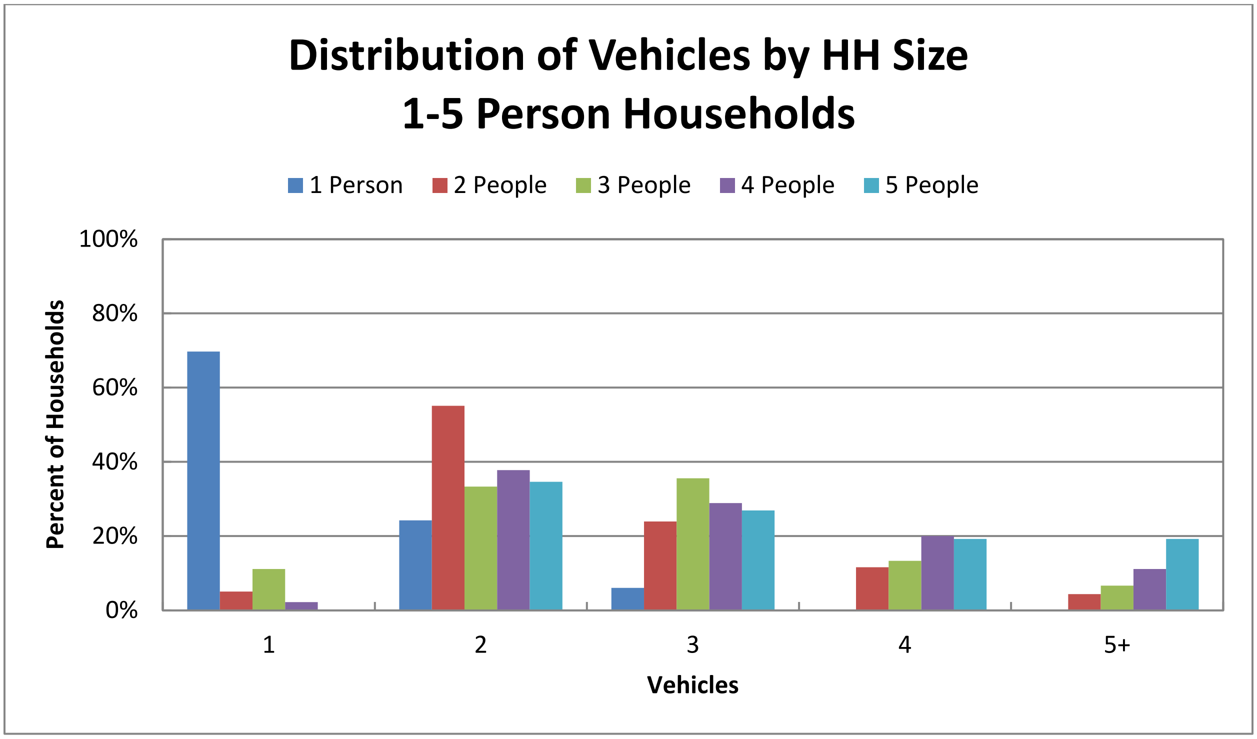


Figure F-3. Vehicle Availability - 1 to 5 Person Households

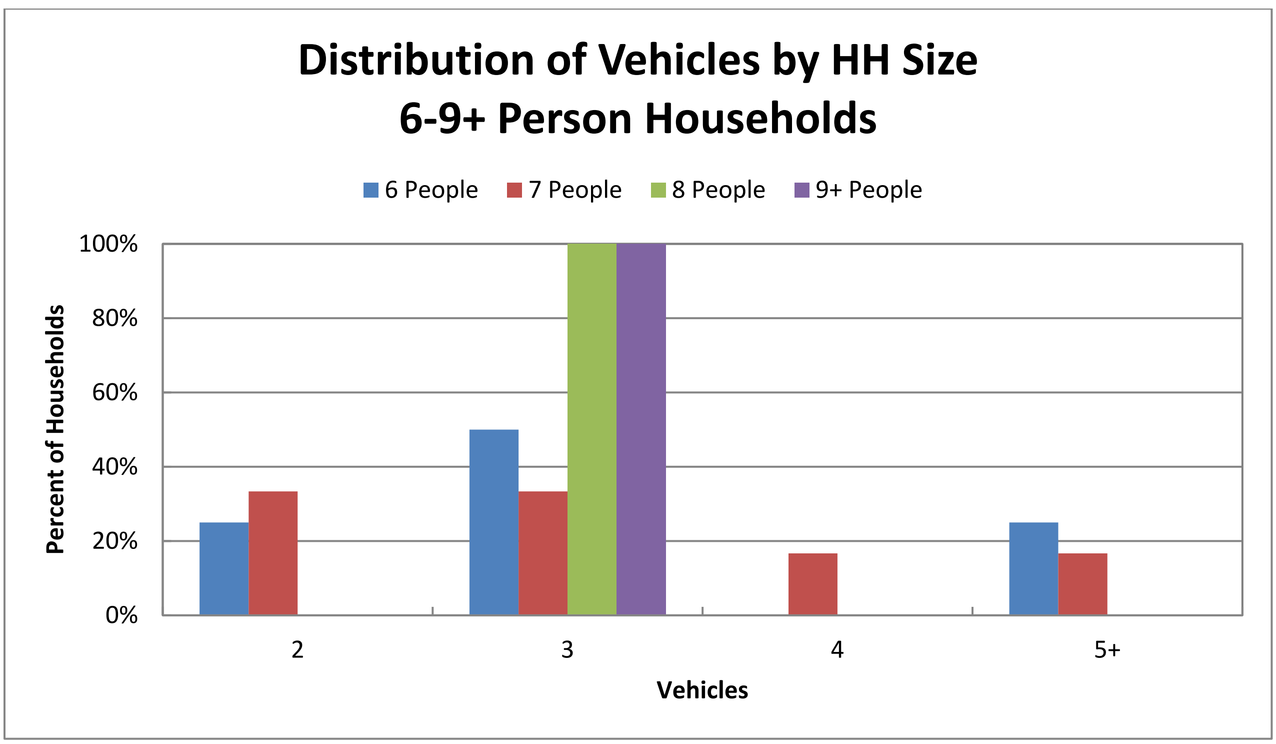


Figure F-4. Vehicle Availability - 6 to 9+ Person Households

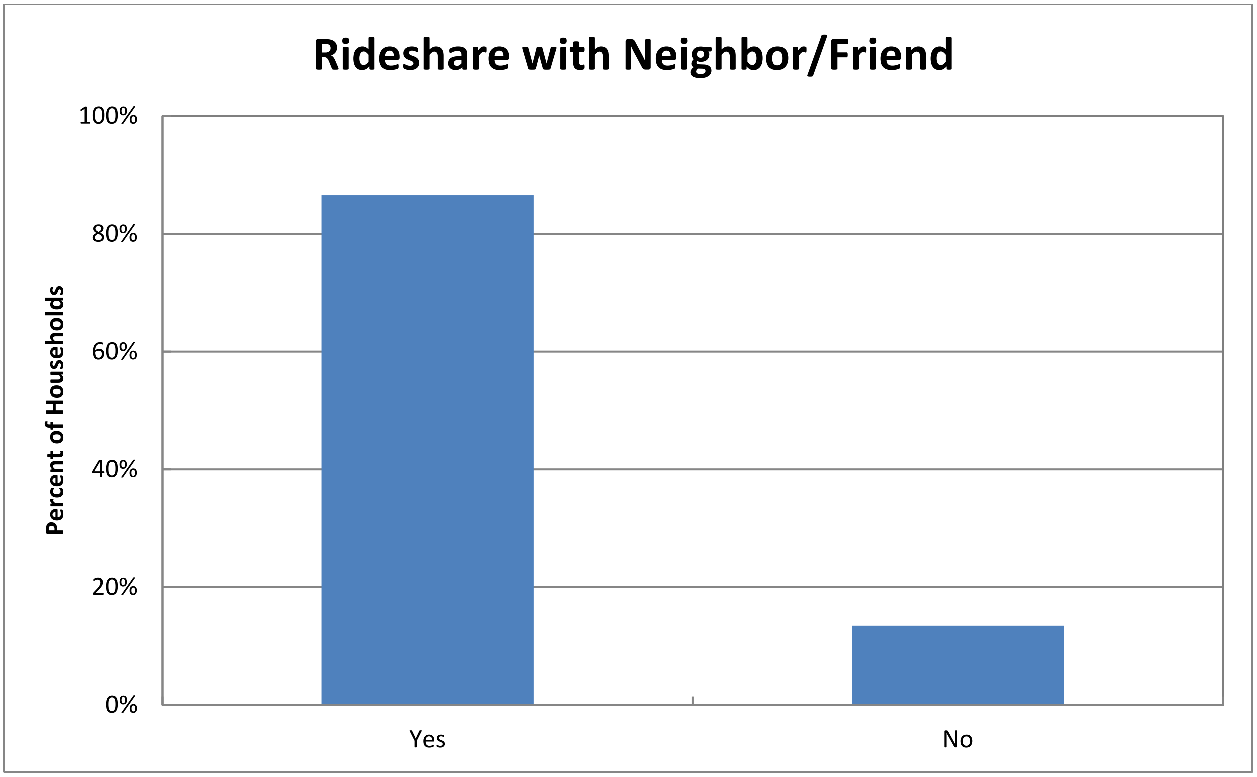


Figure F-5**. Household Ridesharing Preference**

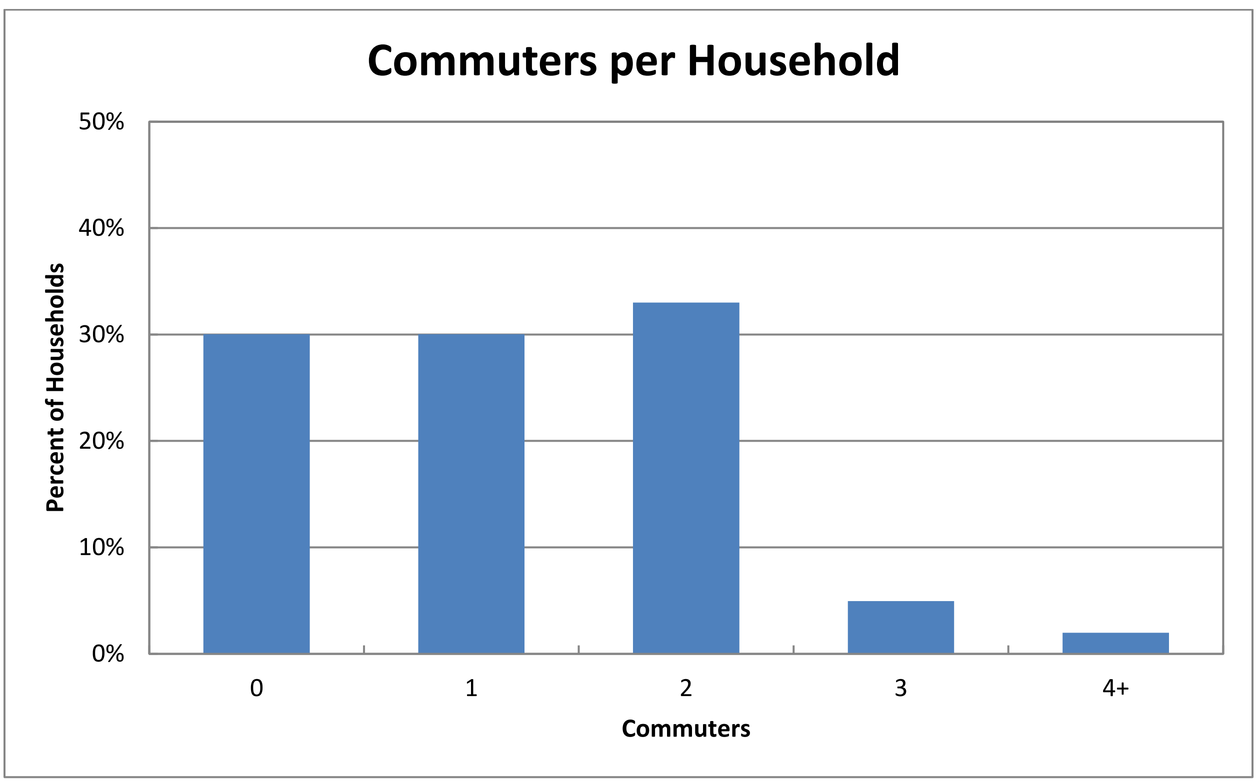


Figure F-6. Commuters per Households in the EPZ

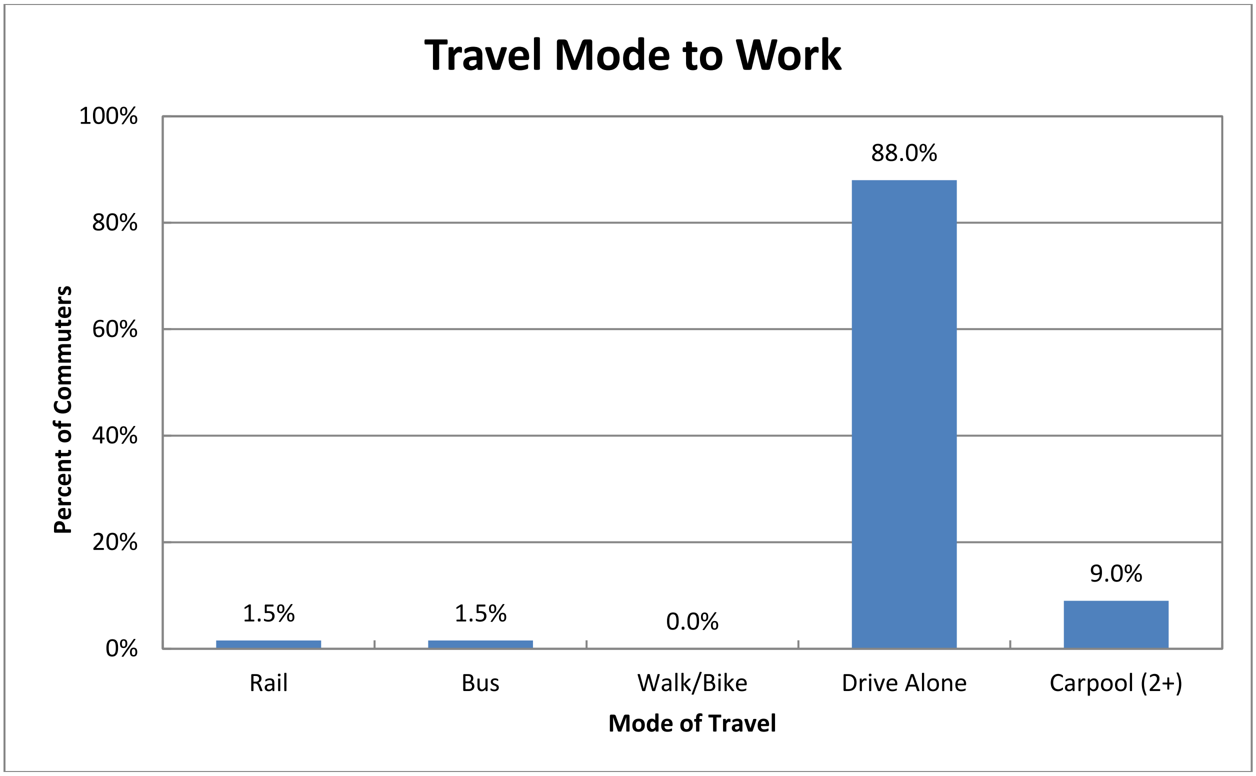


Figure F-7. Modes of Travel in the EPZ

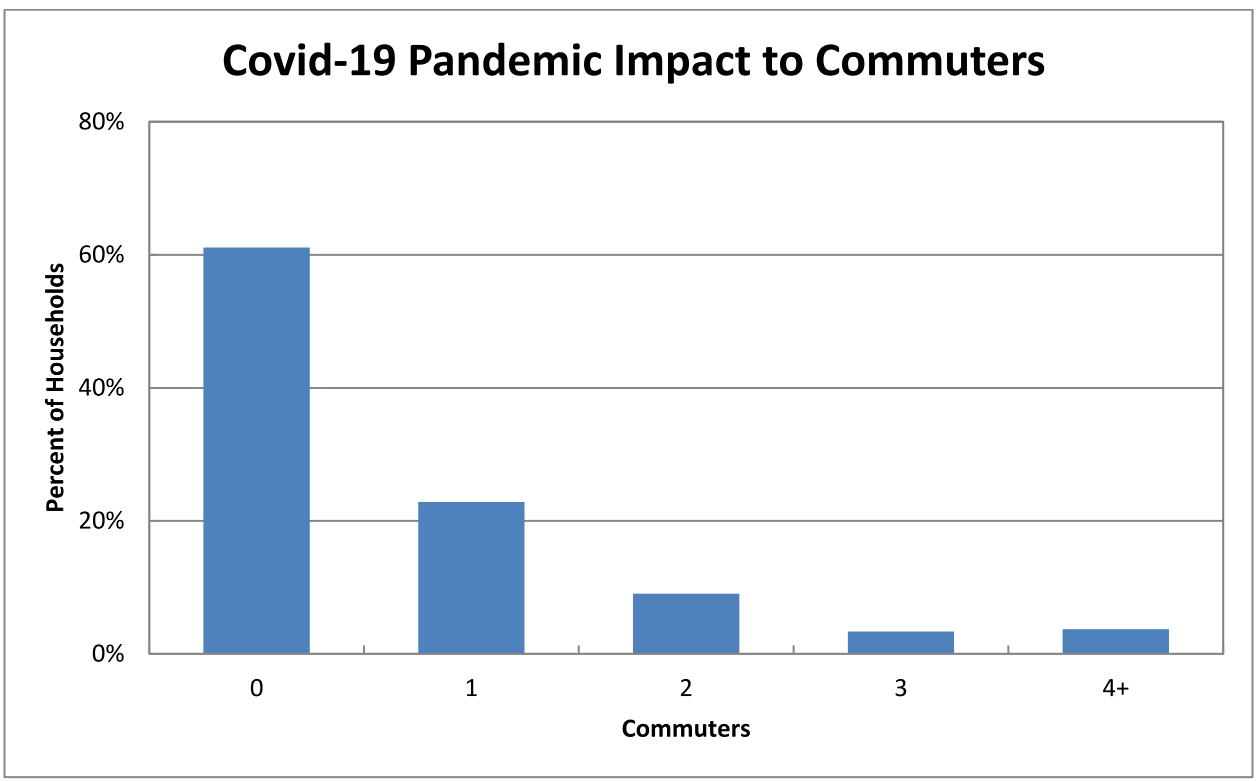


Figure F-8. Commuters Impacted by COVID-19

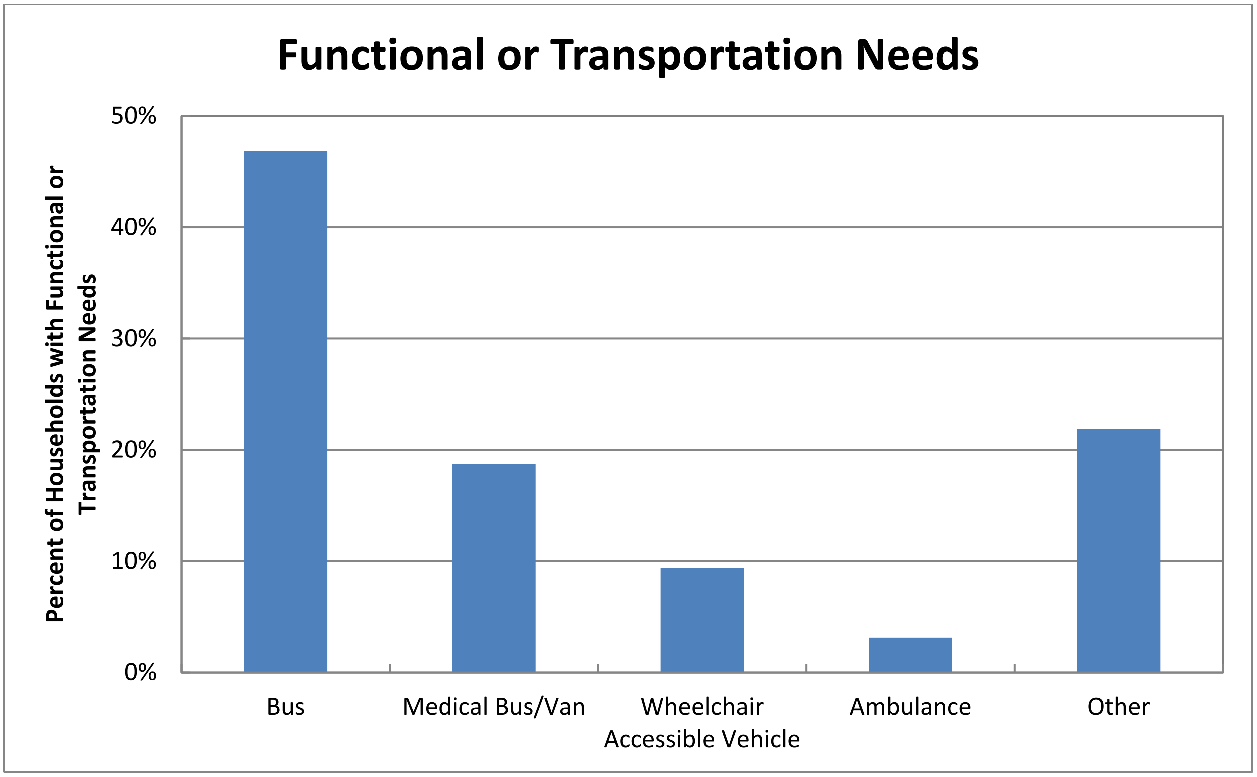


Figure F-9. Households with Functional or Transportation Needs

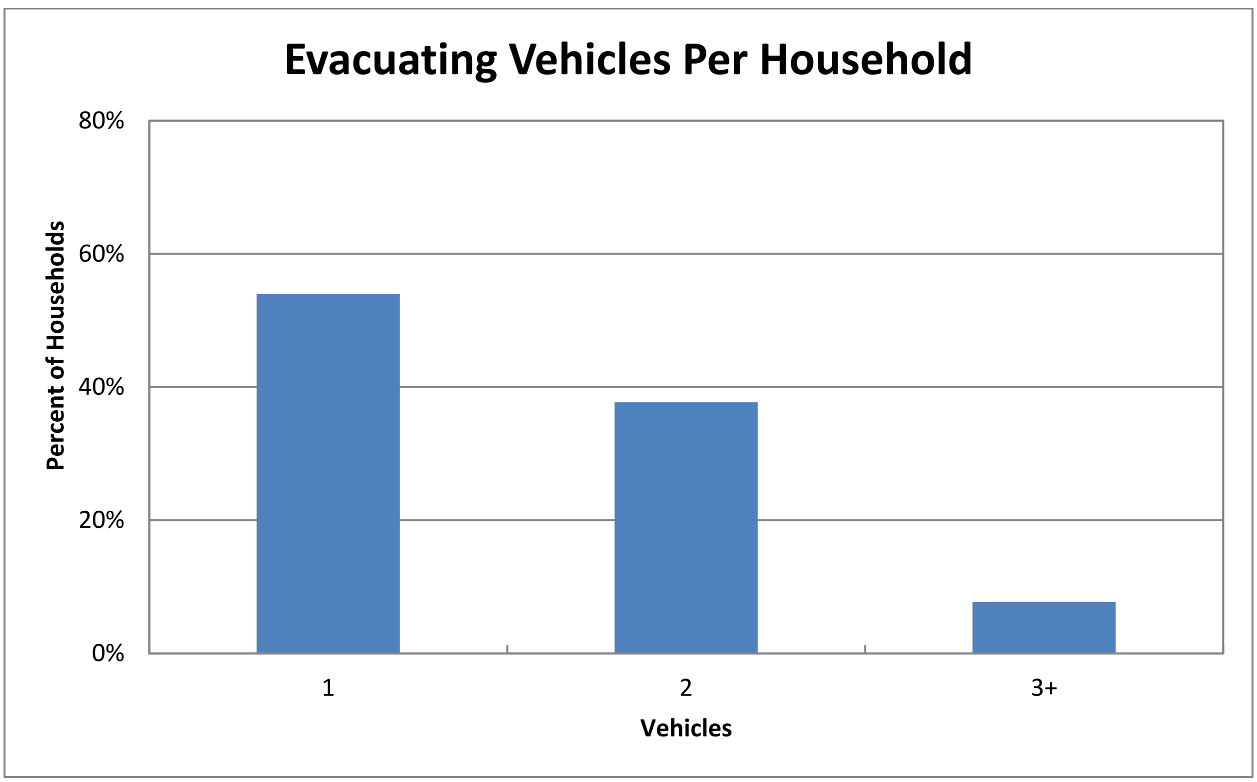


Figure F-10. Number of Vehicles Used for Evacuation

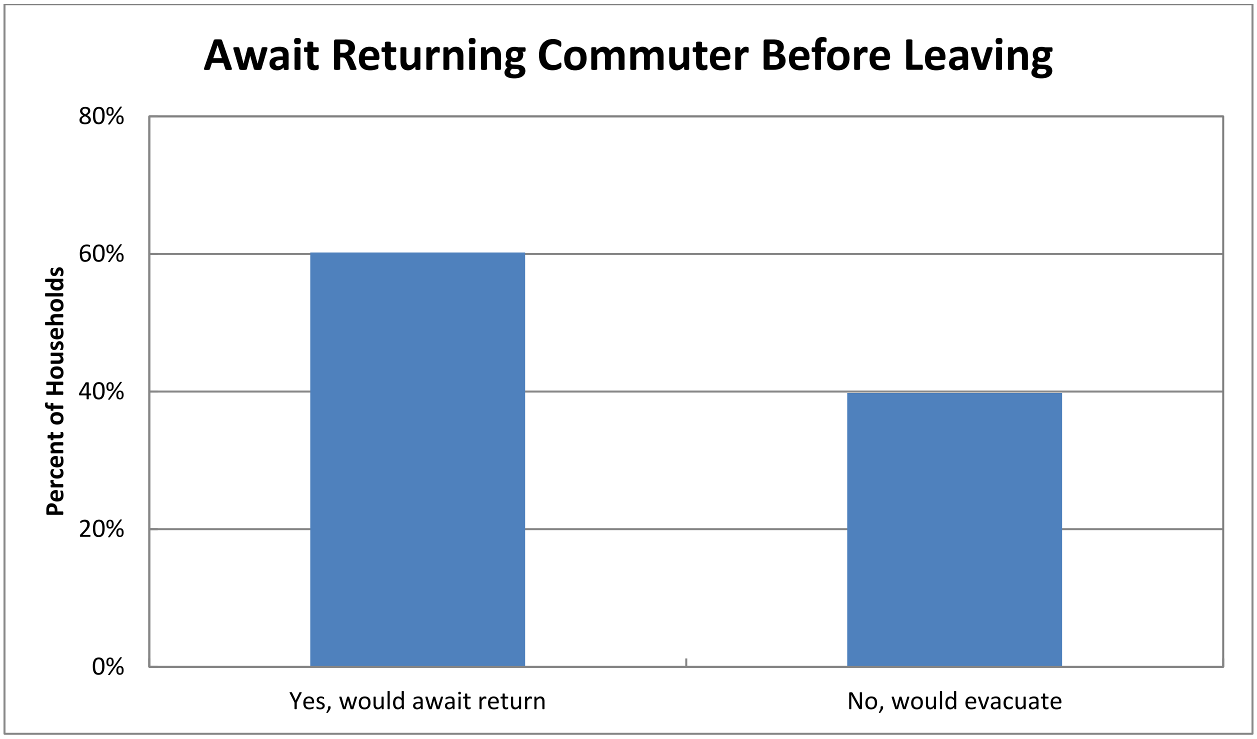


Figure F-11. Percent of Households that Await Returning Commuter Before Leaving

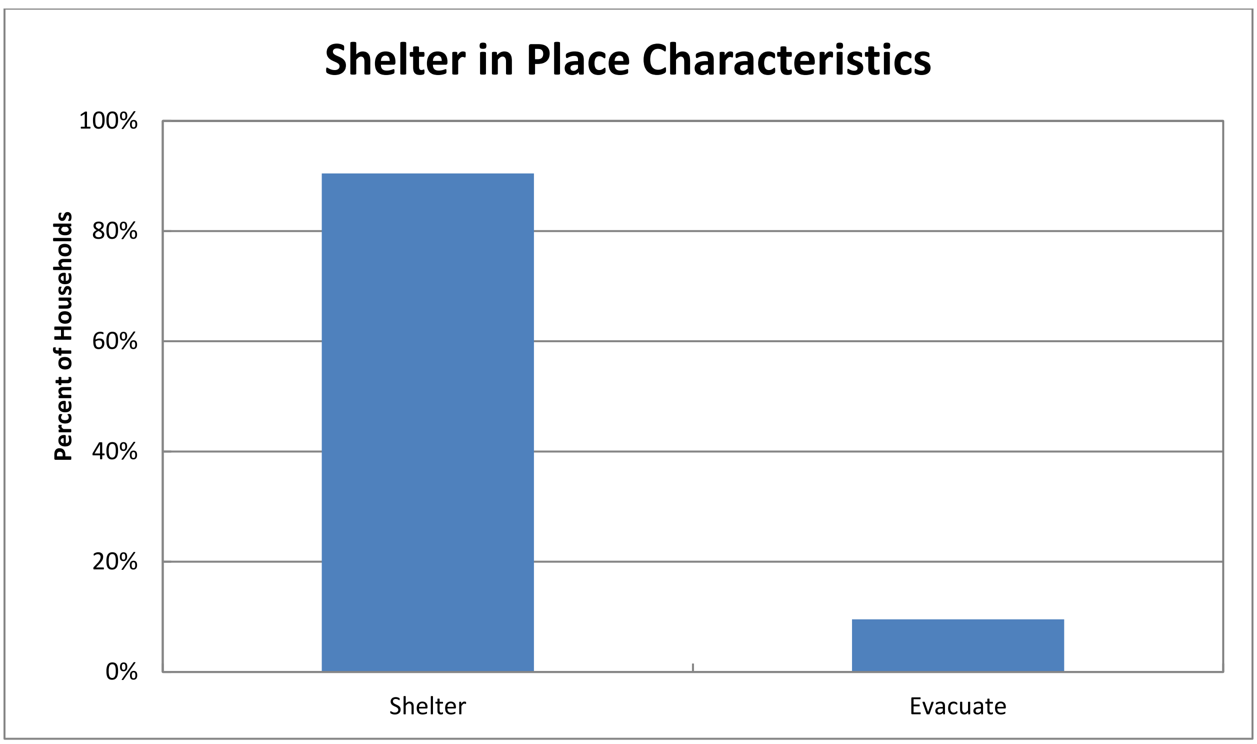


Figure F-12. Shelter in Place Characteristics

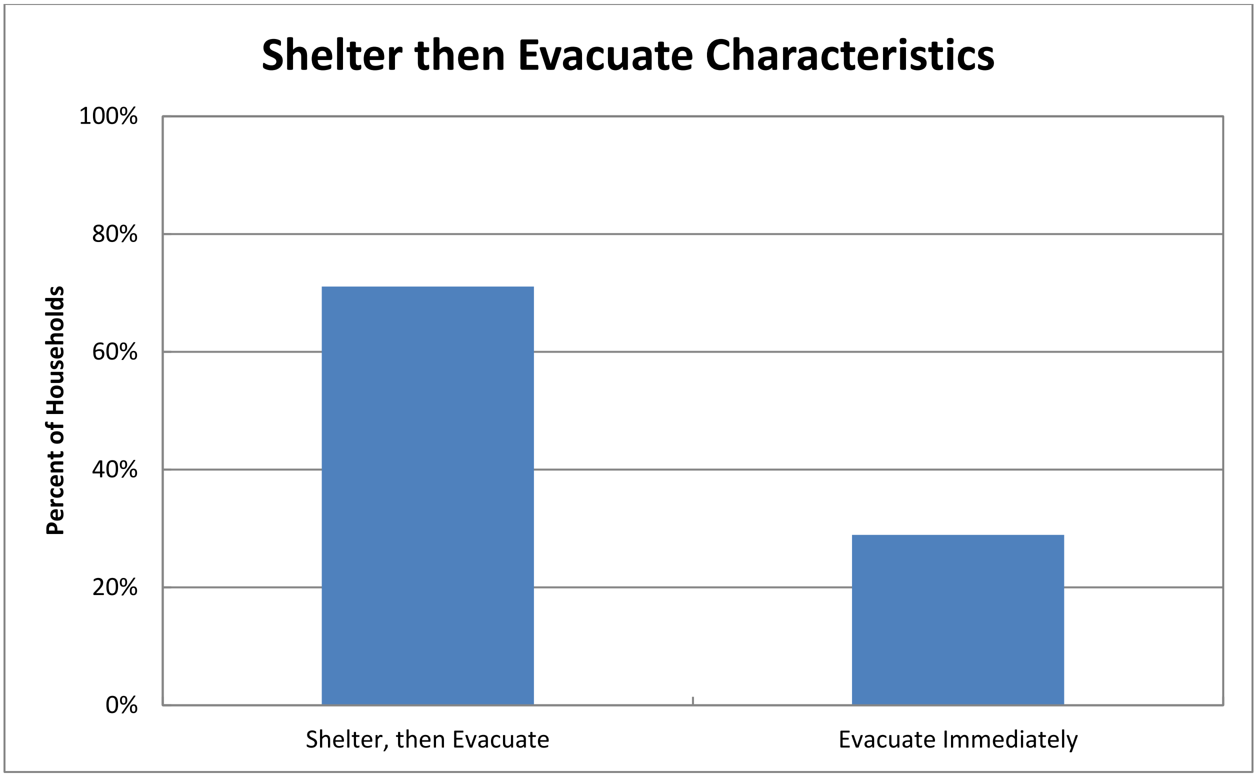


Figure F-13. Shelter in Place Characteristics – Staged Evacuation

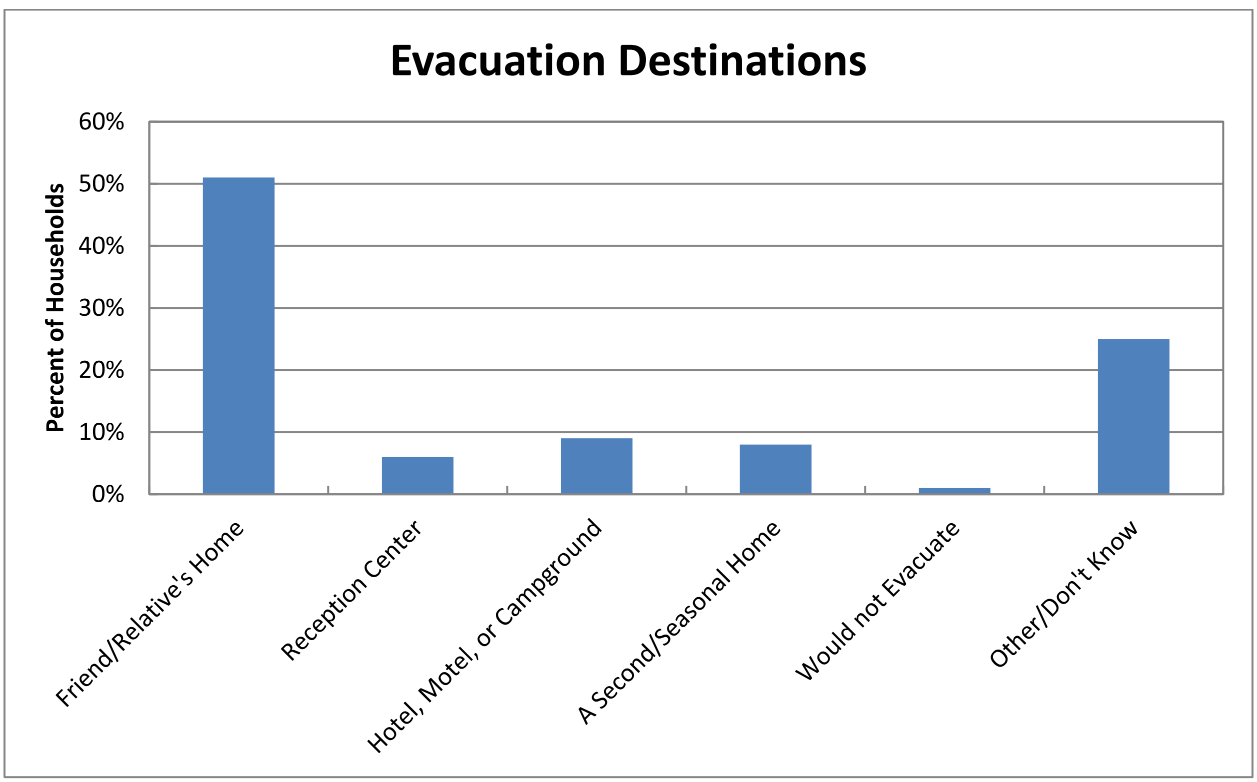


Figure F-14. Study Area Evacuation Destinations

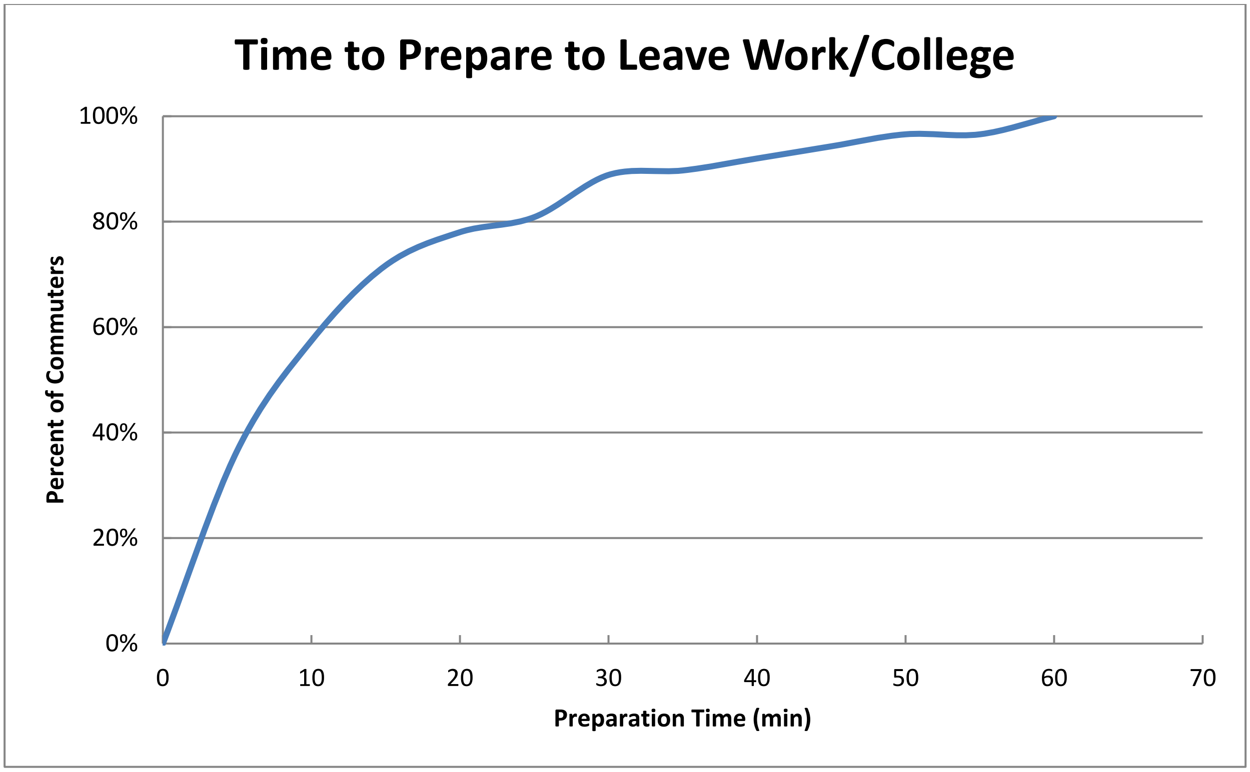


Figure F-15. Time Required to Prepare to Leave Work/School

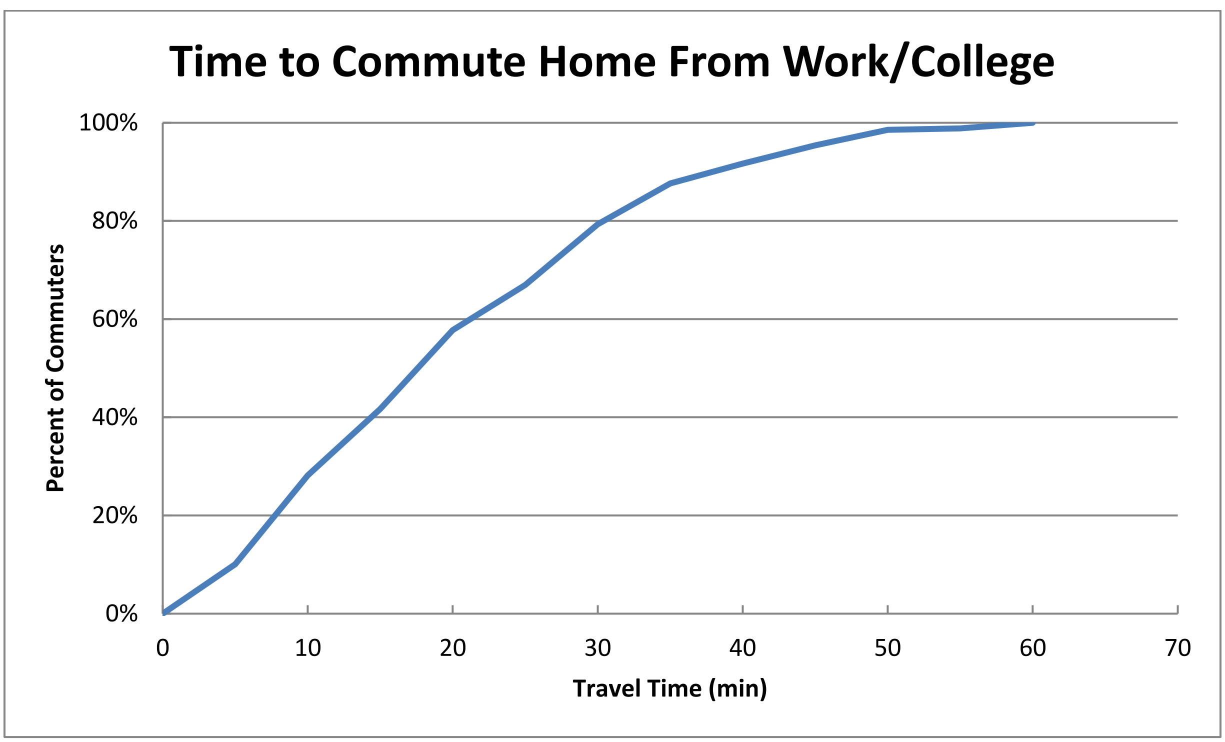


Figure F-16. Work to Home Travel Time

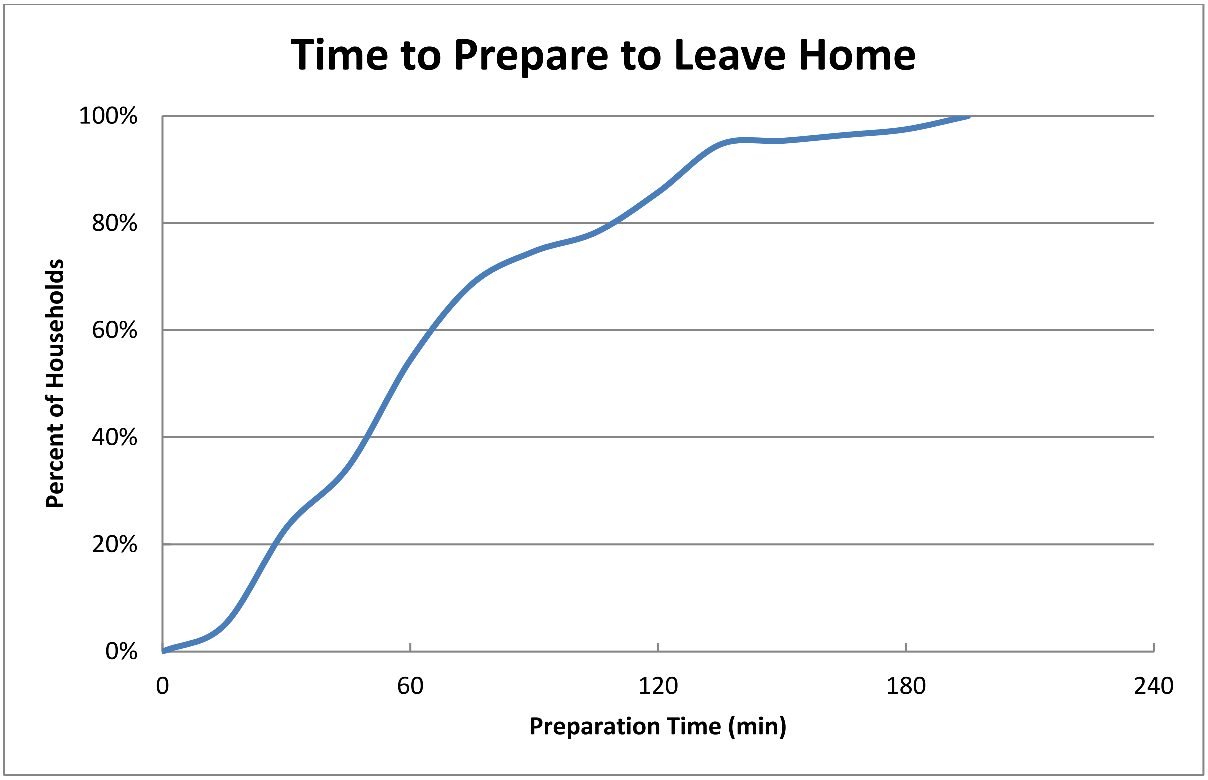


Figure F-17. Time to Prepare Home for Evacuation

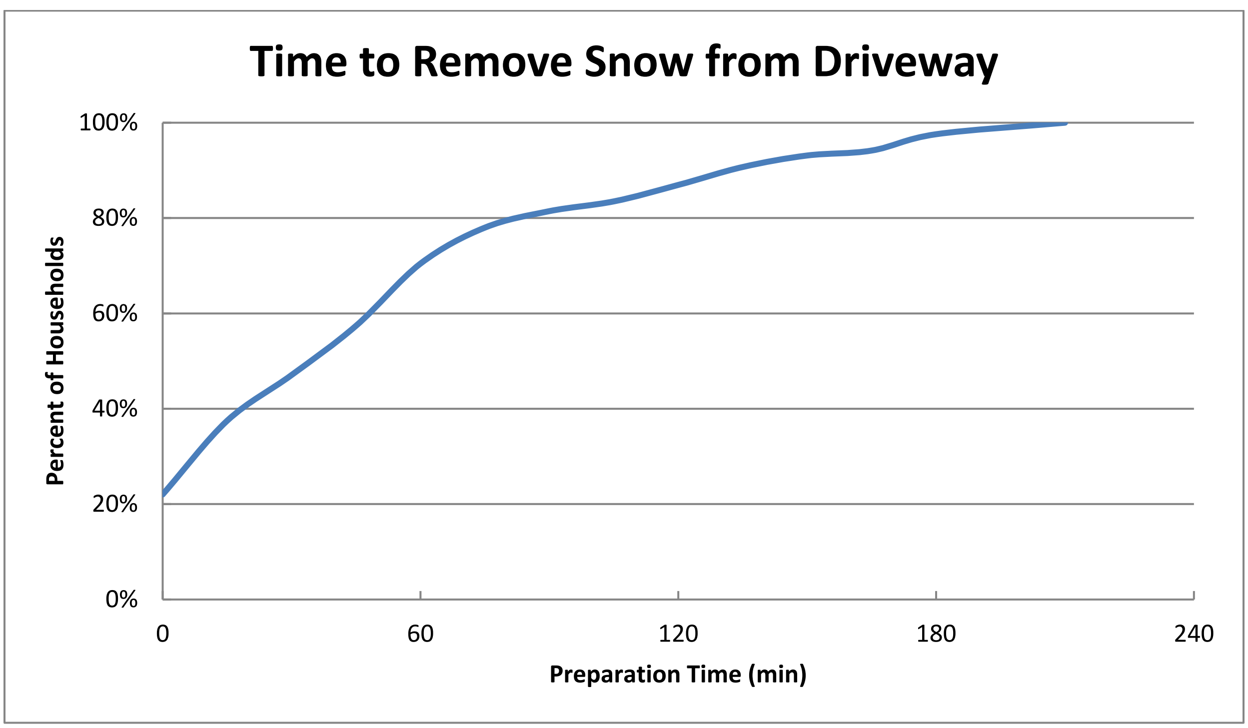


Figure F-18. Time to Clear Driveway of 6"-8" of Snow

ATTACHMENT A

Demographic Survey Instrument

Callaway Energy Center Demographic Survey

* Required

Purpose

The purpose of this survey is to identify local behavior during emergency situations. The information gathered in this survey will be shared with Ameren Missouri to enhance emergency response plans in your area. Your responses will greatly contribute to local emergency preparedness. Please do not provide your name or any personal information, and the survey will take less than 5 minutes to complete.

1. 1. What is your gender?

   Mark only one oval.

   - Male
   - Female
   - Decline to State
   - Other: ______________________

2. 2. What is your home zip code? *

   ____

3. 3A. In total, how many running cars, or other vehicles are usually available to the household?

Mark only one oval.

- ONE
- TWO
- THREE
- FOUR
- FIVE
- SIX
- SEVEN
- EIGHT
- NINE OR MORE
- ZERO (NONE)
- DECLINE TO STATE

4. 3B. In an emergency, could you get a ride out of the area with a neighbor or friend?

Mark only one oval.

- YES
- NO
- DECLINE TO STATE

5. 4. How many vehicles would your household use during an evacuation?

Mark only one oval.

- ONE
- TWO
- THREE
- FOUR
- FIVE
- SIX
- SEVEN
- EIGHT
- NINE OR MORE
- ZERO (NONE)
- I WOULD EVACUATE BY BICYCLE
- I WOULD EVACUATE BY BUS
- DECLINE TO STATE

6. 5. How many people usually live in this household?

Mark only one oval.

- ONE
- TWO
- THREE
- FOUR
- FIVE
- SIX
- SEVEN
- EIGHT
- NINE
- TEN
- ELEVEN
- TWELVE
- THIRTEEN
- FOURTEEN
- FIFTEEN
- SIXTEEN
- SEVENTEEN
- EIGHTEEN
- NINETEEN OR MORE
- DECLINE TO STATE

COVID-19

7. 6. How many people in your household have a work and/or school commute that has been temporarily impacted due to the COVID-19 pandemic?

Mark only one oval.

- ZERO
- ONE
- TWO
- THREE
- FOUR OR MORE
- DECLINE TO STATE

Skip to question 8

Commuters

8. 7. How many people in the household commute to a job, or to college on a daily basis? *

Mark only one oval.

- ZERO *Skip to question 53*
- ONE *Skip to question 9*
- TWO *Skip to question 10*
- THREE *Skip to question 11*
- FOUR OR MORE *Skip to question 12*
- DECLINE TO STATE *Skip to question 53*

Mode of Travel

9. 8. Thinking about each commuter, how does each person usually travel to work or college?

Mark only one oval per row.

	Rail	Bus	Walk/Bicycle	Drive Alone	Carpool-2 or more people	Don't know
Commuter 1	⬭	⬭	⬭	⬭	⬭	⬭

Skip to question 13

Mode of Travel

10. 8. Thinking about each commuter, how does each person usually travel to work or college?

Mark only one oval per row.

	Rail	Bus	Walk/Bicycle	Drive Alone	Carpool-2 or more people	Don't know
Commuter 1	⬭	⬭	⬭	⬭	⬭	⬭
Commuter 2	⬭	⬭	⬭	⬭	⬭	⬭

Skip to question 15

Mode of Travel

11. 8. Thinking about each commuter, how does each person usually travel to work or college?

Mark only one oval per row.

	Rail	Bus	Walk/Bicycle	Drive Alone	Carpool-2 or more people	Don't know
Commuter 1	⬭	⬭	⬭	⬭	⬭	⬭
Commuter 2	⬭	⬭	⬭	⬭	⬭	⬭
Commuter 3	⬭	⬭	⬭	⬭	⬭	⬭

Skip to question 19

Mode of Travel

12. 8. Thinking about each commuter, how does each person usually travel to work or college?

Mark only one oval per row.

	Rail	Bus	Walk/Bicycle	Drive Alone	Carpool-2 or more people	Don't know
Commuter 1	⬭	⬭	⬭	⬭	⬭	⬭
Commuter 2	⬭	⬭	⬭	⬭	⬭	⬭
Commuter 3	⬭	⬭	⬭	⬭	⬭	⬭
Commuter 4	⬭	⬭	⬭	⬭	⬭	⬭

Skip to question 25

Travel Home From Work/College

13. 9-1. How much time on average, would it take Commuter #1 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

14. If Over 2 Hours for Question 9-1, Specify Here

leave blank if your answer for Question 9-1, is under 2 hours.

____

Skip to question 33

Travel Home From Work/College

15. 9-1. How much time on average, would it take Commuter #1 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

16. If Over 2 Hours for Question 9-1, Specify Here

leave blank if your answer for Question 9-1, is under 2 hours.

____

17. 9-2. How much time on average, would it take Commuter #2 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

18. If Over 2 Hours for Question 9-2, Specify Here

leave blank if your answer for Question 9-2, is under 2 hours.

____

Skip to question 35

Travel Home From Work/College

19. 9-1. How much time on average, would it take Commuter #1 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

20. If Over 2 Hours for Question 9-1, Specify Here

leave blank if your answer for Question 9-1, is under 2 hours.

____

21. 9-2. How much time on average, would it take Commuter #2 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

22. If Over 2 Hours for Question 9-2, Specify Here

leave blank if your answer for Question 9-2, is under 2 hours.

____

23. 9-3. How much time on average, would it take Commuter #3 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

24. If Over 2 Hours for Question 9-3, Specify Here

leave blank if your answer for Question 9-3, is under 2 hours.

____

Skip to question 39

Travel Home From Work/College

25. 9-1. How much time on average, would it take Commuter #1 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

26. If Over 2 Hours for Question 9-1, Specify Here

leave blank if your answer for Question 9-1, is under 2 hours.

____

27. 9-2. How much time on average, would it take Commuter #2 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

28. If Over 2 Hours for Question 9-2, Specify Here

leave blank if your answer for Question 9-2, is under 2 hours.

____

29. 9-3. How much time on average, would it take Commuter #3 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

30. If Over 2 Hours for Question 9-3, Specify Here

leave blank if your answer for Question 9-3, is under 2 hours.

____

31. 9-4. How much time on average, would it take Commuter #4 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

32. If Over 2 Hours for Question 9-4, Specify Here

leave blank if your answer for Question 9-4, is under 2 hours.

____

Skip to question 45

Preparation to leave Work/College

33. 10-1. Approximately how much time would it take Commuter #1 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

34. If Over 2 Hours for Question 10-1, Specify Here

leave blank if your answer for Question 10-1, is under 2 hours.

____

Skip to question 53

Preparation to leave Work/College

35. 10-1. Approximately how much time would it take Commuter #1 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

36. If Over 2 Hours for Question 10-1, Specify Here

leave blank if your answer for Question 10-1, is under 2 hours.

____

37. 10-2. Approximately how much time would it take Commuter #2 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

38. If Over 2 Hours for Question 10-2, Specify Here

leave blank if your answer for Question 10-2, is under 2 hours.

____

Skip to question 53

Preparation to leave Work/College

39. 10-1. Approximately how much time would it take Commuter #1 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

40. If Over 2 Hours for Question 10-1, Specify Here

leave blank if your answer for Question 10-1, is under 2 hours.

41. 10-2. Approximately how much time would it take Commuter #2 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

42. If Over 2 Hours for Question 10-2, Specify Here

leave blank if your answer for Question 10-2, is under 2 hours.

____

43. 10-3. Approximately how much time would it take Commuter #3 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

44. If Over 2 Hours for Question 10-3, Specify Here

leave blank if your answer for Question 10-3, is under 2 hours.

____

Skip to question 53

Preparation to leave Work/College

45. 10-1. Approximately how much time would it take Commuter #1 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

46. If Over 2 Hours for Question 10-1, Specify Here

leave blank if your answer for Question 10-1, is under 2 hours.

____

47. 10-2. Approximately how much time would it take Commuter #2 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

48. If Over 2 Hours for Question 10-2, Specify Here

leave blank if your answer for Question 10-2, is under 2 hours.

____

49. 10-3. Approximately how much time would it take Commuter #3 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

50. If Over 2 Hours for Question 10-3, Specify Here

leave blank if your answer for Question 10-3, is under 2 hours.

____

51. 10-4. Approximately how much time would it take Commuter #4 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

52. If Over 2 Hours for Question 10-4, Specify Here

leave blank if your answer for Question 10-4, is under 2 hours.

Skip to question 53

Additional Questions

53. 11. If you were advised by local authorities to evacuate, how much time would it take the household to pack clothing, medications, secure the house, load the car, and complete preparations prior to evacuating the area?

Mark only one oval.

- LESS THAN 15 MINUTES
- 15-30 MINUTES
- 31-45 MINUTES
- 46 MINUTES - 1 HOUR
- 1 HOUR TO 1 HOUR 15 MINUTES
- 1 HOUR 16 MINUTES TO 1 HOUR 30 MINUTES
- 1 HOUR 31 MINUTES TO 1 HOUR 45 MINUTES
- 1 HOUR 46 MINUTES TO 2 HOURS
- 2 HOURS TO 2 HOURS 15 MINUTES
- 2 HOURS 16 MINUTES TO 2 HOURS 30 MINUTES
- 2 HOURS 31 MINUTES TO 2 HOURS 45 MINUTES
- 2 HOURS 46 MINUTES TO 3 HOURS
- 3 HOURS TO 3 HOURS 15 MINUTES
- 3 HOURS 16 MINUTES TO 3 HOURS 30 MINUTES
- 3 HOURS 31 MINUTES TO 3 HOURS 45 MINUTES
- 3 HOURS 46 MINUTES TO 4 HOURS
- 4 HOURS TO 4 HOURS 15 MINUTES
- 4 HOURS 16 MINUTES TO 4 HOURS 30 MINUTES
- 4 HOURS 31 MINUTES TO 4 HOURS 45 MINUTES
- 4 HOURS 46 MINUTES TO 5 HOURS
- 5 HOURS TO 5 HOURS 30 MINUTES
- 5 HOURS 31 MINUTES TO 6 HOURS
- OVER 6 HOURS
- WILL NOT EVACUATE
- DECLINE TO STATE

54. If Over 6 Hours for Question 11, Specify Here

leave blank if your answer for Question 11, is under 6 hours.

---

55. 12. If there are 6-8 inches of snow on your driveway or curb, would you need to shovel out to evacuate? If yes, how much time, on average, would it take you to clear the 6-8 inches of snow to move the car from the driveway or curb to begin the evacuation trip? Assume the roads are passable.

Mark only one oval.

- LESS THAN 15 MINUTES
- 15-30 MINUTES
- 31-45 MINUTES
- 46 MINUTES – 1 HOUR
- 1 HOUR TO 1 HOUR 15 MINUTES
- 1 HOUR 16 MINUTES TO 1 HOUR 30 MINUTES
- 1 HOUR 31 MINUTES TO 1 HOUR 45 MINUTES
- 1 HOUR 46 MINUTES TO 2 HOURS
- 2 HOURS TO 2 HOURS 15 MINUTES
- 2 HOURS 16 MINUTES TO 2 HOURS 30 MINUTES
- 2 HOURS 31 MINUTES TO 2 HOURS 45 MINUTES
- 2 HOURS 46 MINUTES TO 3 HOURS
- NO, WILL NOT SHOVEL OUT
- OVER 3 HOURS
- DECLINE TO STATE

56. If Over 3 Hours for Question 12, Specify Here

leave blank if your answer for Question 12, is under 3 hours.

---

57. 13. Please specify the number of people in your household who require Functional or Transportation needs in an evacuation:

Mark only one oval per row.

	0	1	2	3	4	More than 4
Bus	◯	◯	◯	◯	◯	◯
Medical Bus/Van	◯	◯	◯	◯	◯	◯
Wheelchair Accessible Vehicle	◯	◯	◯	◯	◯	◯
Ambulance	◯	◯	◯	◯	◯	◯
Other	◯	◯	◯	◯	◯	◯

58. Specify "Other" Transporation Need Below

____

59. 14. Please choose one of the following:

Mark only one oval.

- ◯ I would await the return of household members to evacuate together.
- ◯ I would evacuate independently and meet other household members later.
- ◯ Decline to State

60. 15A. Emergency officials advise you to shelter-in-place in an emergency because you are not in the area of risk. Would you:

Mark only one oval.

- SHELTER-IN-PLACE
- EVACUATE
- DECLINE TO STATE

61. 15B. Emergency officials advise you to shelter-in-place now in an emergency and possibly evacuate later while people in other areas are advised to evacuate now. Would you:

Mark only one oval.

- SHELTER-IN-PLACE
- EVACUATE
- DECLINE TO STATE

62. 15C. Emergency officials advise you to evacuate due to an emergency. Where would you evacuate to?

Mark only one oval.

- A RELATIVE'S OR FRIEND'S HOME
- A RECEPTION CENTER
- A HOTEL, MOTEL OR CAMPGROUND
- A SECOND/SEASONAL HOME
- WOULD NOT EVACUATE
- DON'T KNOW
- OTHER (Specify Below)
- DECLINE TO STATE

63. Fill in OTHER answers for question 15C

____

Pet Questions

64. 16A. Do you have any pet(s) and/or animal(s)?

Mark only one oval.

- ( ) YES
- ( ) NO
- ( ) DECLINE TO STATE

Pet Questions

65. 16B. What type of pet(s) and/or animal(s) do you have?

Check all that apply.

- [ ] DOG
- [ ] CAT
- [ ] BIRD
- [ ] REPTILE
- [ ] HORSE
- [ ] FISH
- [ ] CHICKEN
- [ ] GOAT
- [ ] PIG
- [ ] OTHER SMALL PETS/ANIMALS (Specify Below)
- [ ] OTHER LARGE PETS/ANIMALS (Specify Below)

Other: [ ] ______________________________

66.

Mark only one oval.

- DECLINE TO STATE

Pet Questions

67. 16C. What would you do with your pet(s) and/or animal(s) if you had to evacuate?

Mark only one oval.

- TAKE PET WITH ME SOMEWHERE ELSE
- LEAVE PET AT HOME
- DECLINE TO STATE

Pet Questions

68. 16D. Do you have sufficient room in your vehicle(s) to evacuate with your pet(s) and/or animal(s)?

Mark only one oval.

- YES
- NO
- DECLINE TO STATE
- Other: ____________________

APPENDIX G

Traffic Management Plan

G. TRAFFIC MANAGEMENT PLAN

NUREG/CR-7002, Rev. 1 indicates that the existing Traffic Control Points (TCPs) and Access Control Points (ACPs) identified by the offsite agencies should be used in the evacuation simulation modeling. The traffic control plans for the Emergency Planning Zone (EPZ) were provided by the offsite response organizations within the EPZ.

These plans were reviewed, and the TCPs and ACPs were modeled accordingly. An analysis of the TCP and ACP locations was performed, and it was determined to model the ETE simulations with existing TCPs and ACPs that were provided in the approved county and state emergency plans, with no additional TCPs or ACPs.

G.1 Manual Traffic Control

TCPs and ACPs are forms of manual traffic control (MTC). As discussed in Section 9, MTC at intersections (which are controlled) are modeled as actuated signals. If an intersection has a pre-timed signal, stop, or yield control, and the intersection is identified as a traffic control point (or ACP), the control type was changed to an actuated signal in the DYNEV II system, in accordance with Section 3.3 of NUREG/CR-7002, Rev. 1. MTCs at existing actuated traffic signalized intersections were essentially left alone. Table K-1 provides the control type and node number for those nodes which are controlled. If the existing control was changed due to the point being a TCP/ACP, the control type is indicated as “TCP/ACP” in Table K-1. The TCPs within the study area are mapped as blue dots in Figure G-1 while ACPs are mapped as red squares. No additional locations for MTC are suggested in this study.

It is assumed that the ACPs will be established within 120 minutes of the advisory to evacuate (ATE) to discourage through travelers from using major through routes which traverse the EPZ. As discussed in Section 3.11, external traffic was considered on Interstate 70 (I-70) and US Highway 54 (US-54) in this analysis.

G.2 Analysis of Key TCP/ACP/SRB Locations

As discussed in Section 5.2 of NUREG/CR-7002, Rev. 1, MTC at intersections could benefit from the ETE analysis. The MTC locations contained within the traffic management plans were analyzed to determine key locations where MTC would be most useful and can be readily implemented. As previously mentioned, signalized intersections that were actuated based on field data collection were essentially left as actuated traffic signals in the model, with modifications to green time allocation as needed. Other controlled intersections (pre-timed signals, stop signs and yield signs) were changed to actuated traffic signals to represent the MTC that would be implemented according to the traffic management plans.

Table G-1 shows a list of the controlled intersections that were identified as MTC points in the TMPs that were not previously actuated signals, including the type of control that currently exists at each location. To determine the impact of MTC at these locations, a winter, midweek, midday, good weather scenario (Scenario 6) evacuation of the 2-Mile, 5-Mile and entire EPZ

(Region R01, R02, R03) were simulated wherein these intersections were left as is (without MTC). The results are shown in Table G-2. The ETE remained unchanged when compared to the cases wherein these controlled intersections were modeled as actuated signals (with MTC) presented in Section 7 for Scenario 6 Regions R01, R02, and R03. Although localized congestion worsened, there is no change in ETE at both the 90th and 100th percentile when MTC was not present at these intersections. The remaining TCPs and ACPs at controlled intersections were left as actuated signals in the model and, therefore, had no impact to ETE.

As shown in Figure 7-3 through Figure 7-7, the only area in the EPZ that experiences any congestion is Fulton (Subarea C9). The congestion in Fulton clears by 2 hours and 30 minutes after the ATE. As a result, the TCPs and ACPs within the EPZ do very little to reduce the 90th percentile ETE as there is very little congestion in the EPZ as a whole. Since Subarea C9 does not evacuate for Regions R01 or R02, there is no congestion when these regions evacuate, and as a result, there is no benefit to ETE from MTC for these regions.

Since all congestion within the EPZ clears prior to trip generation time, the time to mobilize dictates the 100th percentile ETE; as a result, MTC has no impact on the 100th percentile ETE.

Although there is no reduction in ETE when MTC is implemented, traffic and access control can be beneficial in the reduction of localized congestion and driver confusion and can be extremely helpful for fixed point surveillance, amongst other things. Should there be a shortfall of personnel to staff the TCPs or ACPs, the list of locations provided in Table G-1 could be considered as priority locations when implementing the TMP.

Table G-1. List of Key Manual Traffic Control Locations

Node #	Type of Control (Prior to being a TCP)
319	Stop Control
157	Stop Control
1283	Stop Control
64	Stop Control
80	Stop Control
876	Stop Control
880	Stop Control
276	Stop Control
298	Stop Control
857	Stop Control
444	Stop Control
55	Stop Control
45	Stop Control
96	Stop Control
967	Yield Sign
966	Yield Sign
968	Yield Sign
64	Stop Control
65	Stop Control
40	Yield Sign
405	Stop Control

Table G-2. ETE with No MTC

	Scenario 6	
Region	90th Percentile ETE	100th Percentile ETE
R01 (2-mile)	1:25	4:45
R02 (5-mile)	2:45	4:50
R03 (full EPZ)	2:50	4:55

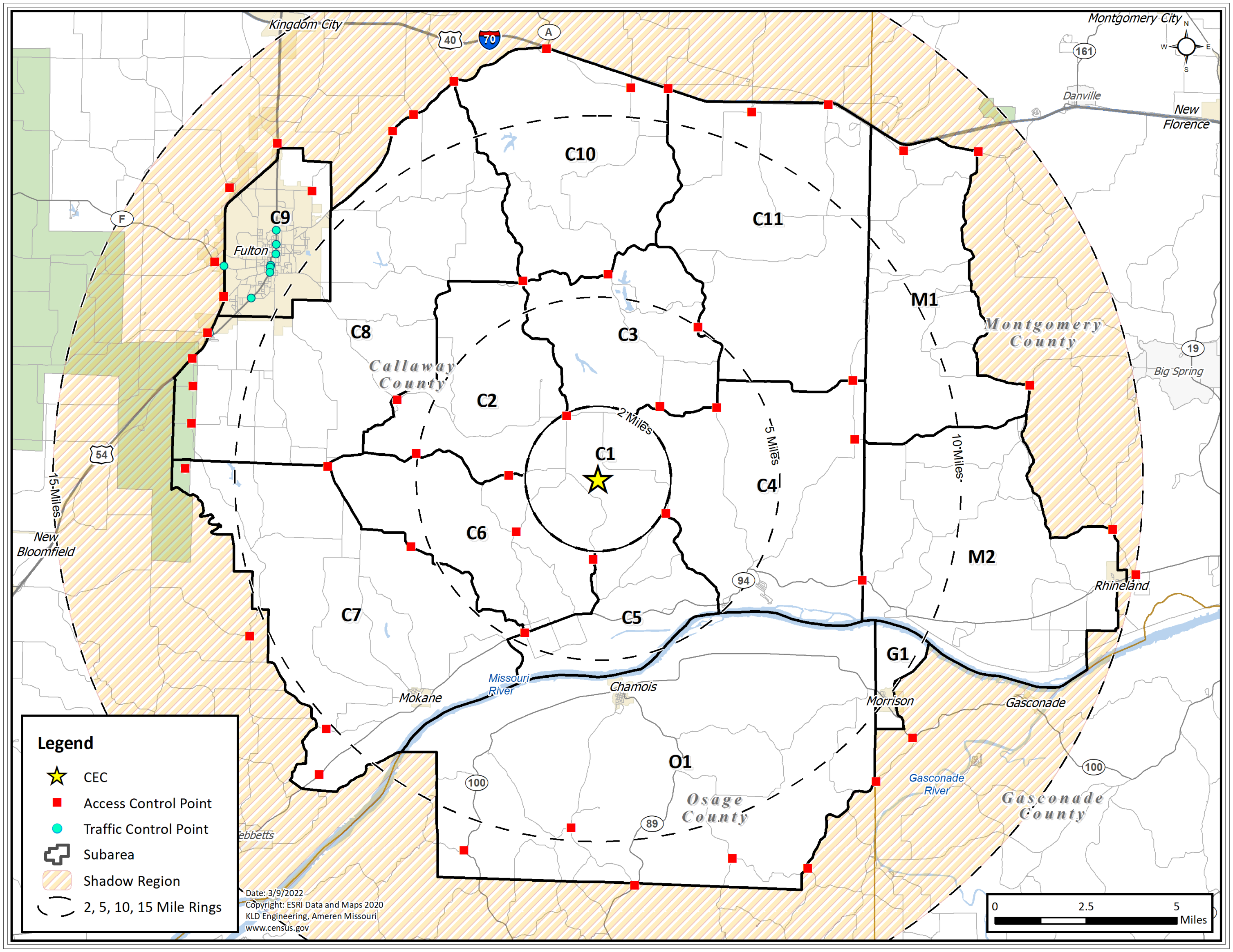


Figure G-1. Traffic Control and Access Control Points for the CEC EPZ

APPENDIX H

Evacuation Regions

H EVACUATION REGIONS

This appendix presents the evacuation percentages for each Evacuation Region (Table H-1) and maps of all Evacuation Regions (Figure H-1 through Figure H-44). The percentages presented in Table H-1 are based on the methodology discussed in assumption 7 of Section 2.2 and shown in Figure 2-1.

Note the baseline ETE study assumes 20 percent of households will not comply with the shelter advisory, as per Section 2.5.2 of NUREG/CR-7002, Rev. 1.

Table H-1. Percent of Subarea Population Evacuating for Each Region

Radial Regions																		
Region	Description:			Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R01	2-Mile Radius			100%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
R02	5-Mile Radius			100%	100%	100%	100%	100%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%
R03	Full EPZ			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Evacuate 2-Mile Region and Downwind to 5 Miles																		
Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R04	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	100%	20%	20%	20%	100%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	See Region R04														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)	See Region R04														
-	38 - 52	K, L, M	NE (3-Sector Keyhole)	See Region R04														
R05	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	100%	100%	20%	20%	100%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%
R06	60 - 75	L, M, N	ENE (3-Sector Keyhole)	100%	100%	20%	20%	20%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
-	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	See Region R06														
-	83 - 97	M, N, P	E (3-Sector Keyhole)															
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)															
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)															
R07	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	**100%**	**100%**	**100%**	**20%**	**20%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**
R08	128 - 142	P, Q, R	SE (3-Sector Keyhole)	**100%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	See Region R08														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)															
-	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)															
-	173 - 187	R, A, B	S (3-Sector Keyhole)															
-	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)															
R09	195 - 210	A, B, C	SSW (3-Sector Keyhole)	**100%**	**20%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R10	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	100%	20%	100%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
-	218 - 232	B, C, D	SW (3-Sector Keyhole)	See Region R10														
-	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)															
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)															
-	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)															
R11	263 - 277	D, E, F	W (3-Sector Keyhole)	100%	20%	20%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
R12	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	100%	20%	20%	100%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
-	285 - 300	E, F, G	WNW (3-Sector Keyhole)	See Region R12														
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)															
-	308 - 322	F, G, H	NW (3-Sector Keyhole)															
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)															
R13	330 - 345	G, H, J	NNW (3-Sector Keyhole)	100%	20%	20%	20%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
-	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	See Region R04														
-	353 - 7	H, J, K	N (3-Sector Keyhole)															

Evacuate 2-Mile Radius and Downwind to the EPZ Boundary																		
Region	**Wind Direction From: (Degrees)**	**Sectors:**	**Cardinal Compass Equivalent:**	**Subarea**														
				C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**G1**	**M1**	**M2**	**O1**
R14	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	100%	20%	20%	20%	100%	100%	100%	20%	20%	20%	20%	20%	20%	20%	100%
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	**See Region R14**														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)															
-	38 - 52	K, L, M	NE (3-Sector Keyhole)															
R15	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	100%	100%	20%	20%	100%	100%	100%	100%	20%	20%	20%	20%	20%	20%	100%
R16	60 - 75	L, M, N	ENE (3-Sector Keyhole)	100%	100%	20%	20%	20%	100%	100%	100%	20%	20%	20%	20%	20%	20%	20%
R17	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	100%	100%	20%	20%	20%	100%	100%	100%	100%	20%	20%	20%	20%	20%	20%
-	83 - 97	M, N, P	E (3-Sector Keyhole)	**See Region R17**														
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)															
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)															
R18	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	100%	100%	100%	20%	20%	100%	100%	100%	100%	100%	20%	20%	20%	20%	20%
R19	128 - 142	P, Q, R	SE (3-Sector Keyhole)	100%	100%	100%	20%	20%	20%	20%	100%	100%	100%	20%	20%	20%	20%	20%
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	**See Region R19**														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)															

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R20	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)	**100%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**100%**	**100%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**
R21	173 - 187	R, A, B	S (3-Sector Keyhole)	**100%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**100%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**
R22	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)	**100%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**100%**	**20%**	**100%**	**100%**	**20%**	**100%**	**20%**	**20%**
R23	195 - 210	A, B, C	SSW (3-Sector Keyhole)	**100%**	**20%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**	**100%**	**20%**	**100%**	**20%**	**20%**
R24	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	**100%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**	**100%**	**20%**	**100%**	**20%**	**20%**
R25	218 - 232	B, C, D	SW (3-Sector Keyhole)	**100%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**	**20%**	**100%**	**20%**	**20%**
R26	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)	**100%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**	**20%**	**100%**	**100%**	**20%**
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)	**See Region R26**														
R27	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)	**100%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**	**100%**	**100%**	**100%**	**20%**
R28	263 - 277	D, E, F	W (3-Sector Keyhole)	**100%**	**20%**	**20%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**	**100%**	**100%**	**100%**	**20%**
R29	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	**100%**	**20%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**	**100%**	**100%**	**100%**	**100%**

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R30	285 - 300	E, F, G	WNW (3-Sector Keyhole)	**100%**	**20%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**	**20%**	**100%**	**100%**
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)	**See Region R30**														
-	308 - 322	F, G, H	NW (3-Sector Keyhole)															
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)															
R31	330 - 345	G, H, J	NNW (3-Sector Keyhole)	**100%**	**20%**	**20%**	**20%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**	**20%**	**20%**	**100%**
R32	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	**100%**	**20%**	**20%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**	**20%**	**20%**	**100%**
R33	353 - 7	H, J, K	N (3-Sector Keyhole)	**100%**	**20%**	**20%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**100%**

Staged Evacuation - 2-Mile Radius Evacuates, then Evacuate Downwind to 5 Miles																		
Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R34	5-Mile Radius			100%	100%	100%	100%	100%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%
R35	8 - 14	H, J, K, L	N/NNE (4-Sector Keyhole)	100%	20%	20%	20%	100%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%
-	15 - 30	J, K, L	NNE (3-Sector Keyhole)	See Region R35														
-	31 - 37	J, K, L, M	NNE/NE (4-Sector Keyhole)															
-	38 - 52	K, L, M	NE (3-Sector Keyhole)															
R36	53 - 59	K, L, M, N	NE/ENE (4-Sector Keyhole)	100%	100%	20%	20%	100%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%
R37	60 - 75	L, M, N	ENE (3-Sector Keyhole)	100%	100%	20%	20%	20%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%
-	76 - 82	L, M, N, P	ENE/E (4-Sector Keyhole)	See Region R37														
-	83 - 97	M, N, P	E (3-Sector Keyhole)															
-	98 - 104	M, N, P, Q	E/ESE (4-Sector Keyhole)															
-	105 - 120	N, P, Q	ESE (3-Sector Keyhole)															
R38	121 - 127	N, P, Q, R	ESE/SE (4-Sector Keyhole)	100%	100%	100%	20%	20%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R39	128 - 142	P, Q, R	SE (3-Sector Keyhole)	**100%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**
-	143 - 149	P, Q, R, A	SE/SSE (4-Sector Keyhole)	**See Region R39**														
-	150 - 165	Q, R, A	SSE (3-Sector Keyhole)															
-	166 - 172	Q, R, A, B	SSE/S (4-Sector Keyhole)															
-	173 - 187	R, A, B	S (3-Sector Keyhole)															
-	188 - 194	R, A, B, C	S/SSW (4-Sector Keyhole)															
R40	195 - 210	A, B, C	SSW (3-Sector Keyhole)	**100%**	**20%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**
R41	211 - 217	A, B, C, D	SSW/SW (4-Sector Keyhole)	**100%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**
-	218 - 232	B, C, D	SW (3-Sector Keyhole)	**See Region R41**														
-	233 - 239	B, C, D, E	SW/WSW (4-Sector Keyhole)															
-	240 - 255	C, D, E	WSW (3-Sector Keyhole)															
-	256 - 262	C, D, E, F	WSW/W (4-Sector Keyhole)															
R42	263 - 277	D, E, F	W (3-Sector Keyhole)	**100%**	**20%**	**20%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**

Region	Wind Direction From: (Degrees)	Sectors:	Cardinal Compass Equivalent:	Subarea														
				C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	G1	M1	M2	O1
R43	278 - 284	D, E, F, G	W/WNW (4-Sector Keyhole)	**100%**	**20%**	**20%**	**100%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**
-	285 - 300	E, F, G	WNW (3-Sector Keyhole)	**See Region R43**														
-	301 - 307	E, F, G, H	WNW/NW (4-Sector Keyhole)															
-	308 - 322	F, G, H	NW (3-Sector Keyhole)															
-	323 - 329	F, G, H, J	NW/NNW (4-Sector Keyhole)															
R44	330 - 345	G, H, J	NNW (3-Sector Keyhole)	**100%**	**20%**	**20%**	**20%**	**100%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**
-	346 -352	G, H, J, K	NNW/N (4-Sector Keyhole)	**See Region R35**														
-	353 - 7	H, J, K	N (3-Sector Keyhole)															

Subarea(s) Evacuate	Subarea(s) Shelter-in-Place	Shelter-in-Place until 90% ETE for R01, then Evacuate

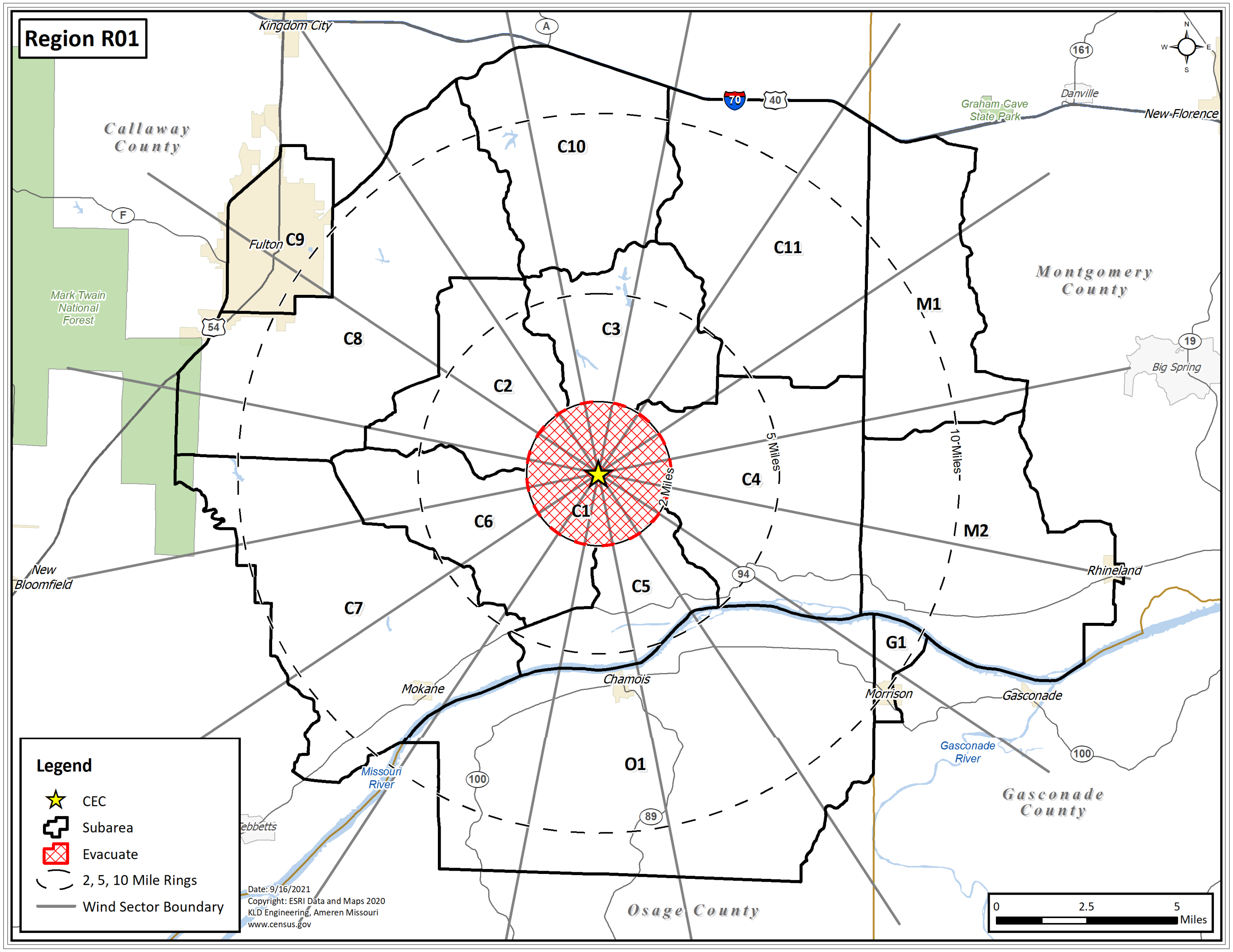


Figure H-1 Region R01

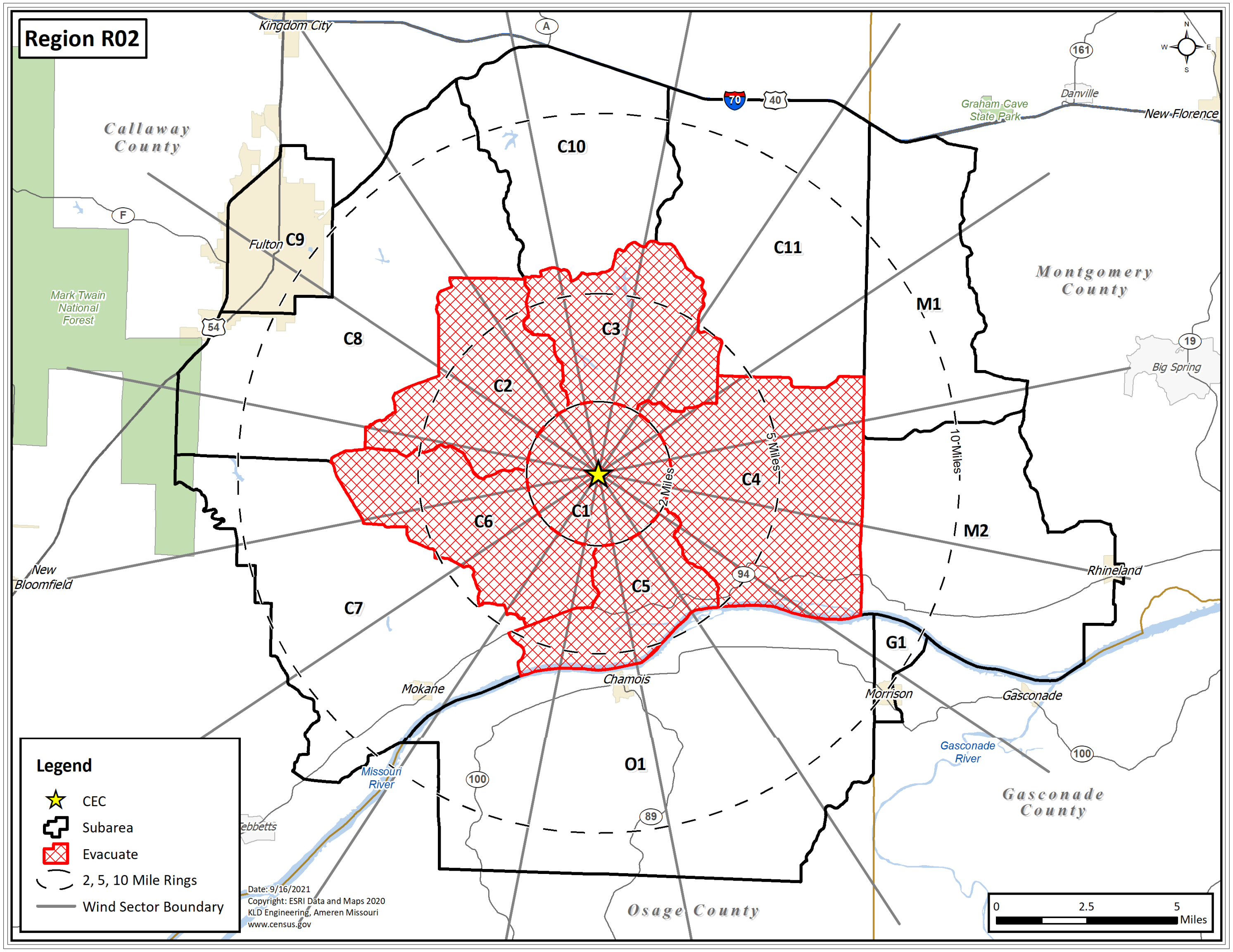


Figure H-2 Region R02

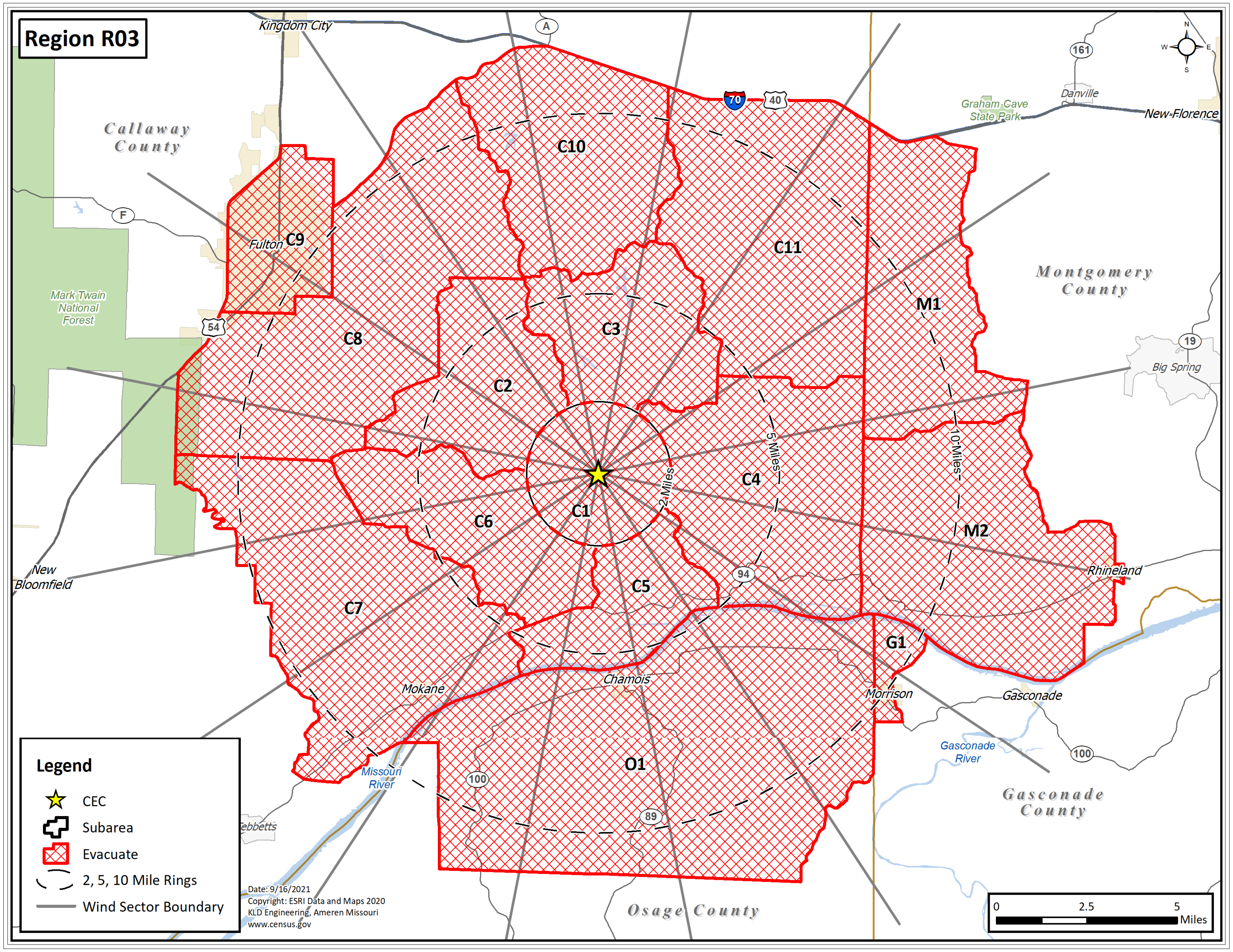


Figure H-3 Region R03

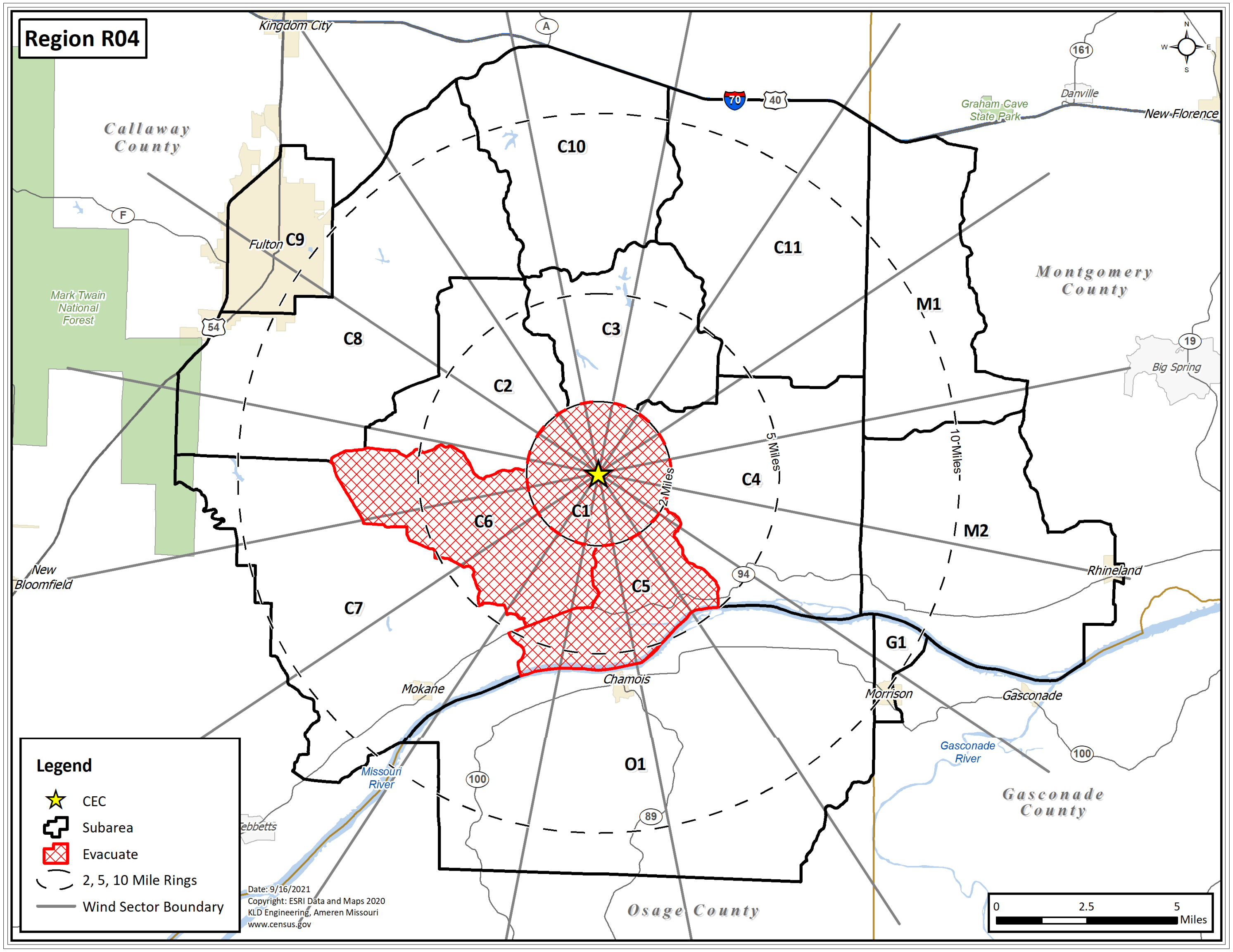


Figure H-4 Region R04

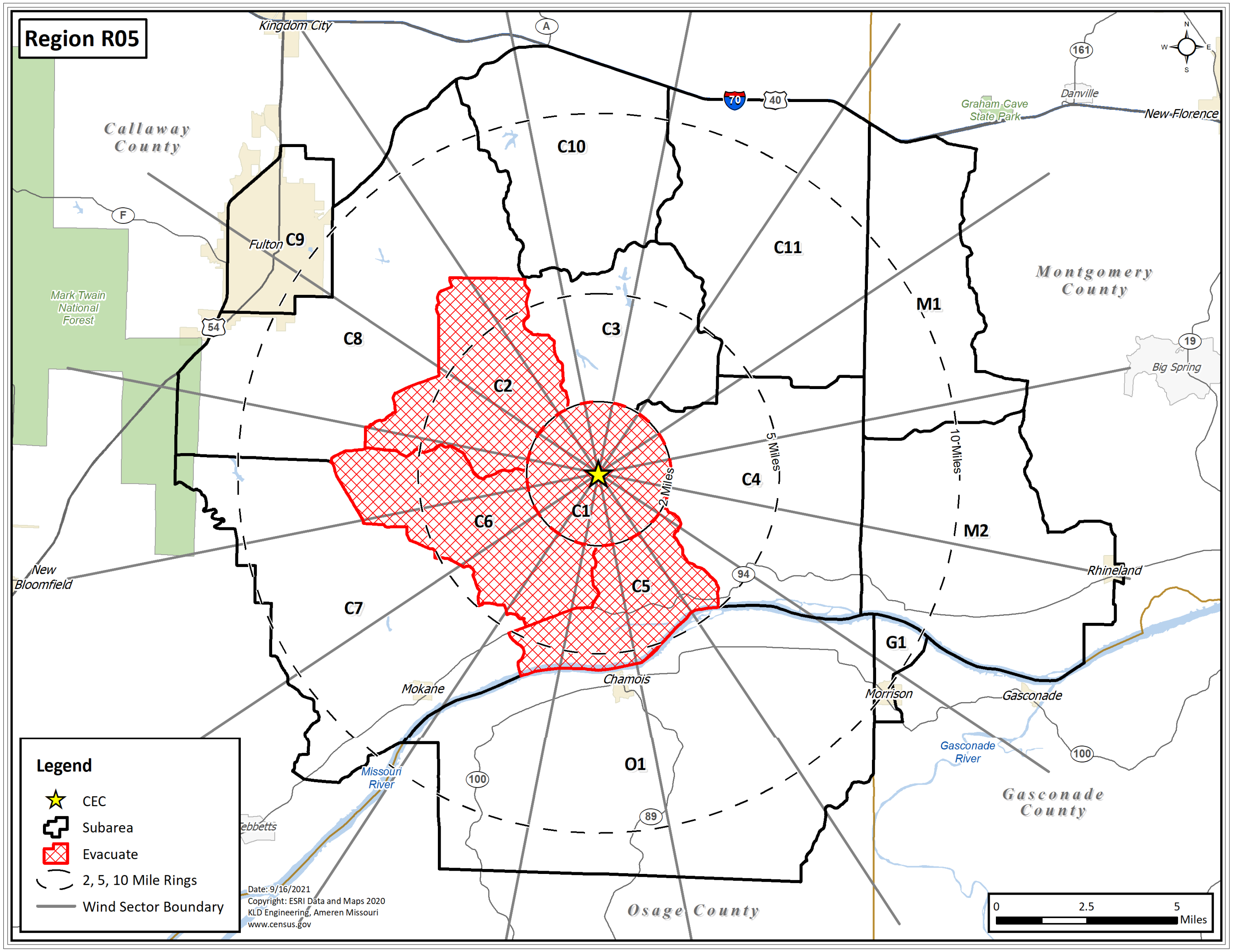


Figure H-5 Region R05

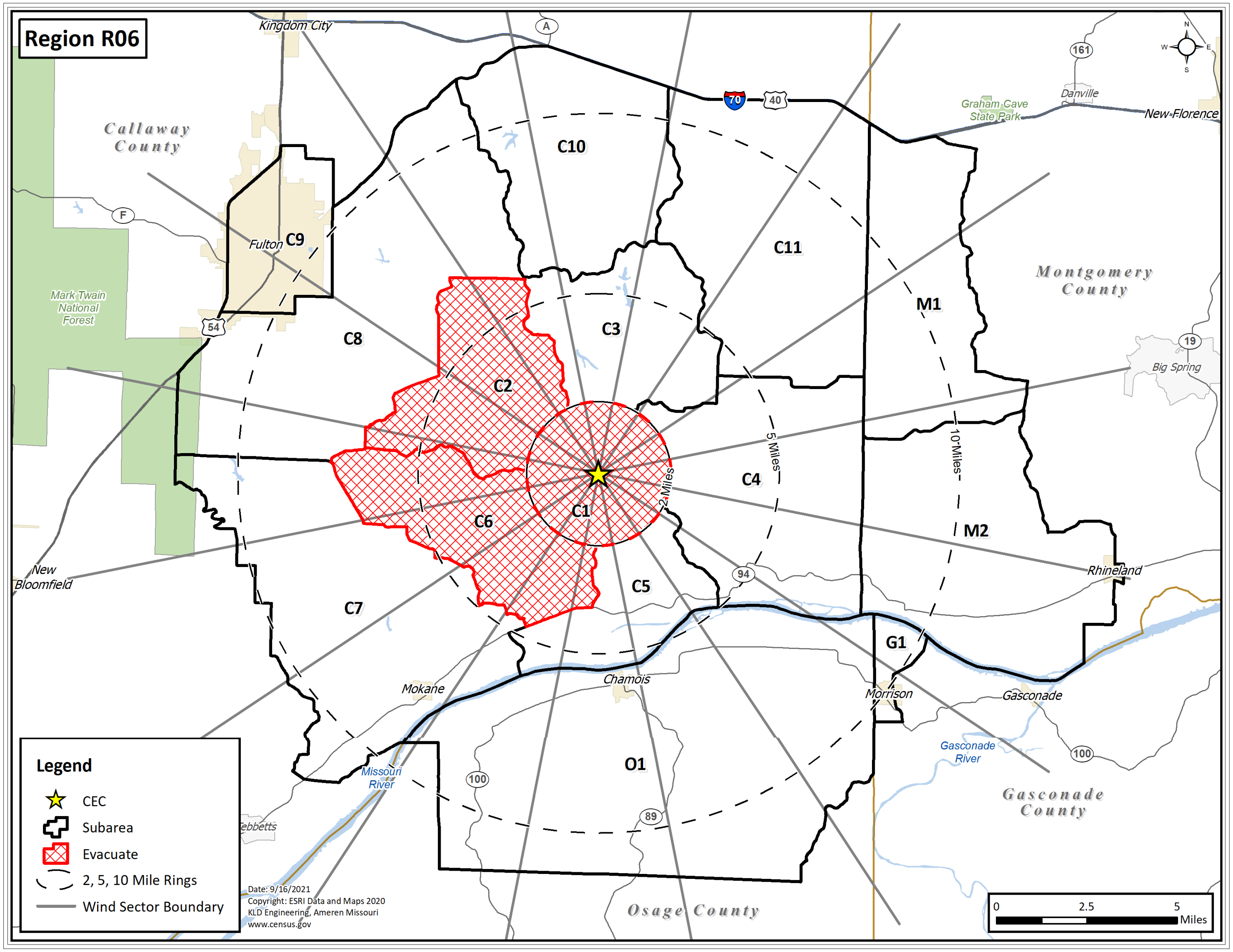


Figure H-6 Region R06

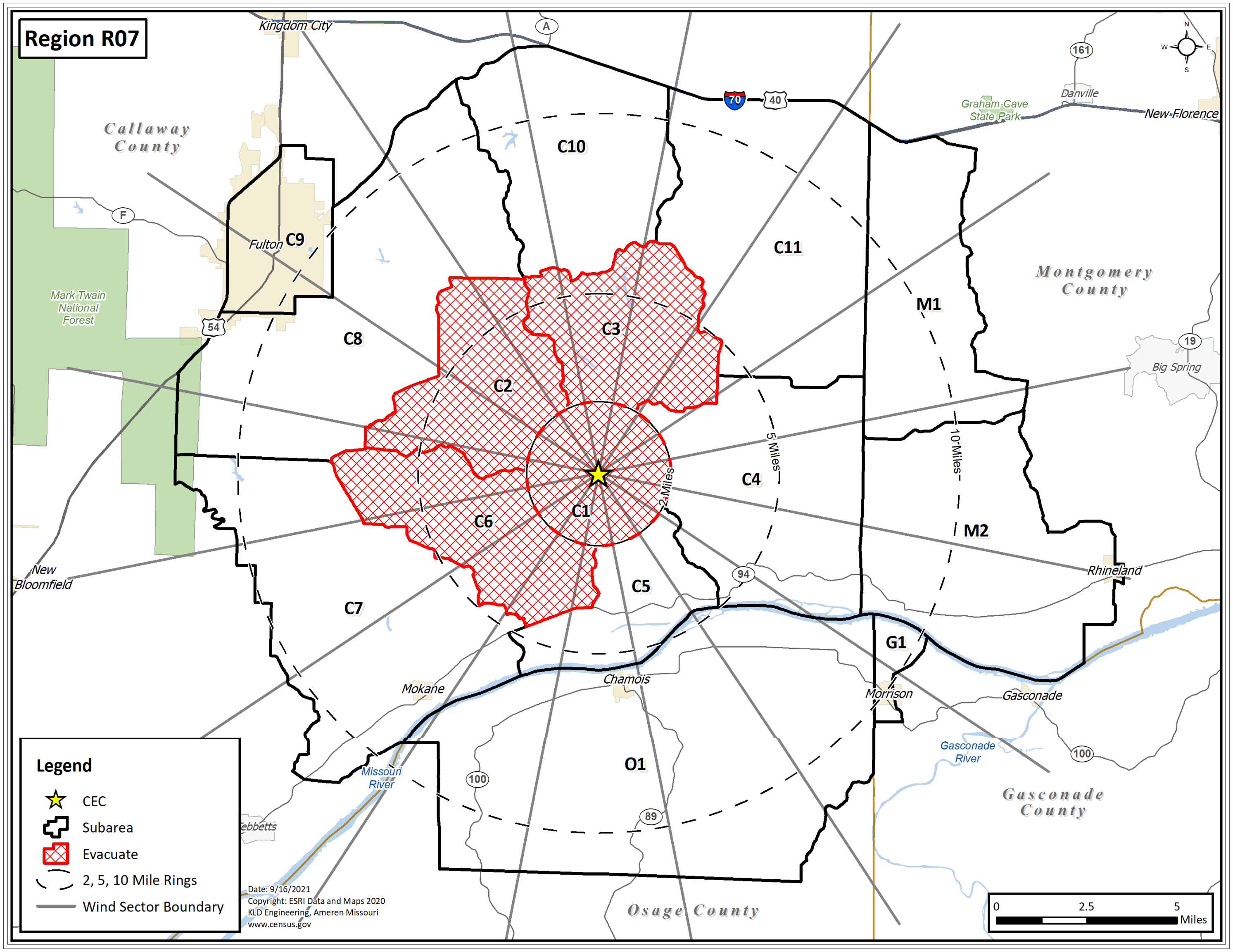


Figure H-7 Region R07

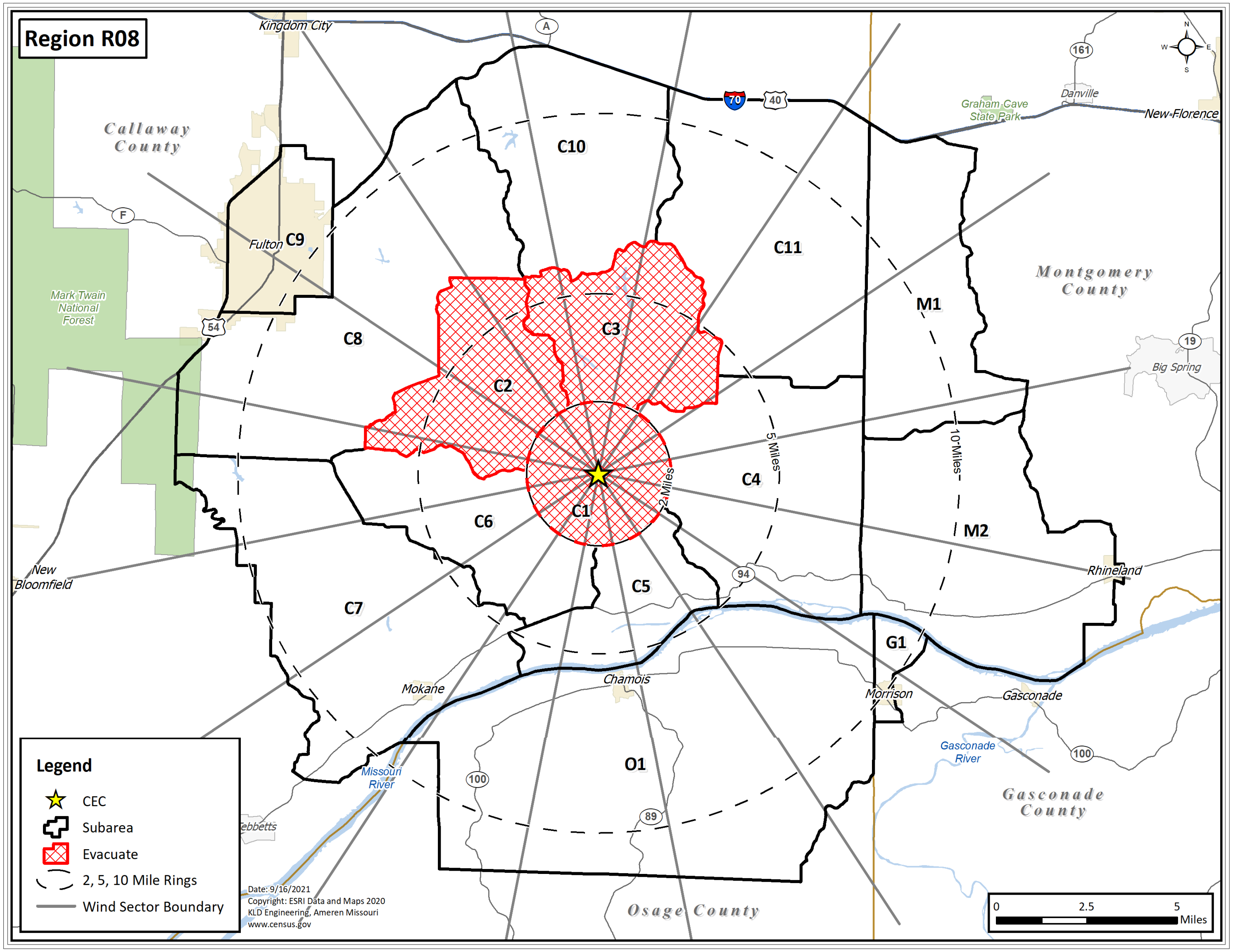


Figure H-8 Region R08

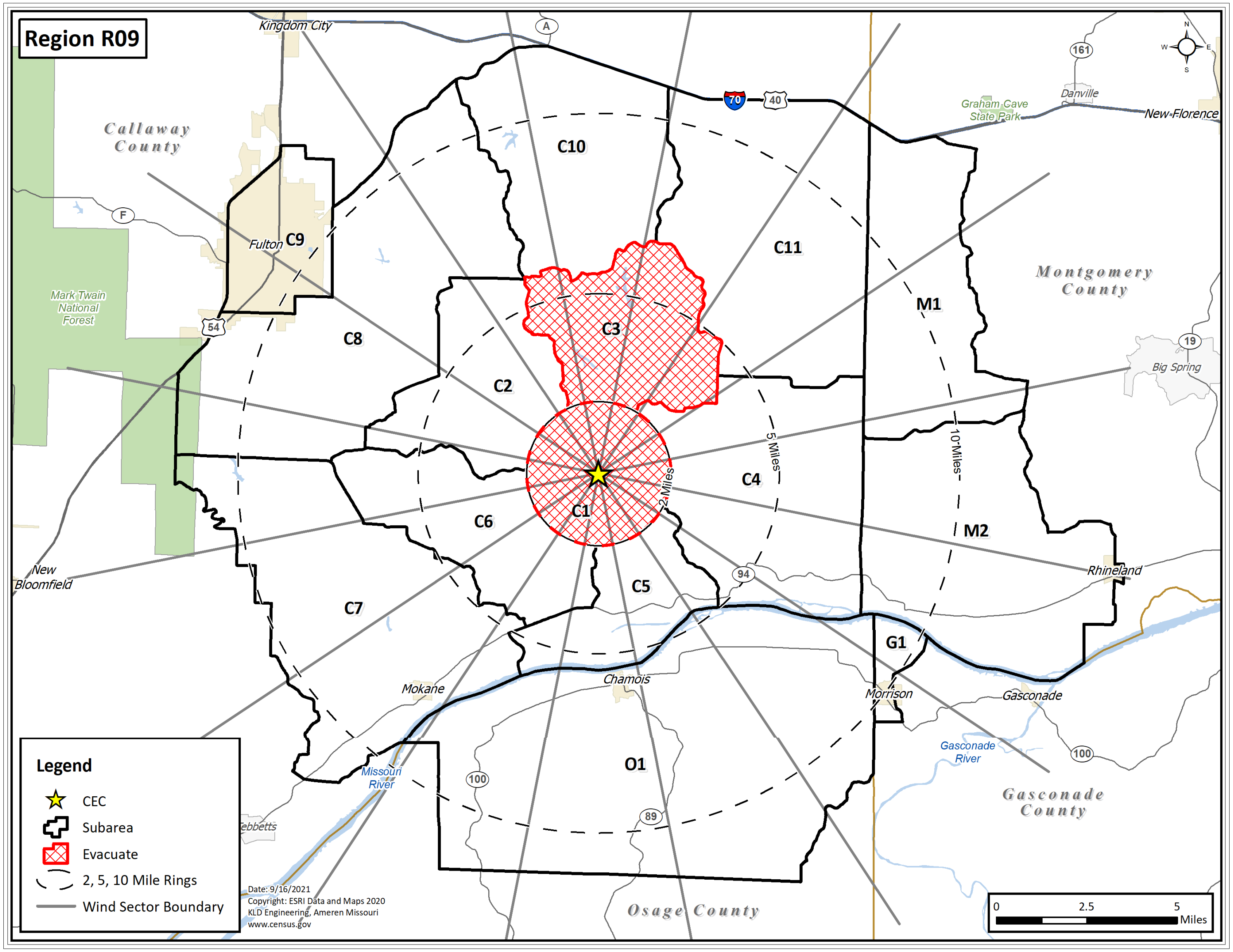


Figure H-9 Region R09

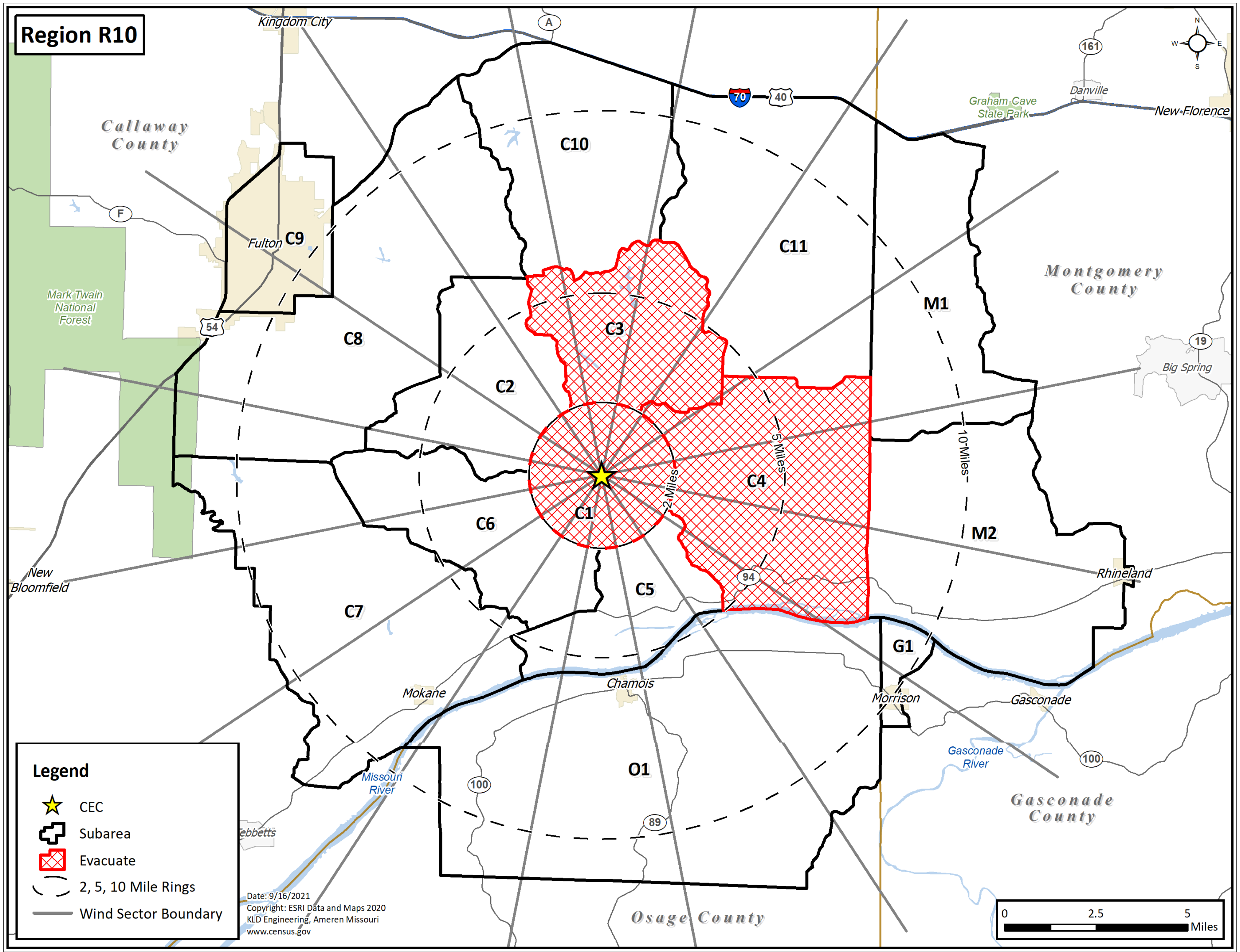


Figure H-10 Region R10

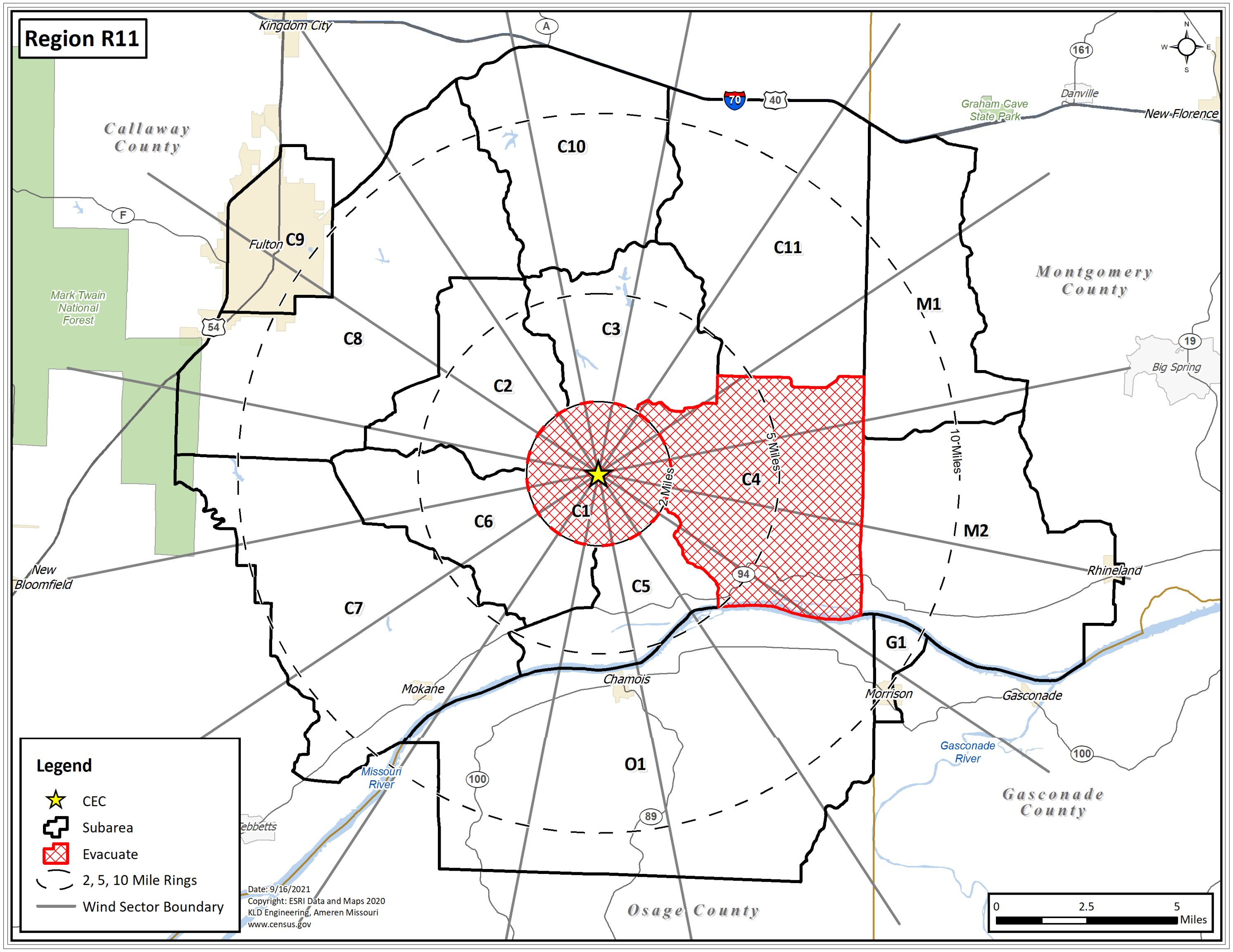


Figure H-11 Region R11

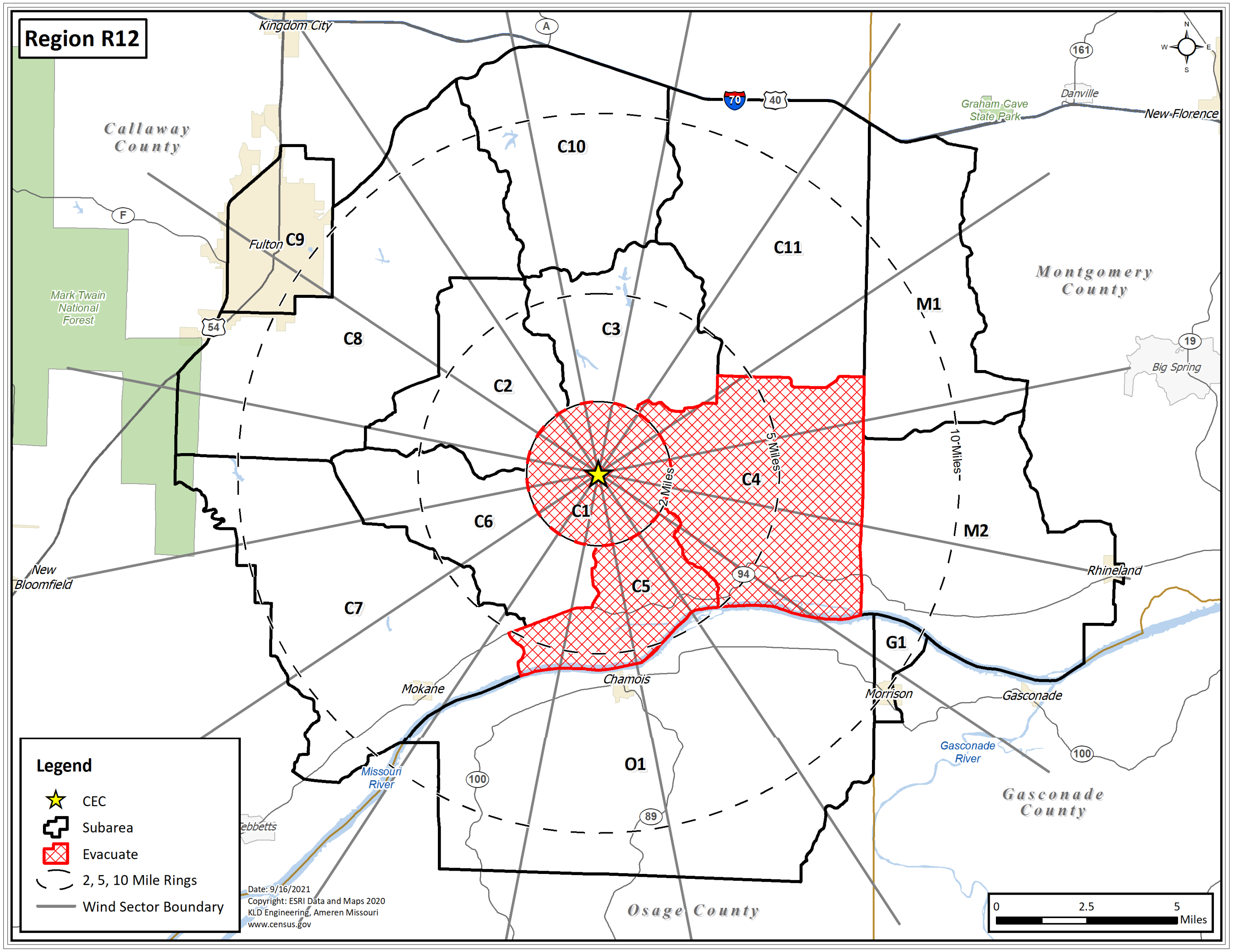


Figure H-12 Region R12

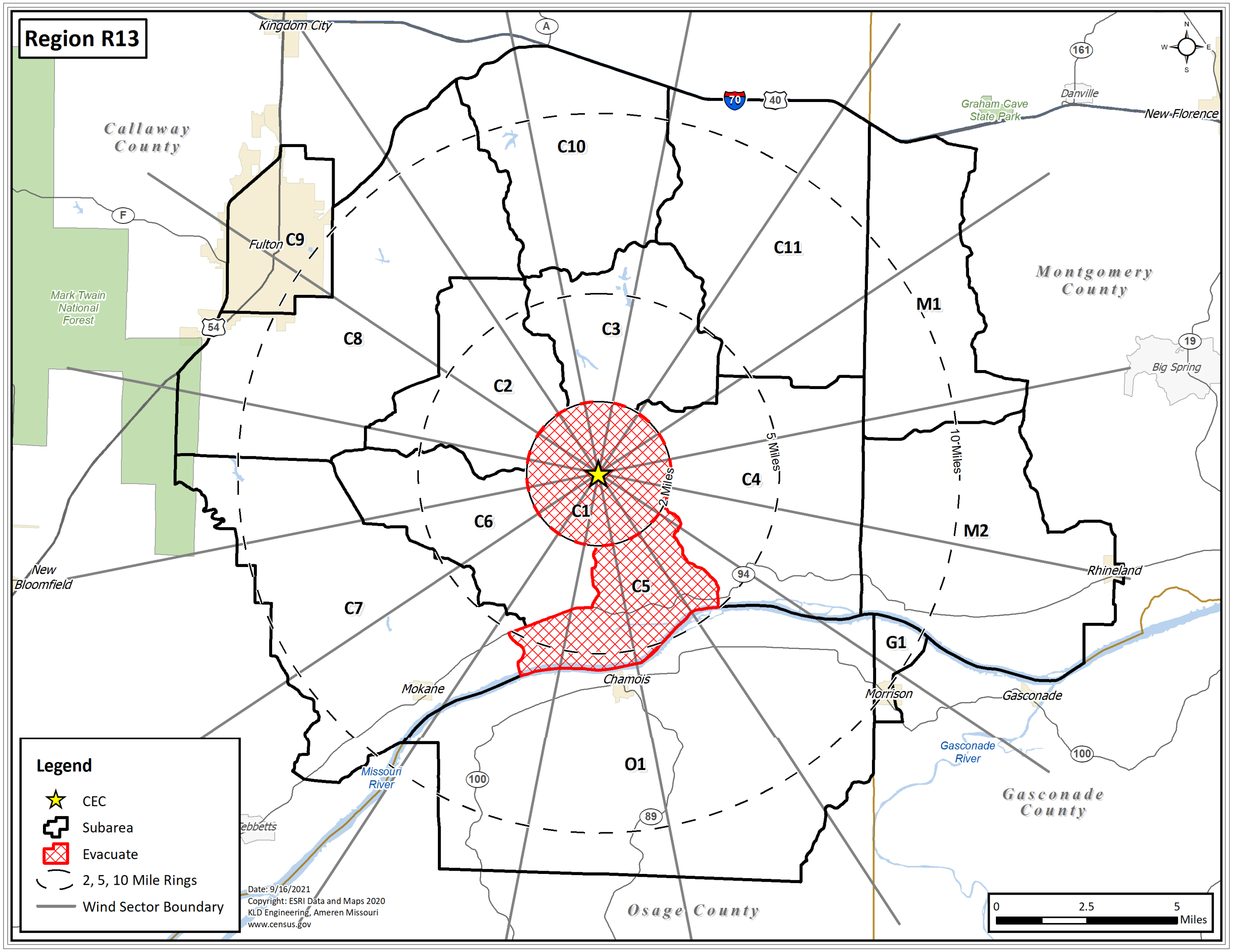


Figure H-13 Region R13

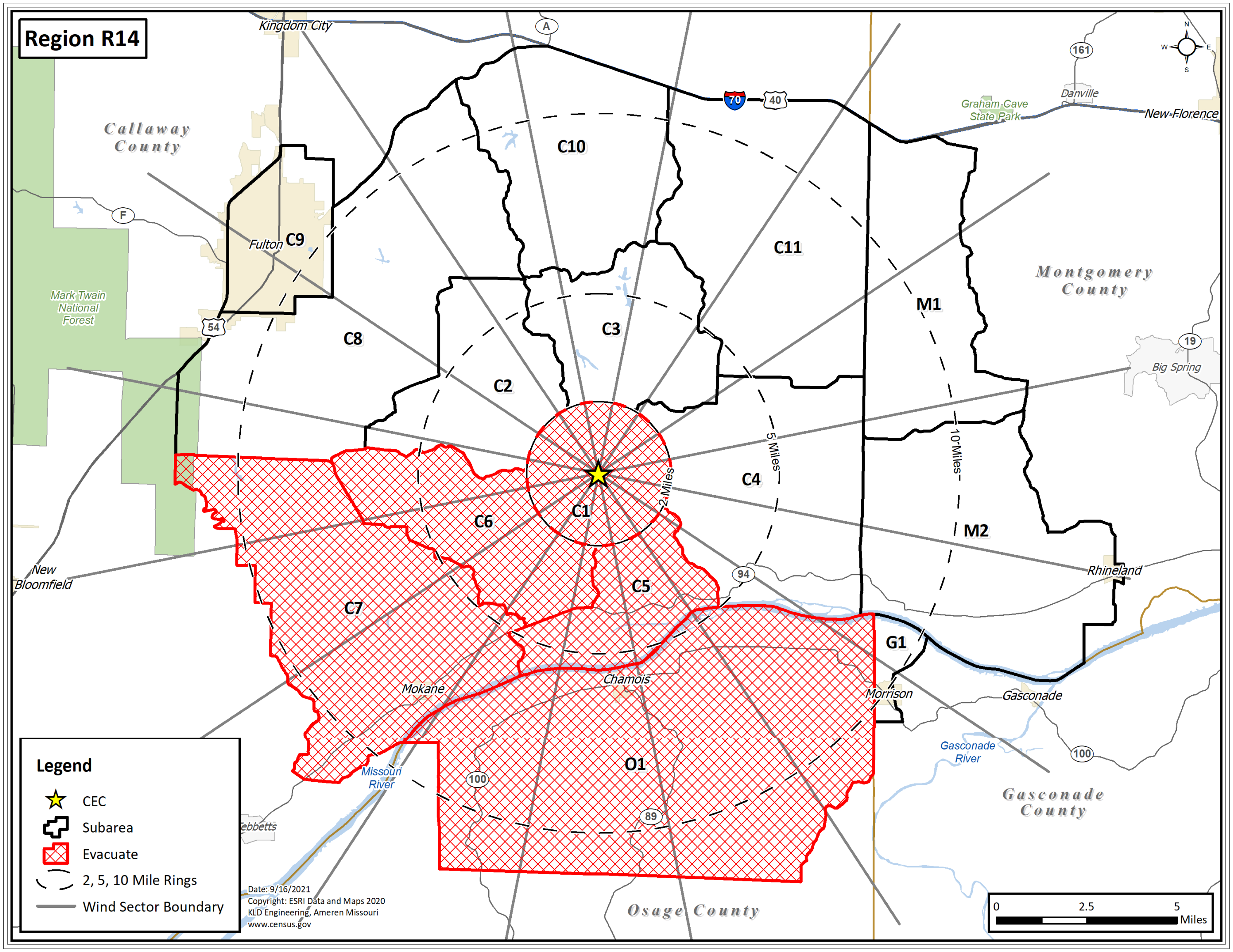


Figure H-14 Region R14

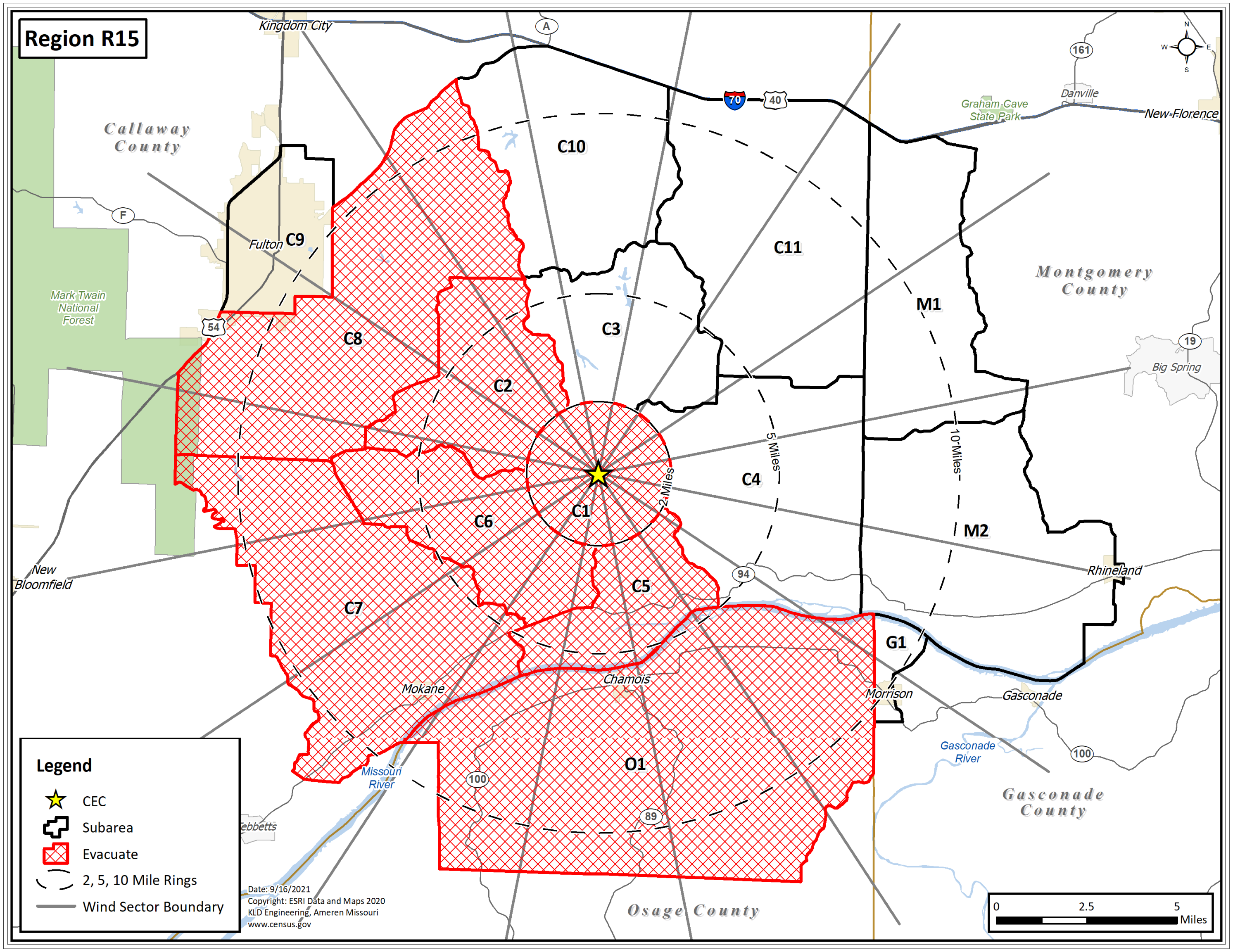


Figure H-15 Region R15

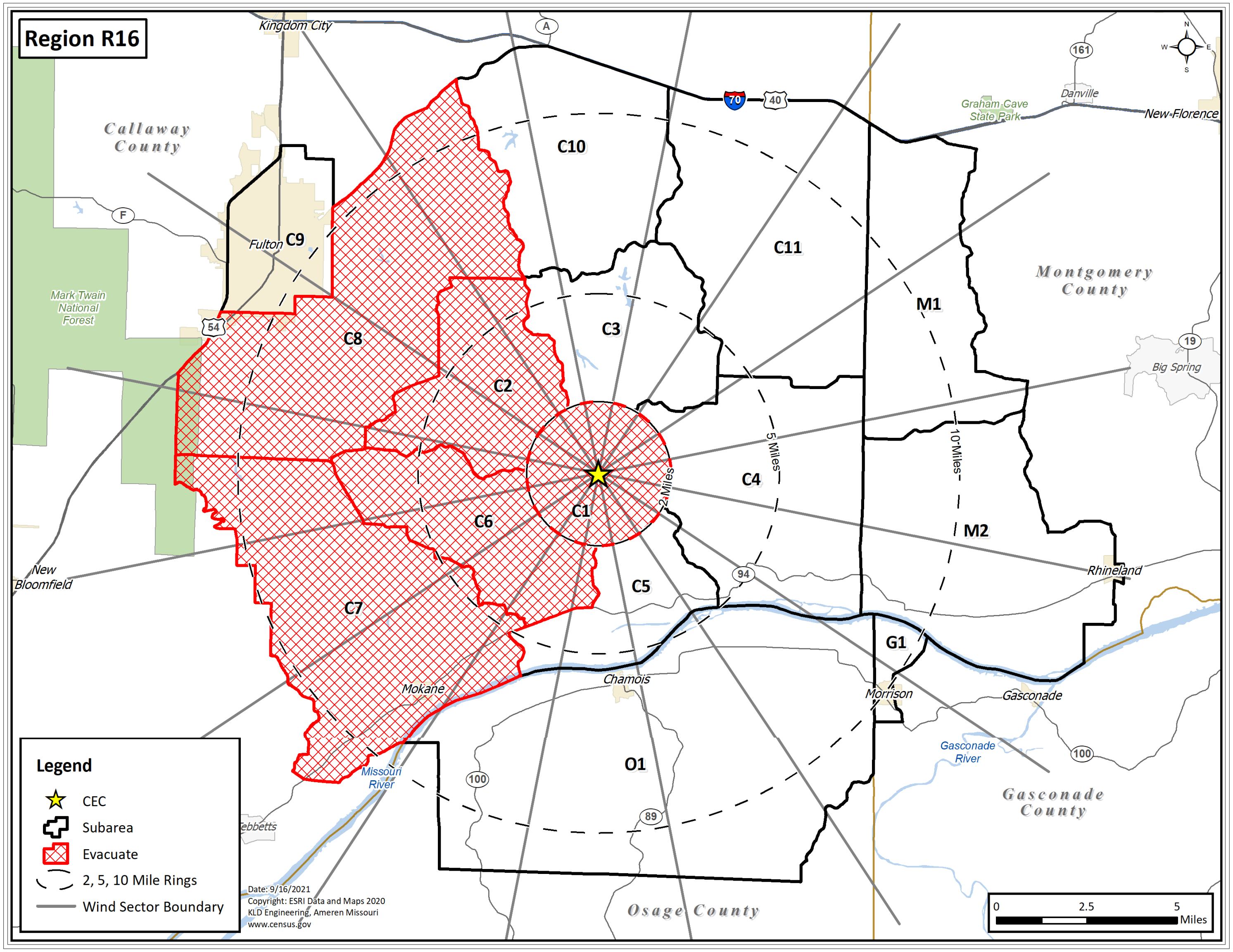


Figure H-16 Region R16

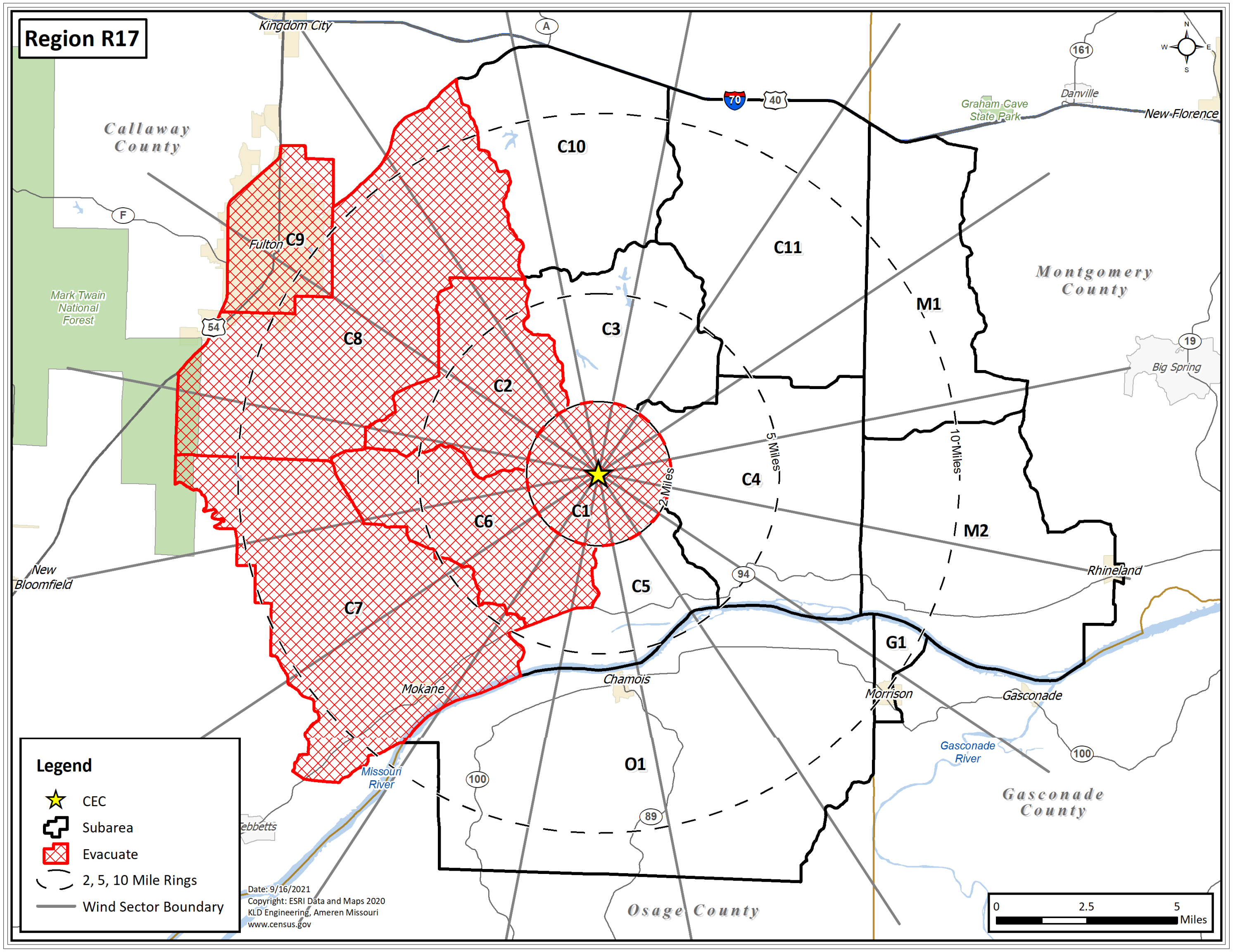


Figure H-17 Region R17

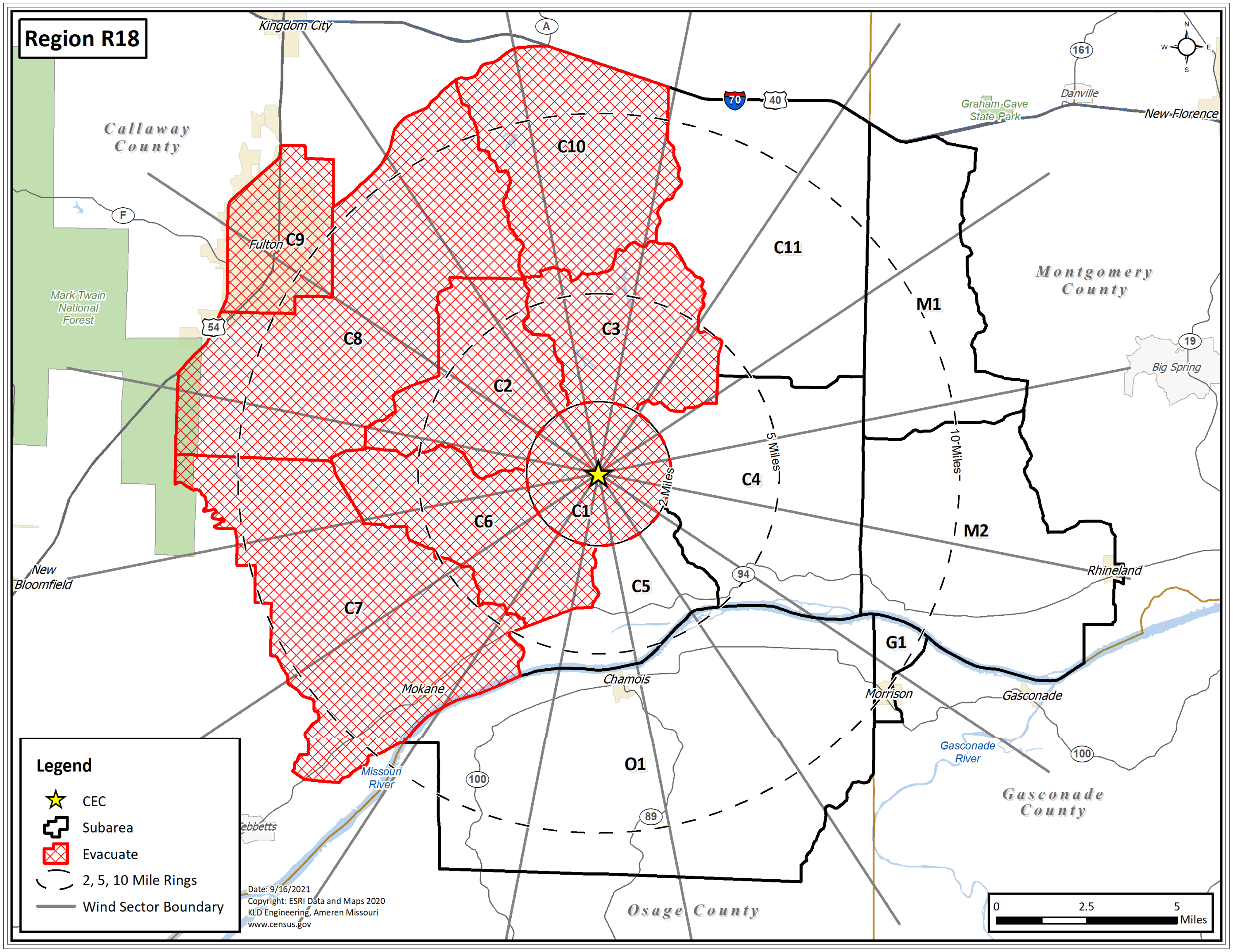


Figure H-18 Region R18

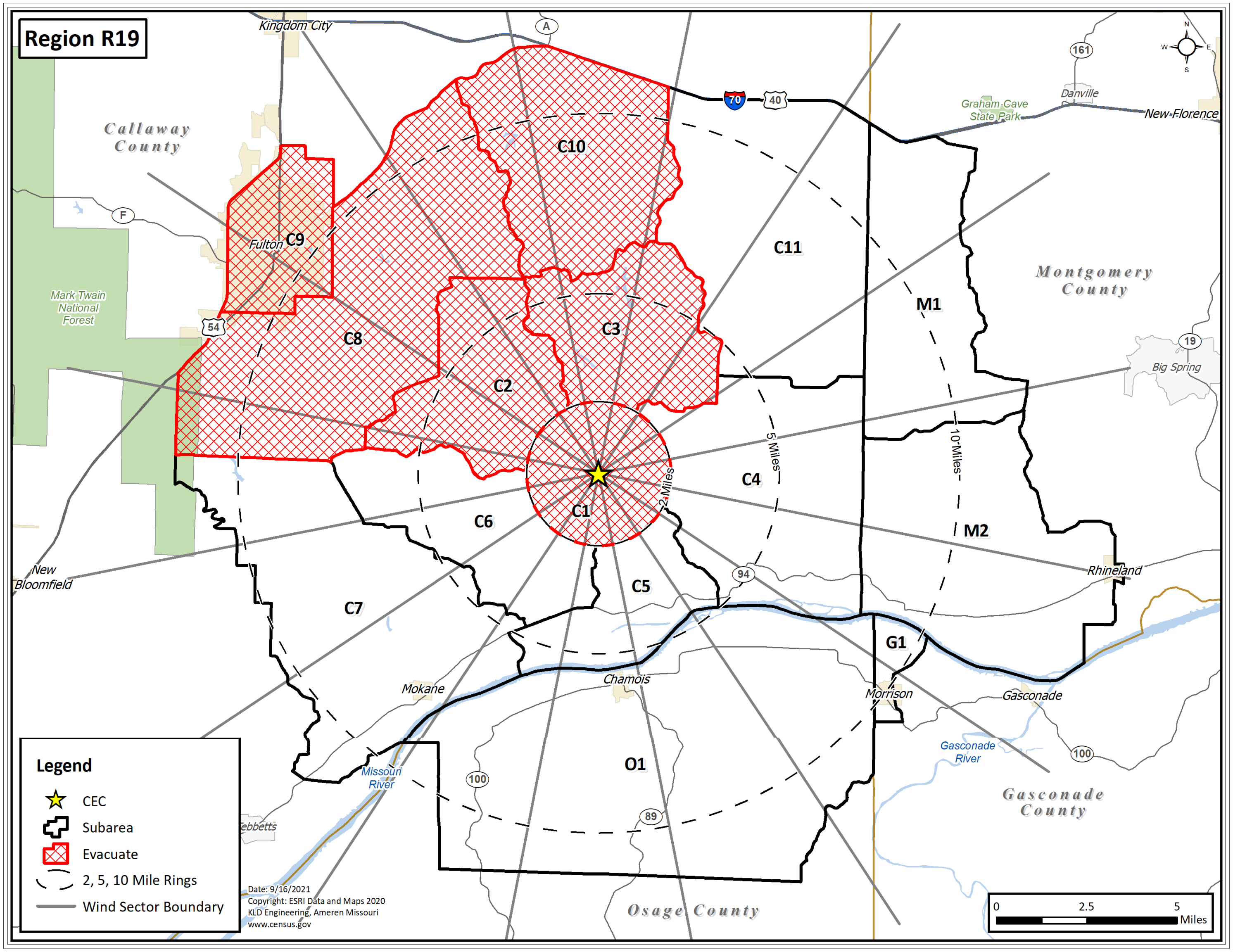


Figure H-19 Region R19

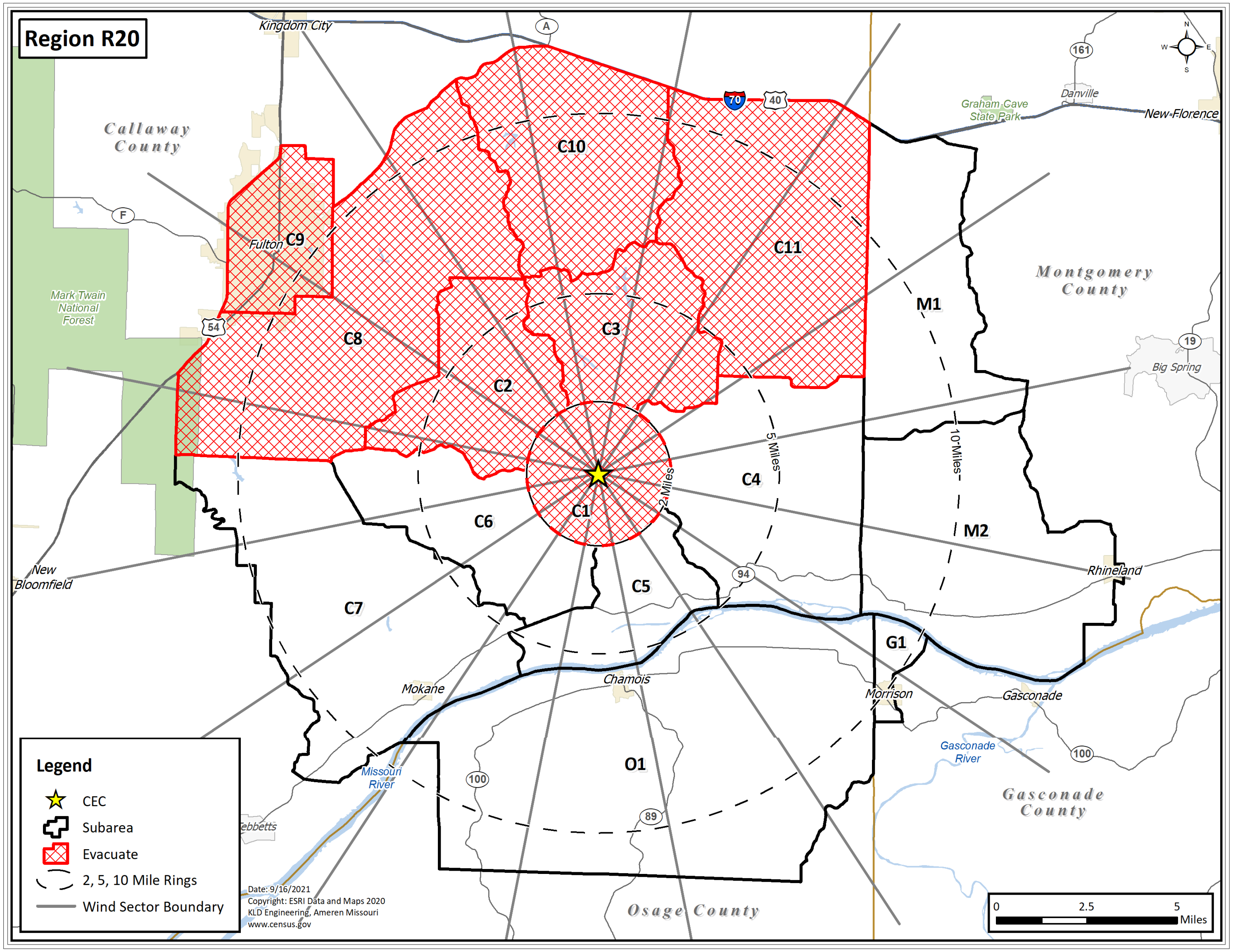


Figure H-20 Region R20

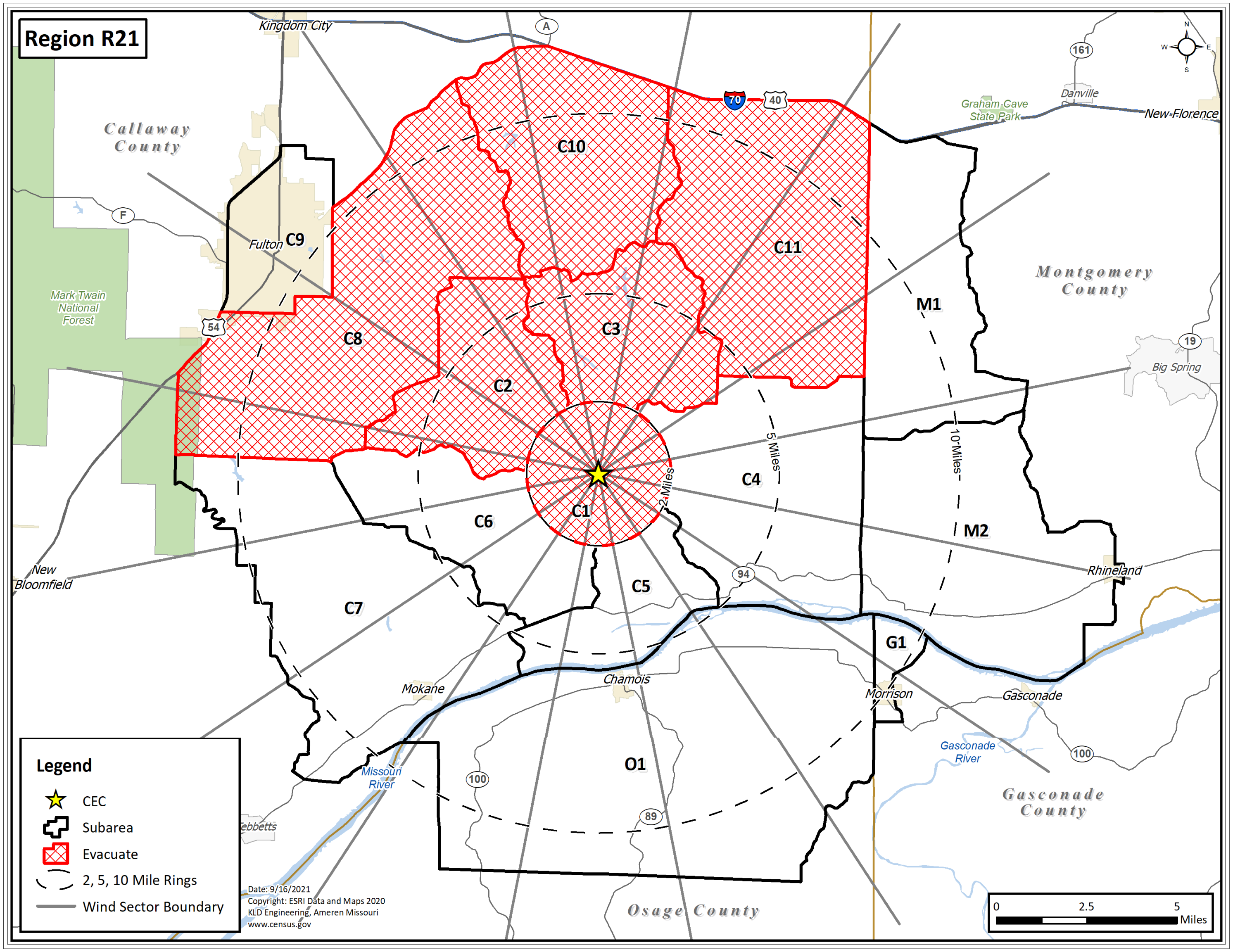


Figure H-21 Region R21

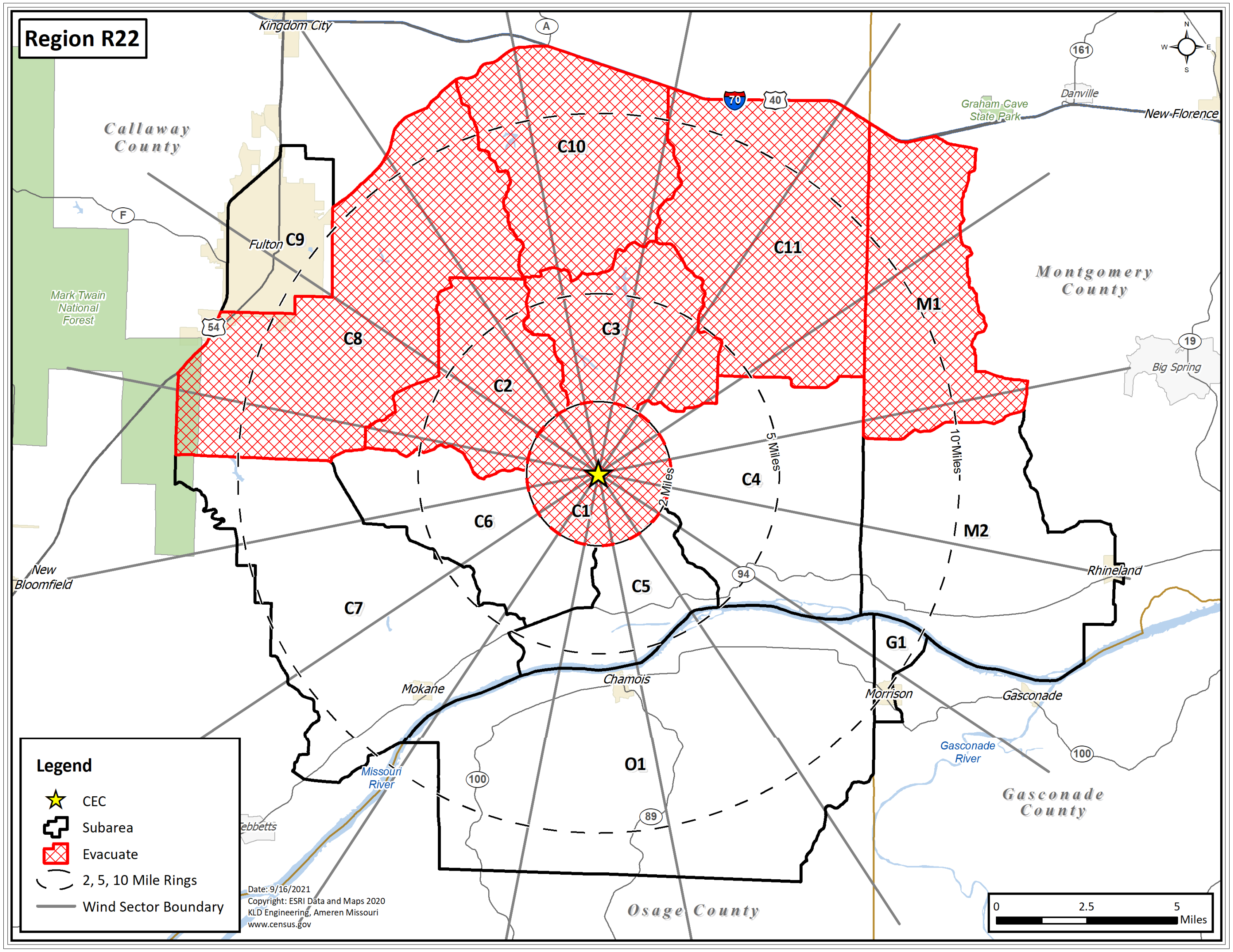


Figure H-22 Region R22

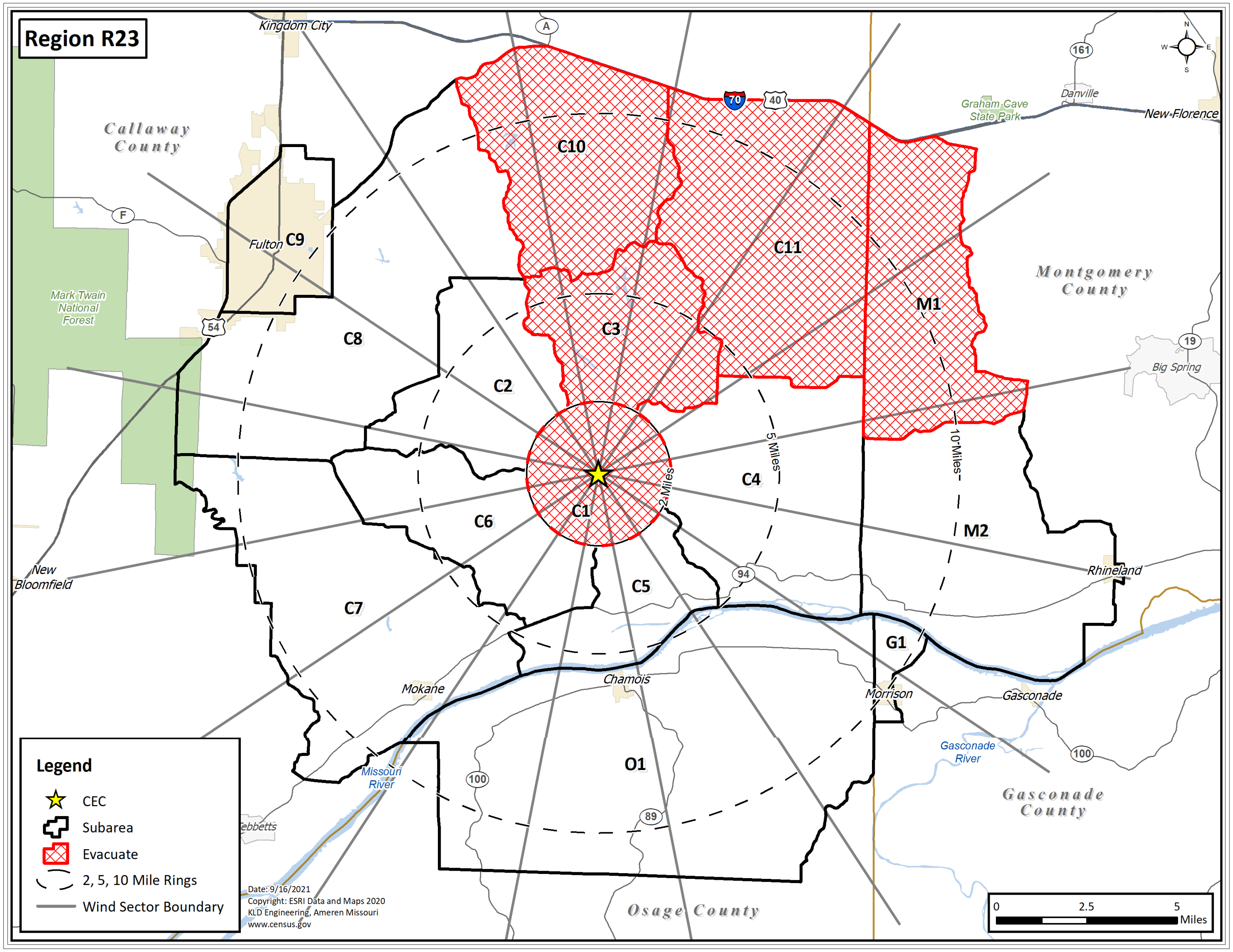


Figure H-23 Region R23

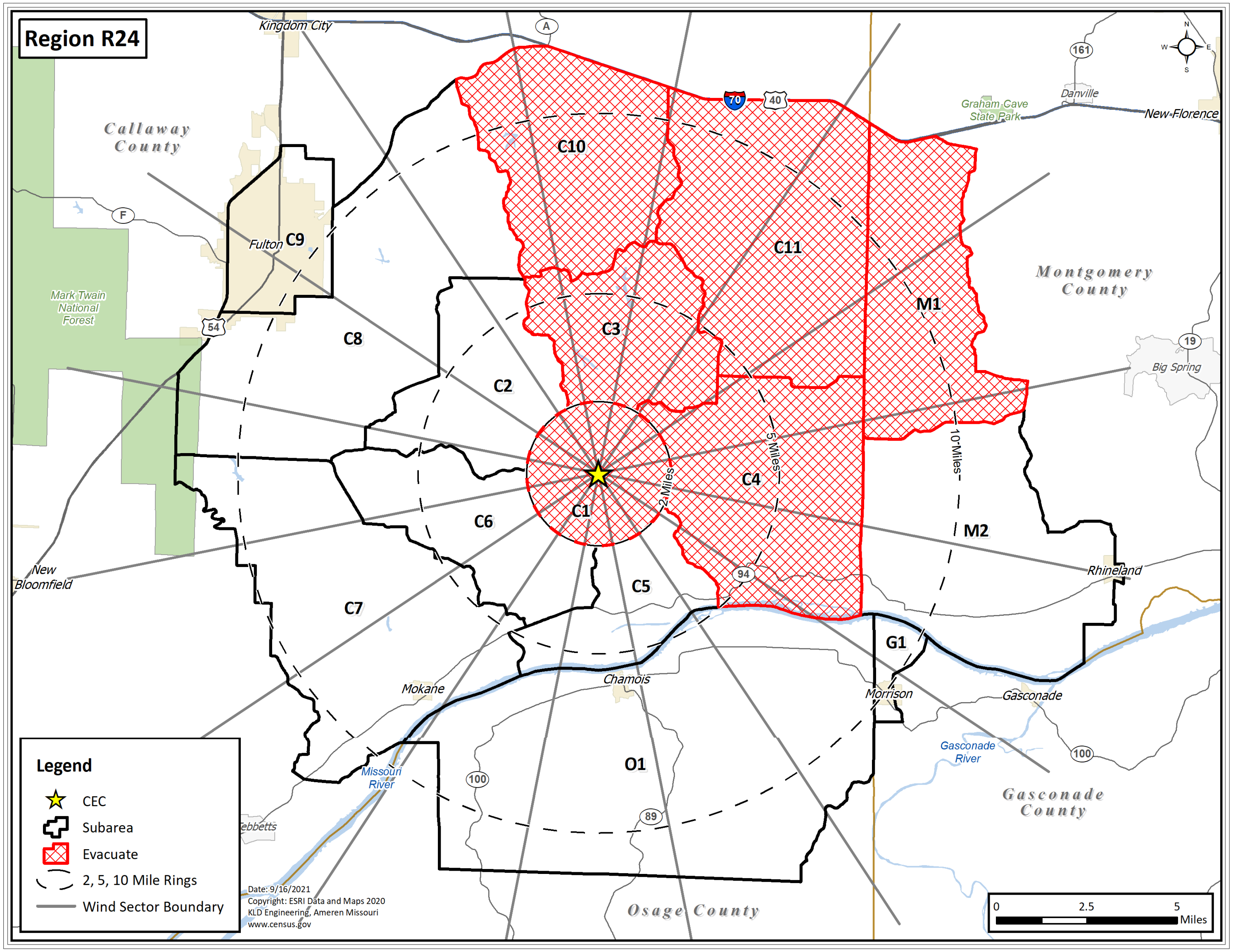


Figure H-24 Region R24

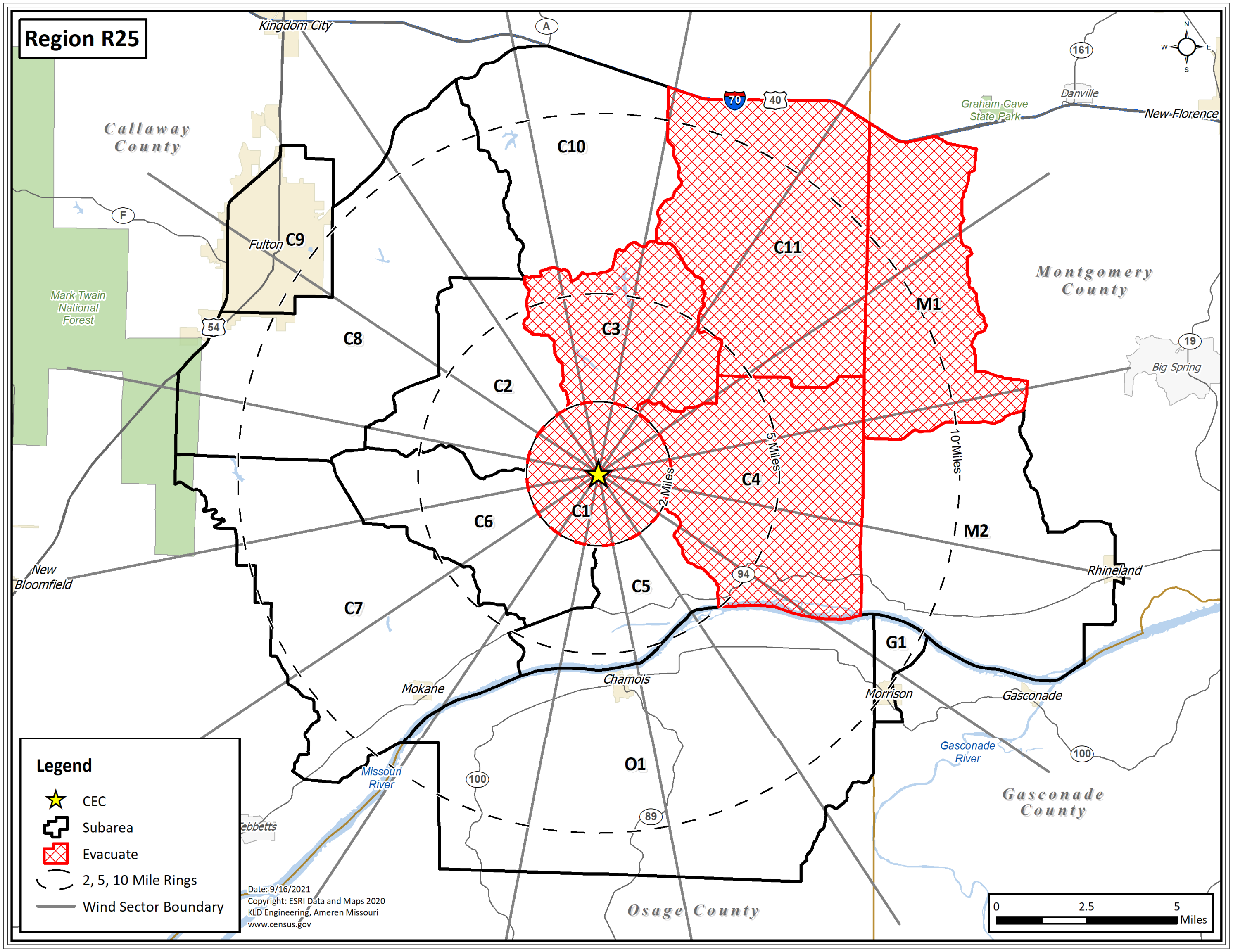


Figure H-25 Region R25

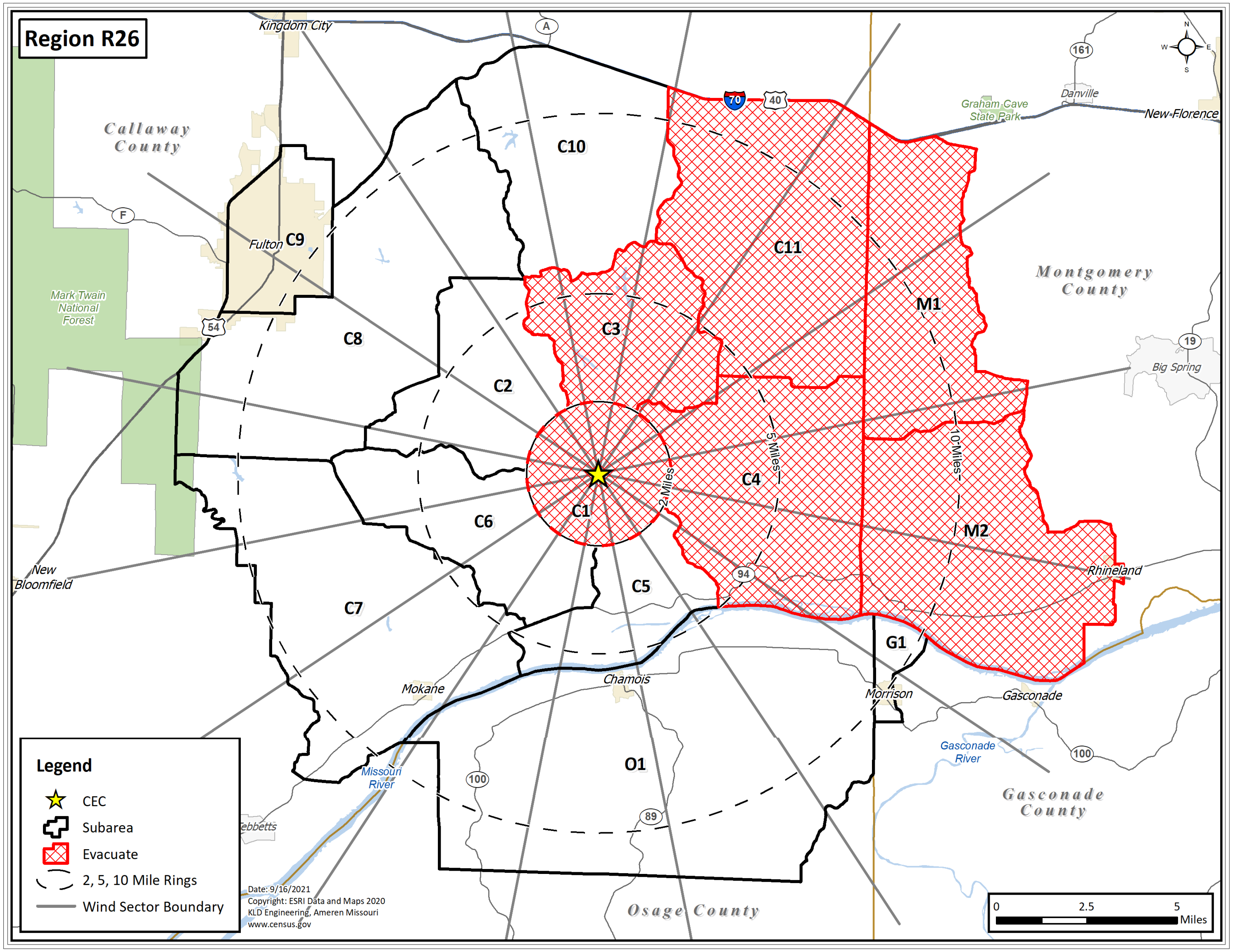


Figure H-26 Region R26

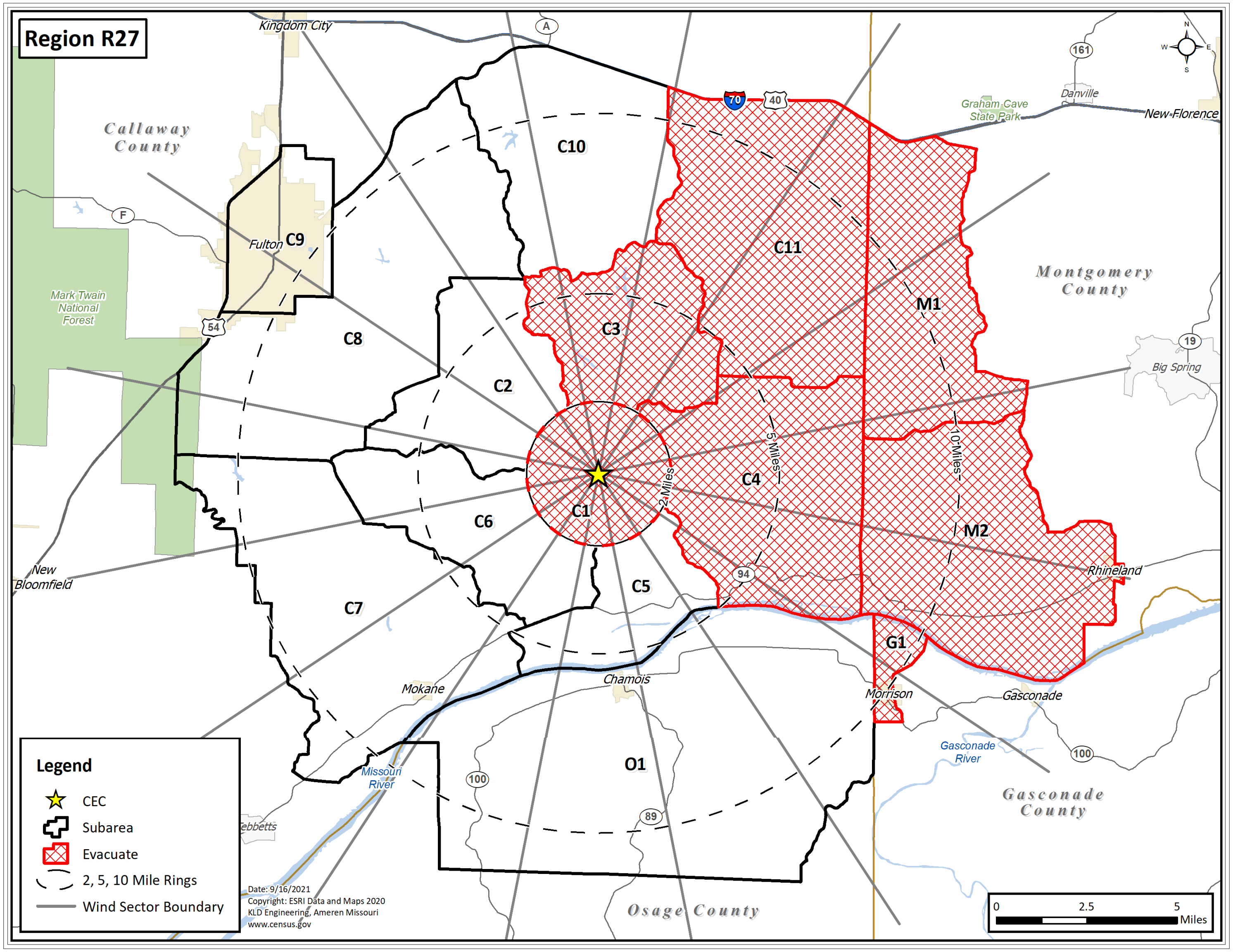


Figure H-27 Region R27

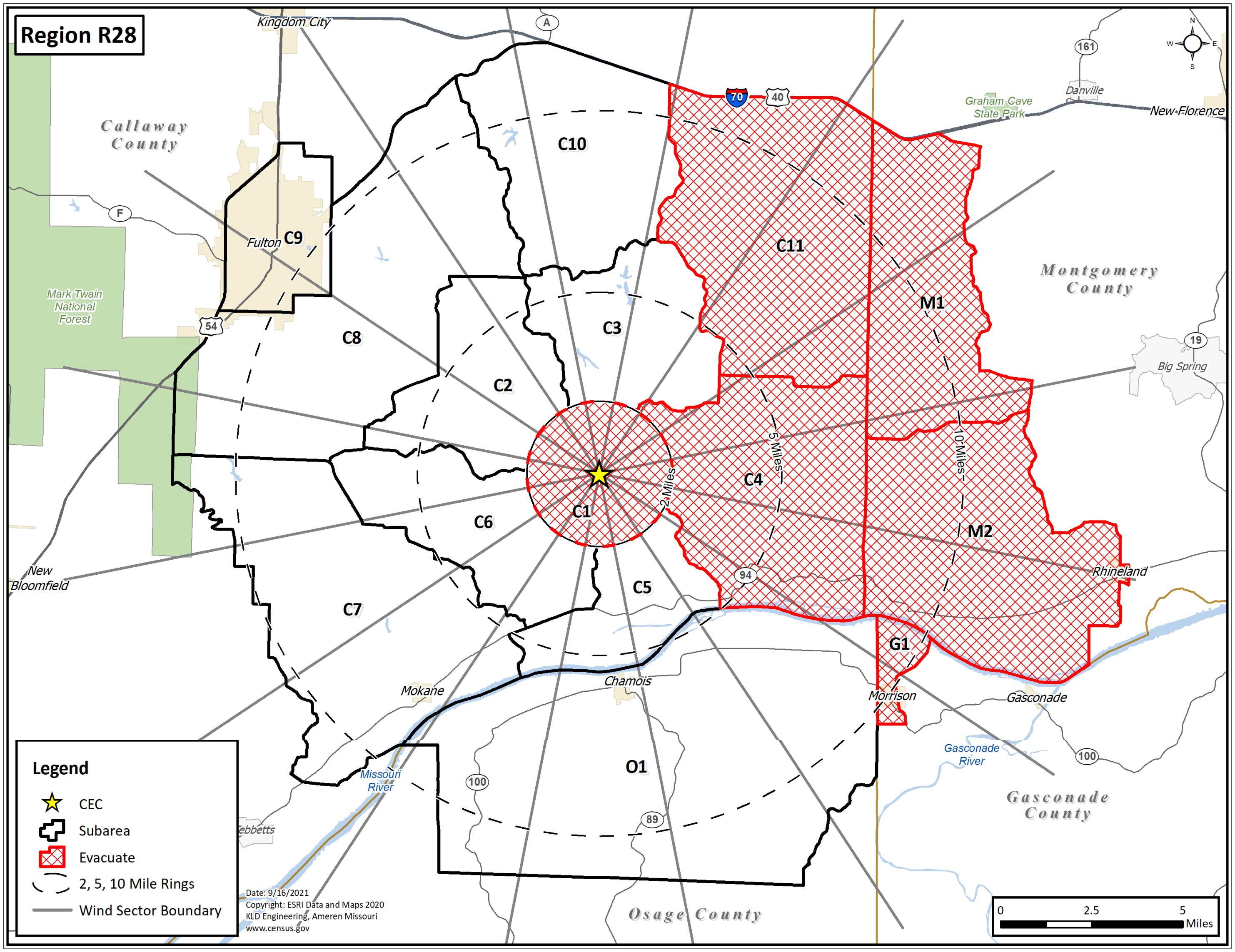


Figure H-28 Region R28

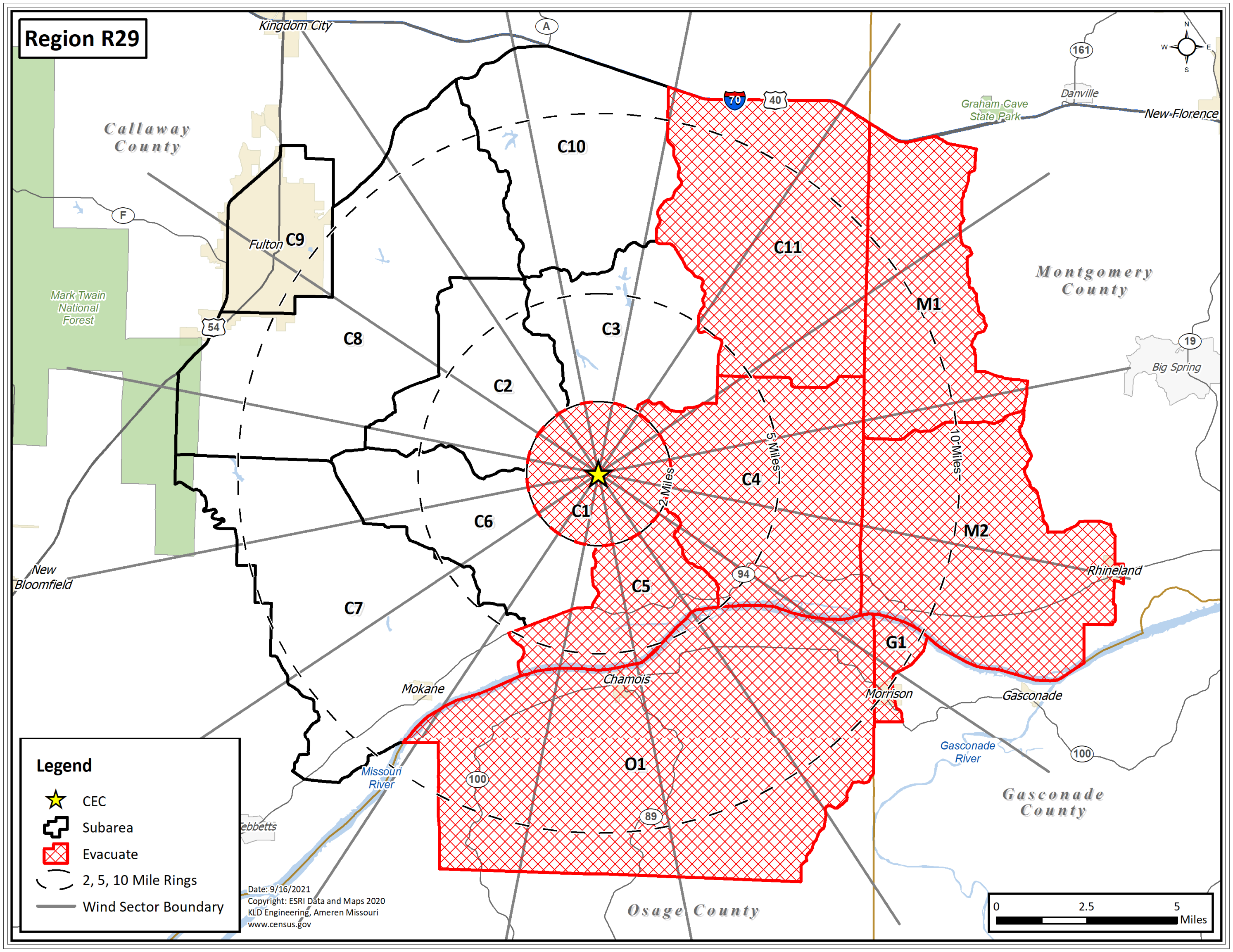


Figure H-29 Region R29

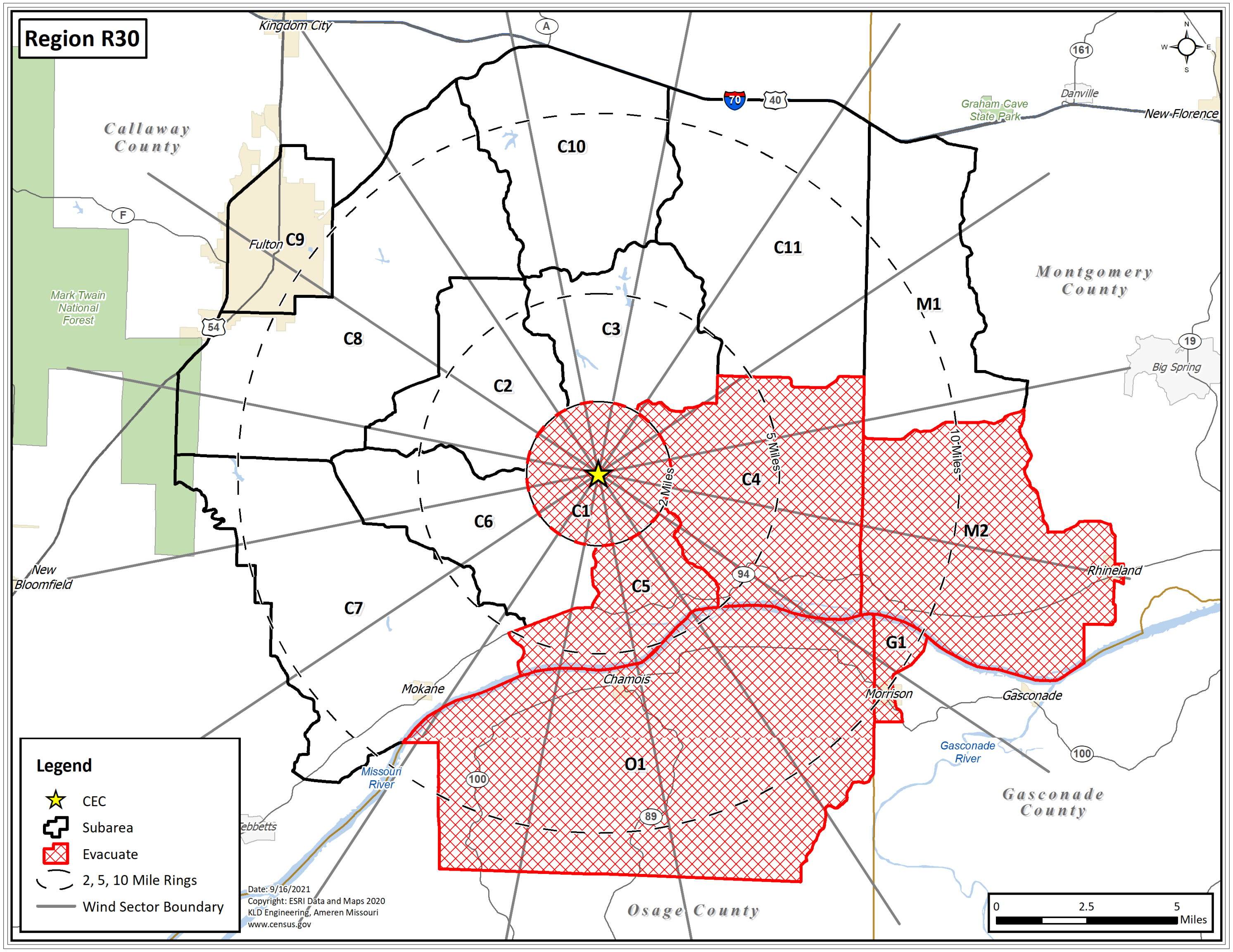


Figure H-30 Region R30

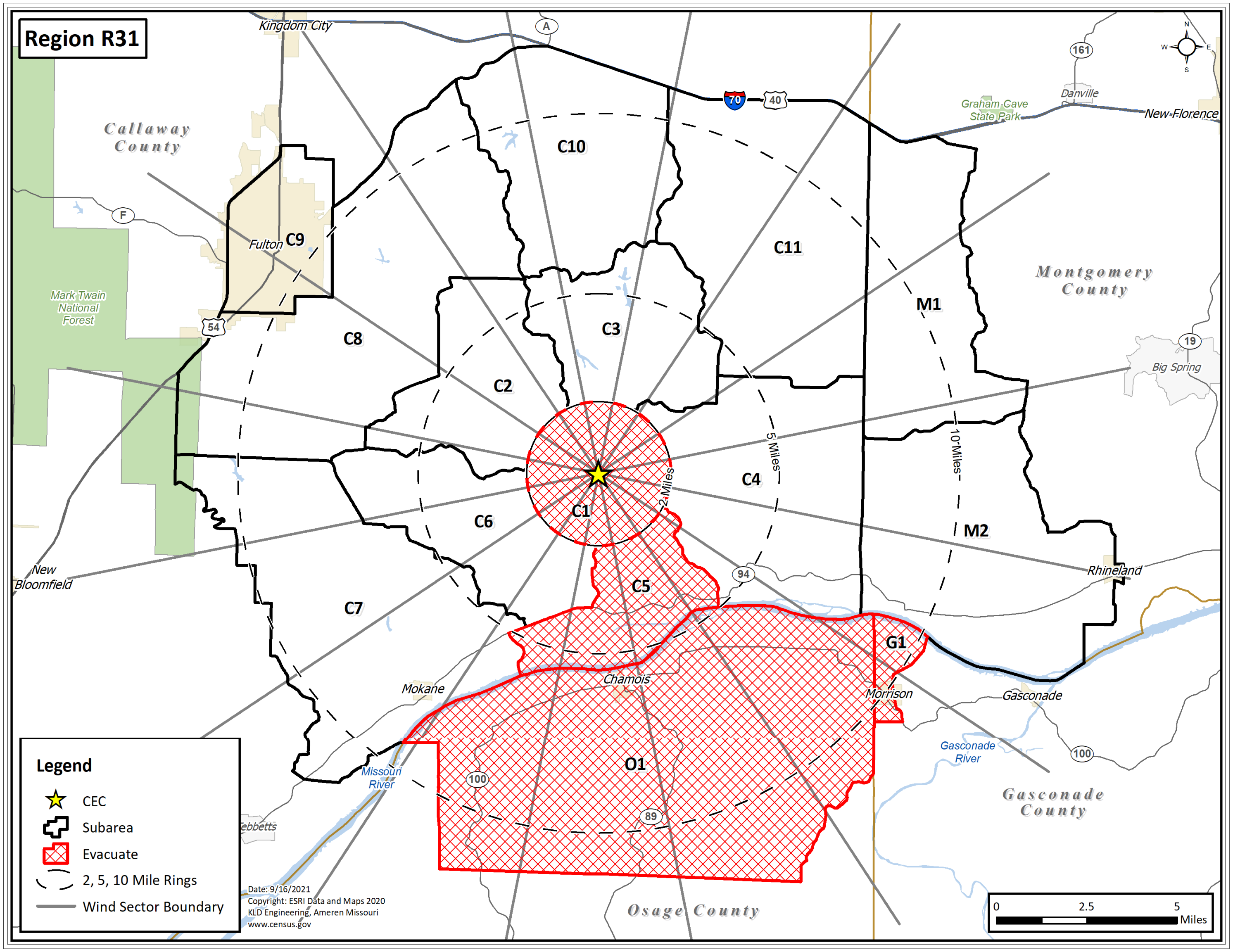


Figure H-31 Region R31

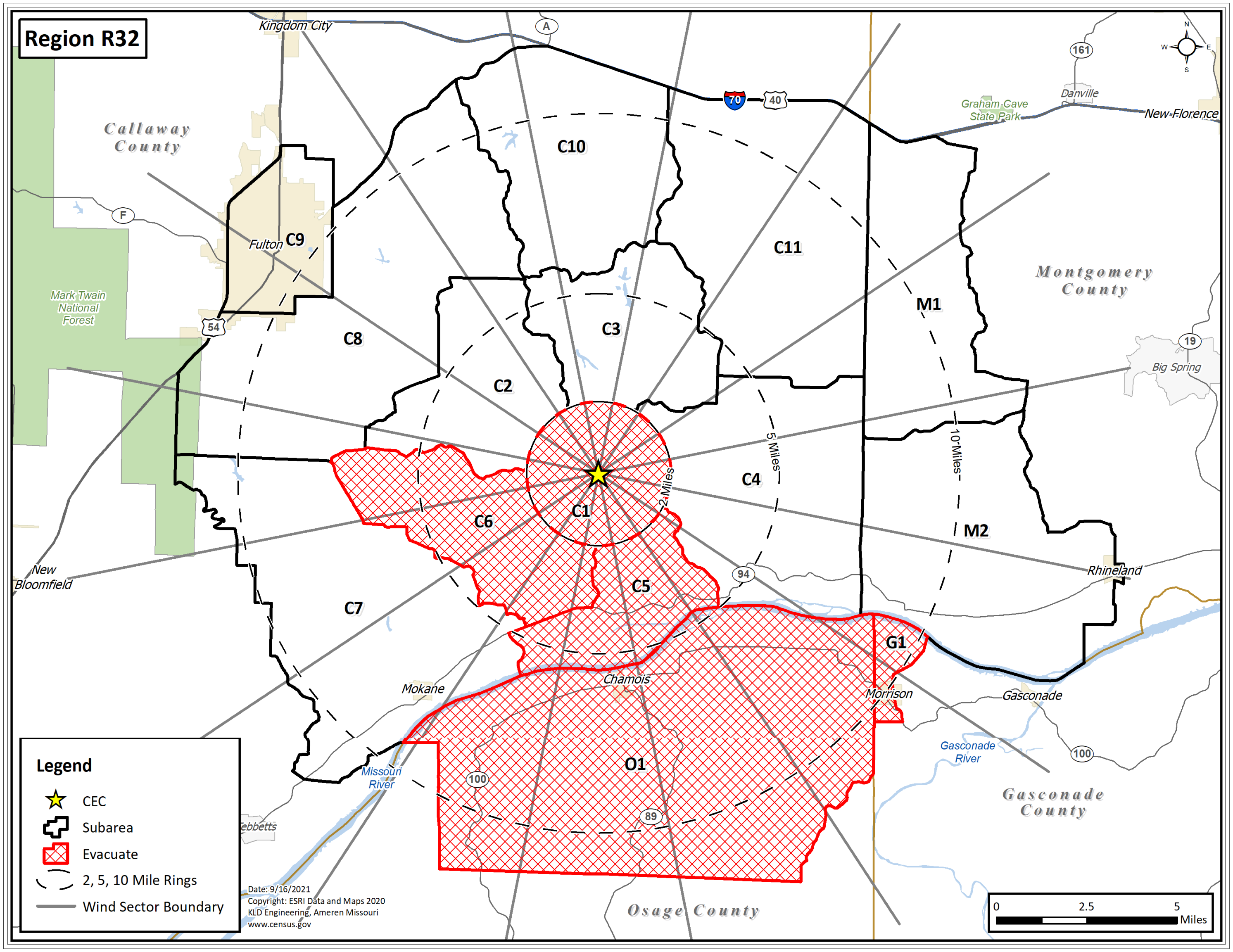


Figure H-32 Region R32

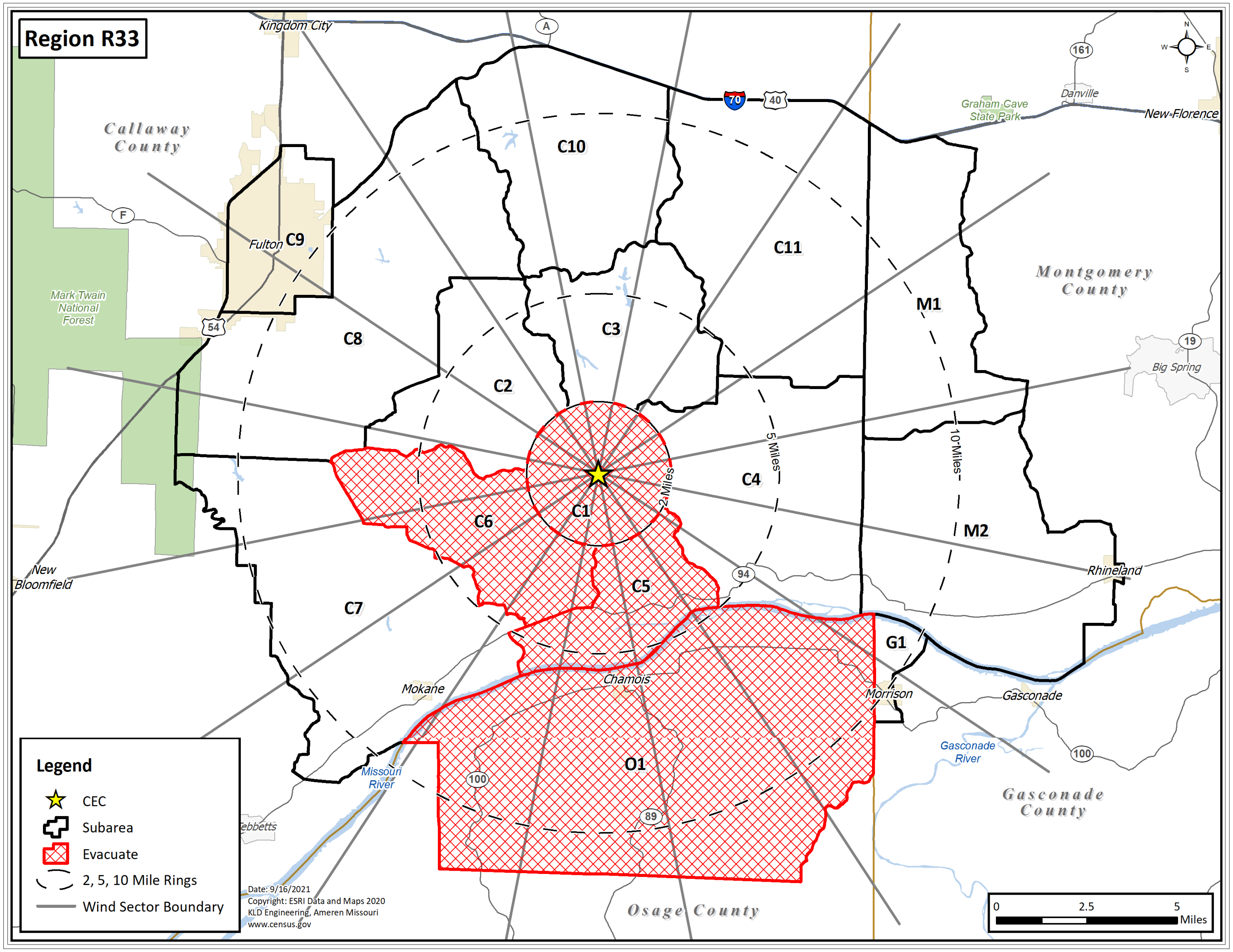


Figure H-33 Region R33

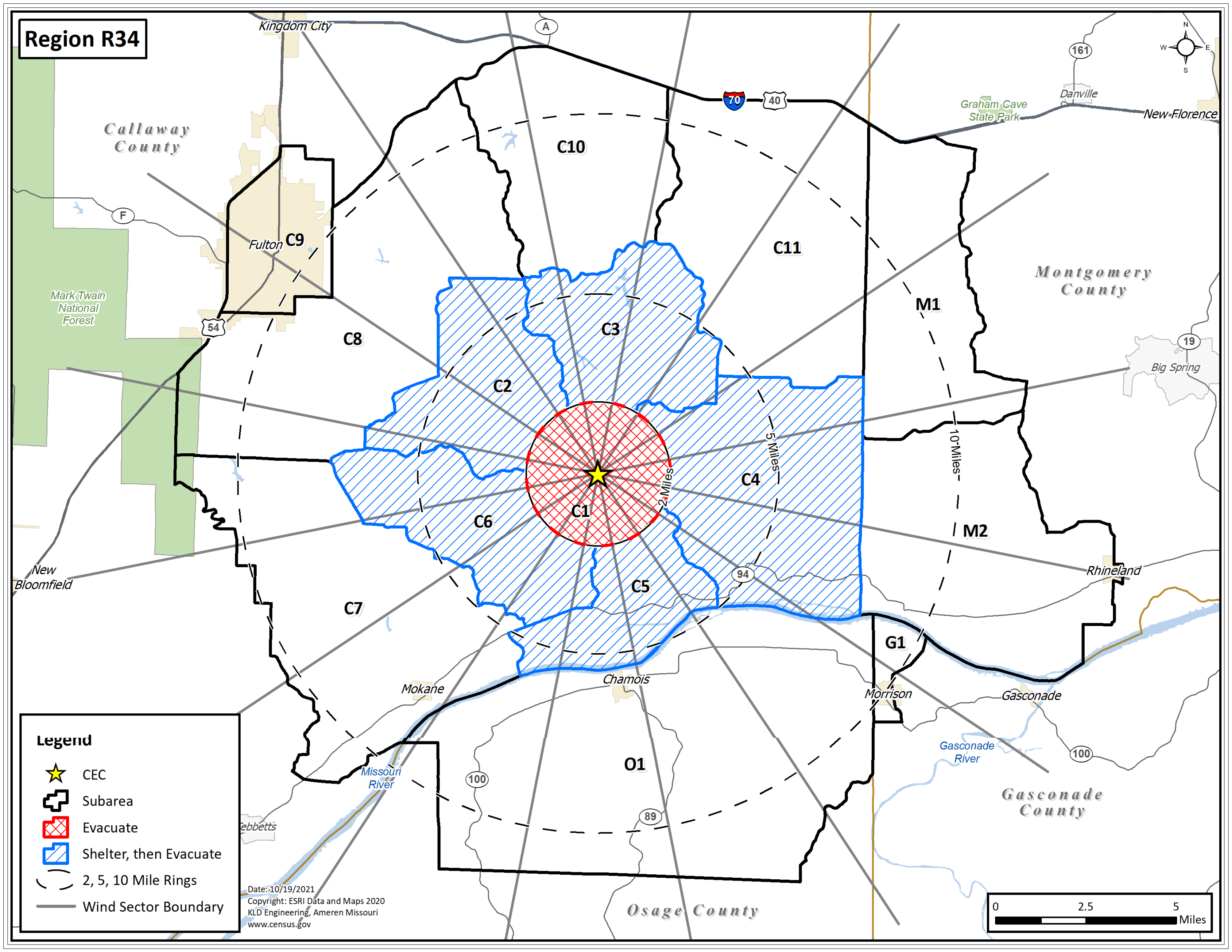


Figure H-34 Region R34

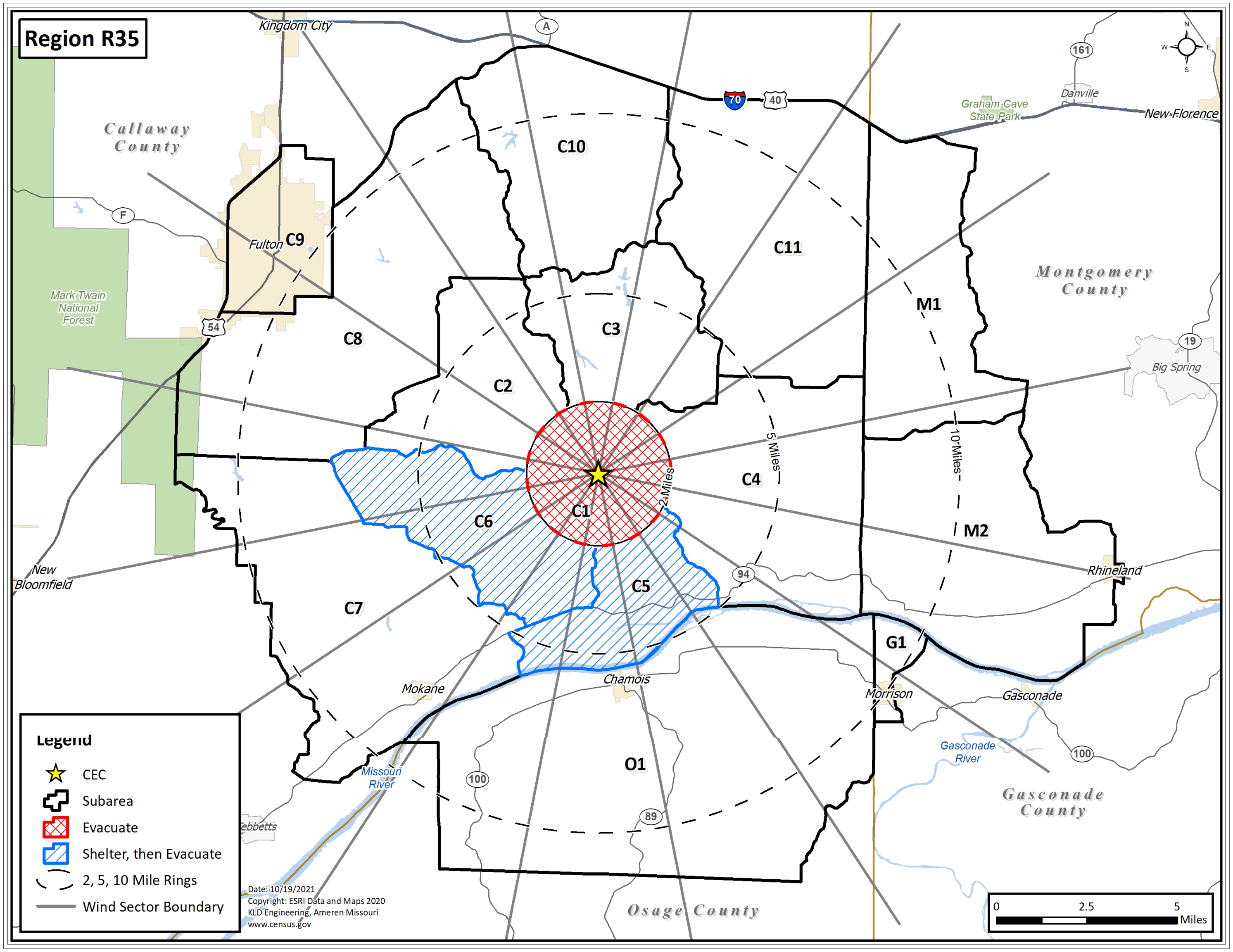


Figure H-35 Region R35

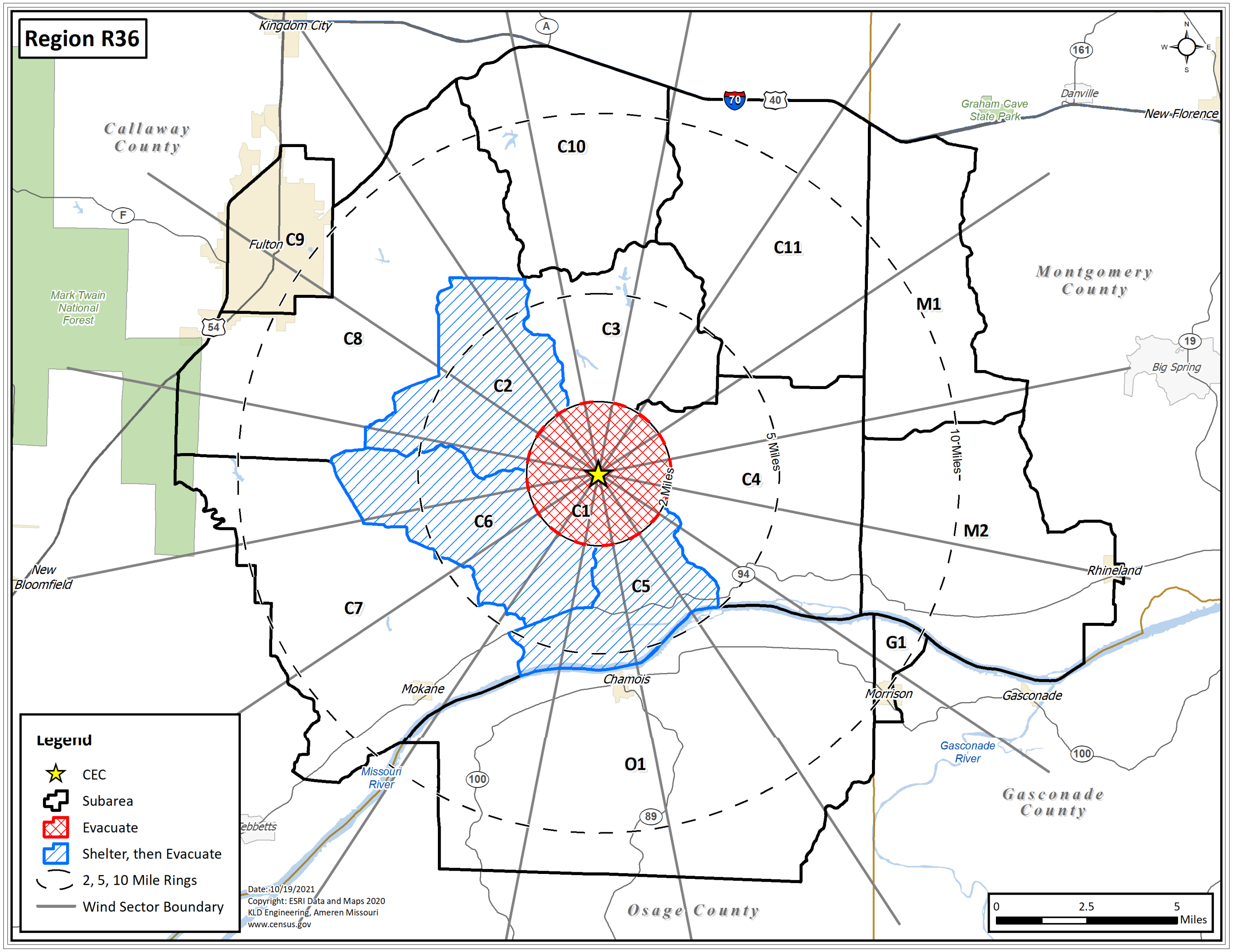


Figure H-36 Region R36

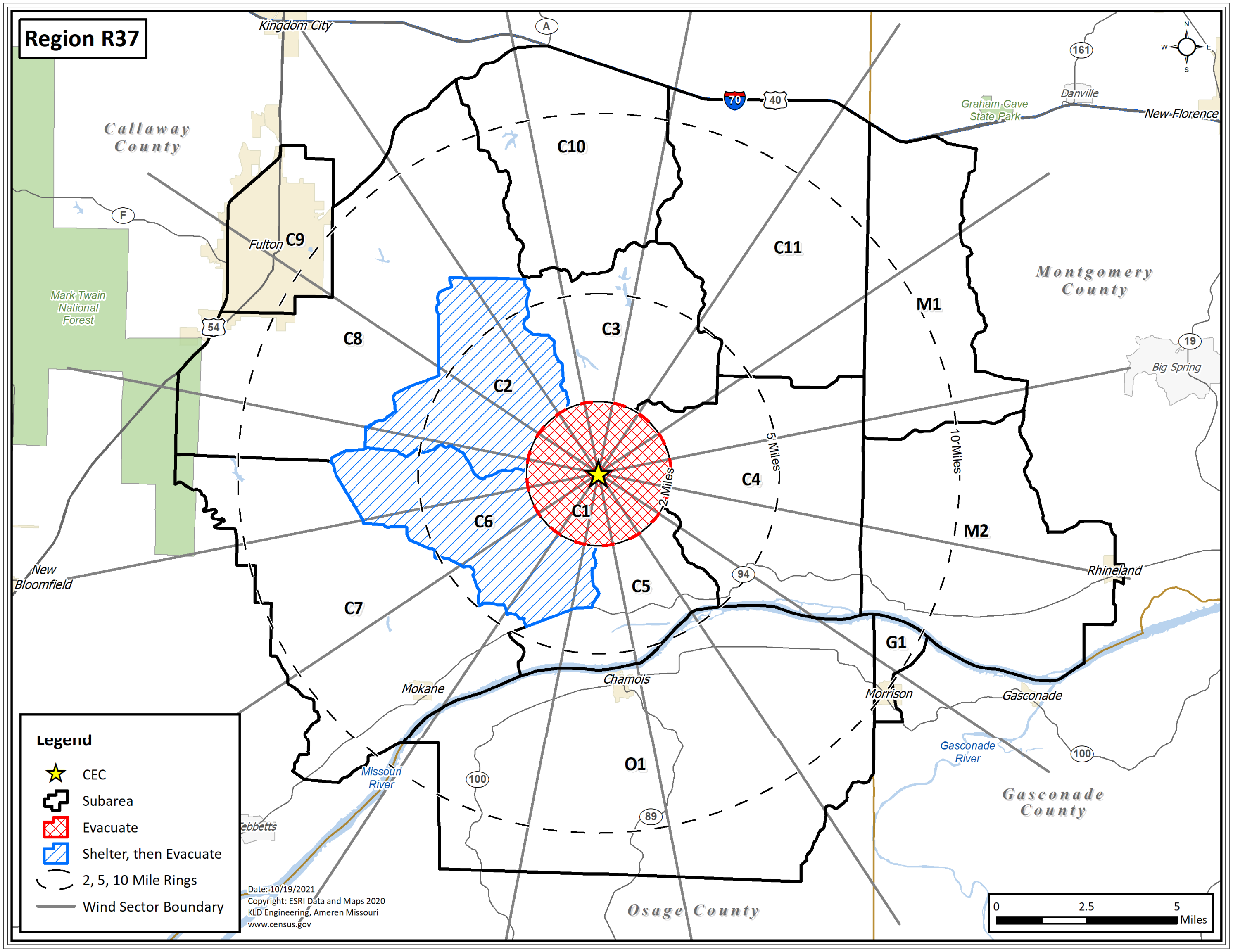


Figure H-37 Region R37

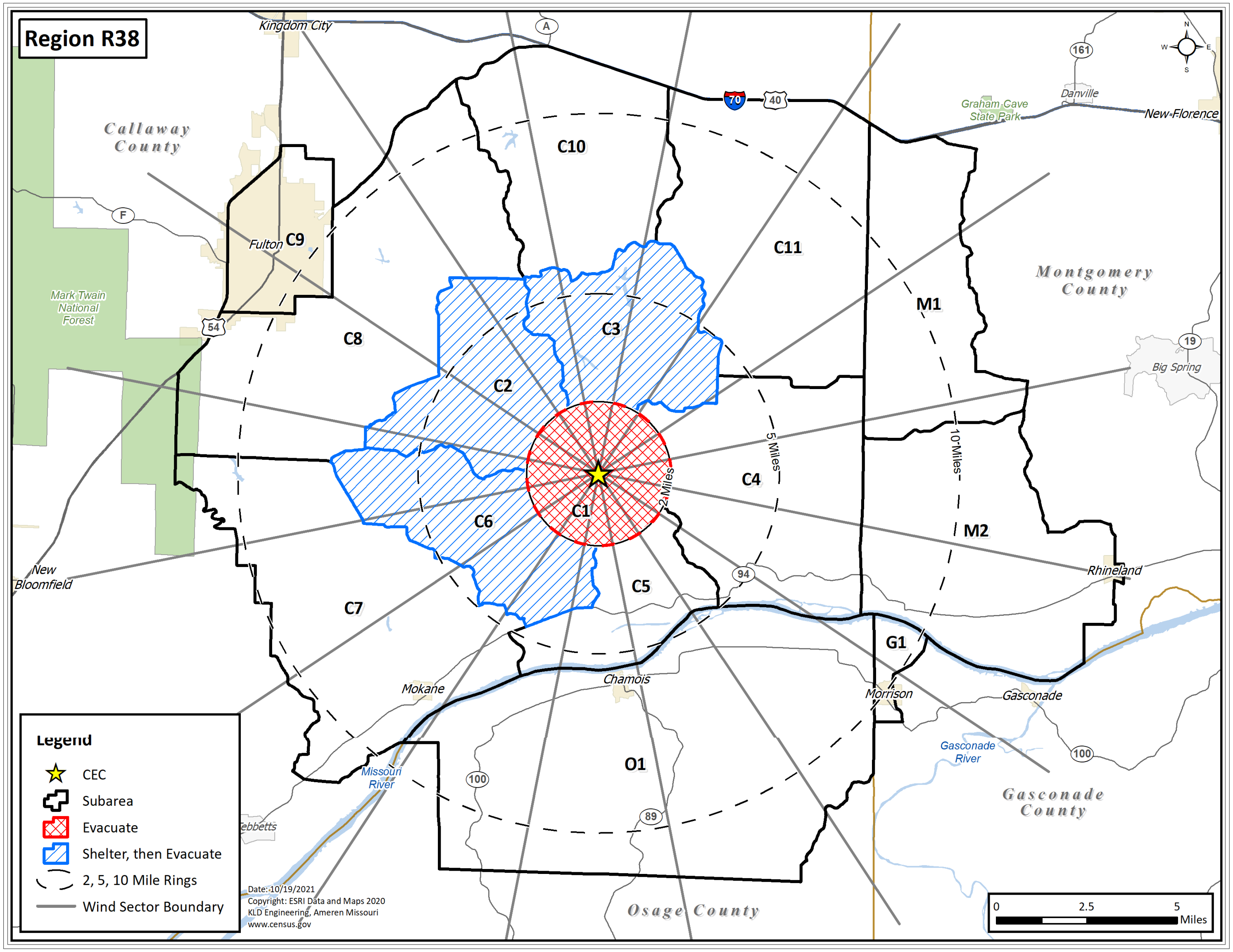


Figure H-38 Region R38

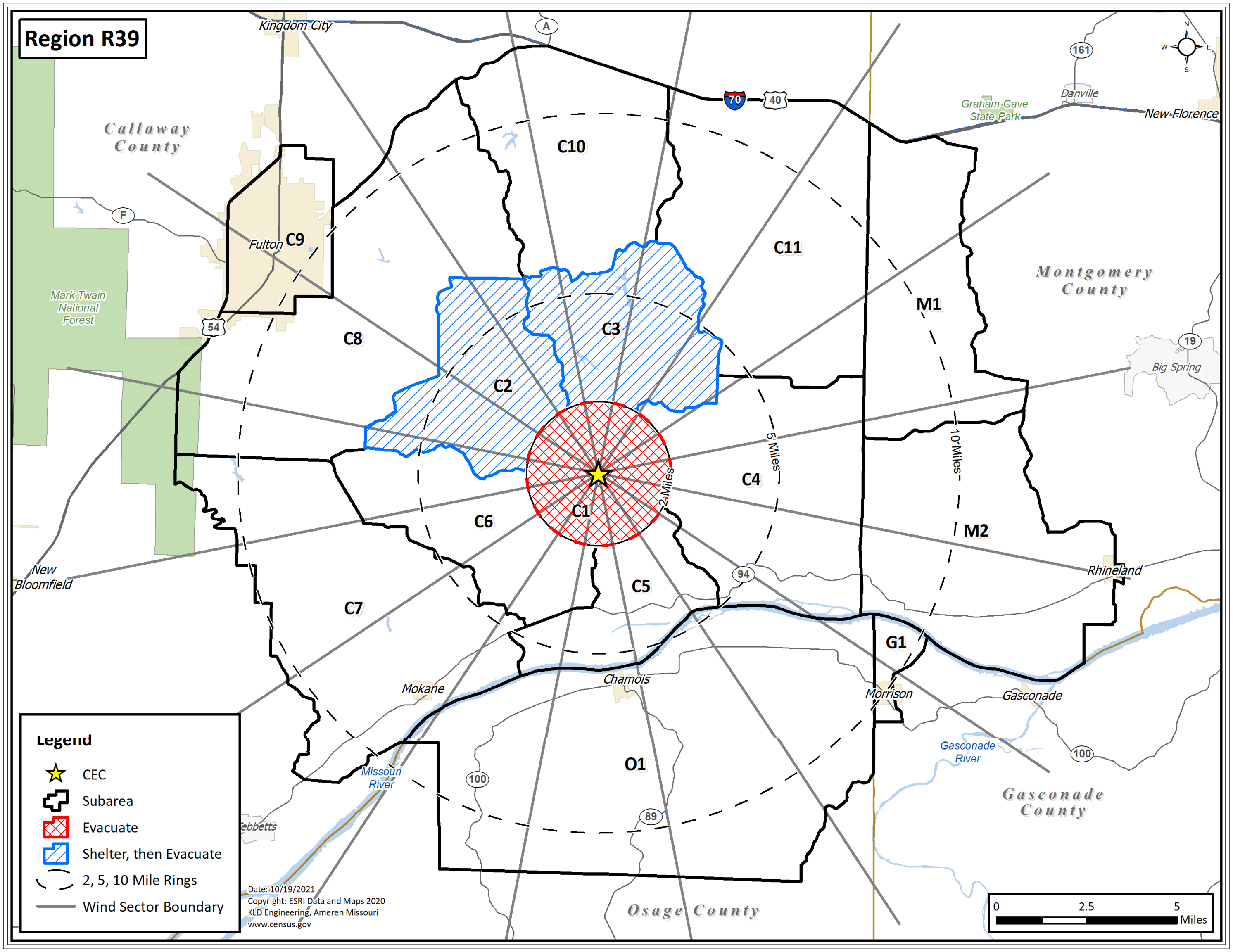


Figure H-39 Region R39

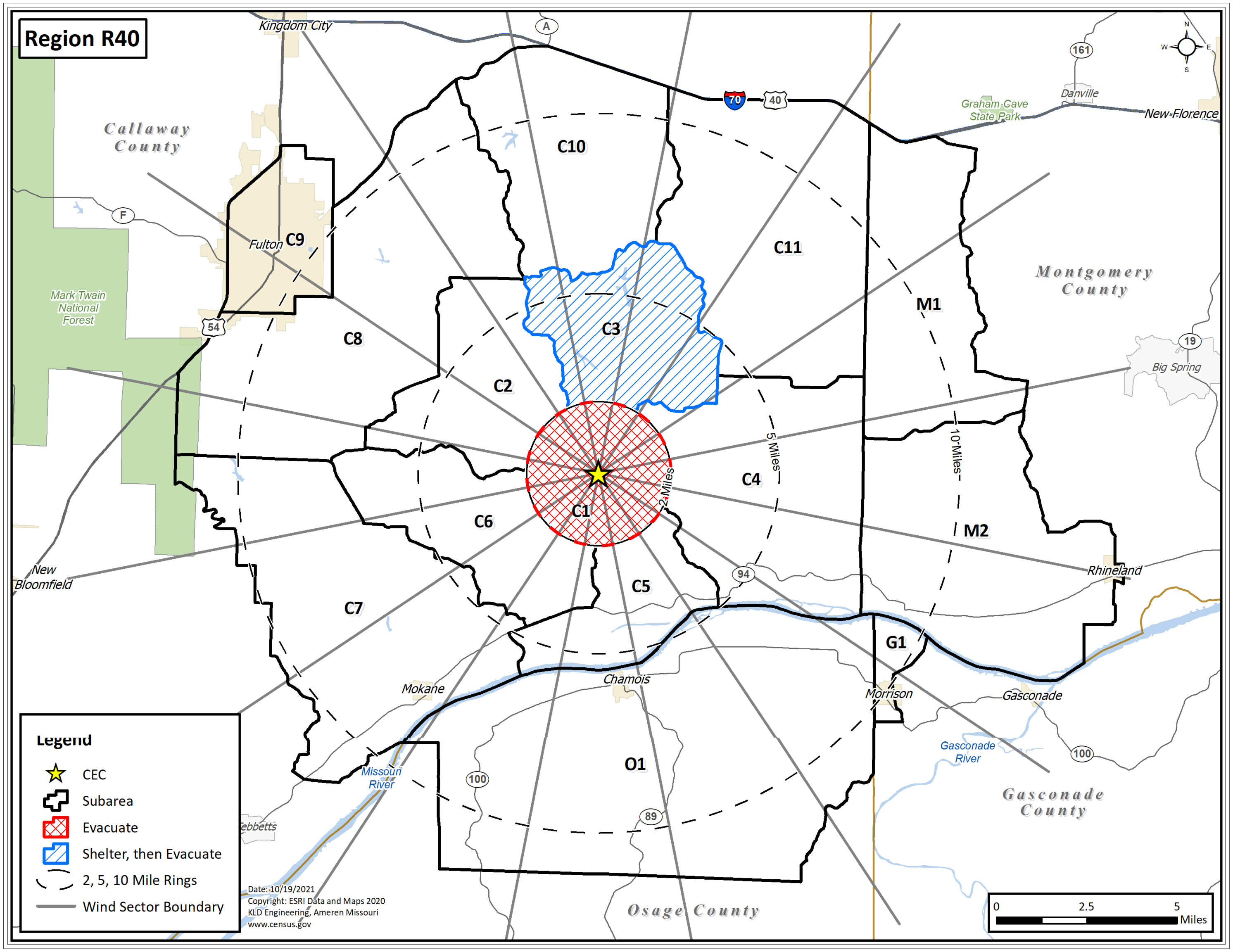


Figure H-40 Region R40

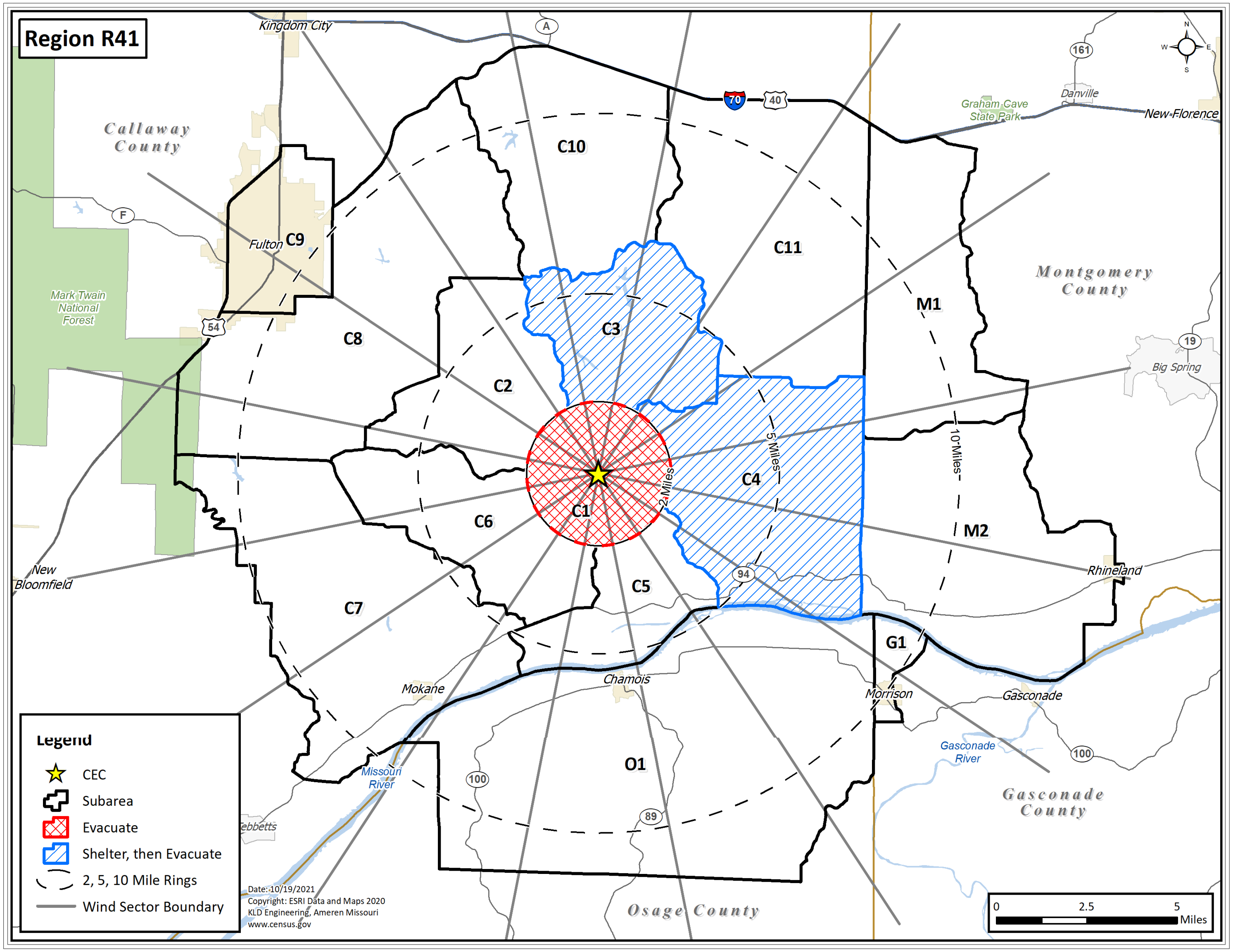


Figure H-41 Region R41

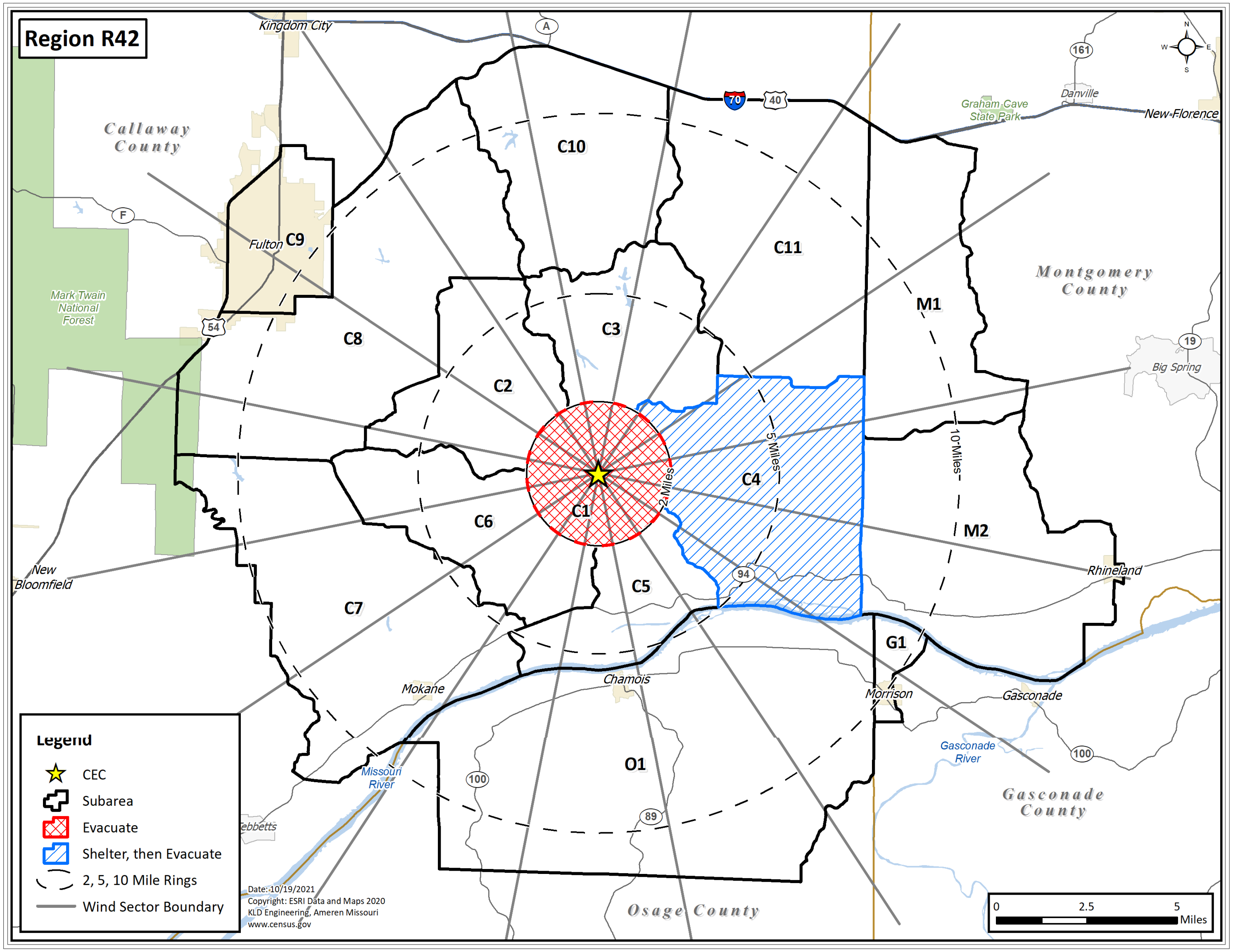


Figure H-42 Region R42

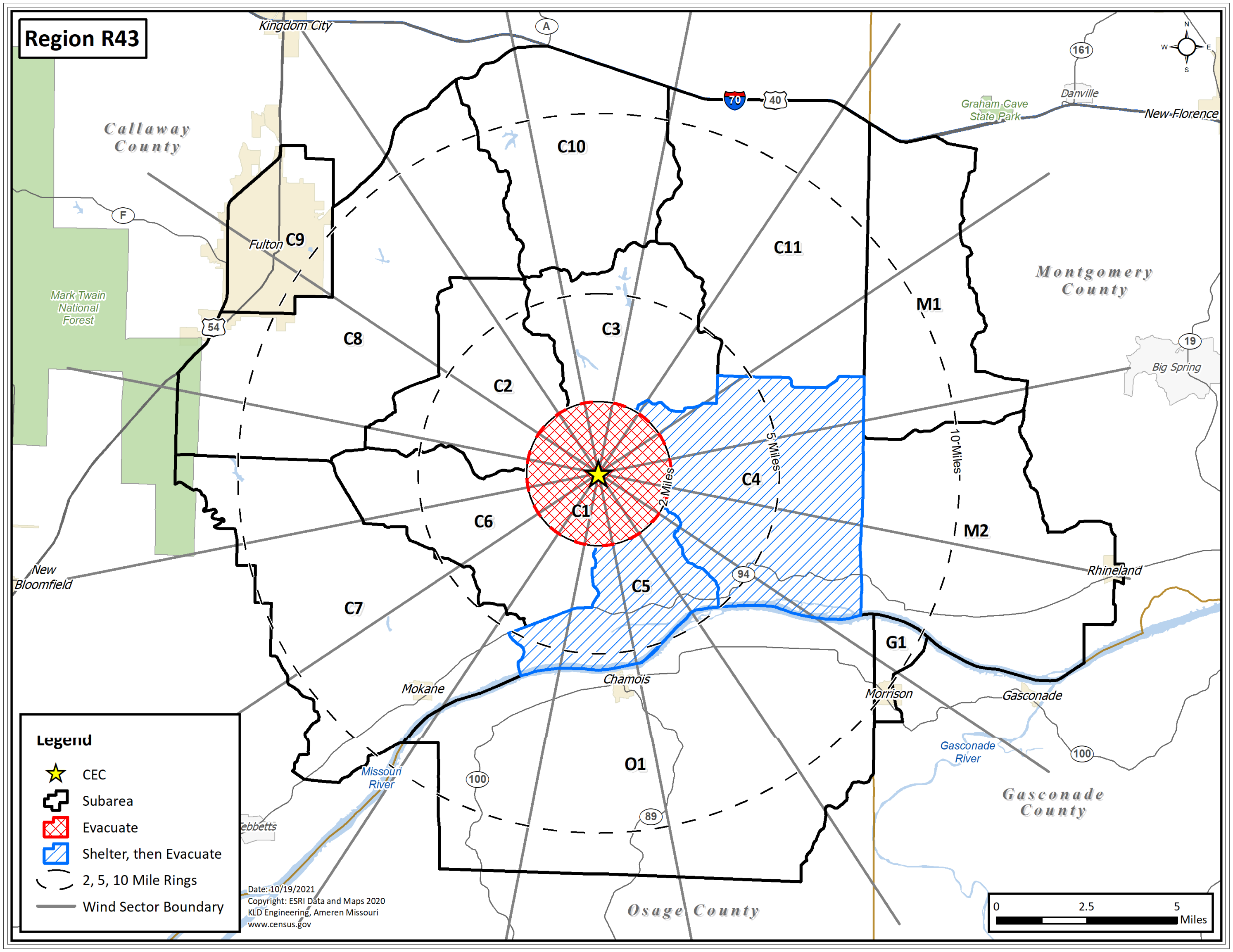


Figure H-43 Region R43

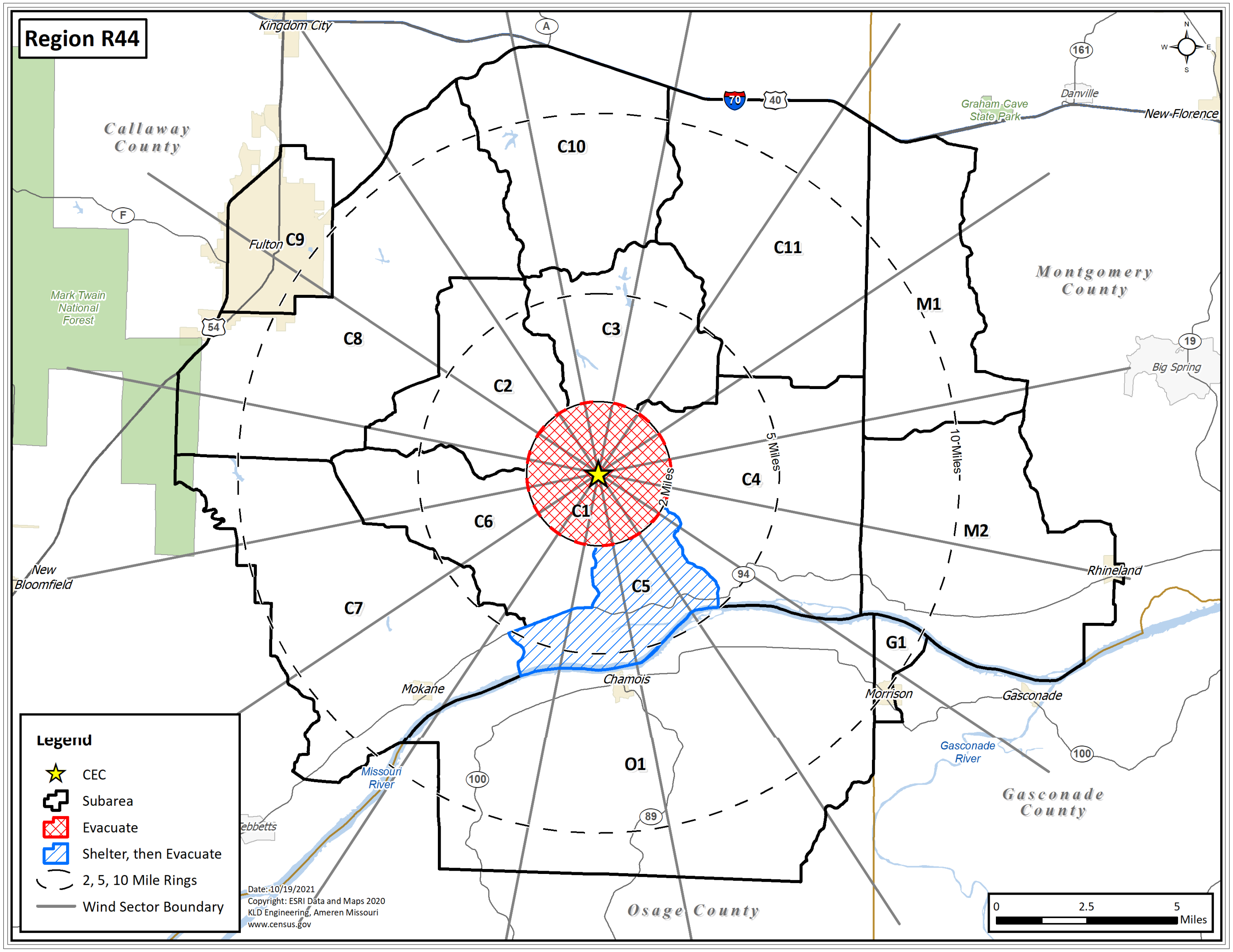


Figure H-44 Region R44

APPENDIX J

Representative Inputs to and Outputs from the DYNEV II System

J. REPRESENTATIVE INPUTS TO AND OUTPUTS FROM THE DYNEV II SYSTEM

This appendix presents data input to and output from the DYNEV II System.

Table J-1 provides source (vehicle loading) and destination information for several roadway segments (links) in the analysis network. there are a total of 295 source links (origins) in the model. The source links are shown as centroid points in Figure J-2. On average, evacuees travel a straight-line distance of 5.10 miles to exit the network.

Table J-2 provides network–wide statistics (average travel time, average delay time[1] average speed and number of vehicles) for an evacuation of the entire EPZ (Region R03) for each scenario. Rain/light snow scenarios (Scenarios 2, 4, 7 and 10) exhibit slower average speeds and longer average travel times compared to good weather scenarios. Heavy snow scenarios (Scenarios 8 and 11) exhibit slower average speeds and longer average travel times compared to rain/light snow and good weather scenarios. On average the network wide average delay is less than one tenth mins per vehicle mile for all scenarios. When comparing scenario 13 (special event) and scenario 6, the additional vehicles the special event introduces slightly lowers the average speeds but has no effect on travel time or average delay. When comparing scenario 14 (roadway closure) and scenario 1, the lane closure along I-70 does not have an impact on travel time, average delay or average speeds for the network as a whole.

Table J-3 provides statistics (average speed and travel time) for the major evacuation routes – Interstate 70 (I-70) and US Highway 54 (US-54) – for an evacuation of the entire EPZ (Region R03) under Scenario 1 conditions. As discussed in Section 7.3 and 7.5, as there is no significant congestion on the mainline of I-70 the travel times and speeds are minimally affected.

Table J-4 provides the number of vehicles discharged and the cumulative percent of total vehicles discharged for each link exiting the analysis network, for an evacuation of the entire EPZ (Region R03) under Scenario 1 conditions.

Figure J-2 through Figure J-15 plot the trip generation time versus the ETE for each of the 14 Scenarios considered. The distance between the trip generation and ETE curves is the travel time. Plots of trip generation versus ETE are indicative of the level of traffic congestion during evacuation. For low population density sites, the curves are close together, indicating short travel times and minimal traffic congestion. For higher population density sites, the curves are farther apart indicating longer travel times and the presence of traffic congestion. As seen in Figure J-2 through Figure J-15, the curves are close together (outside of heavy snow scenarios) as a result of limited traffic congestion in the EPZ, which was discussed in detail in Section 7.3.

[1] Computed as the difference of the average travel time and the average ideal travel time under free flow condition.

Table J-1. Sample Simulation Model Input

Link Number	Upstream Node	Downstream Node	Vehicles Entering Network on this Link	Directional Preference	Destination Nodes	Destination Capacity
1398	1284	1283	78	W	8005	4,500
					8073	4,500
					8221	1,700
1272	1171	374	69	NW	8005	4,500
					8028	3,800
					8073	4,500
905	833	832	35	NW	8028	3,800
					8005	4,500
					8073	4,500
468	387	865	48	NW	8028	3,800
					8005	4,500
					8073	4,500
1239	1138	1139	28	N	8113	1,700
					8005	4,500
					8028	3,800
1379	1265	1266	7	E	8550	1,700
					8300	1,700
1679	1562	1551	7	N	8028	3,800

Table J-2. Selected Model Outputs for the Evacuation of the Entire EPZ (Region R03)

Scenario	1	2	3	4	5	6	7
Network-Wide Average Travel Time (Min/Veh-Mi)	1.0	1.0	1.0	1.0	1.0	1.0	1.1
Network-Wide Average Delay Time (Min/Veh-Mi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Network-Wide Average Speed (mph)	60.0	57.5	60.0	57.8	58.6	60.0	55.8
Total Vehicles Exiting Network	19,560	19,700	18,875	19,019	13,666	21,794	21,944
Scenario	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Network-Wide Average Travel Time (Min/Veh-Mi)	1.2	1.0	1.0	1.1	1.0	1.0	1.0
Network-Wide Average Delay Time (Min/Veh-Mi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Network-Wide Average Speed (mph)	51.4	60.0	57.9	53.5	58.8	58.7	60.0
Total Vehicles Exiting Network	22,072	18,720	18,850	18,967	13,498	22,911	19,560

Table J-3. Average Speed (mph) and Travel Time (min) for Major Evacuation Routes (Region R03, Scenario 1)

Elapsed Time (hours)												
		1:00		2:00		3:00		4:00		4:55	
Route#	Length (miles)	Speed (mph)	Travel Time (min)	Speed	Travel Time	Speed	Travel Time	Speed	Travel Time	Speed	Travel Time
I-70 Westbound	13.3	75.0	10.6	71.7	11.1	72.1	11.0	69.0	11.5	75.0	10.6
I-70 Eastbound	13.3	75.0	10.6	73.5	10.8	73.8	10.8	70.7	11.3	75.0	10.6
US-54 Westbound	8.0	72.5	6.6	71.6	6.7	71.2	6.8	70.9	6.8	74.2	6.5
US-54 Eastbound	8.0	72.0	6.7	71.4	6.7	70.5	6.8	70.1	6.9	74.6	6.5

Table J-4. Simulation Model Outputs at Network Exit Links for Region R03, Scenario 1

Network Exit Link	Upstream Node	Downstream Node	Elapsed Time (hours)				
			1:00	2:00	3:00	4:00	4:55
			Cumulative Vehicles Discharged by the Indicated Time				
			Cumulative Percent of Vehicles Discharged by the Indicated Time Interval				
585	489	488	0	10	21	25	25
			0%	0%	0%	0%	0%
1095	997	756	687	1,906	2,829	3,189	3,242
			13%	14%	15%	16%	17%
1099	999	976	1,570	3,202	3,854	3,879	3,881
			30%	23%	21%	20%	20%
1314	1213	682	91	434	656	733	743
			2%	3%	4%	4%	4%
1375	1261	133	28	176	274	308	313
			1%	1%	1%	2%	2%
1418	1302	221	323	1,402	1,852	1,960	1,975
			6%	10%	10%	10%	10%
1566	1449	904	3	32	56	64	66
			0%	0%	0%	0%	0%
1620	1504	1503	4	28	46	49	49
			0%	0%	0%	0%	0%
1639	1523	300	29	167	263	299	303
			1%	1%	1%	2%	2%
1665	1548	1549	38	216	339	382	386
			1%	2%	2%	2%	2%
1681	1564	28	710	2,228	2,988	3,208	3,236
			13%	16%	16%	17%	17%
1683	1565	975	1,827	4,111	5,095	5,215	5,235
			34%	29%	28%	27%	27%
1710	1587	589	3	45	84	94	95
			0%	0%	0%	0%	0%
1729	1606	1607	0	6	10	12	12
			0%	0%	0%	0%	0%

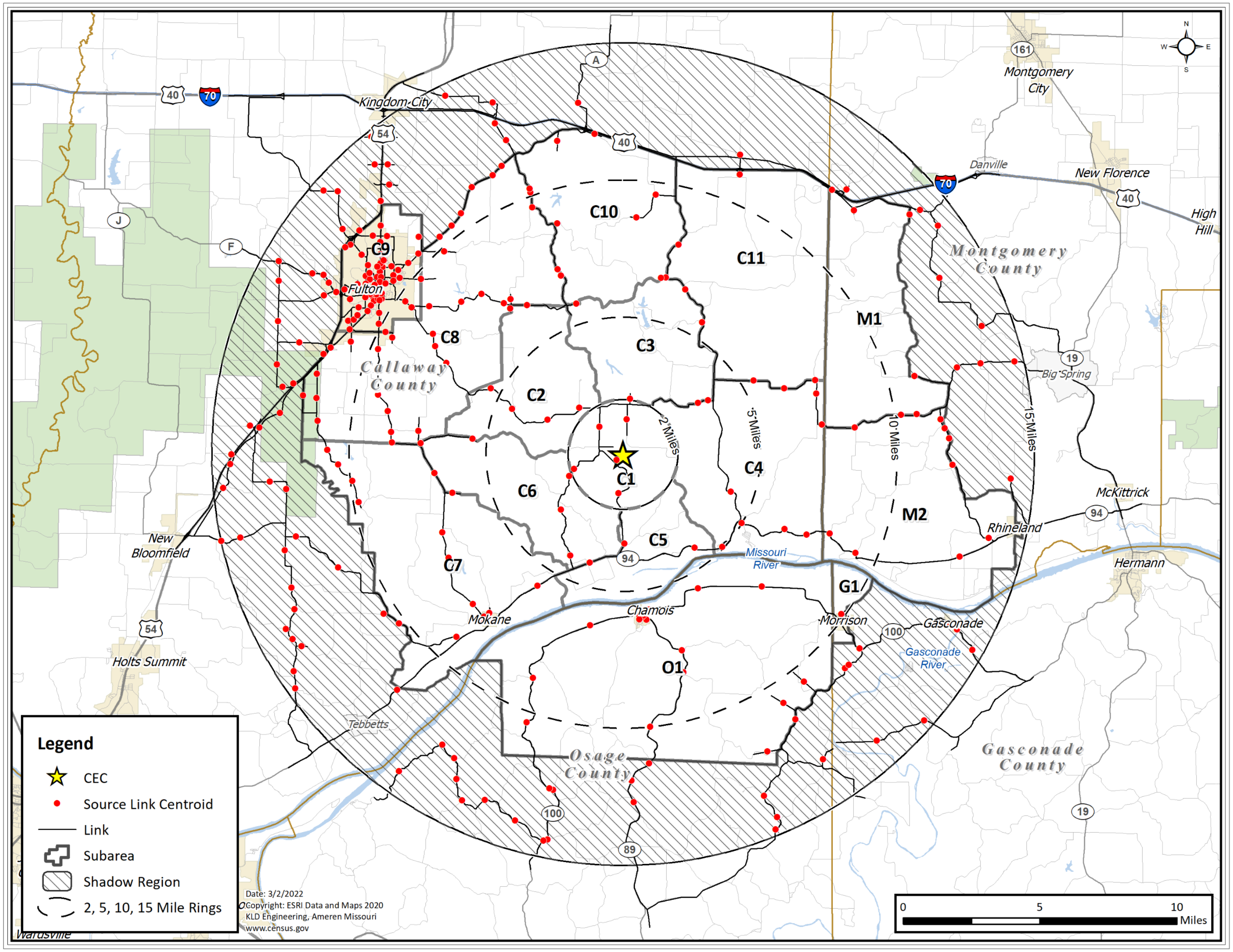


Figure J-1. Network Sources/Origins

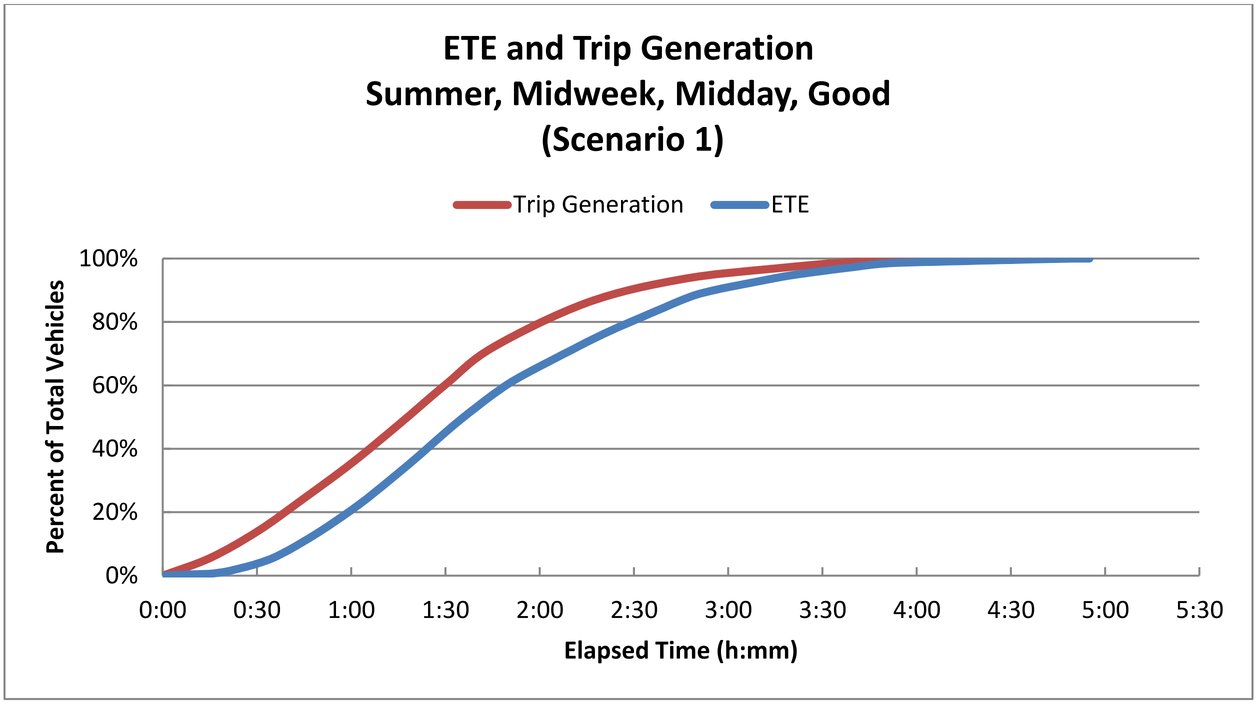


Figure J-2. ETE and Trip Generation: Summer, Midweek, Midday, Good Weather (Scenario 1)

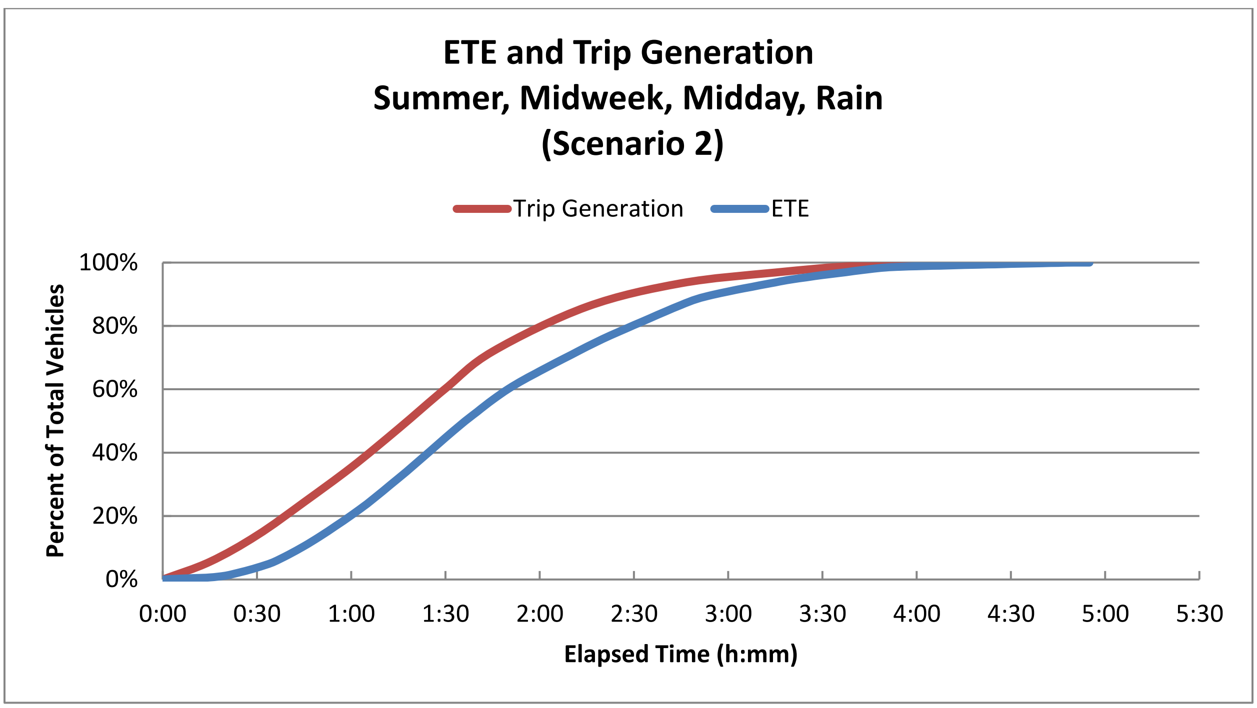


Figure J-3. ETE and Trip Generation: Summer, Midweek, Midday, Rain/Light Snow (Scenario 2)

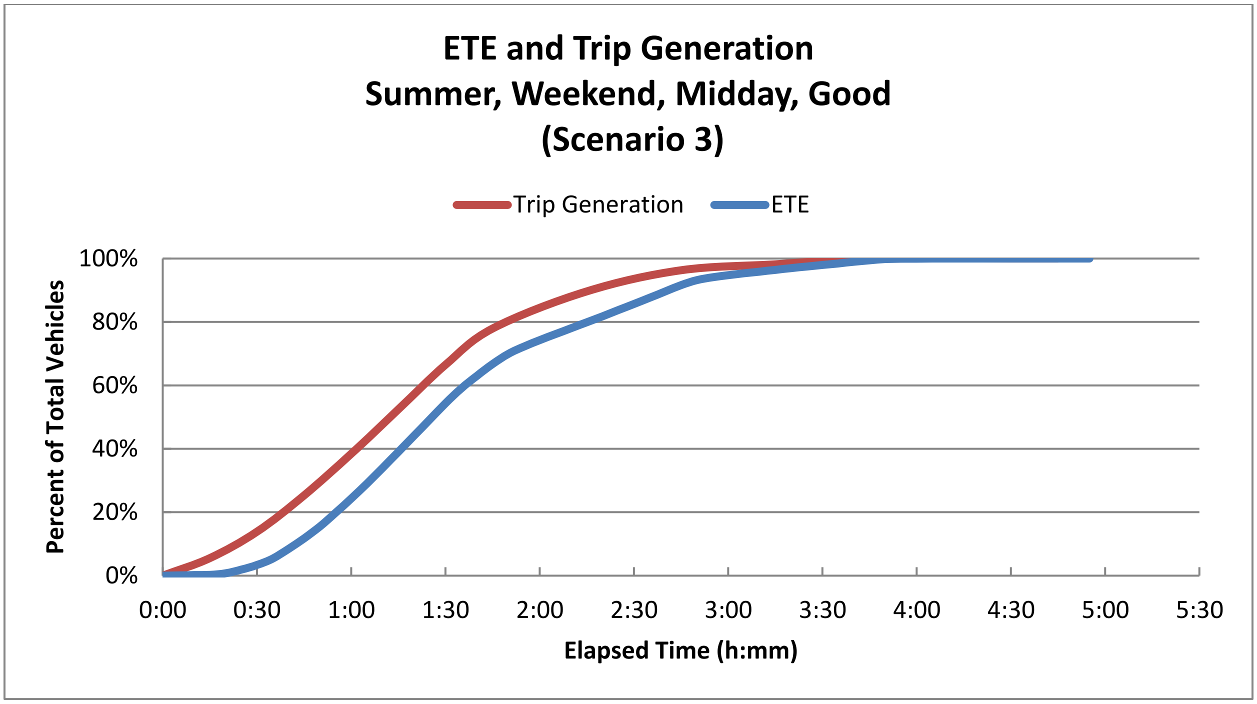


Figure J-4. ETE and Trip Generation: Summer, Weekend, Midday, Good Weather (Scenario 3)

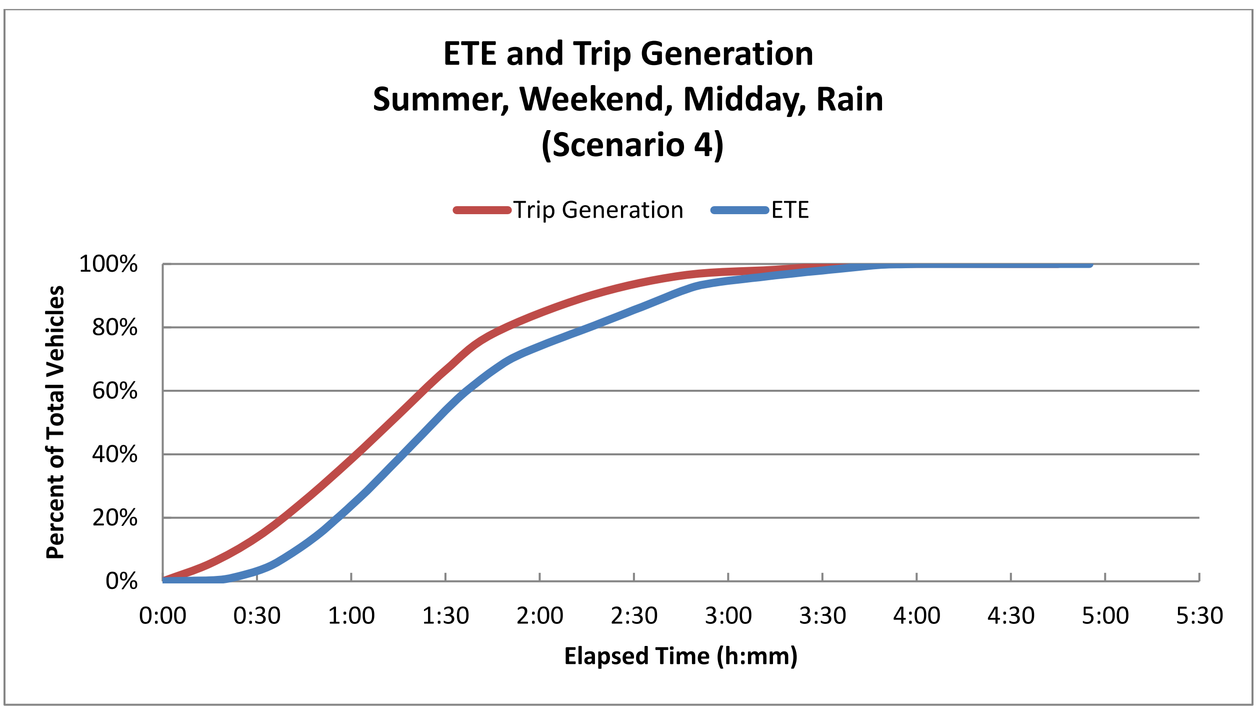


Figure J-5. ETE and Trip Generation: Summer, Weekend, Midday, Rain/Light Snow (Scenario 4)

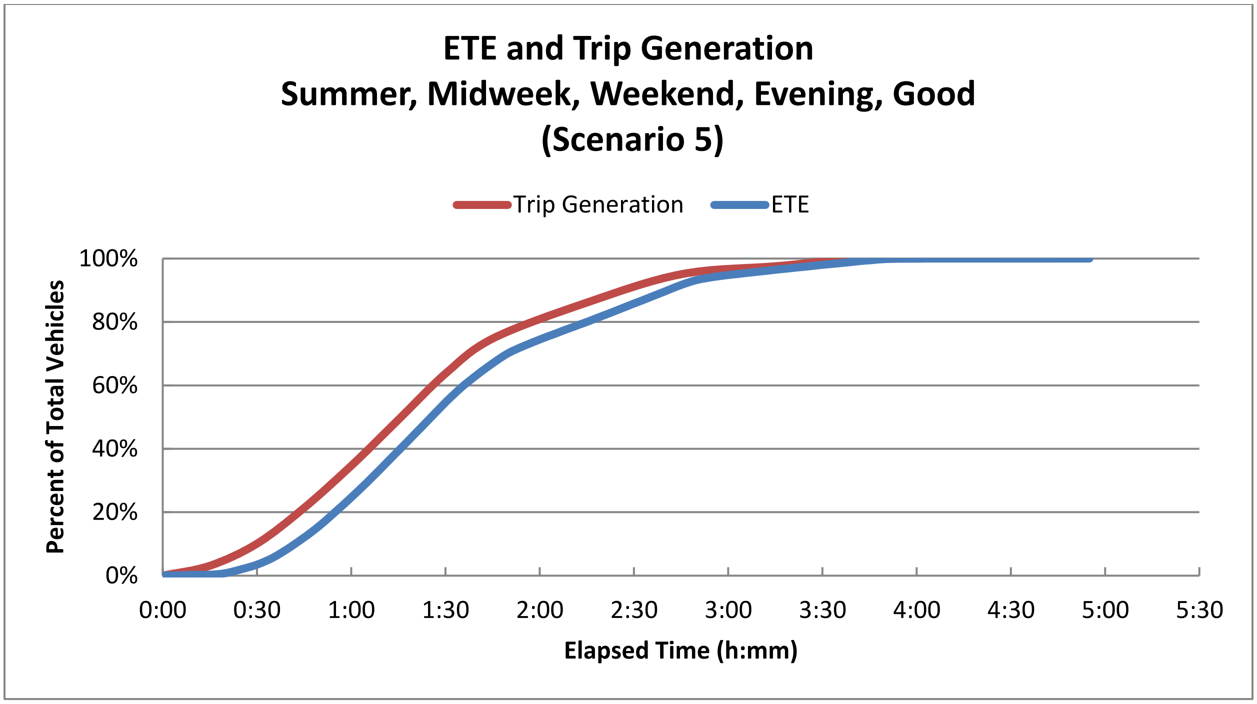


Figure J-6. ETE and Trip Generation: Summer, Midweek, Weekend, Evening, Good Weather (Scenario 5)

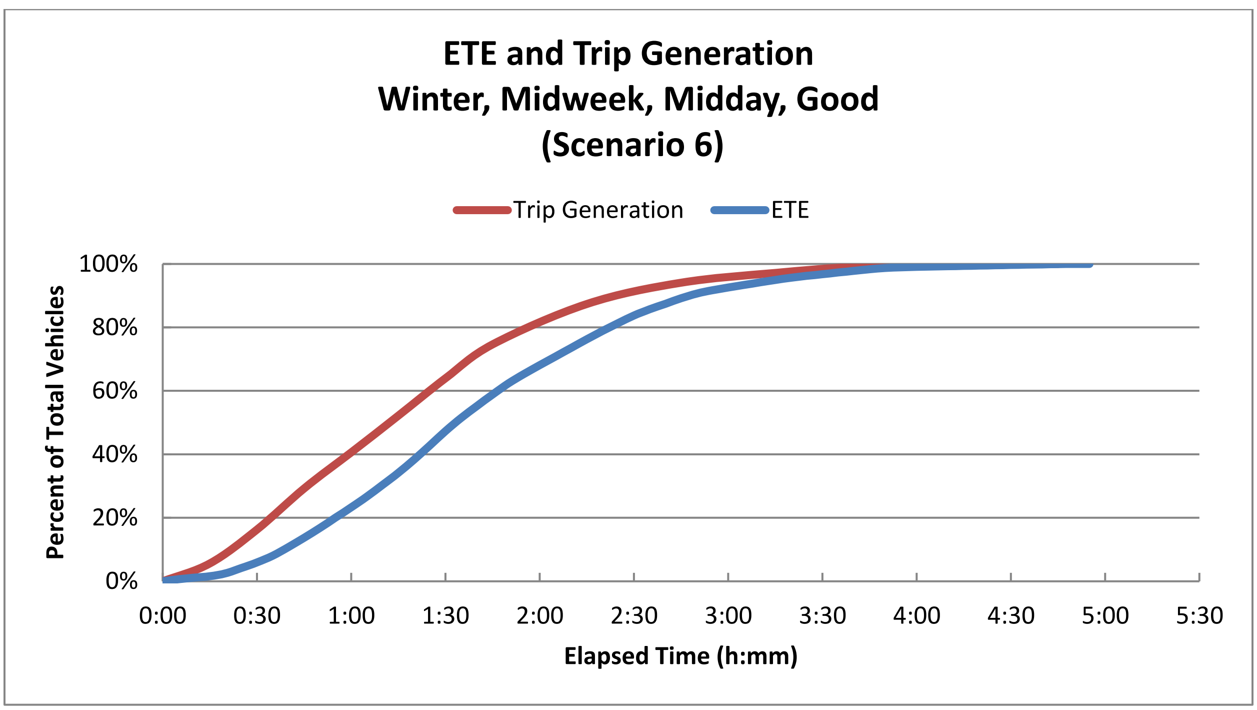


Figure J-7. ETE and Trip Generation: Winter, Midweek, Midday, Good Weather (Scenario 6)

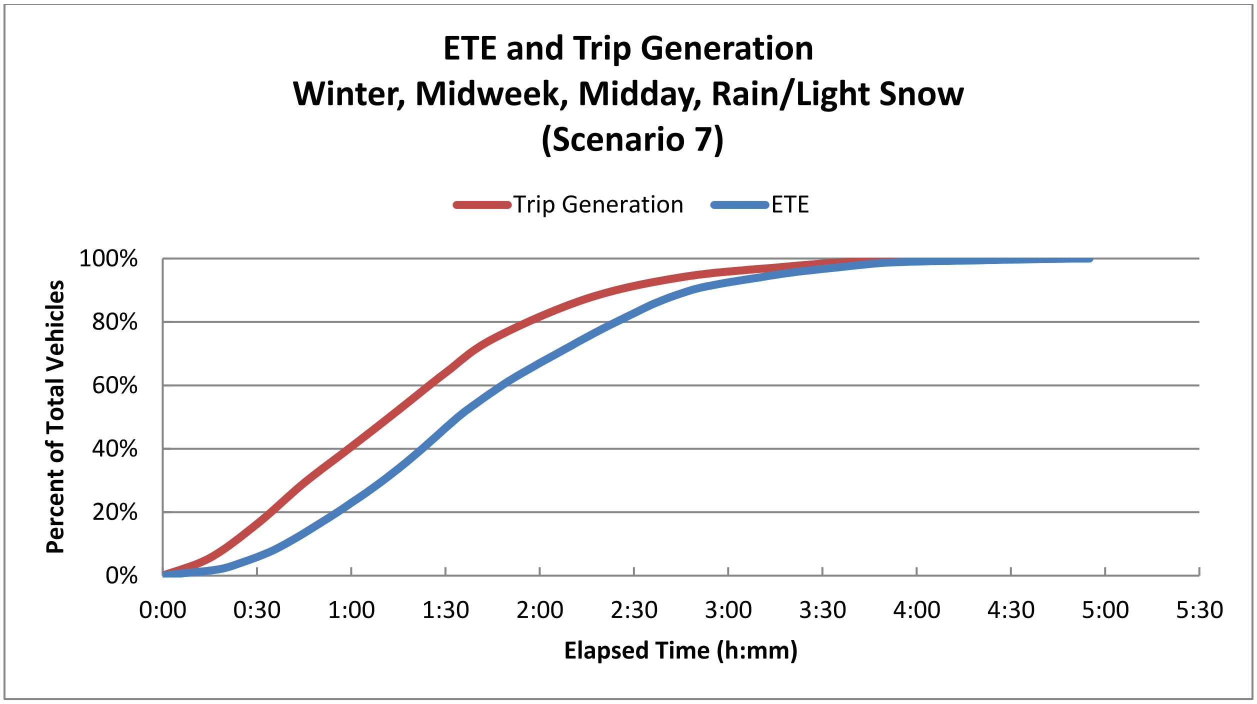


Figure J-8. ETE and Trip Generation: Winter, Midweek, Midday, Rain/Light Snow (Scenario 7)

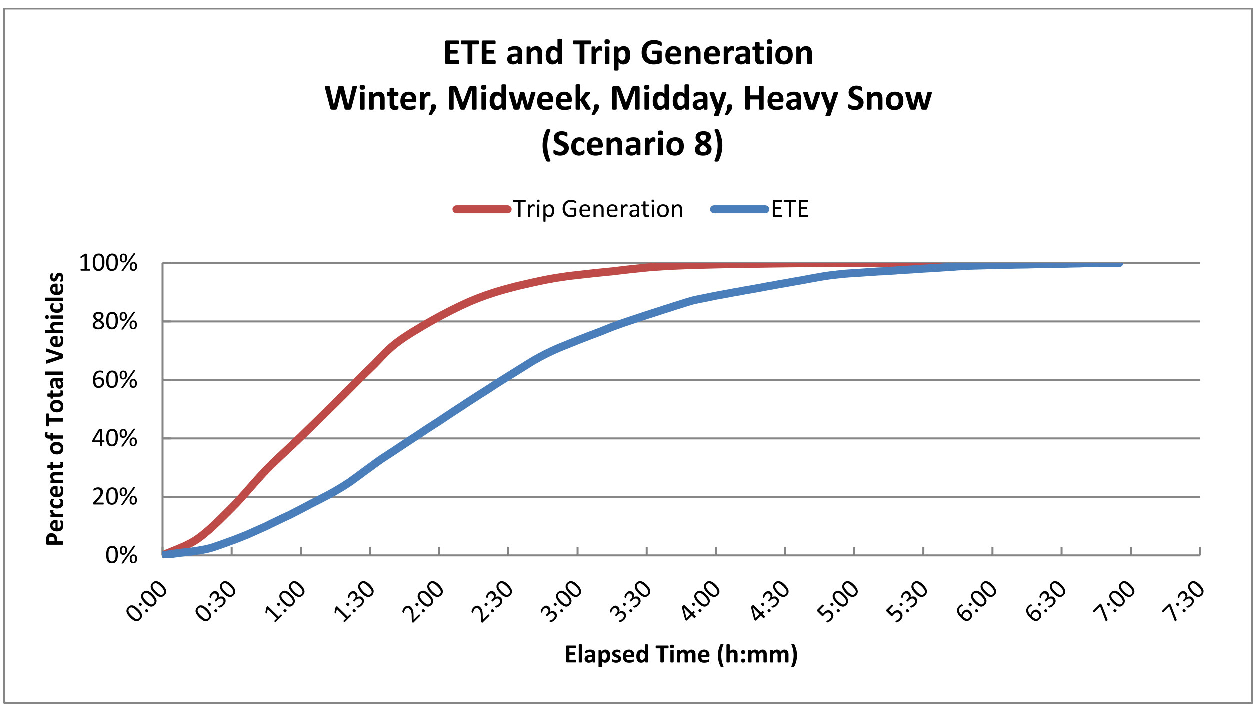


Figure J-9. ETE and Trip Generation: Winter, Midweek, Midday, Heavy Snow (Scenario 8)

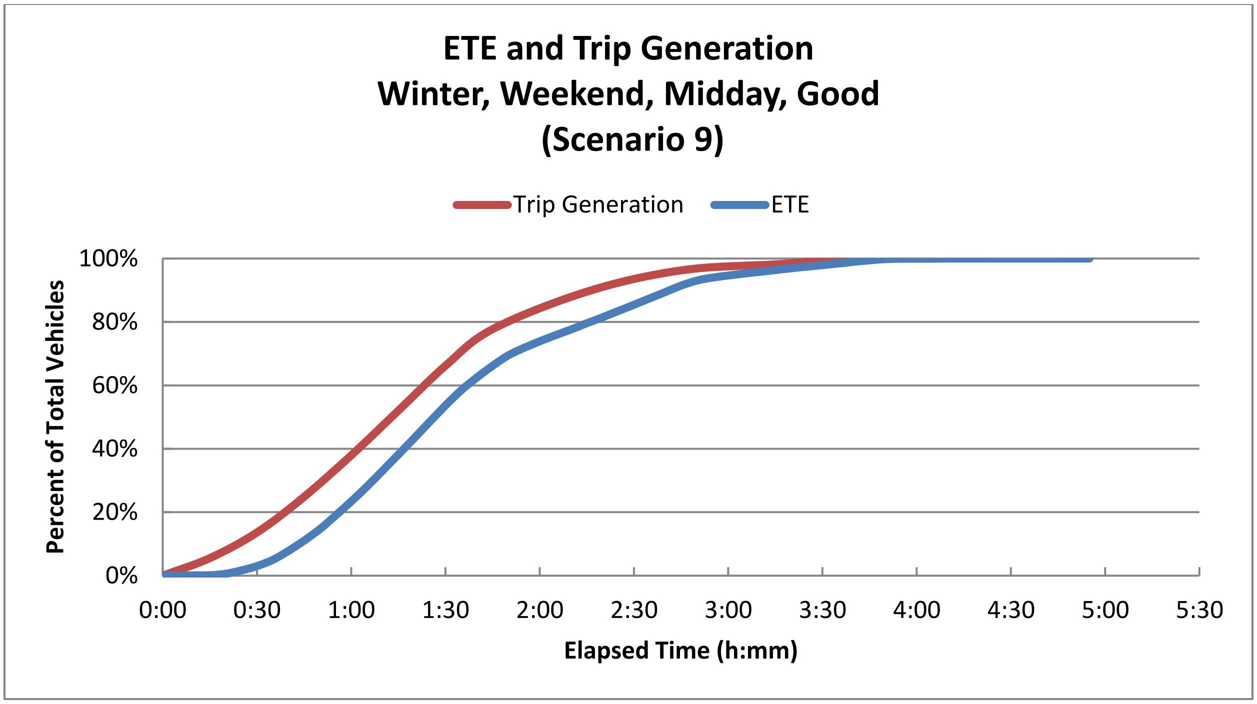


Figure J-10. ETE and Trip Generation: Winter, Weekend, Midday, Good Weather (Scenario 9)

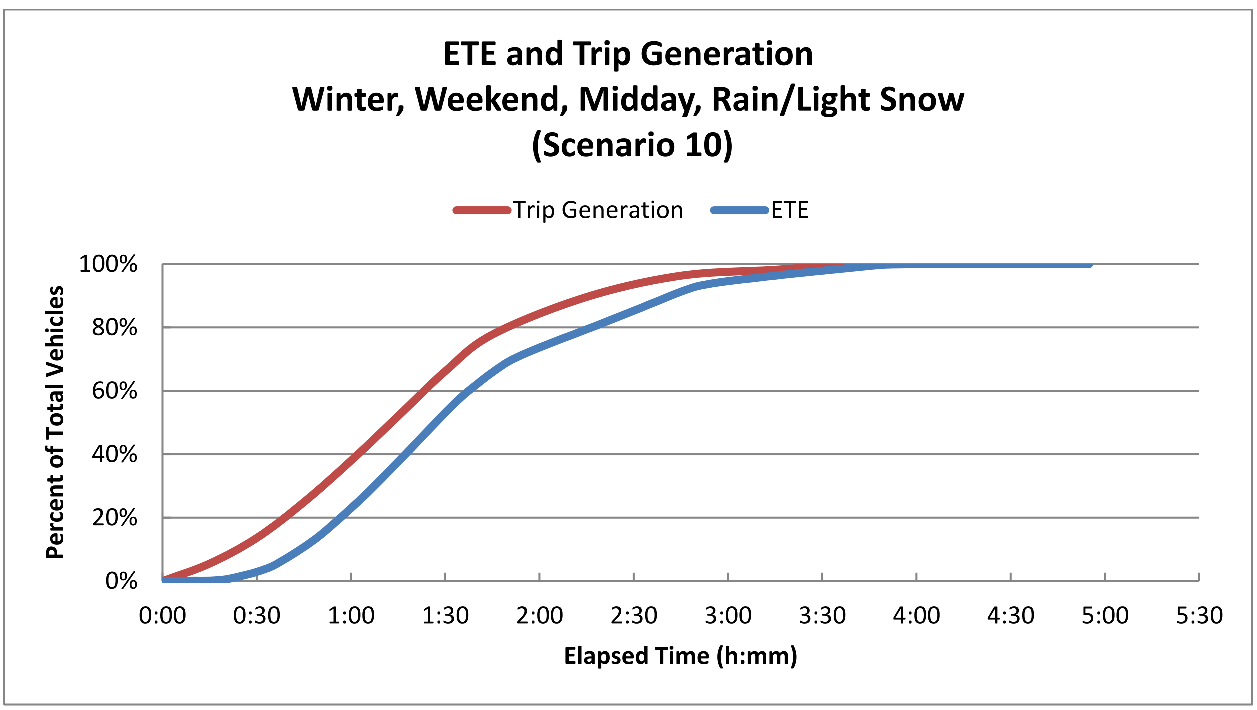


Figure J-11. ETE and Trip Generation: Winter, Weekend, Midday, Rain/Light Snow (Scenario 10)

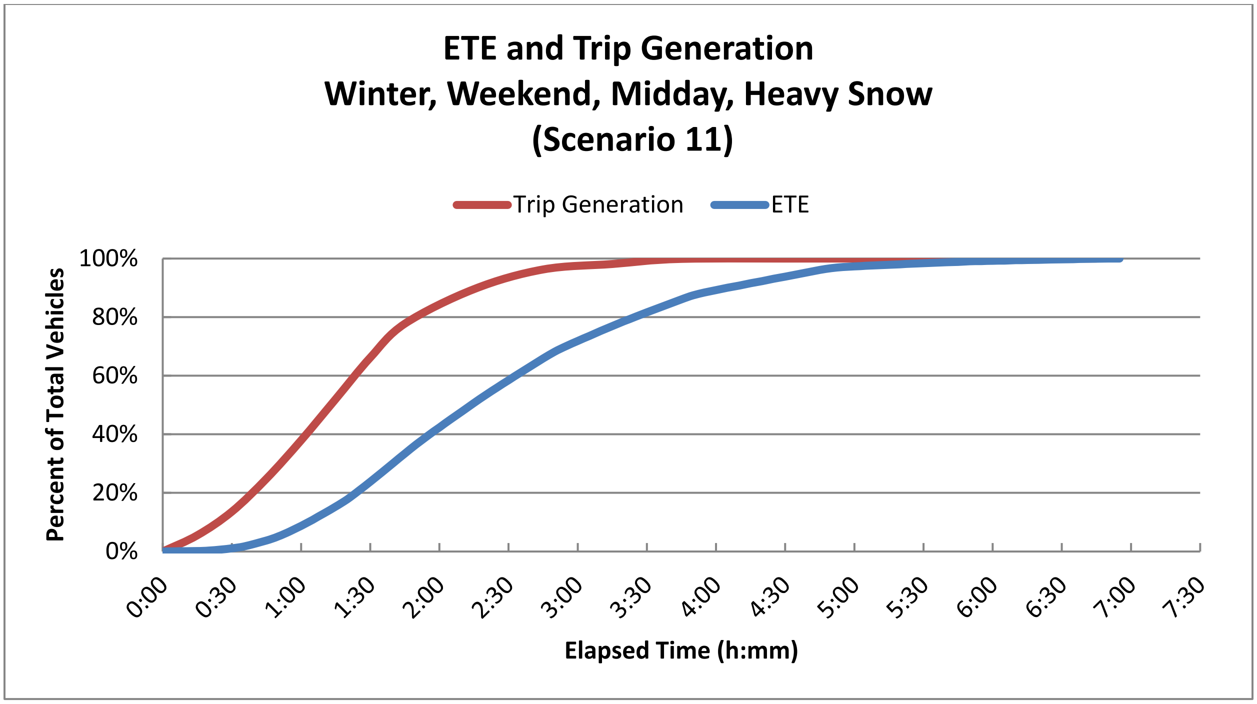


Figure J-12. ETE and Trip Generation: Winter, Weekend, Midday, Heavy Snow (Scenario 11)

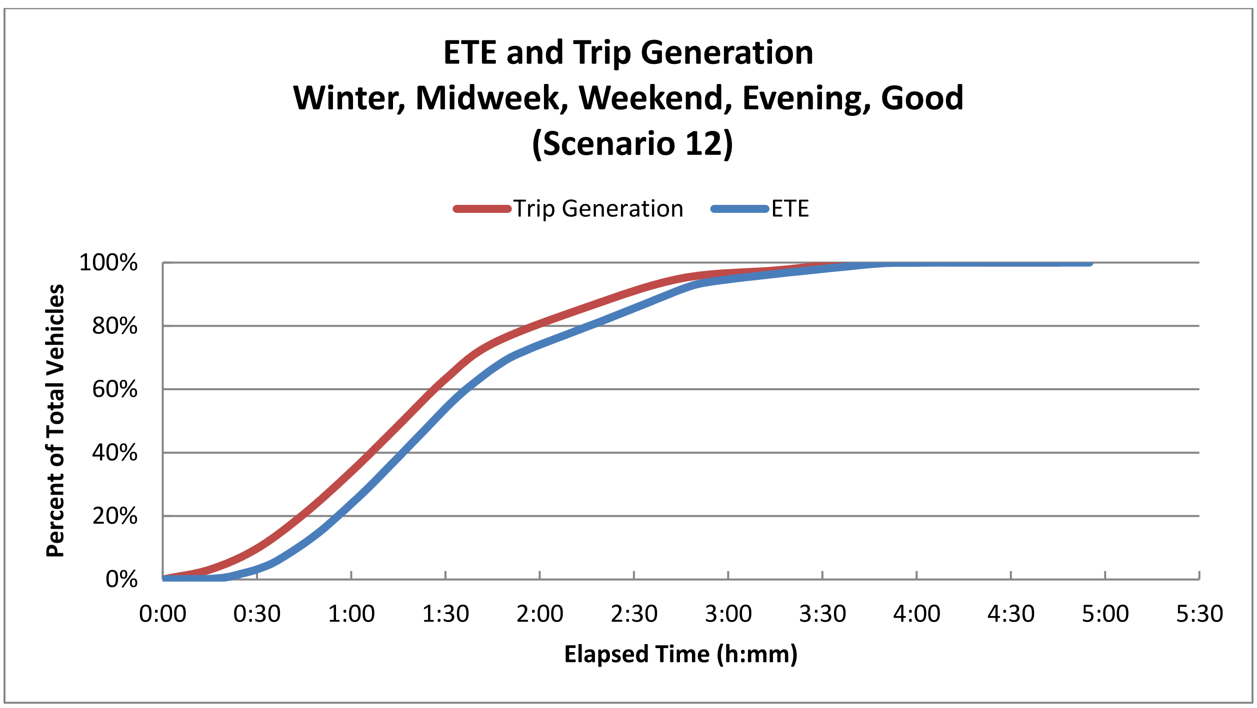


Figure J-13. ETE and Trip Generation: Winter, Midweek, Weekend, Evening, Good Weather (Scenario 12)

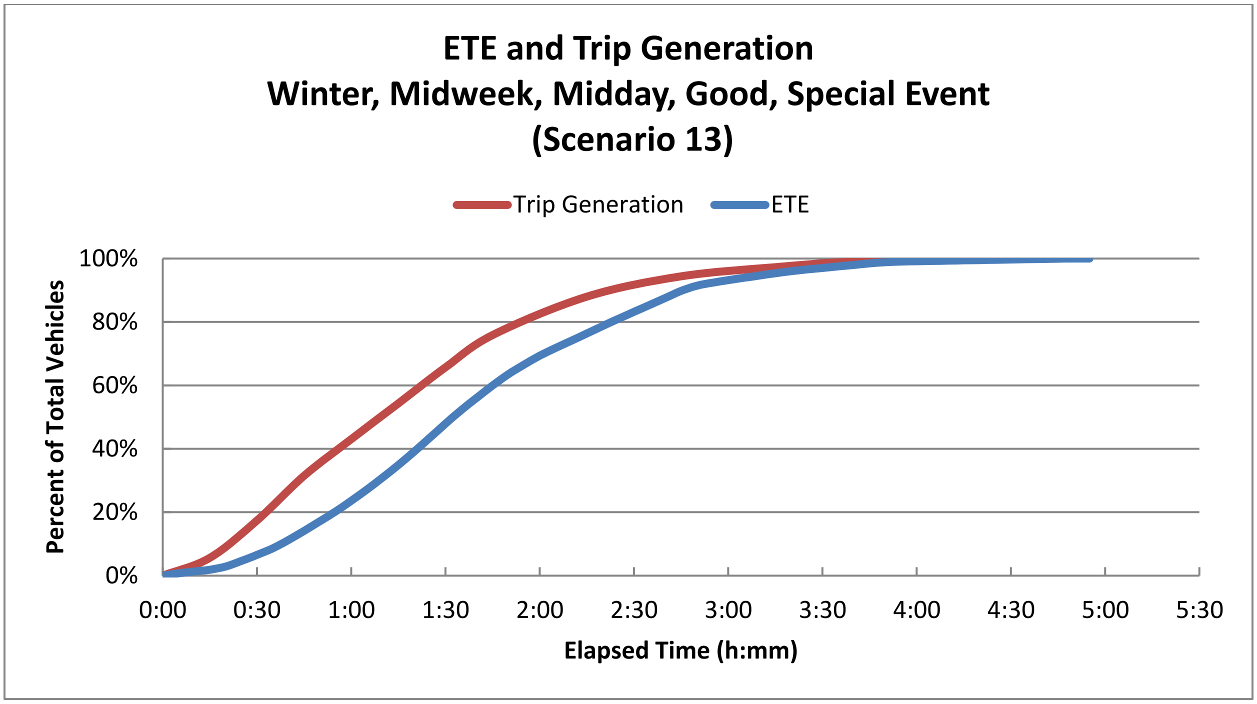


Figure J-14. ETE and Trip Generation: Winter, Midweek, Midday, Good Weather, Special Event (Scenario 13)

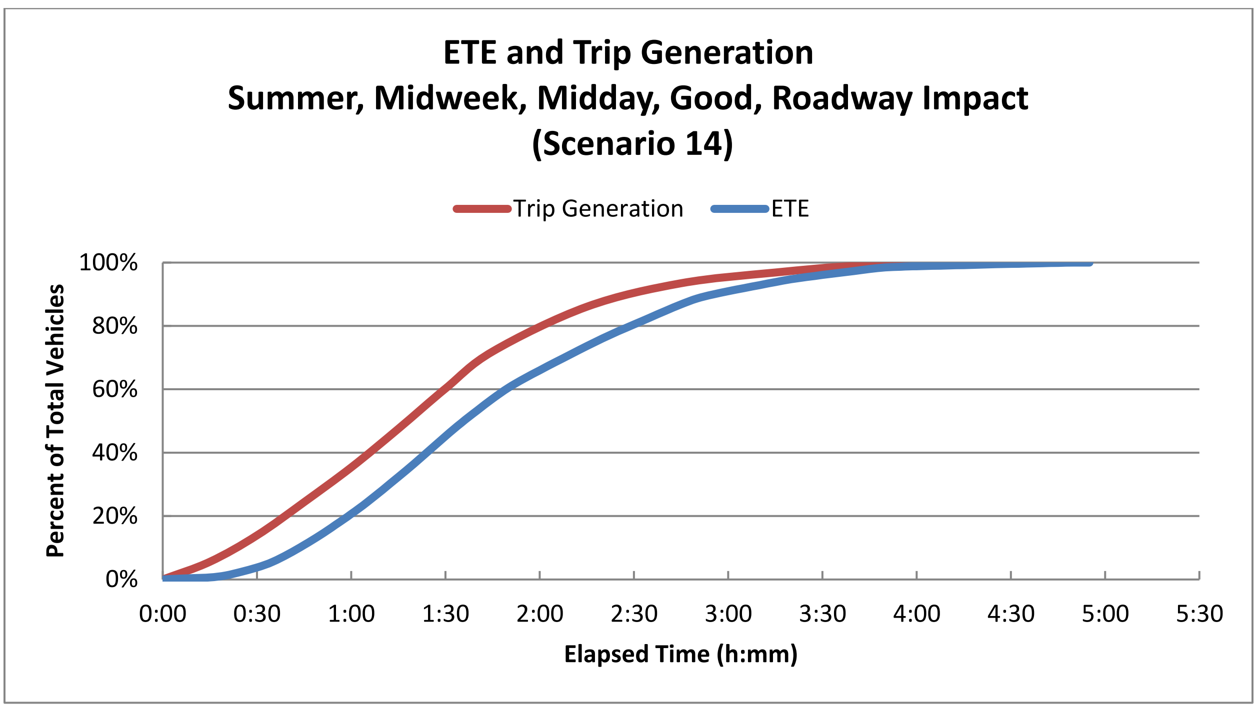


Figure J-15. ETE and Trip Generation: Summer, Midweek, Midday, Good Weather, Roadway Impact (Scenario 14)

APPENDIX K

Evacuation Roadway Network

K. EVACUATION ROADWAY NETWORK

As discussed in Section 1.3, a link-node analysis network was constructed to model the roadway network within the study area. Figure K-1 provides an overview of the link-node analysis network. The figure has been divided up into 43 more detailed figures (Figure K-2 through Figure K-44) which show each of the links and nodes in the network.

The analysis network was calibrated using the observations made during the field surveys conducted in October 2020.

Table K-1 summarizes the number of nodes by the type of control (stop sign, yield sign, pre-timed signal, actuated signal, traffic or access control point [TCP/ACP], or uncontrolled).

Table K-1. Summary of Nodes by the Type of Control

Control Type	Number of Nodes
Uncontrolled	1,377
Pretimed Signal	0
Actuated Signal	7
Stop Sign	115
TCP/ACP	51
Yield Sign	8
Total:	**1,558**

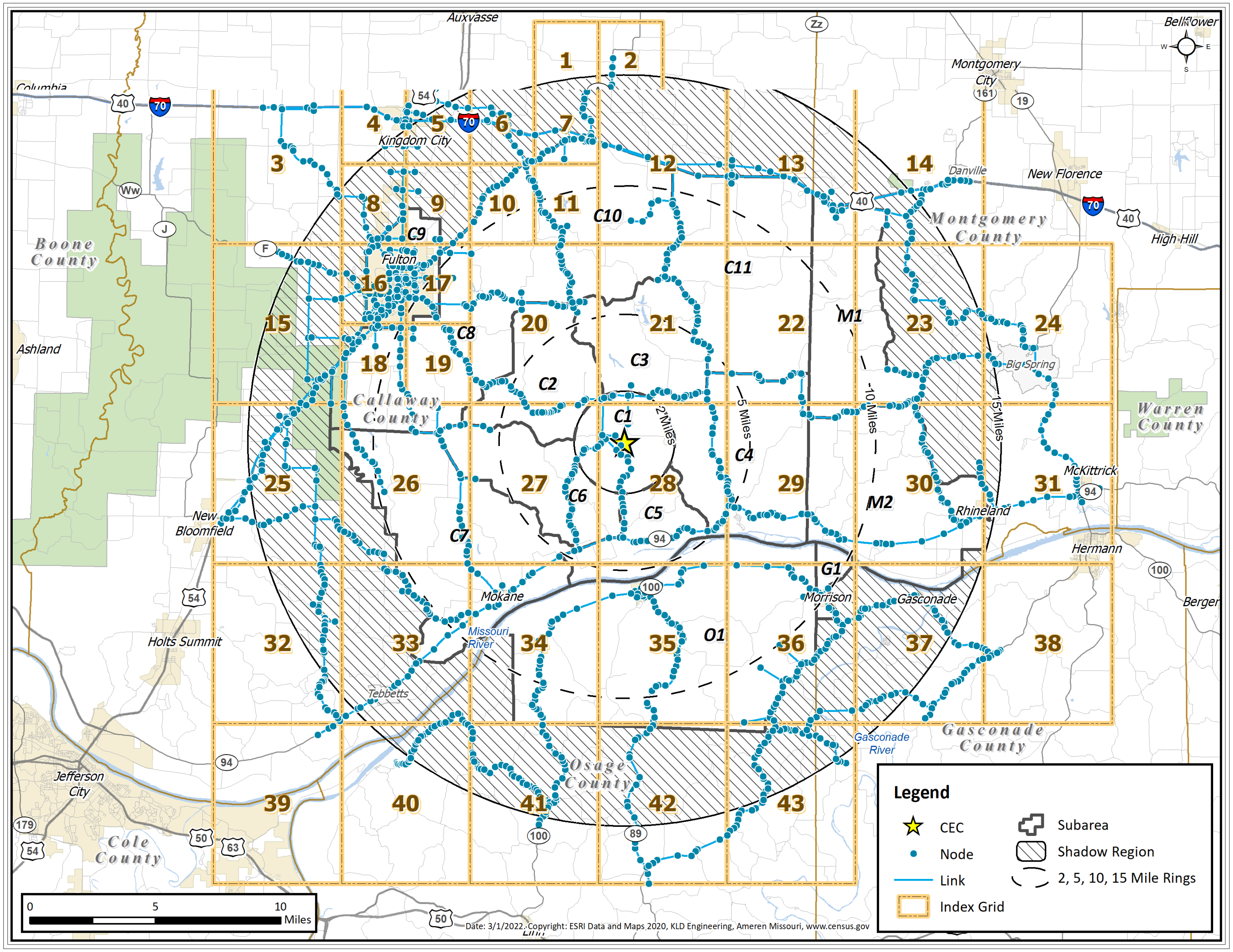


Figure K-1 Callaway Link-Node Analysis Network

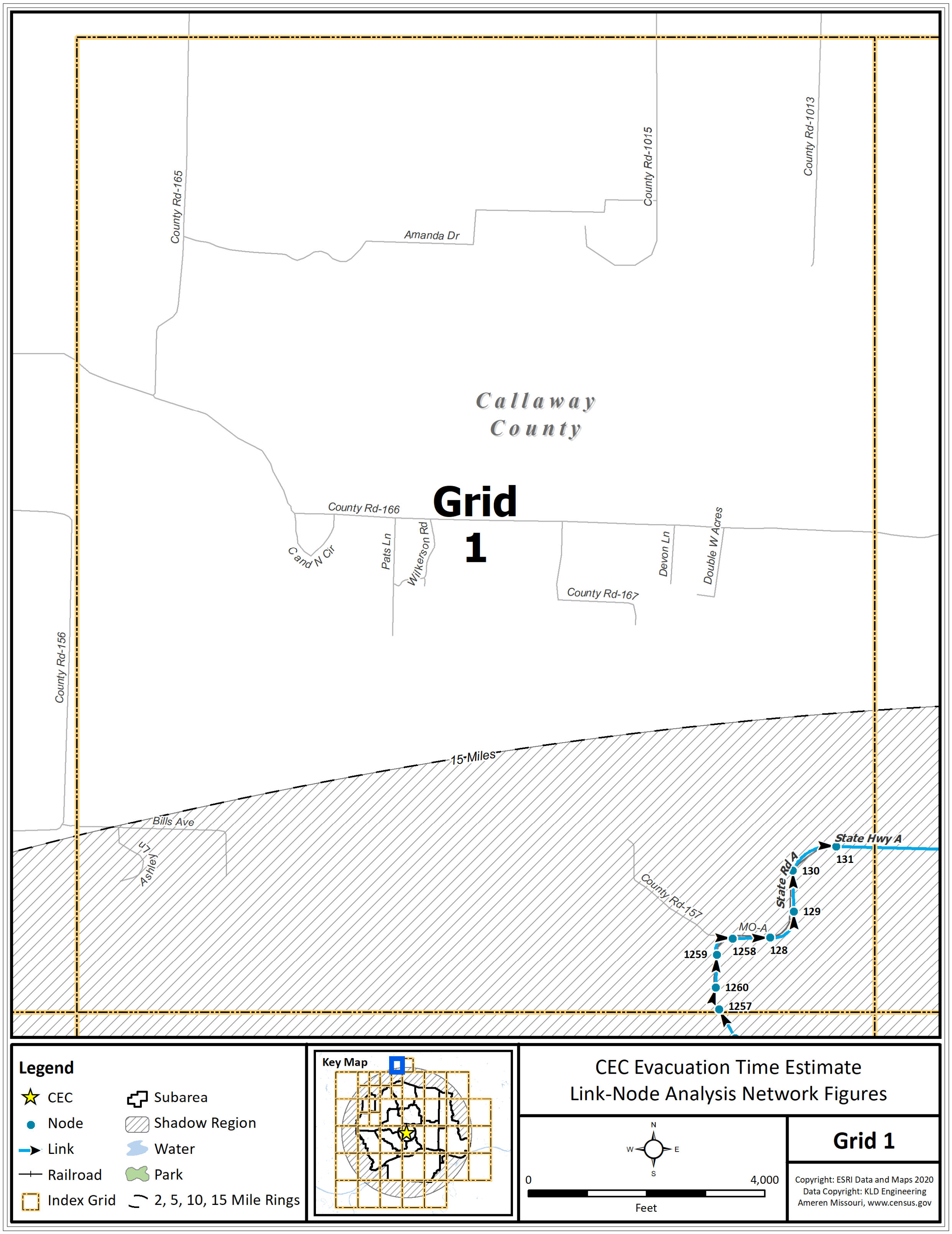


Figure K-2 Link-Node Analysis Network – Grid 1

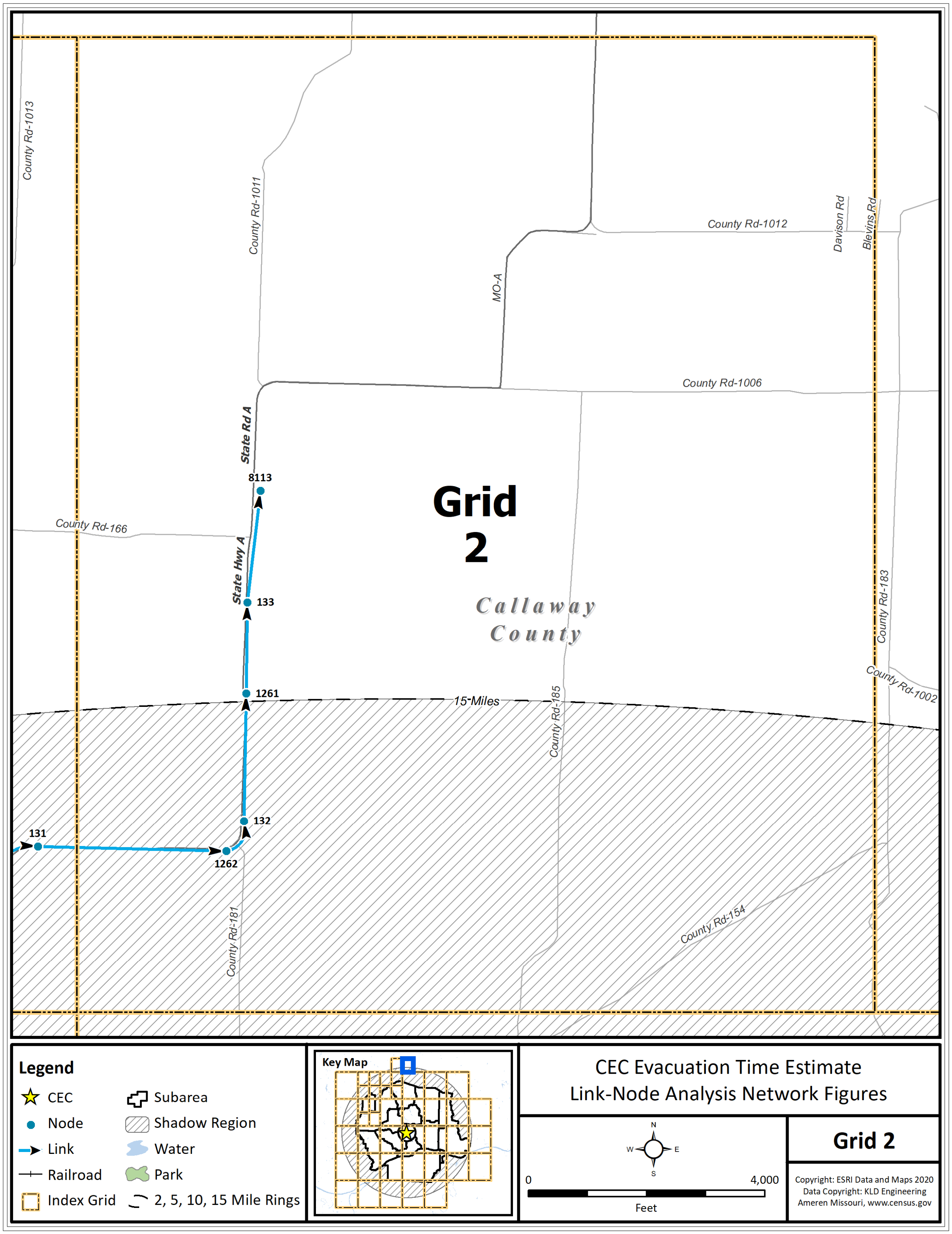


Figure K-3 Link-Node Analysis Network – Grid 2

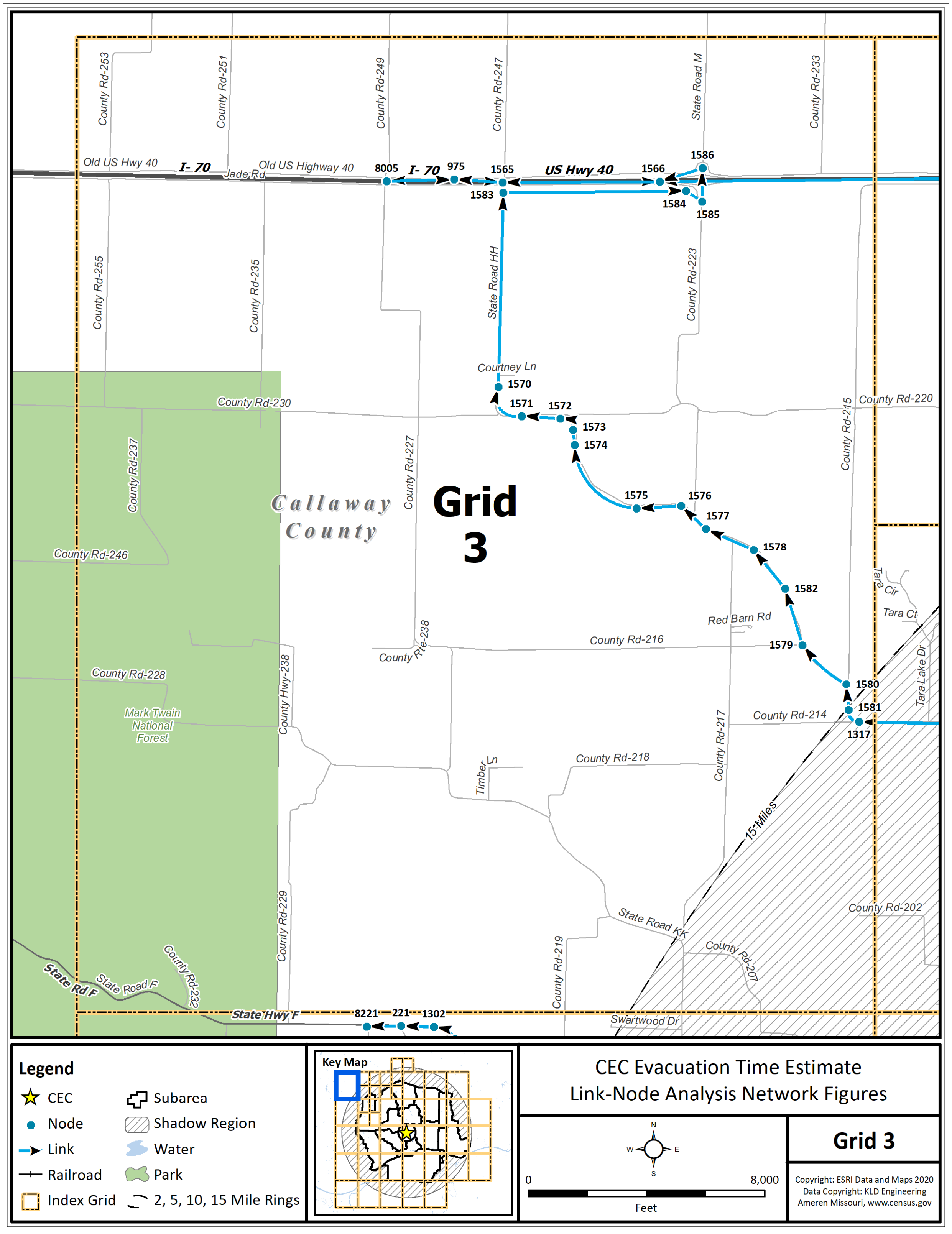


Figure K-4 Link-Node Analysis Network – Grid 3

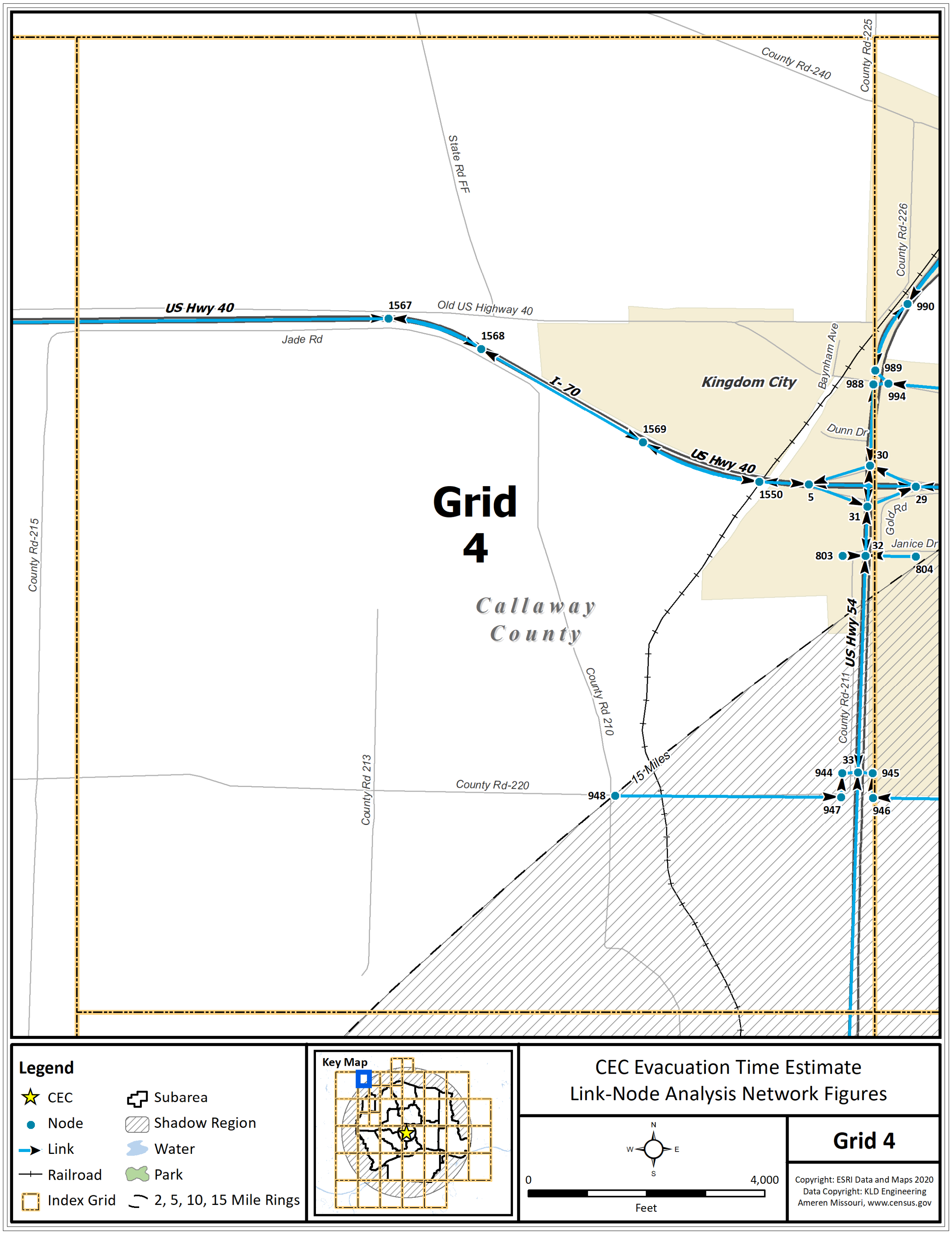


Figure K-5 Link-Node Analysis Network – Grid 4

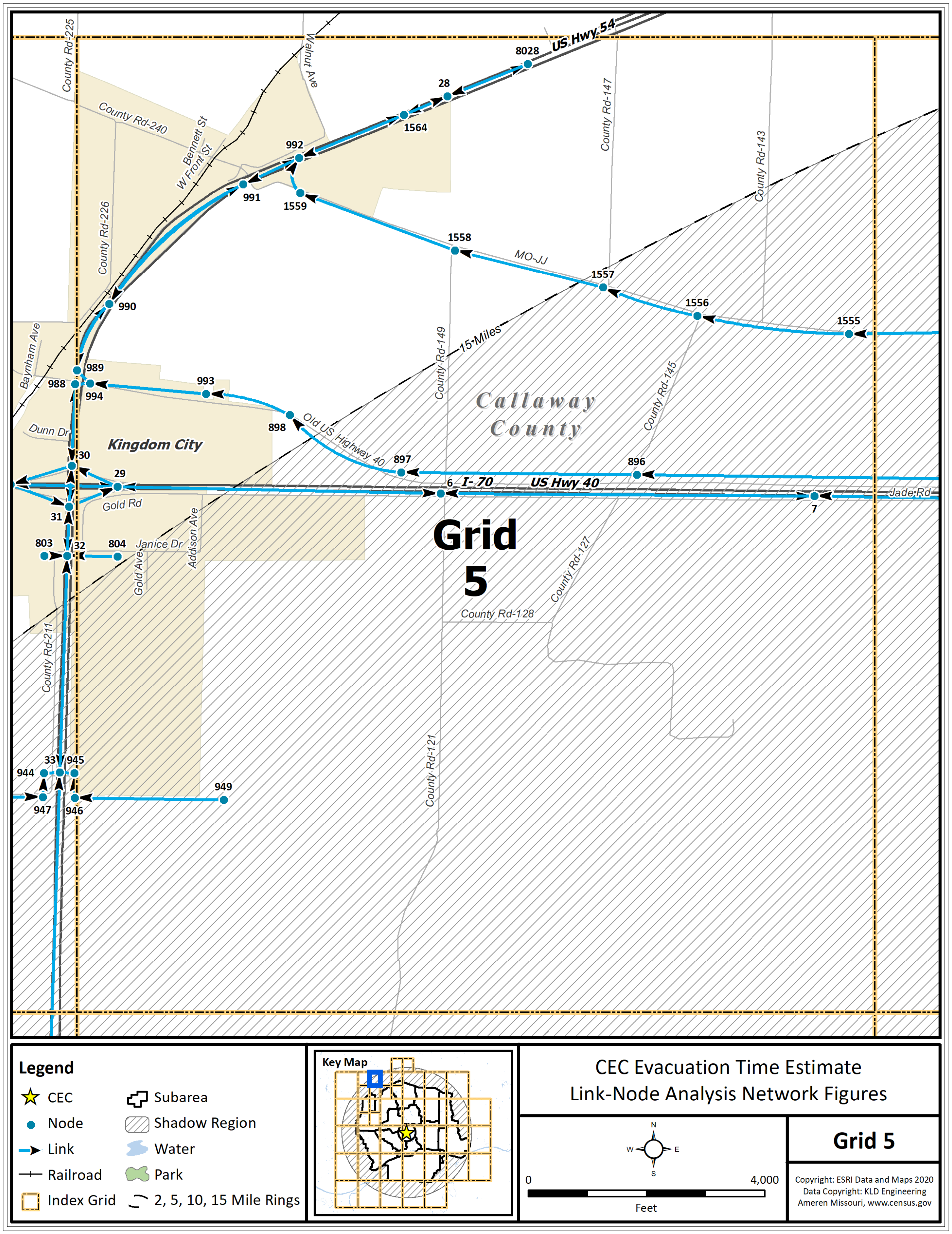


Figure K-6 Link-Node Analysis Network – Grid 5

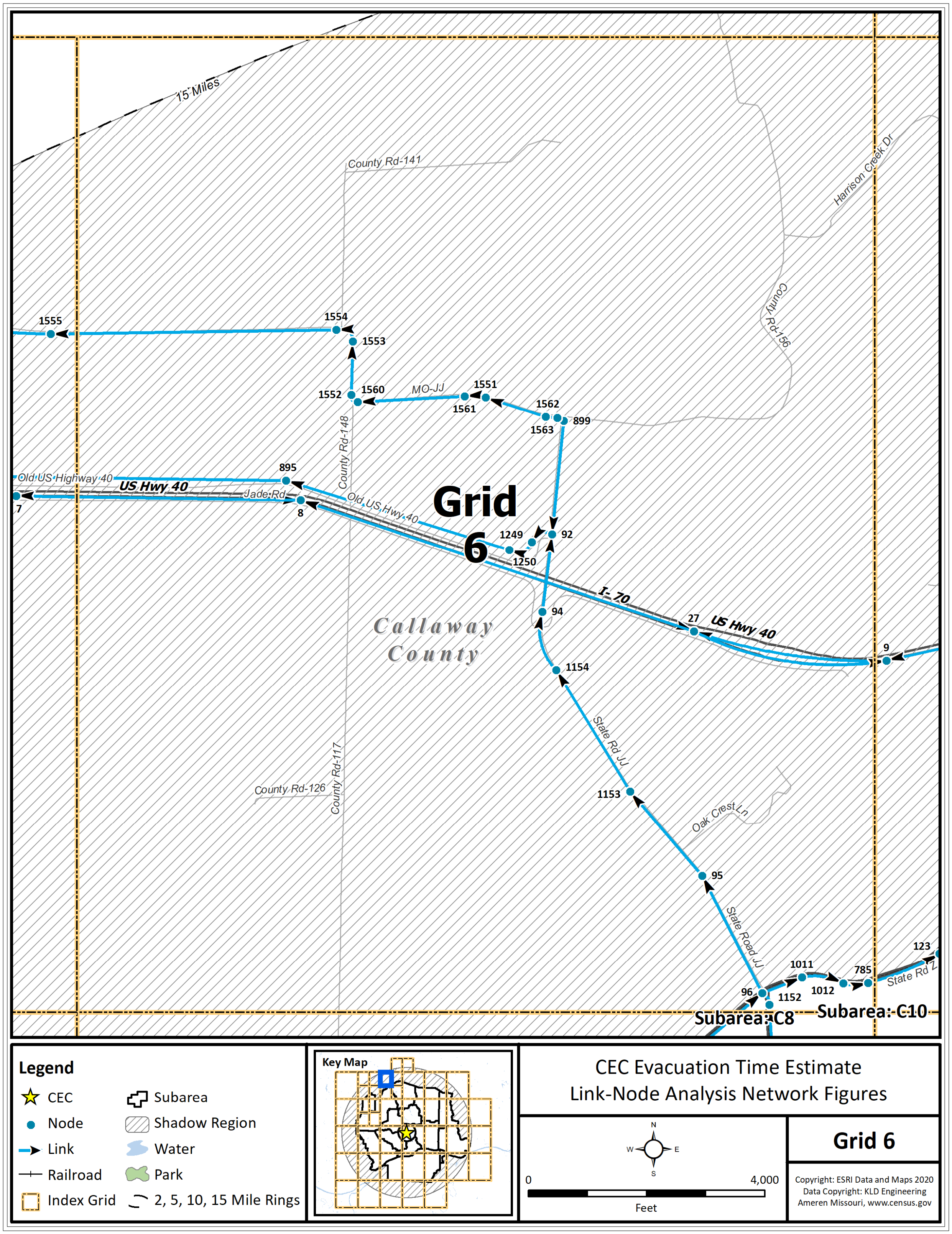


Figure K-7 Link-Node Analysis Network – Grid 6

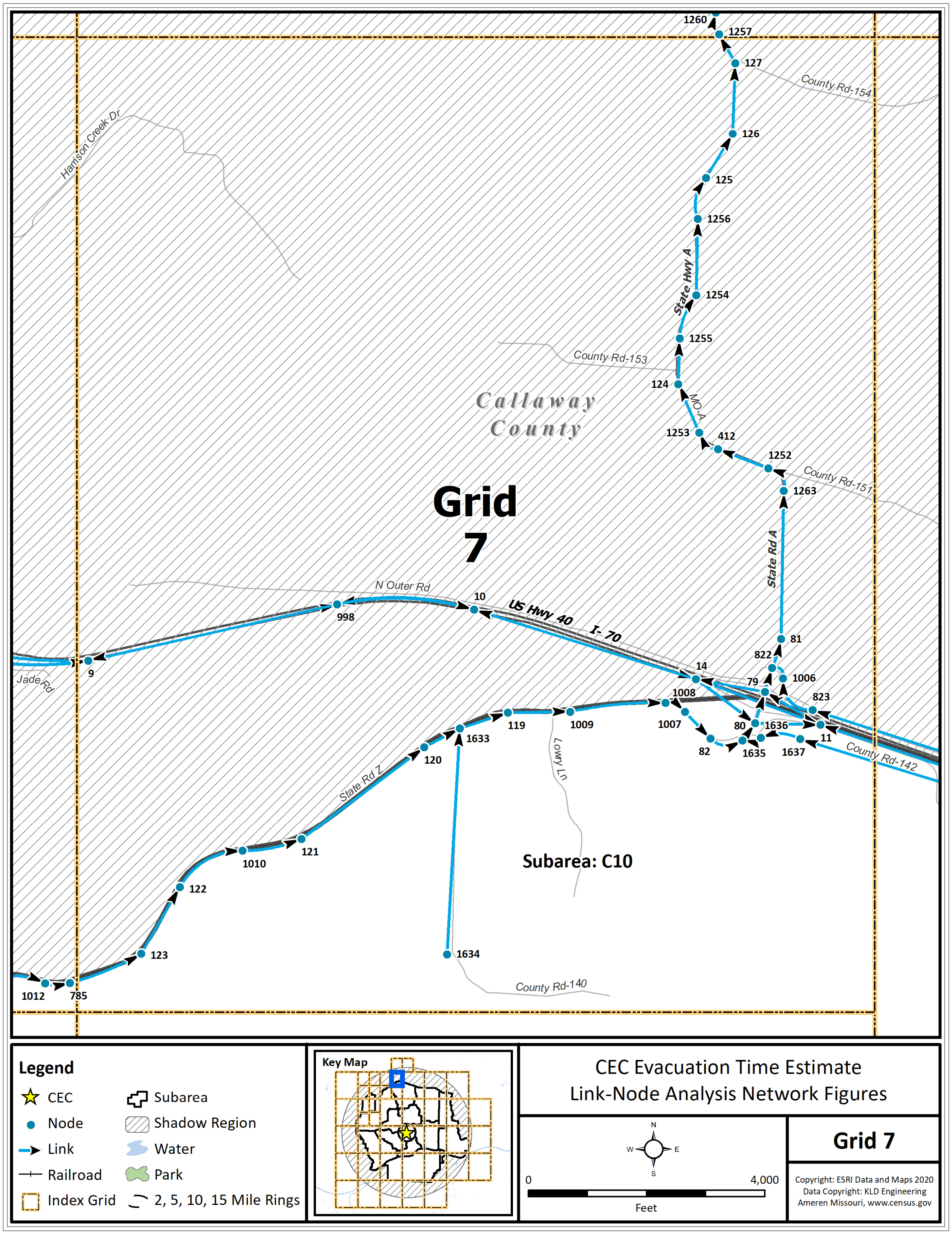


Figure K-8 Link-Node Analysis Network – Grid 7

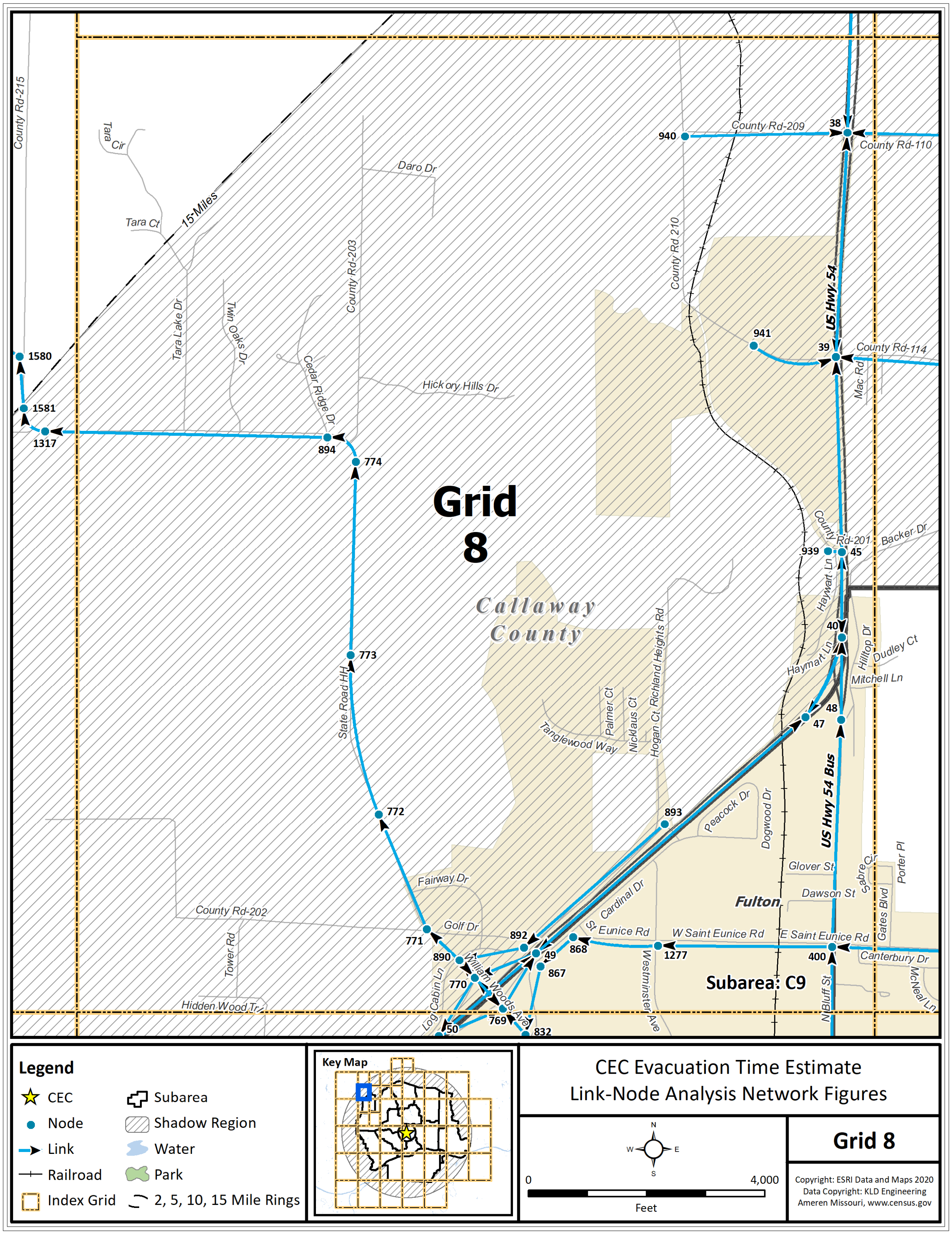


Figure K-9 Link-Node Analysis Network – Grid 8

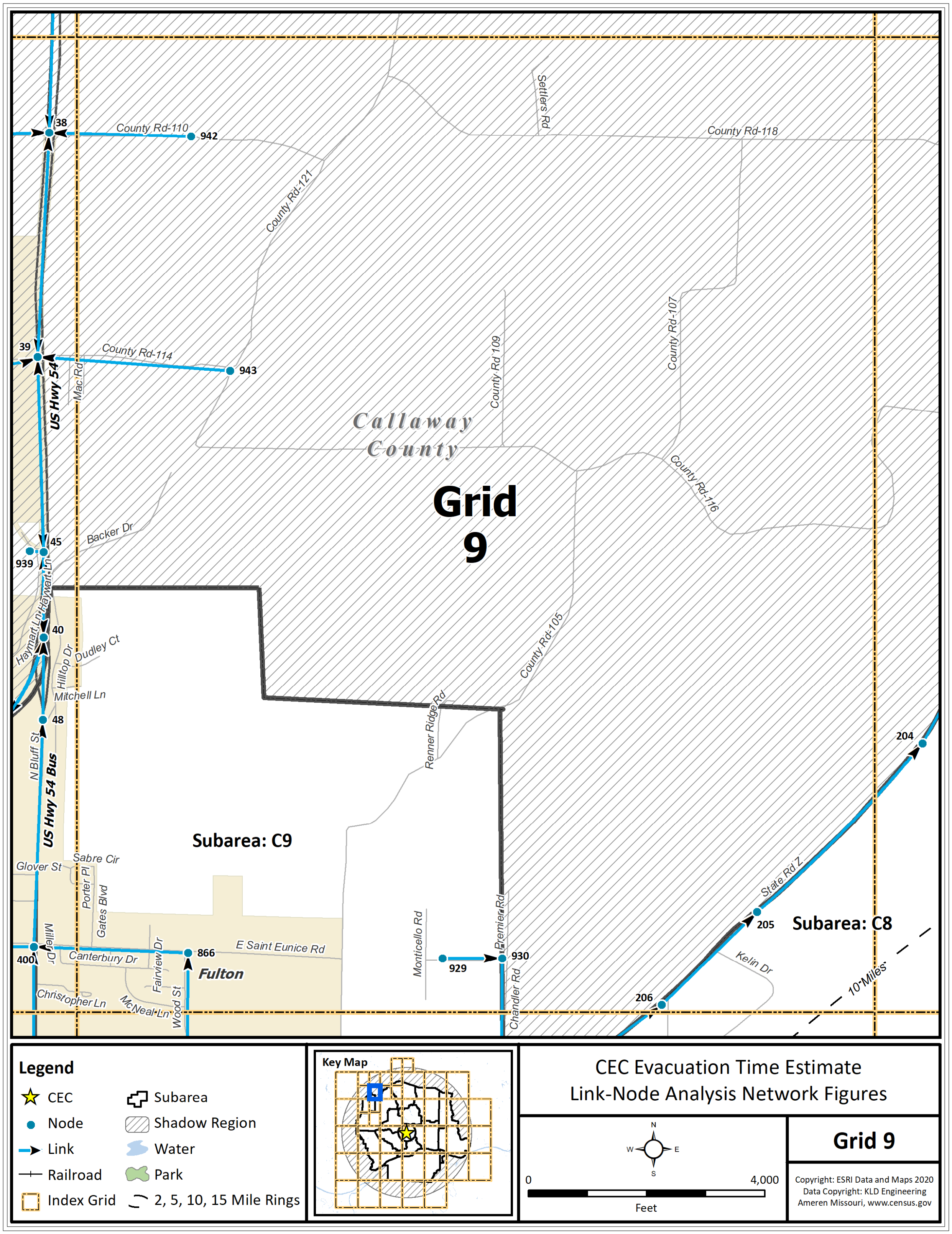


Figure K-10 Link-Node Analysis Network – Grid 9

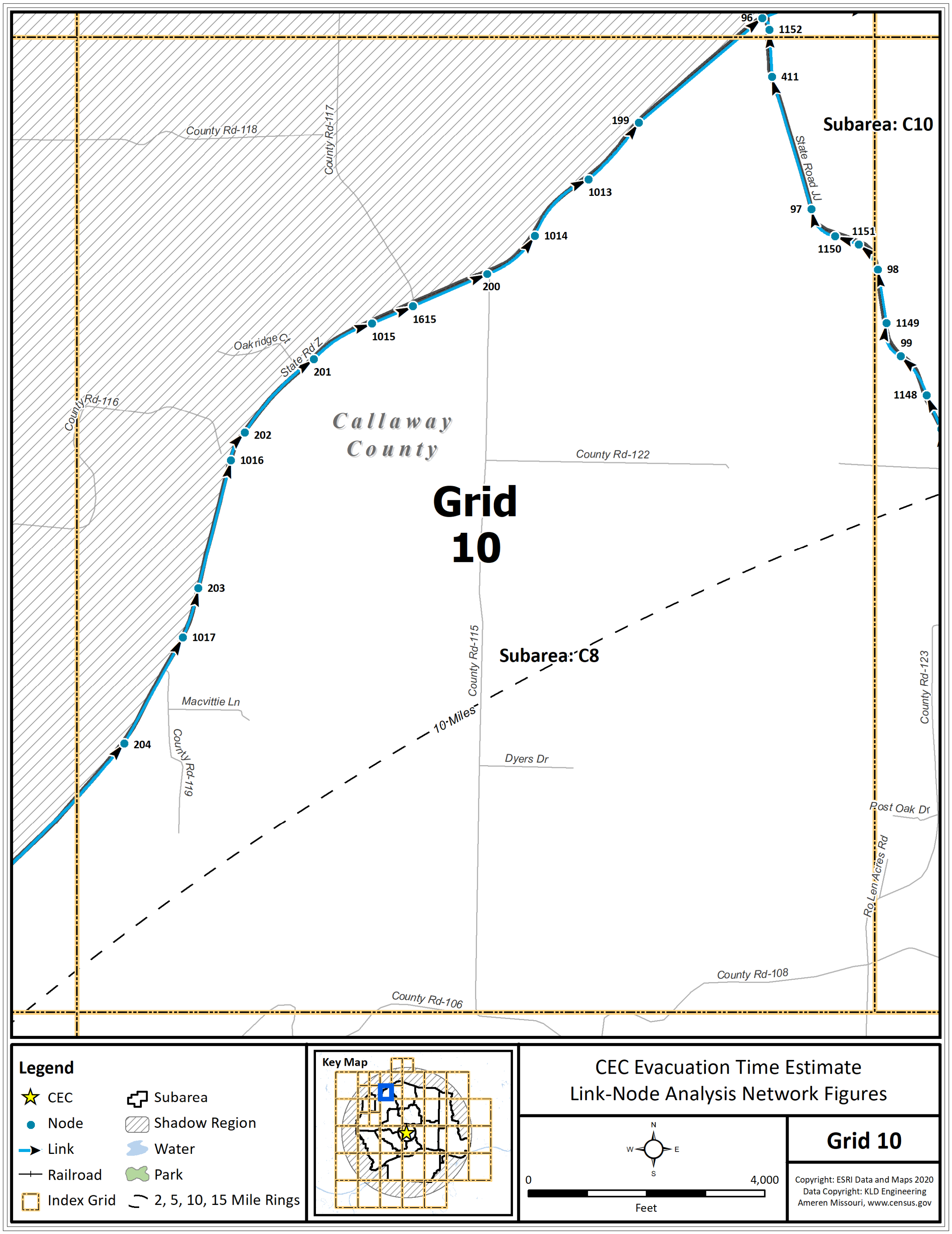


Figure K-11 Link-Node Analysis Network – Grid 10

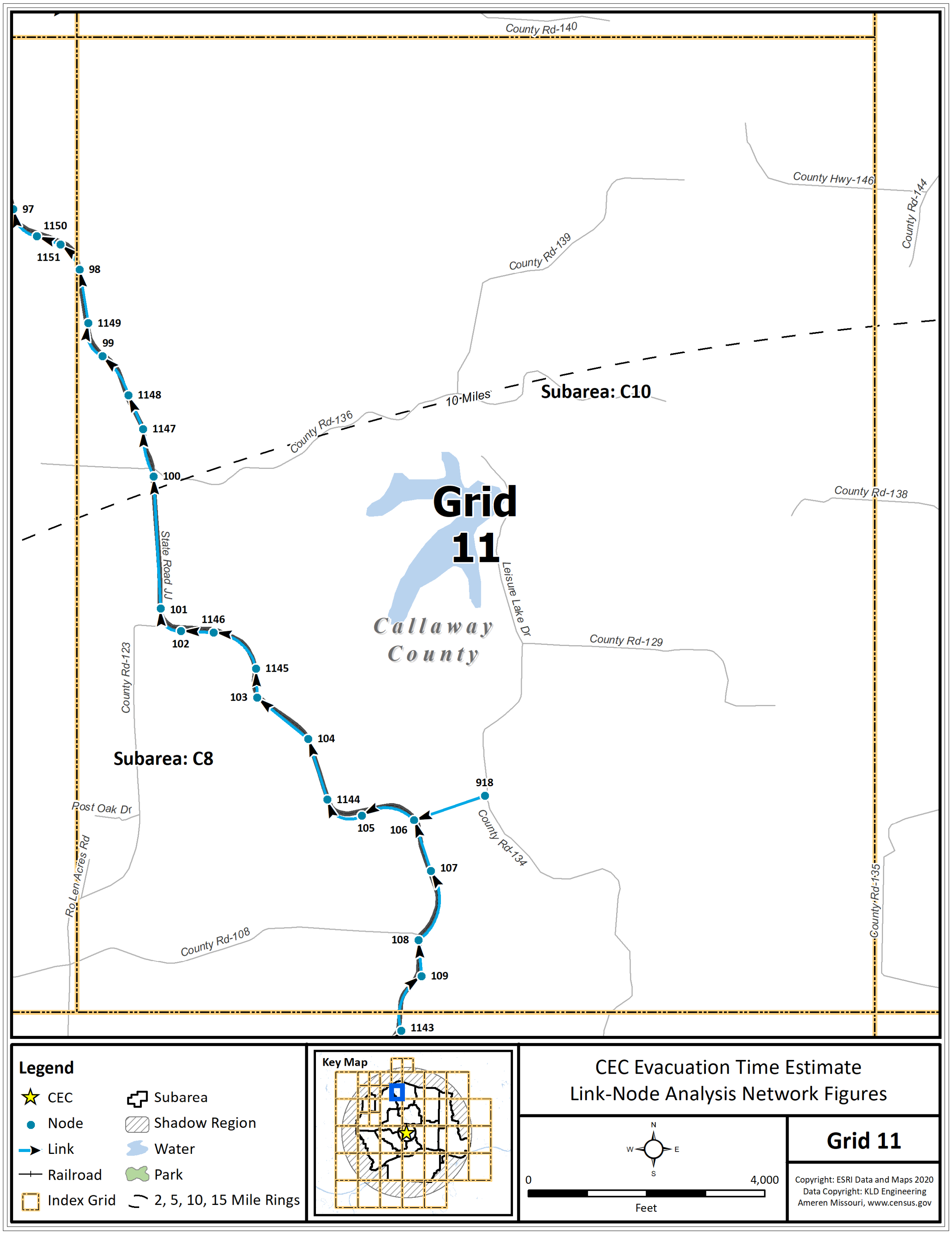


Figure K-12 Link-Node Analysis Network – Grid 11

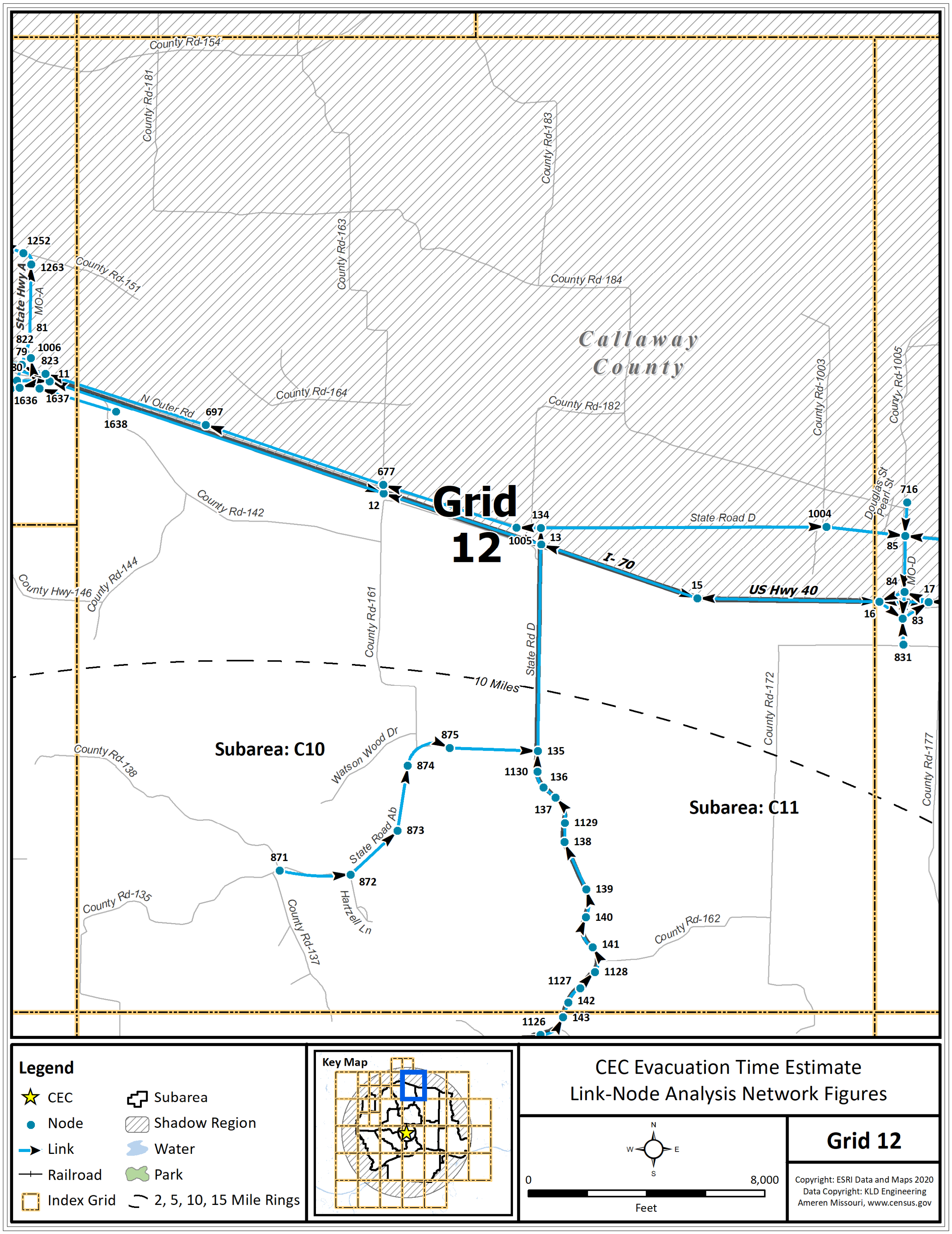


Figure K-13 Link-Node Analysis Network – Grid 12

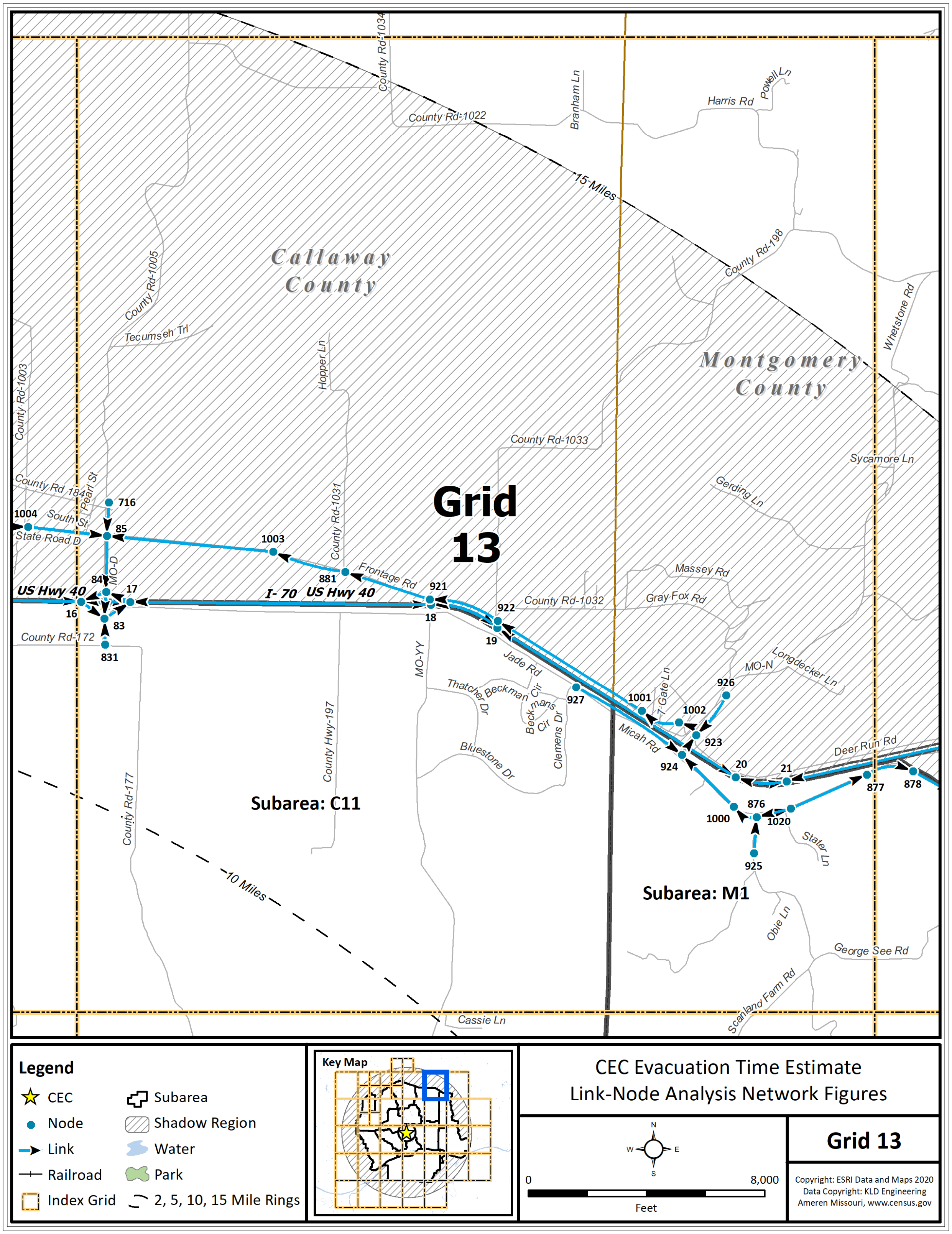


Figure K-14 Link-Node Analysis Network – Grid 13

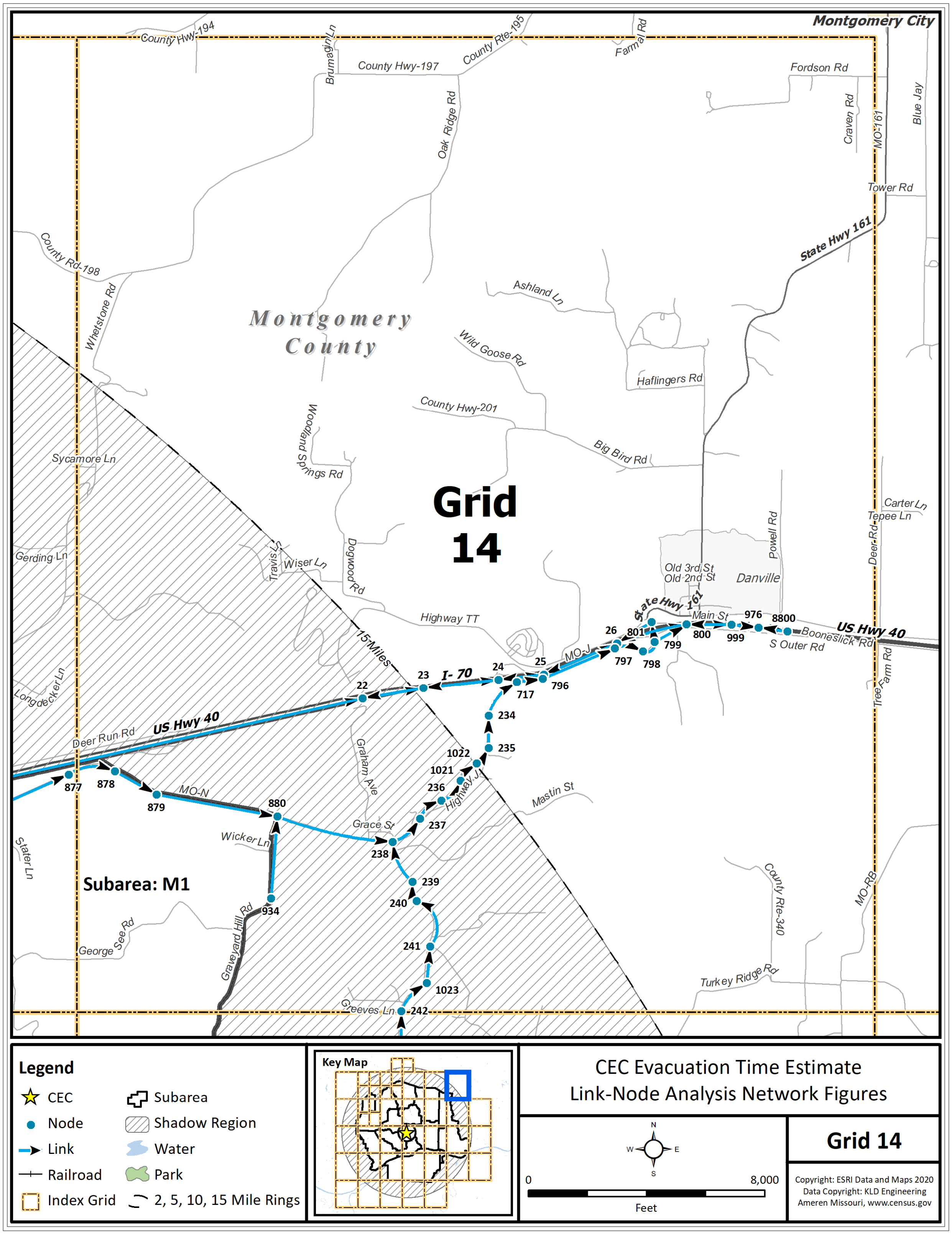


Figure K-15 Link-Node Analysis Network – Grid 14

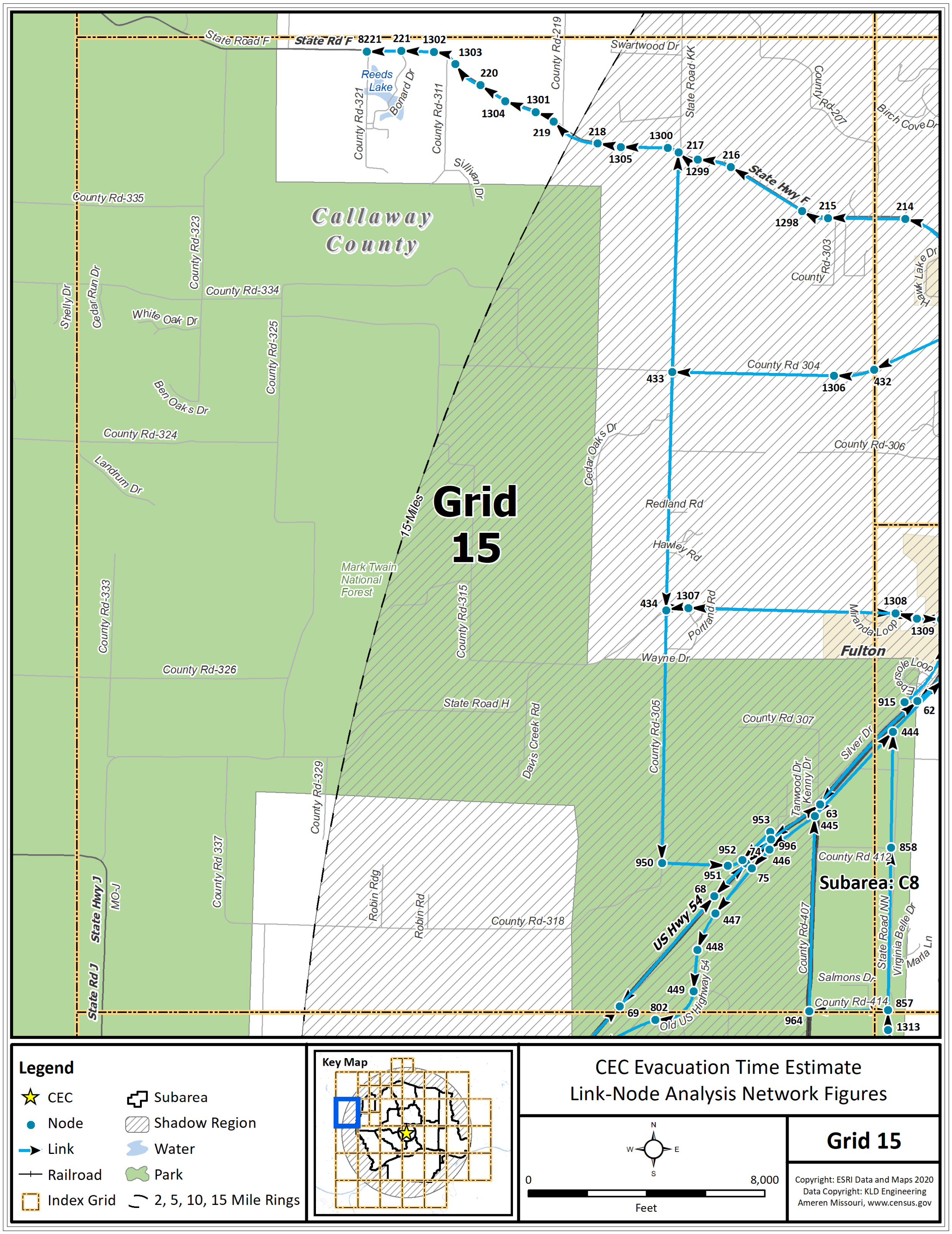


Figure K-16 Link-Node Analysis Network – Grid 15

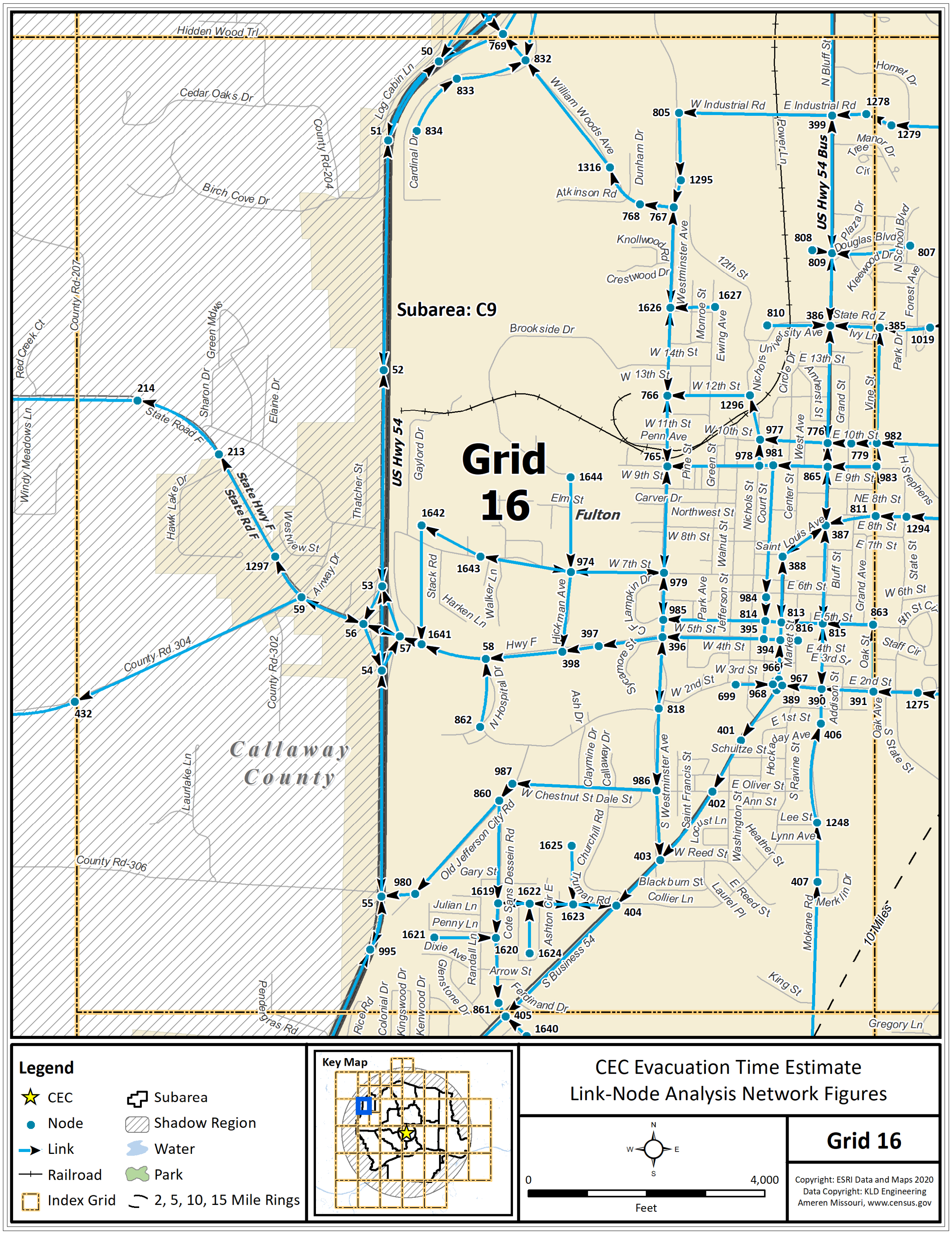


Figure K-17 Link-Node Analysis Network – Grid 16

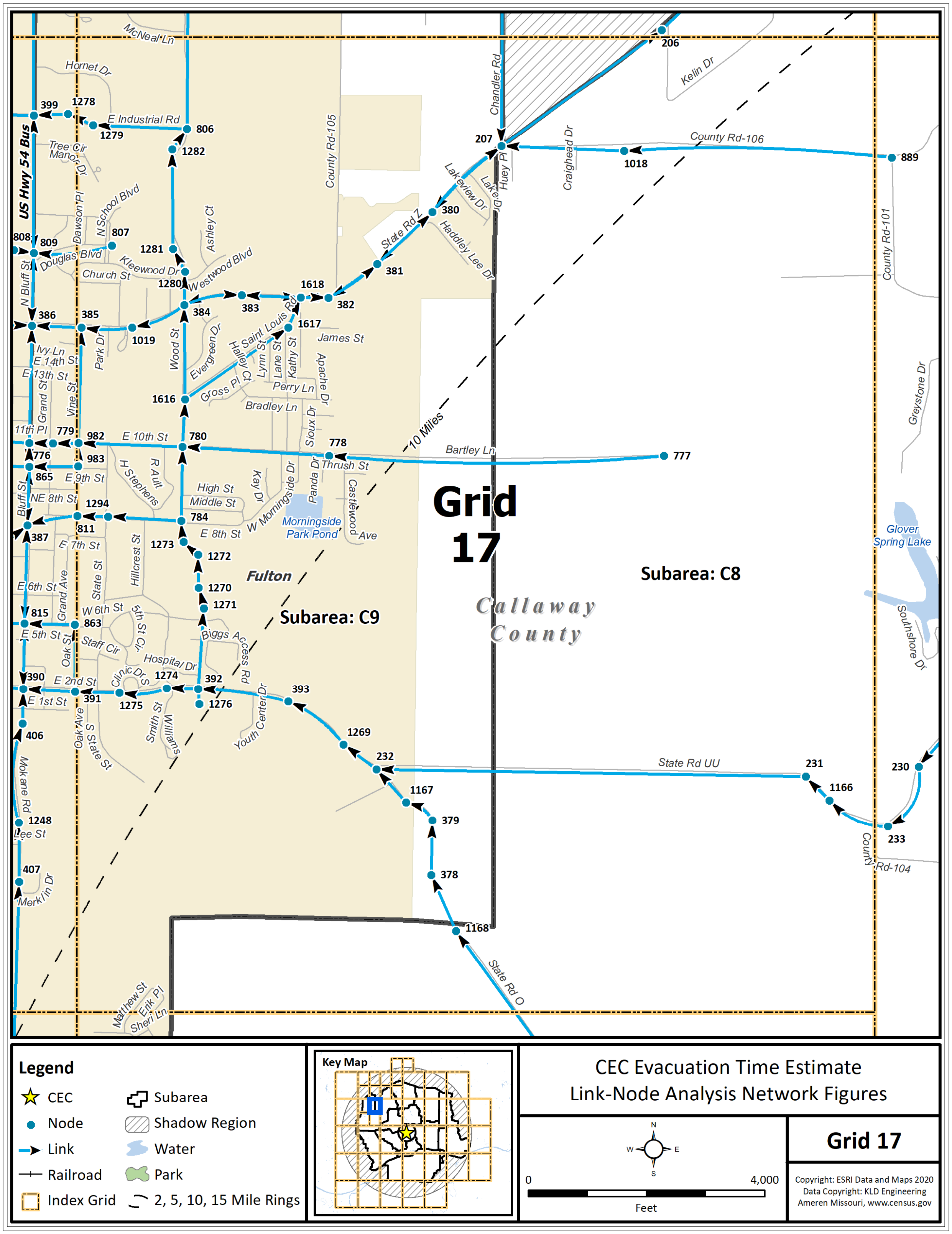


Figure K-18 Link-Node Analysis Network – Grid 17

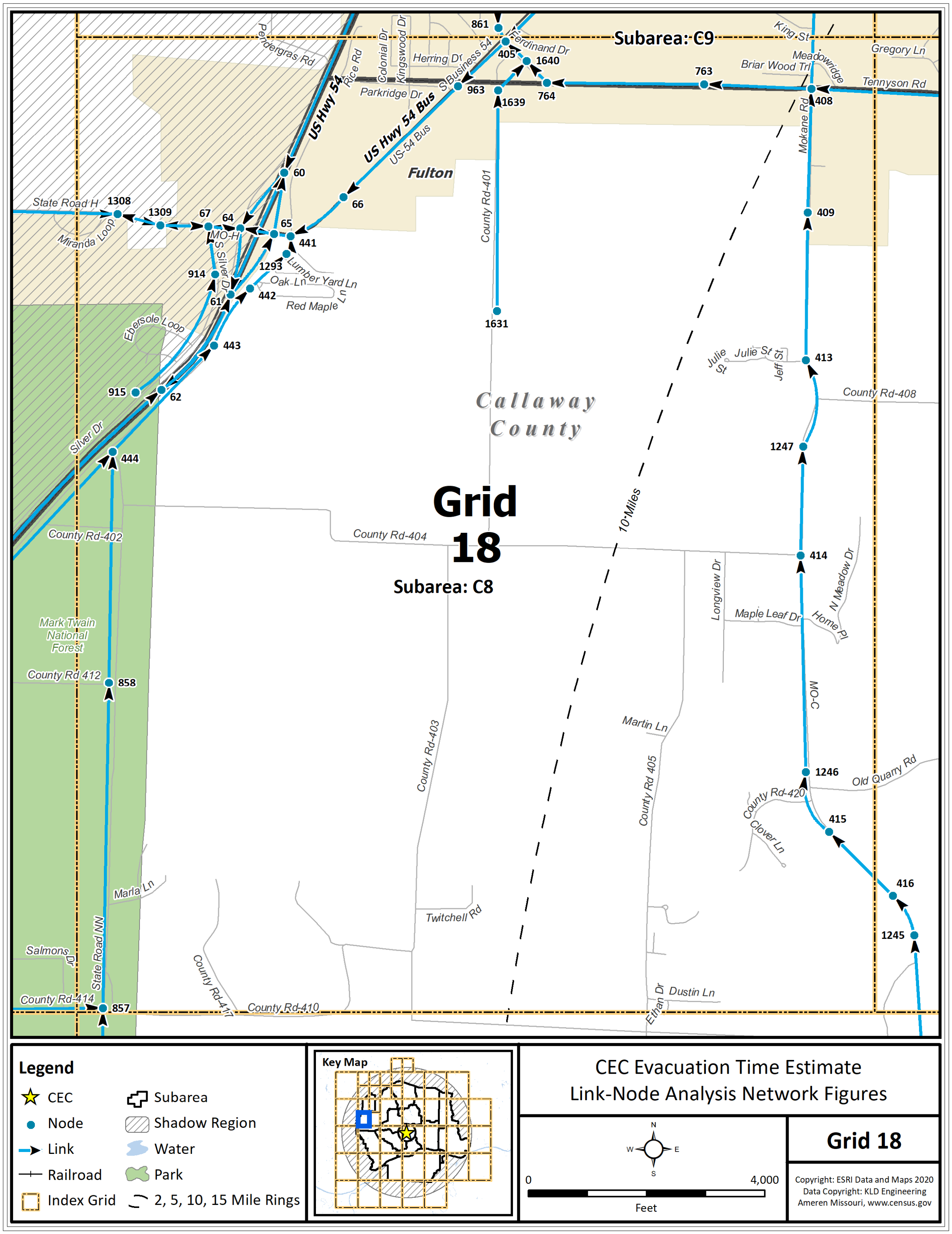


Figure K-19 Link-Node Analysis Network – Grid 18

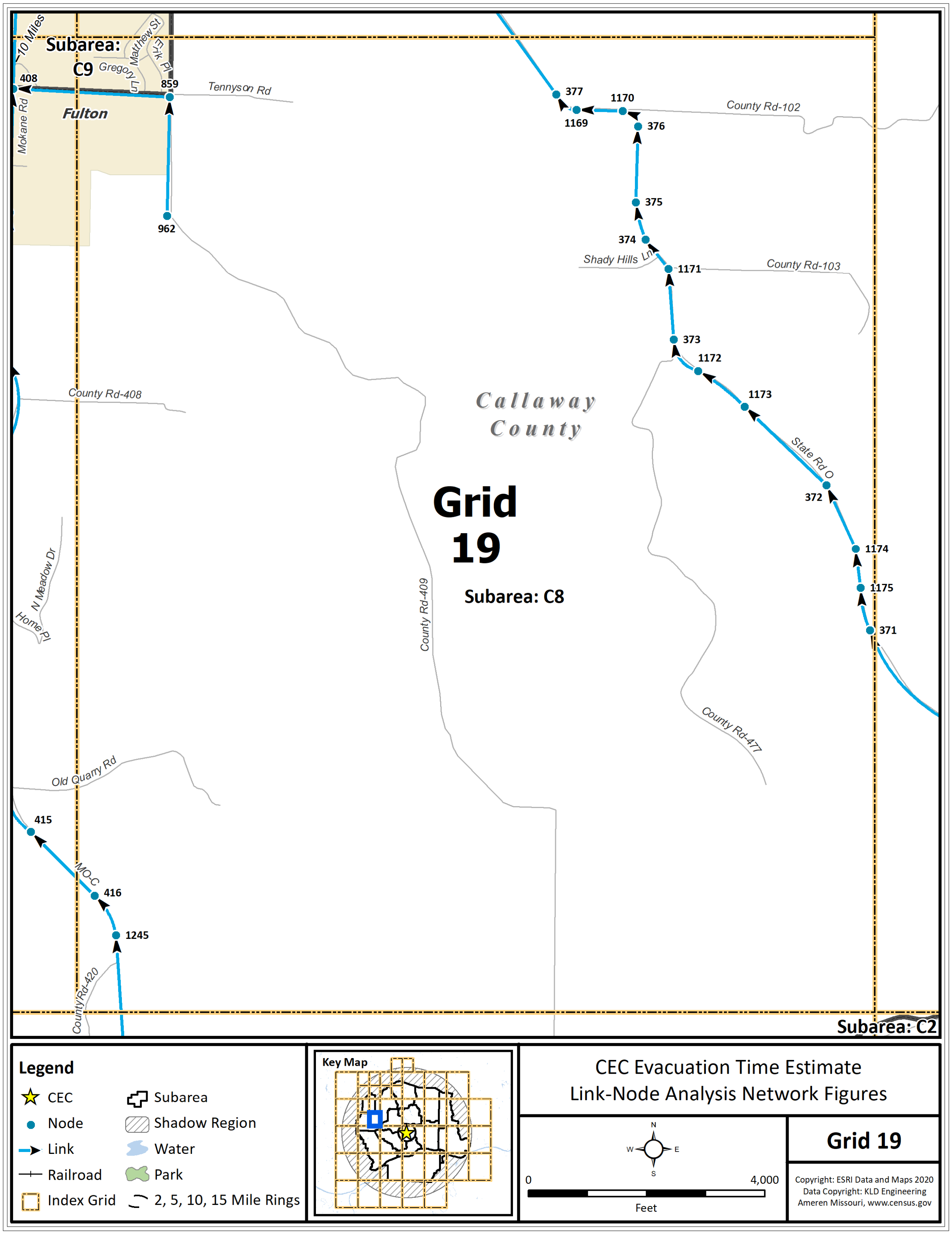


Figure K-20 Link-Node Analysis Network – Grid 19

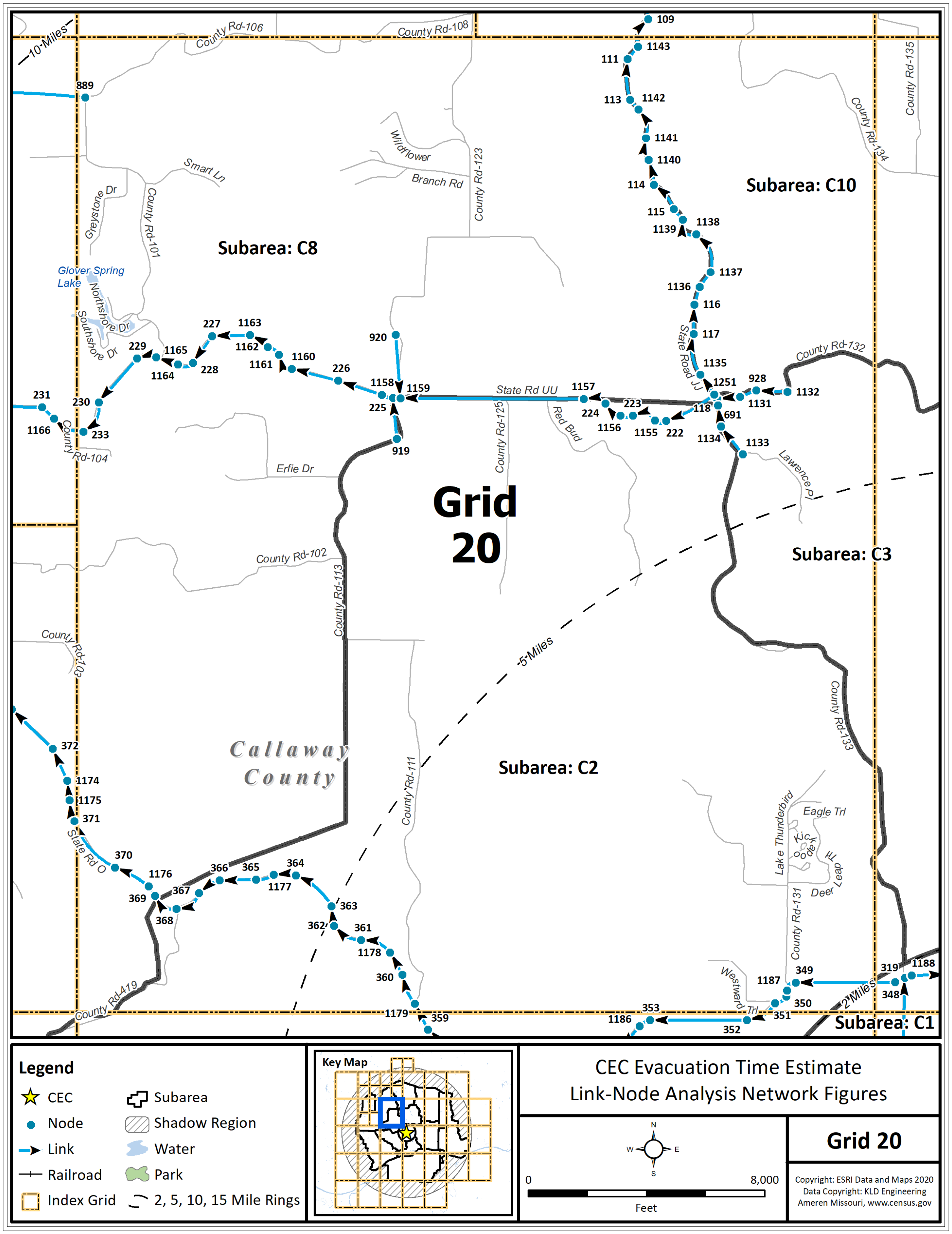


Figure K-21 Link-Node Analysis Network – Grid 20

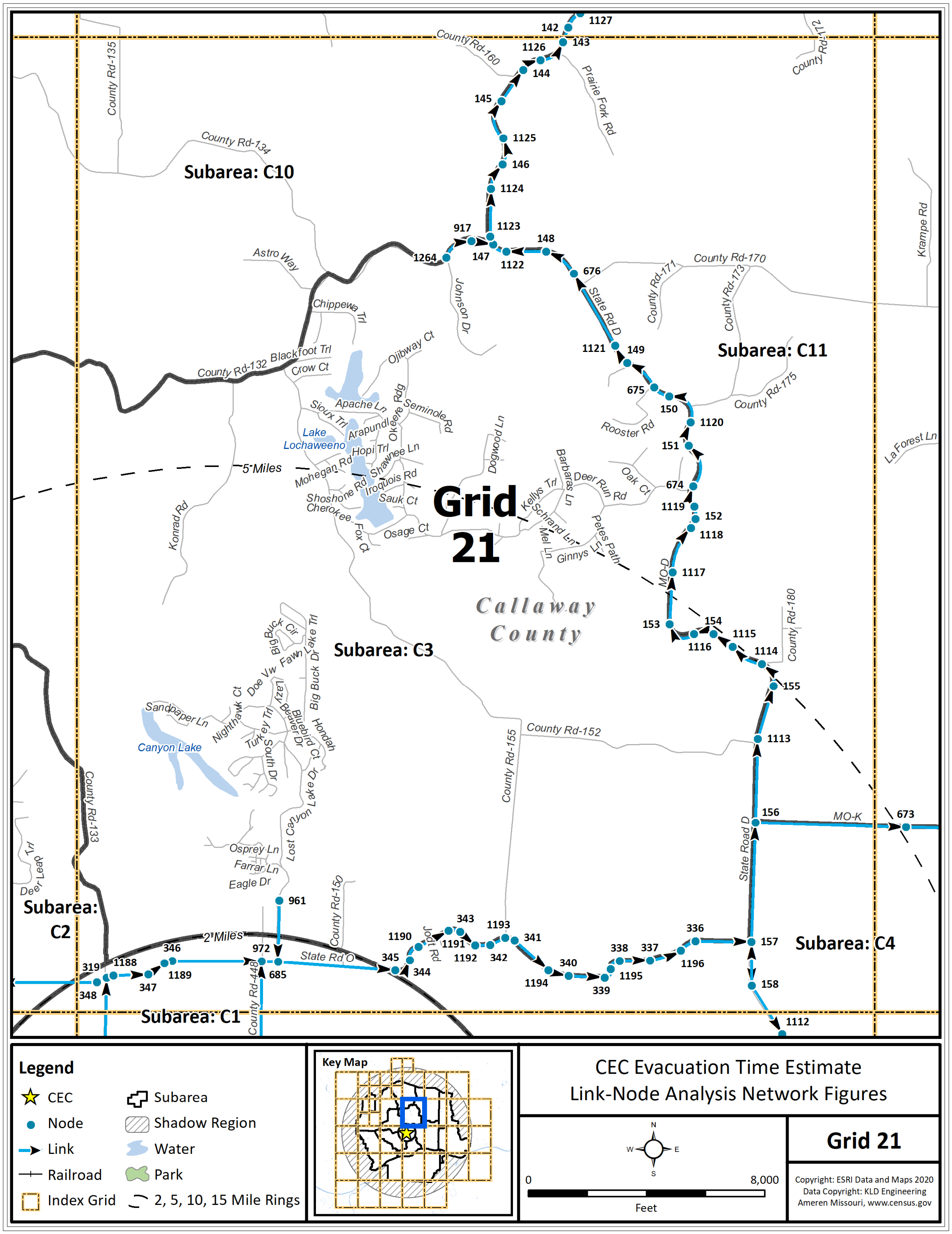


Figure K-22 Link-Node Analysis Network – Grid 21

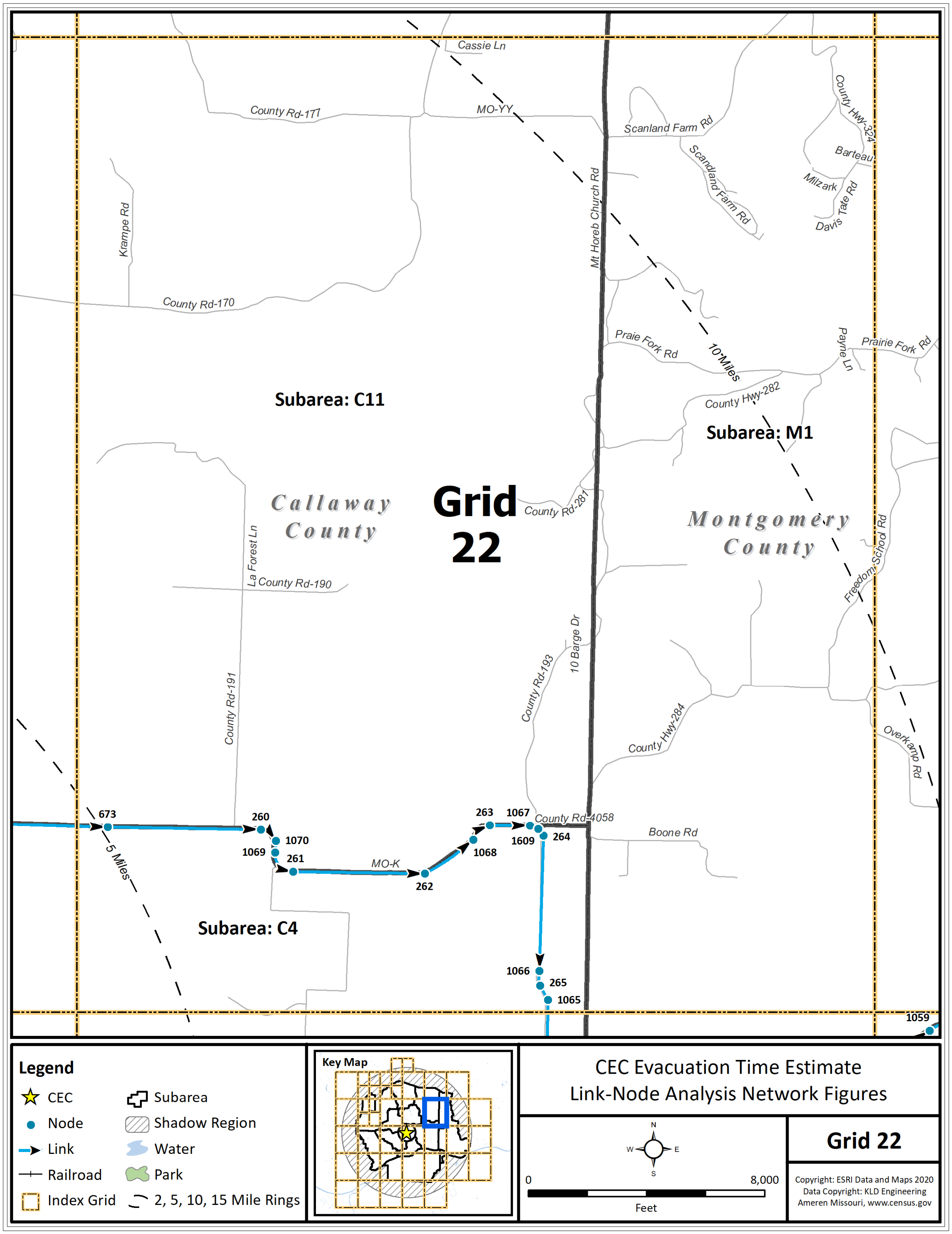


Figure K-23Link-Node Analysis Network – Grid 22

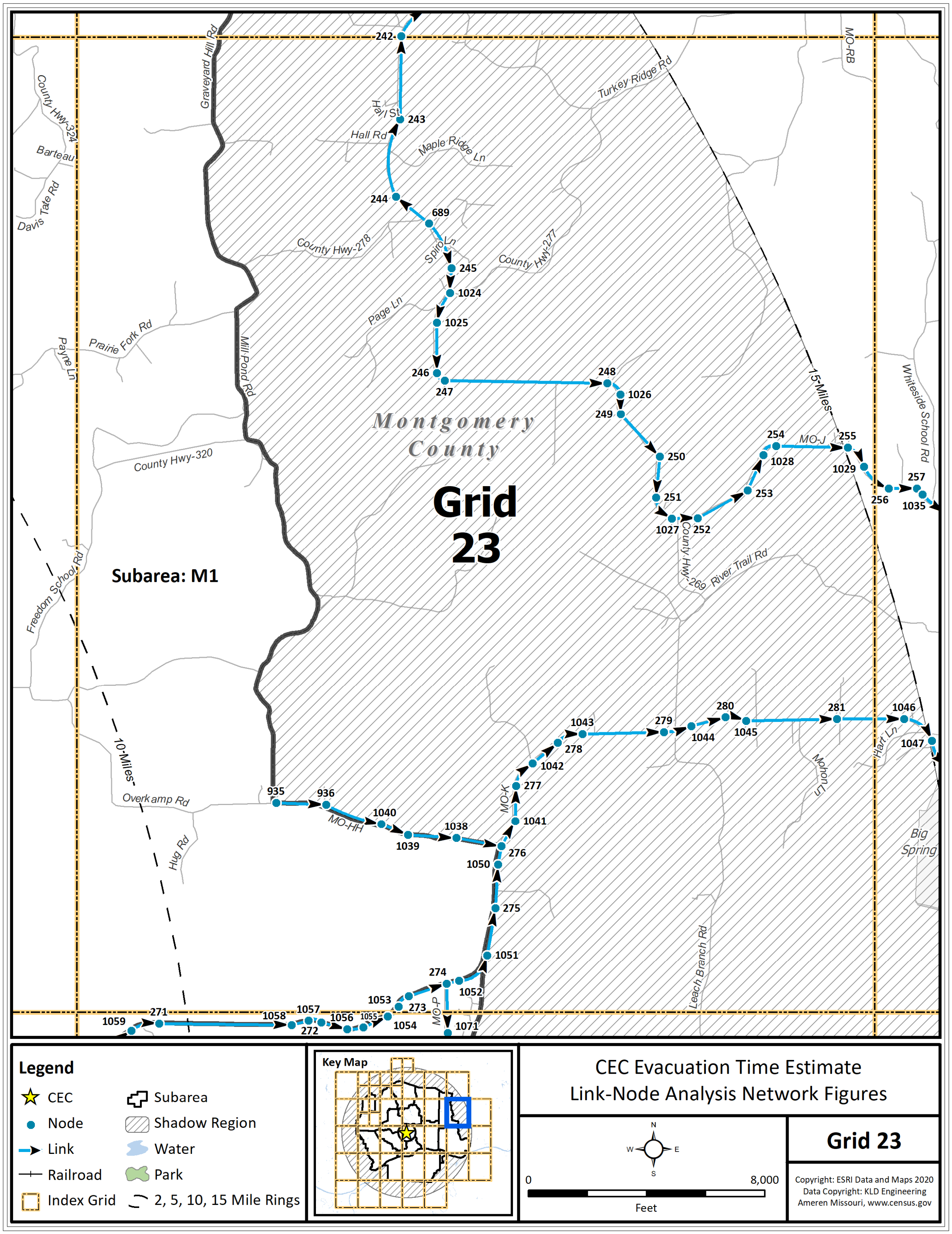


Figure K-24 Link-Node Analysis Network – Grid 23

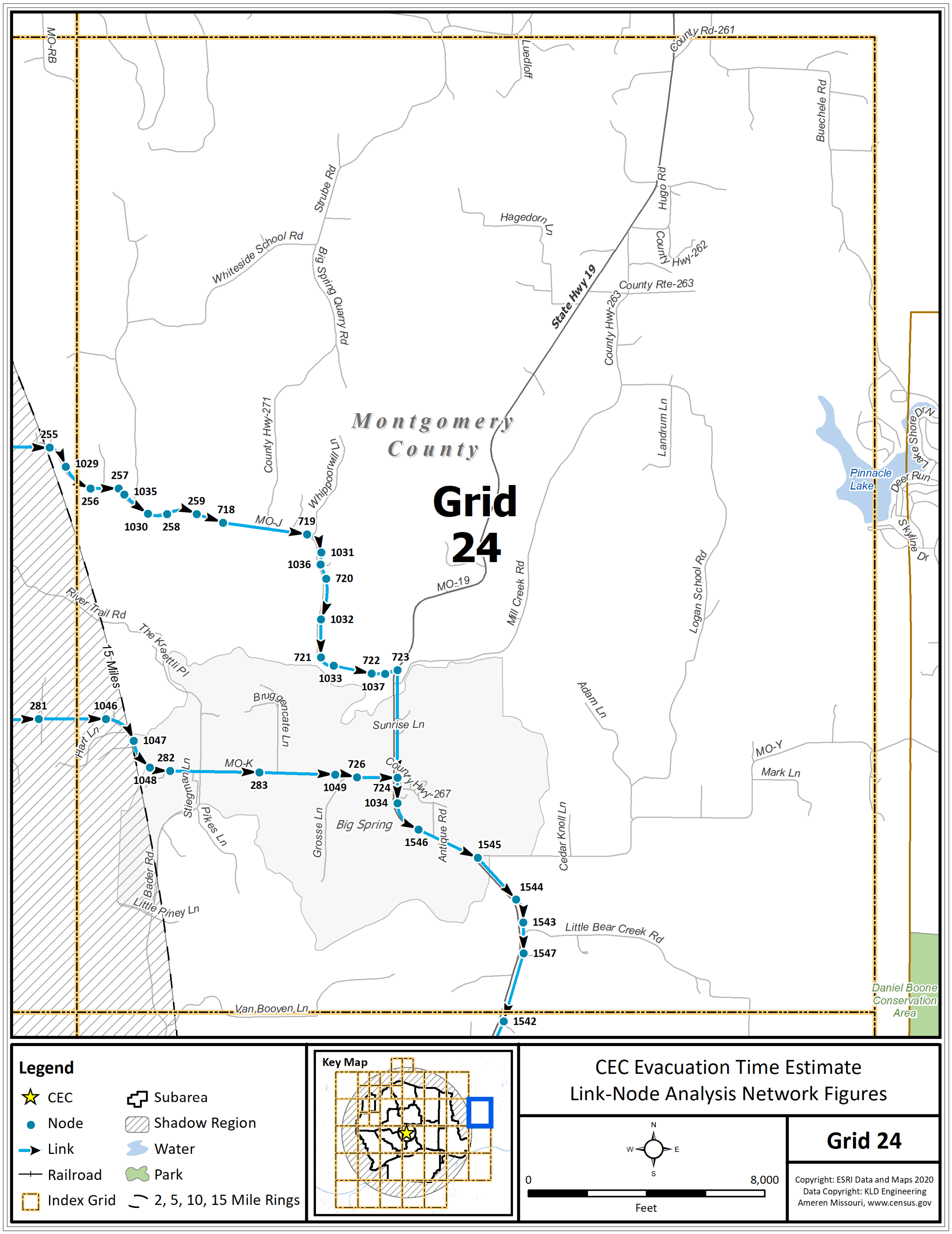


Figure K-25 Link-Node Analysis Network – Grid 24

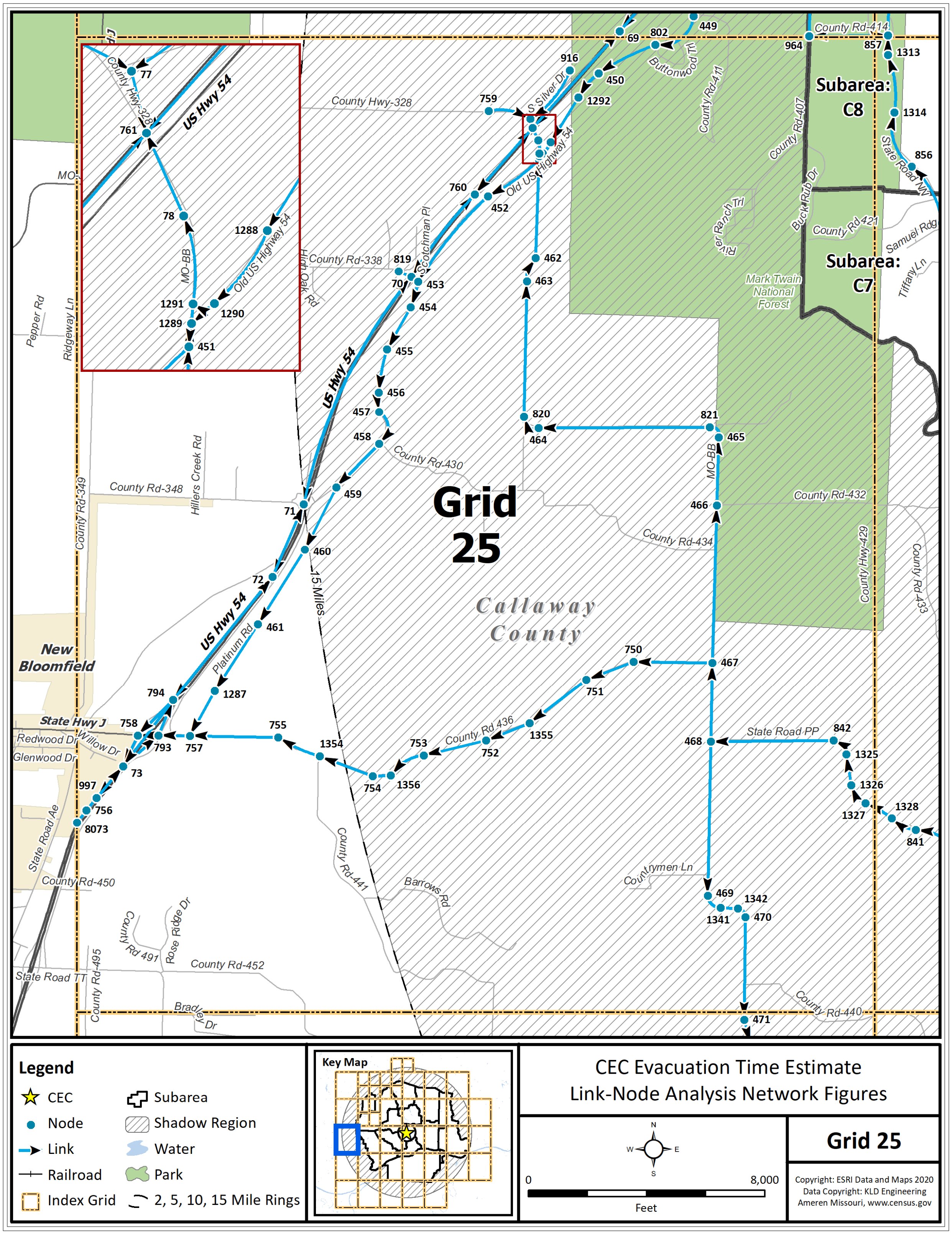


Figure K-26 Link-Node Analysis Network – Grid 25

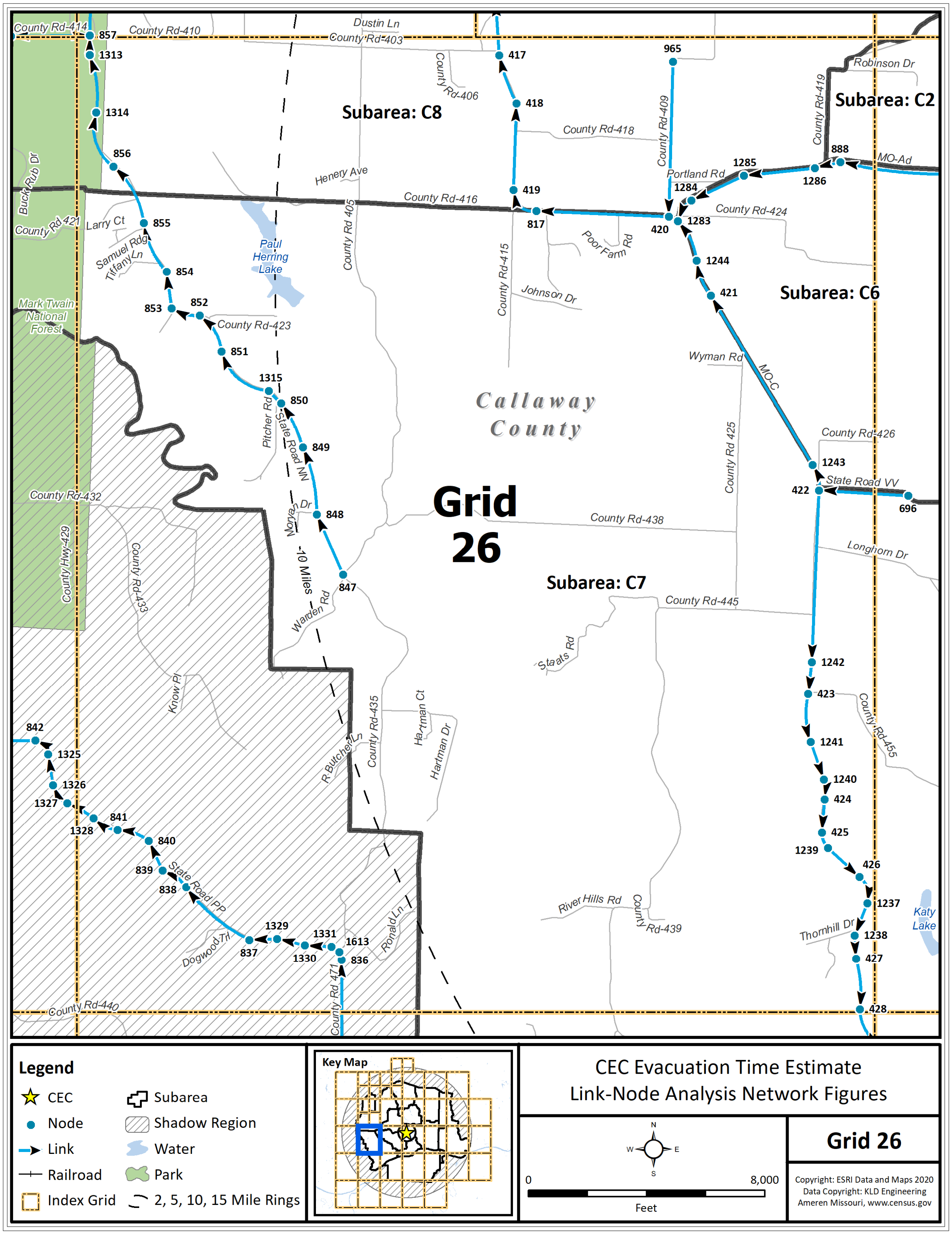


Figure K-27 Link-Node Analysis Network – Grid 26

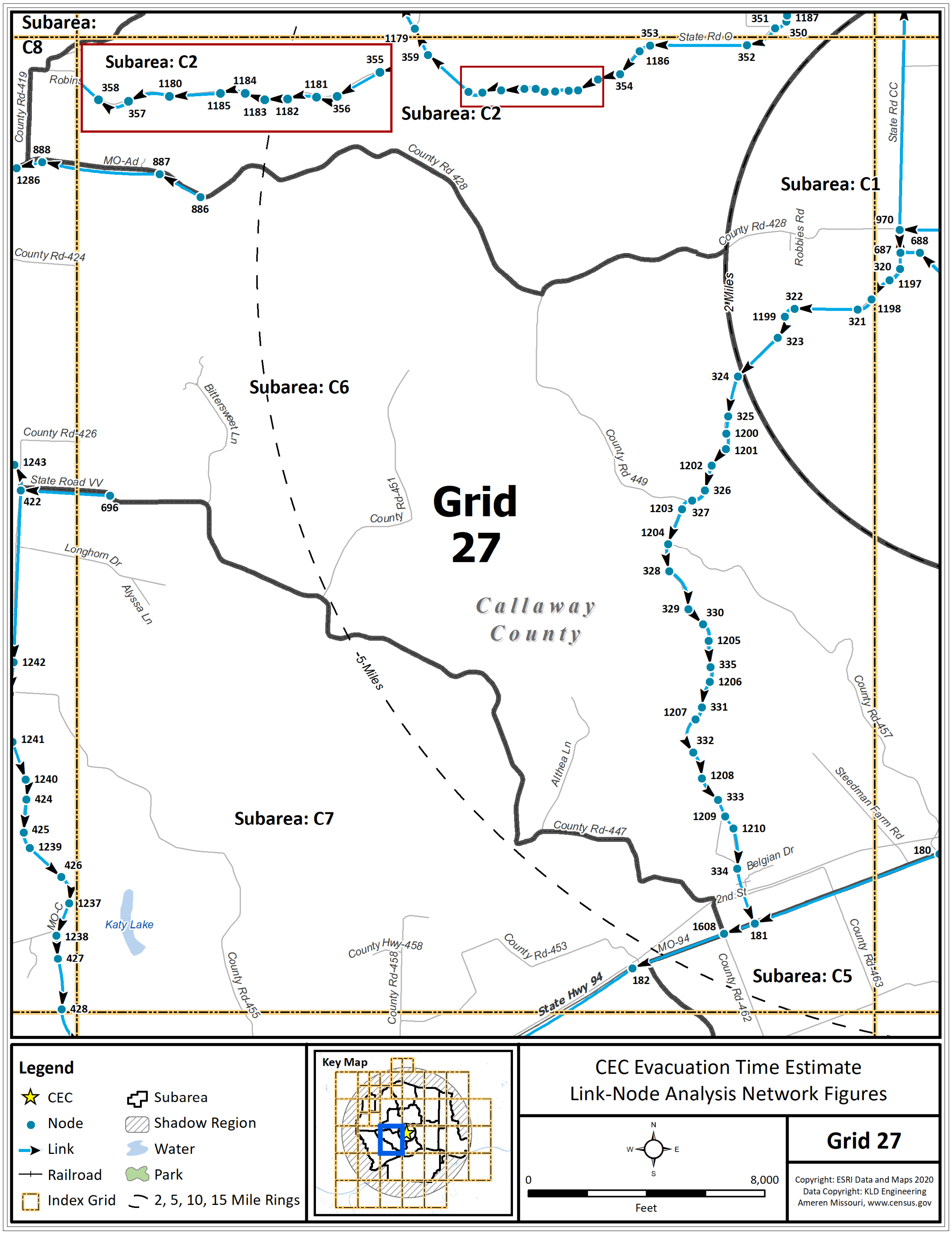


Figure K-28 Link-Node Analysis Network – Grid 27

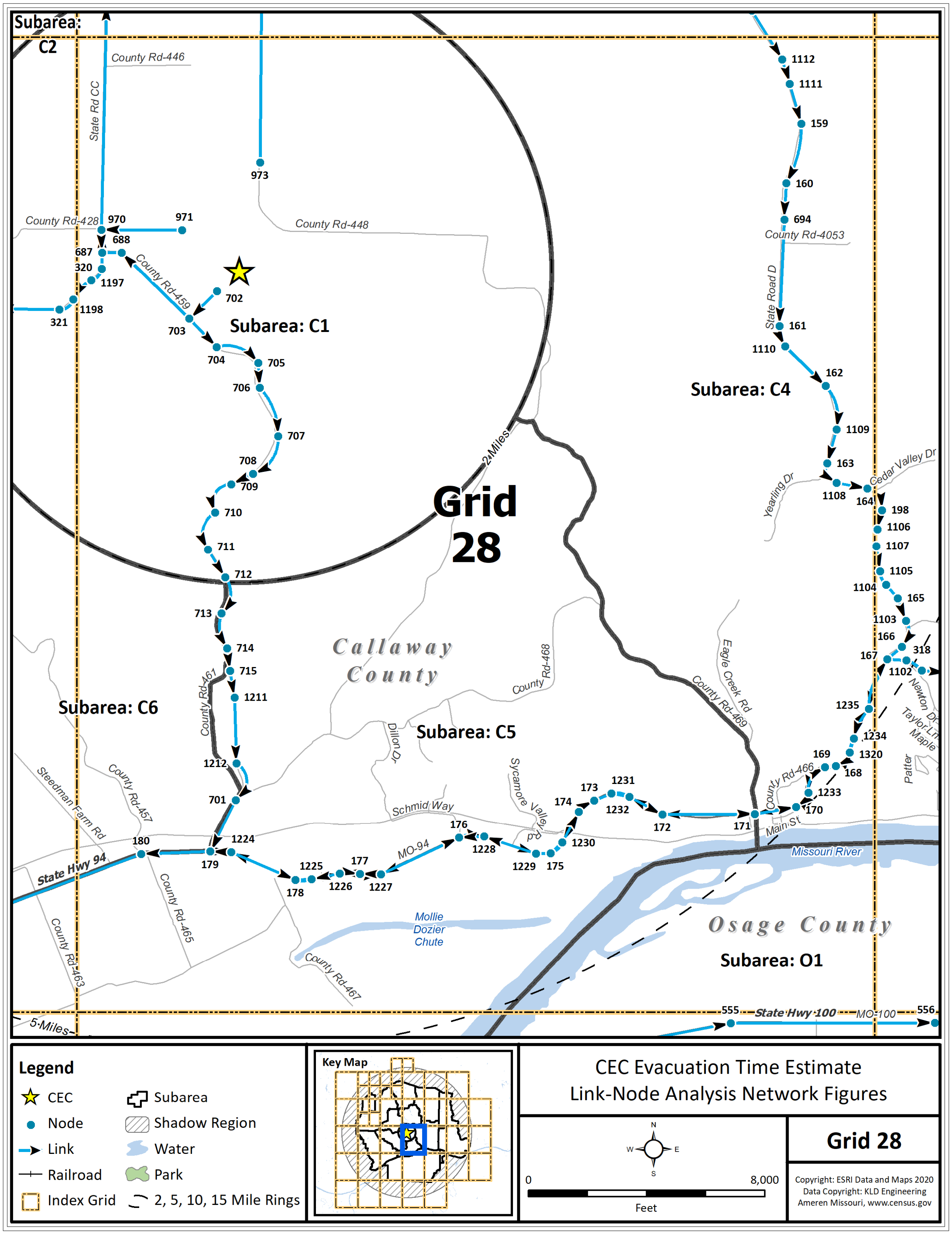


Figure K-29 Link-Node Analysis Network – Grid 28

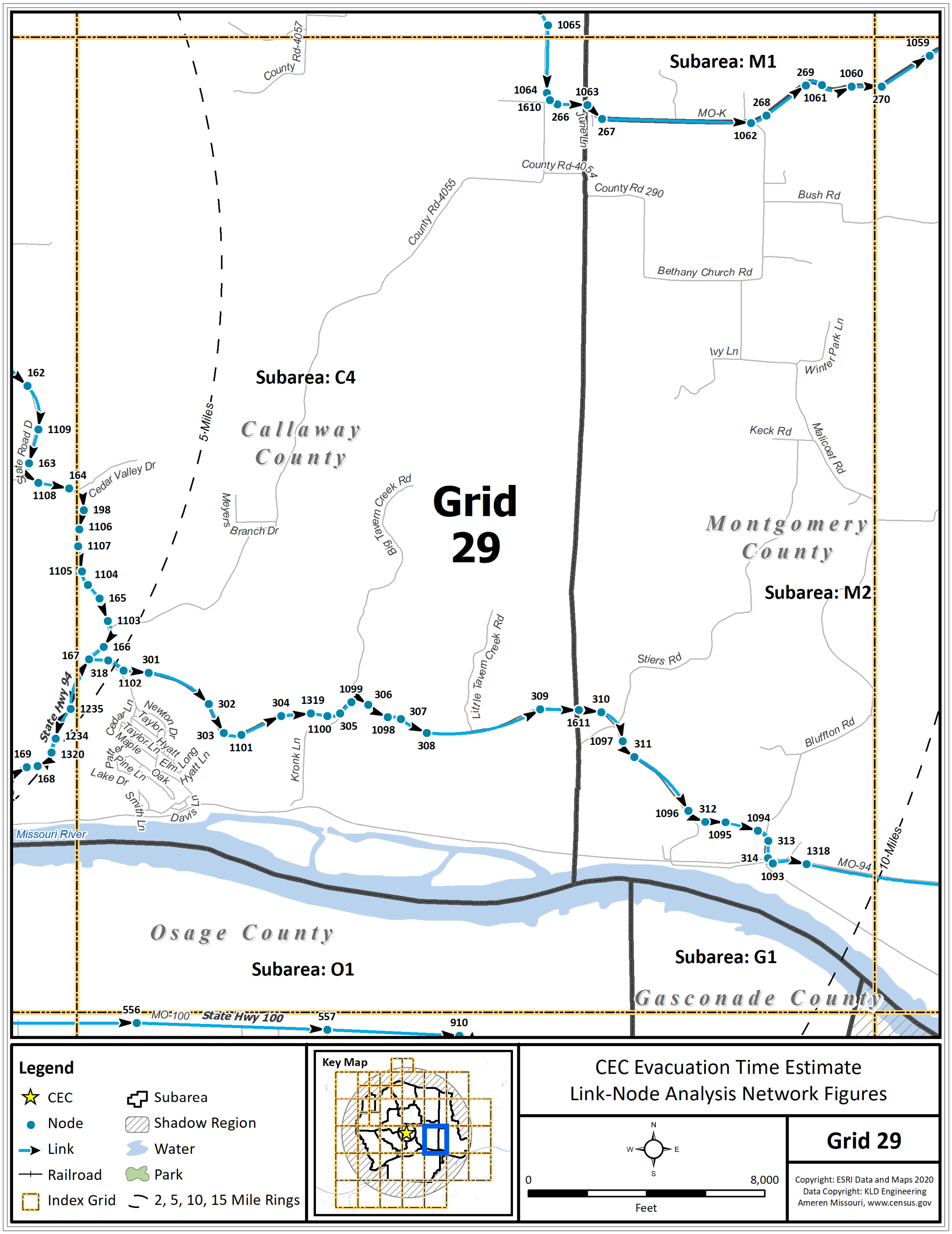


Figure K-30 Link-Node Analysis Network – Grid 29

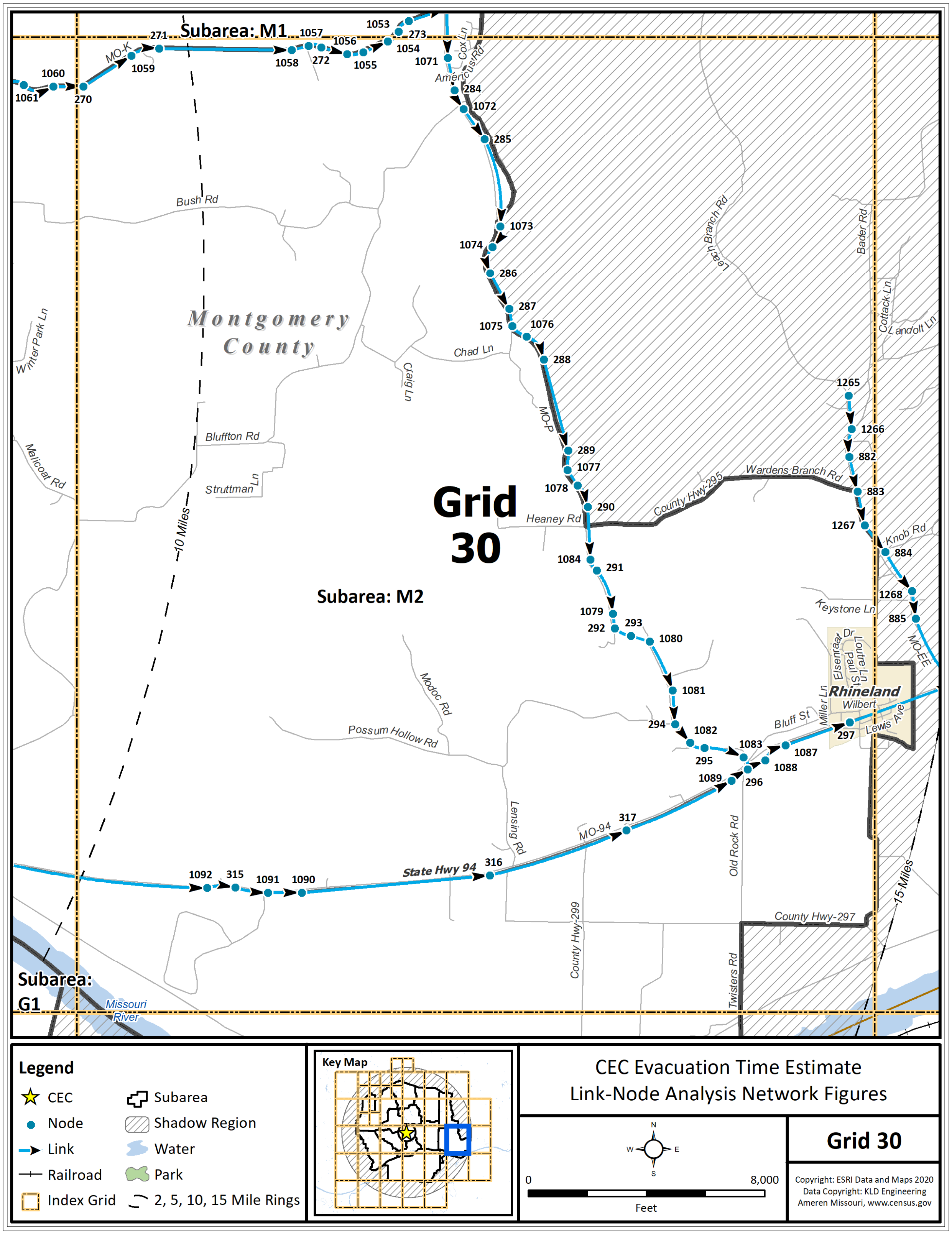


Figure K-31 Link-Node Analysis Network – Grid 30

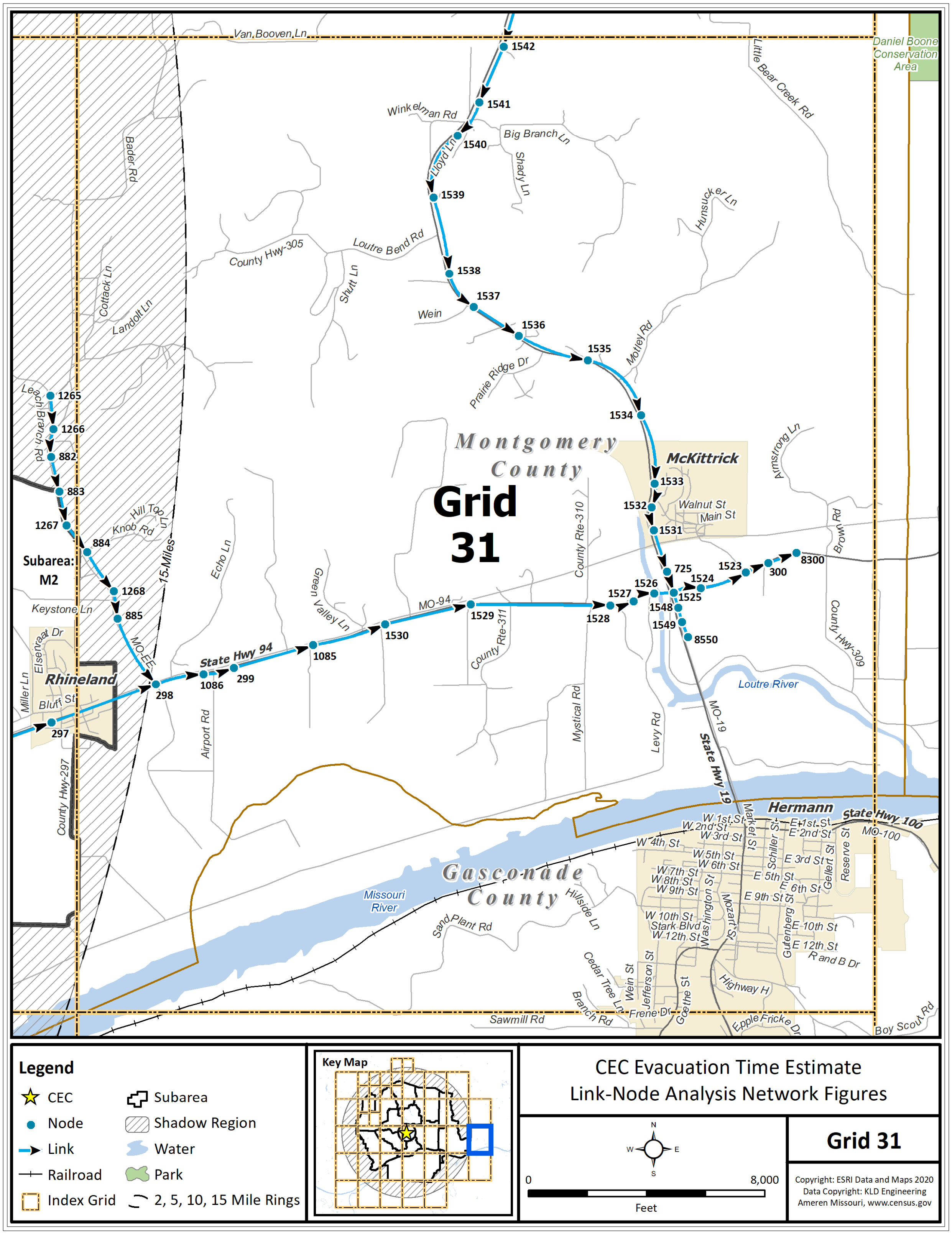


Figure K-32 Link-Node Analysis Network – Grid 31

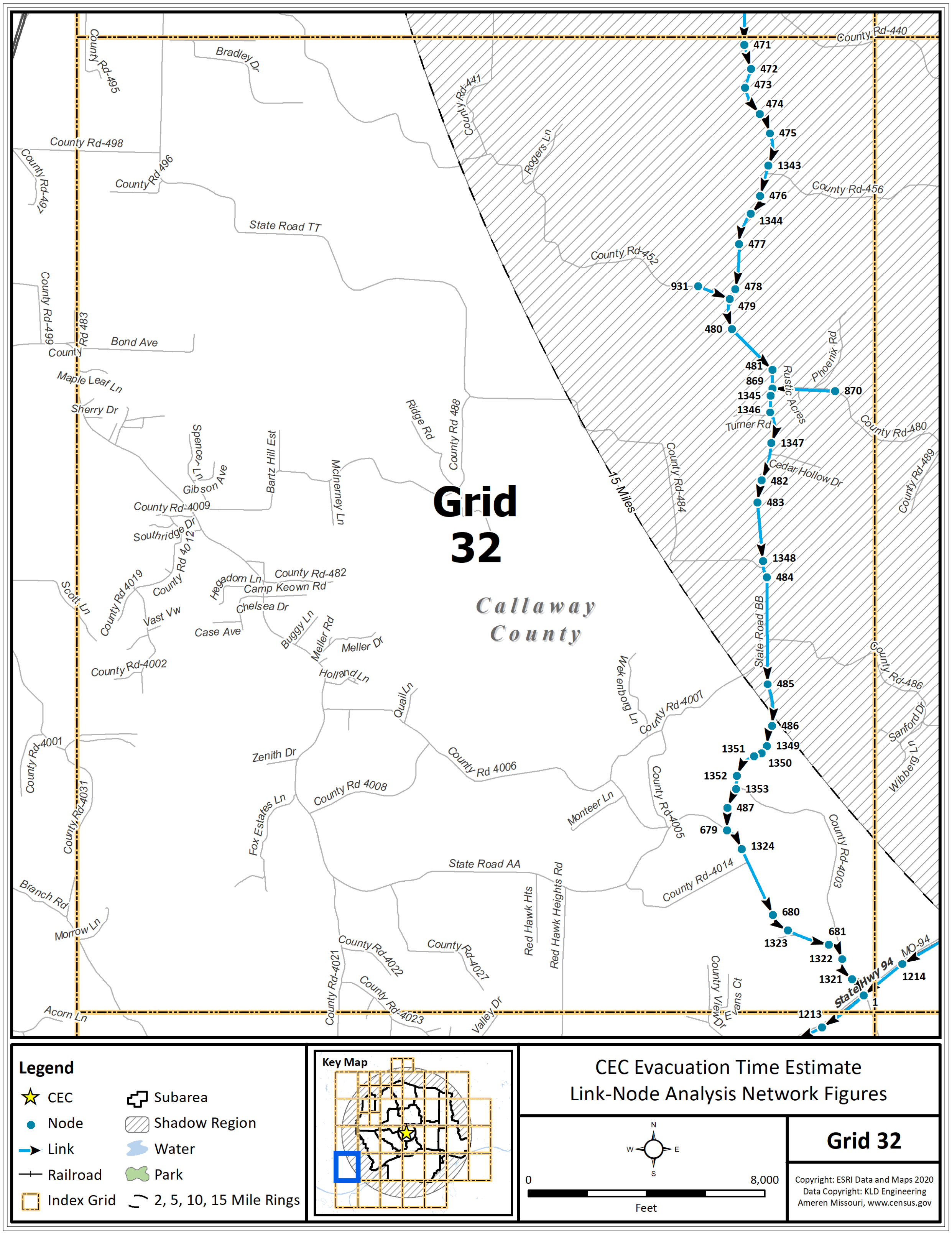


Figure K-33 Link-Node Analysis Network – Grid 32

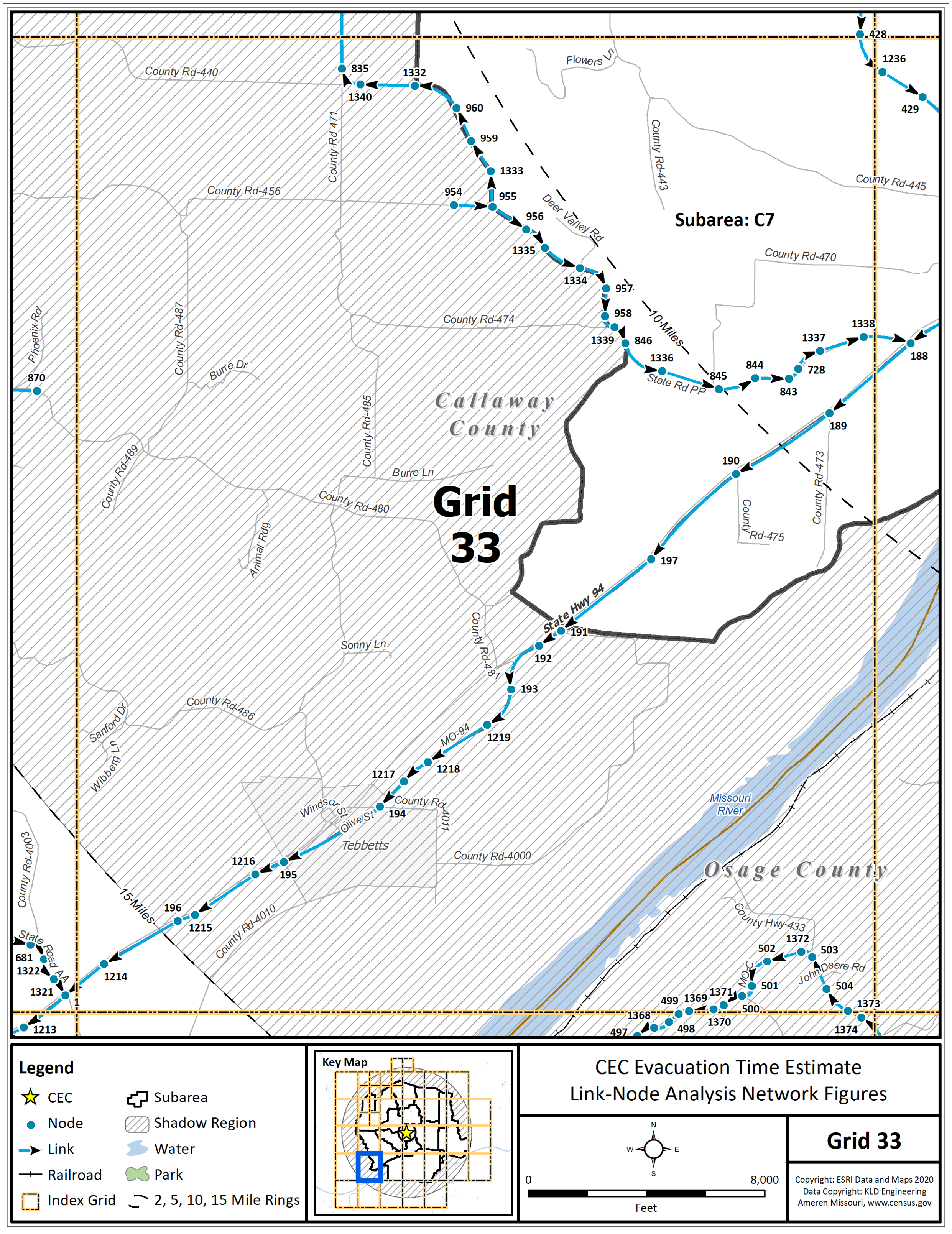


Figure K-34 Link-Node Analysis Network – Grid 33

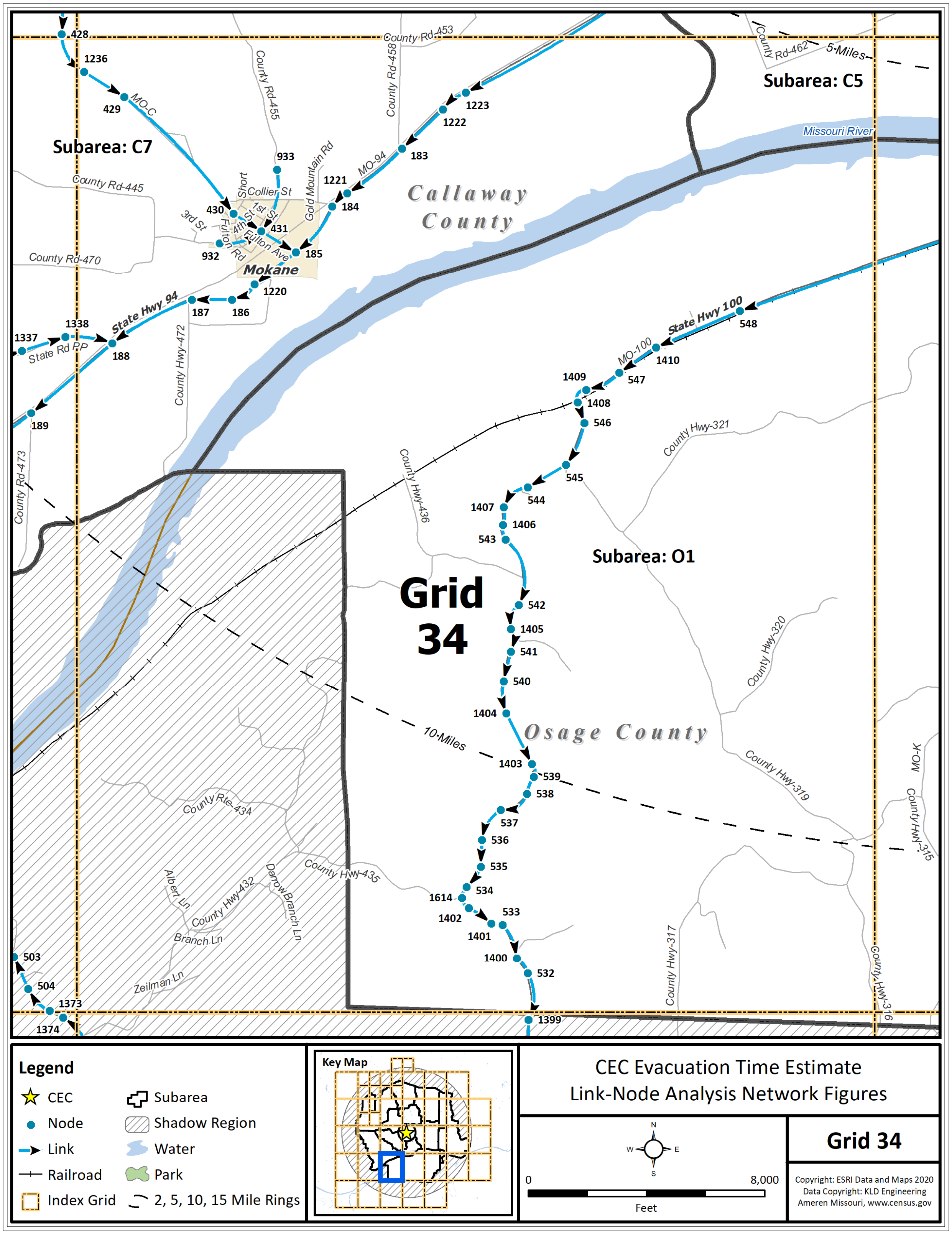


Figure K-35 Link-Node Analysis Network – Grid 34

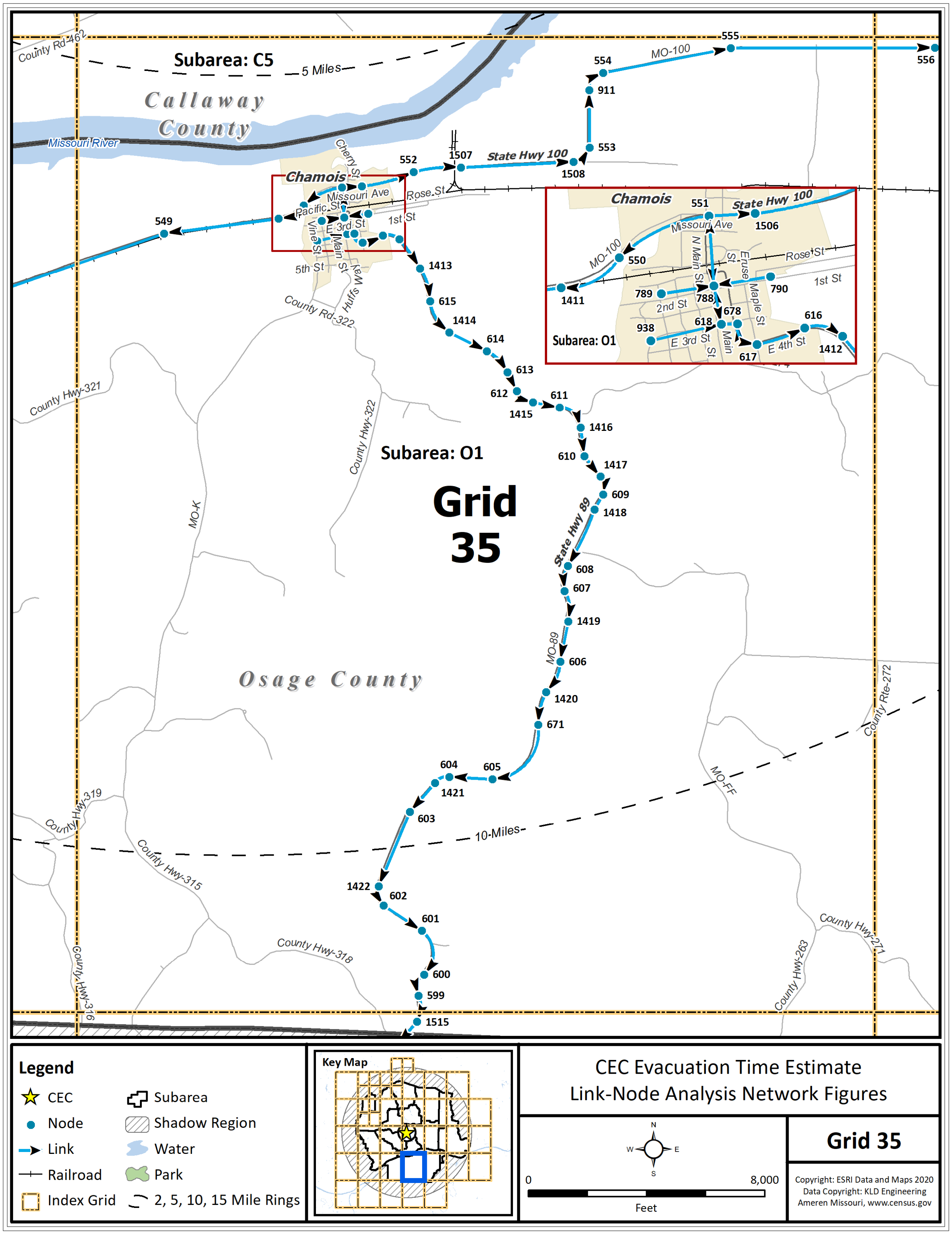


Figure K-36 Link-Node Analysis Network – Grid 35

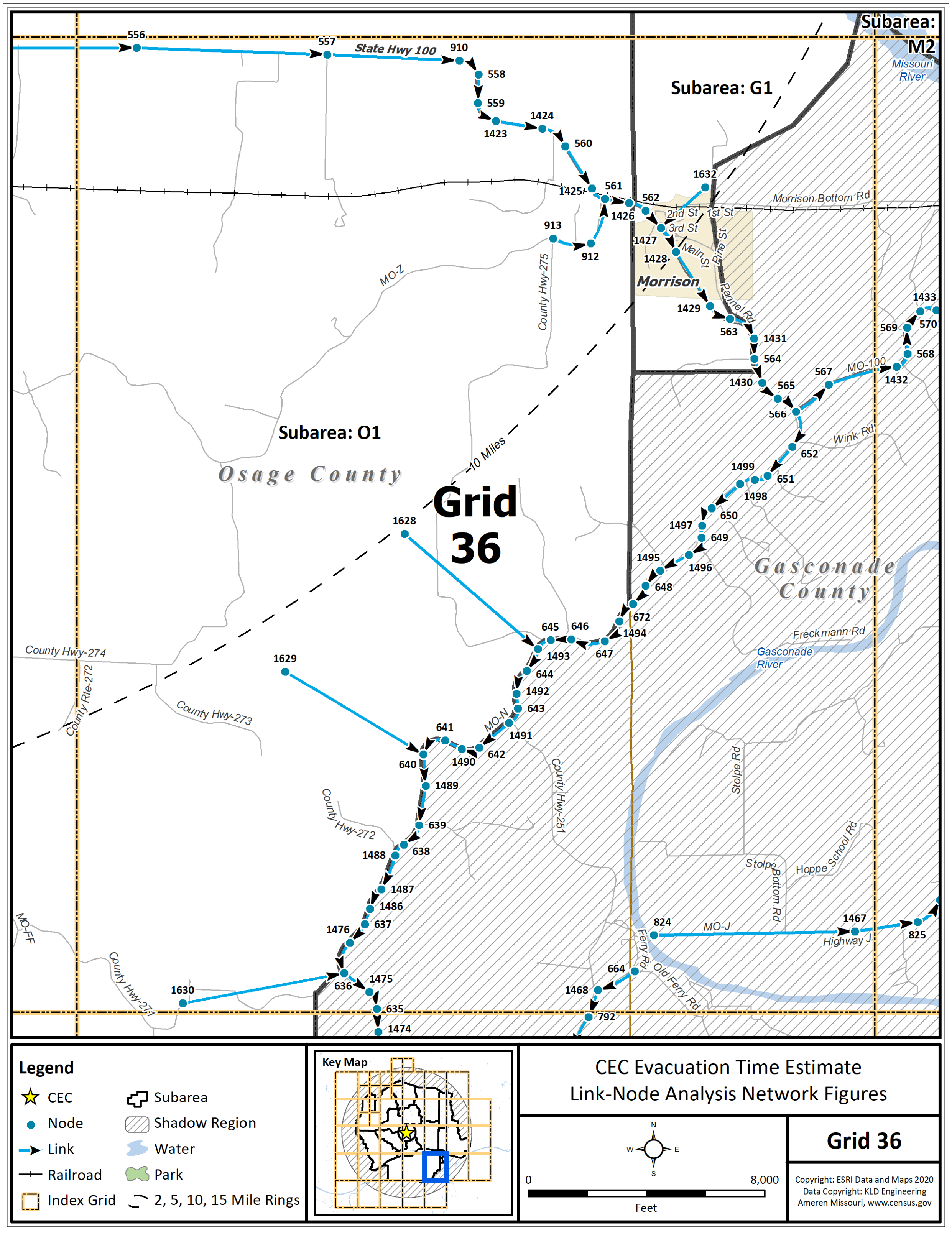


Figure K-37 Link-Node Analysis Network – Grid 36

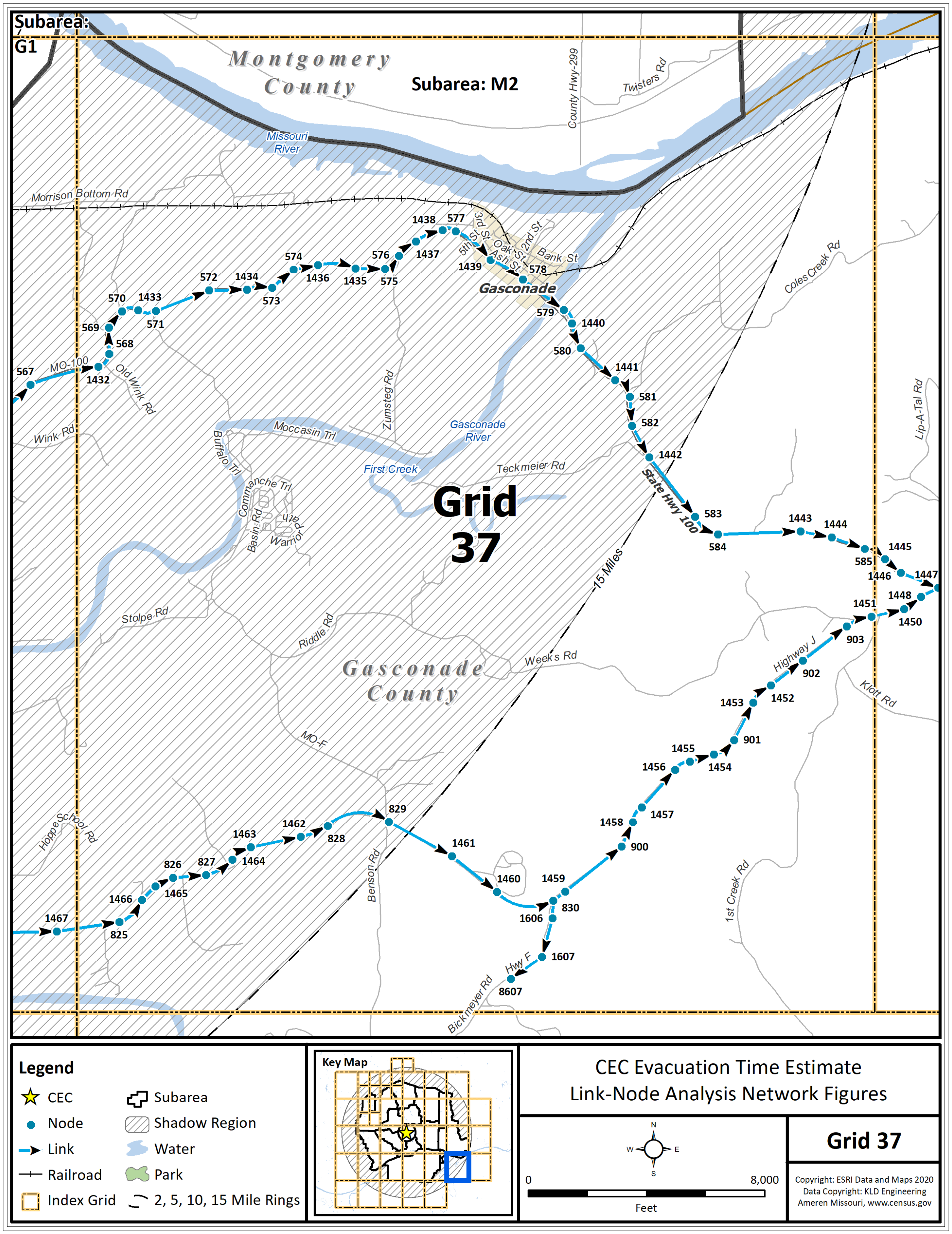


Figure K-38 Link-Node Analysis Network – Grid 37

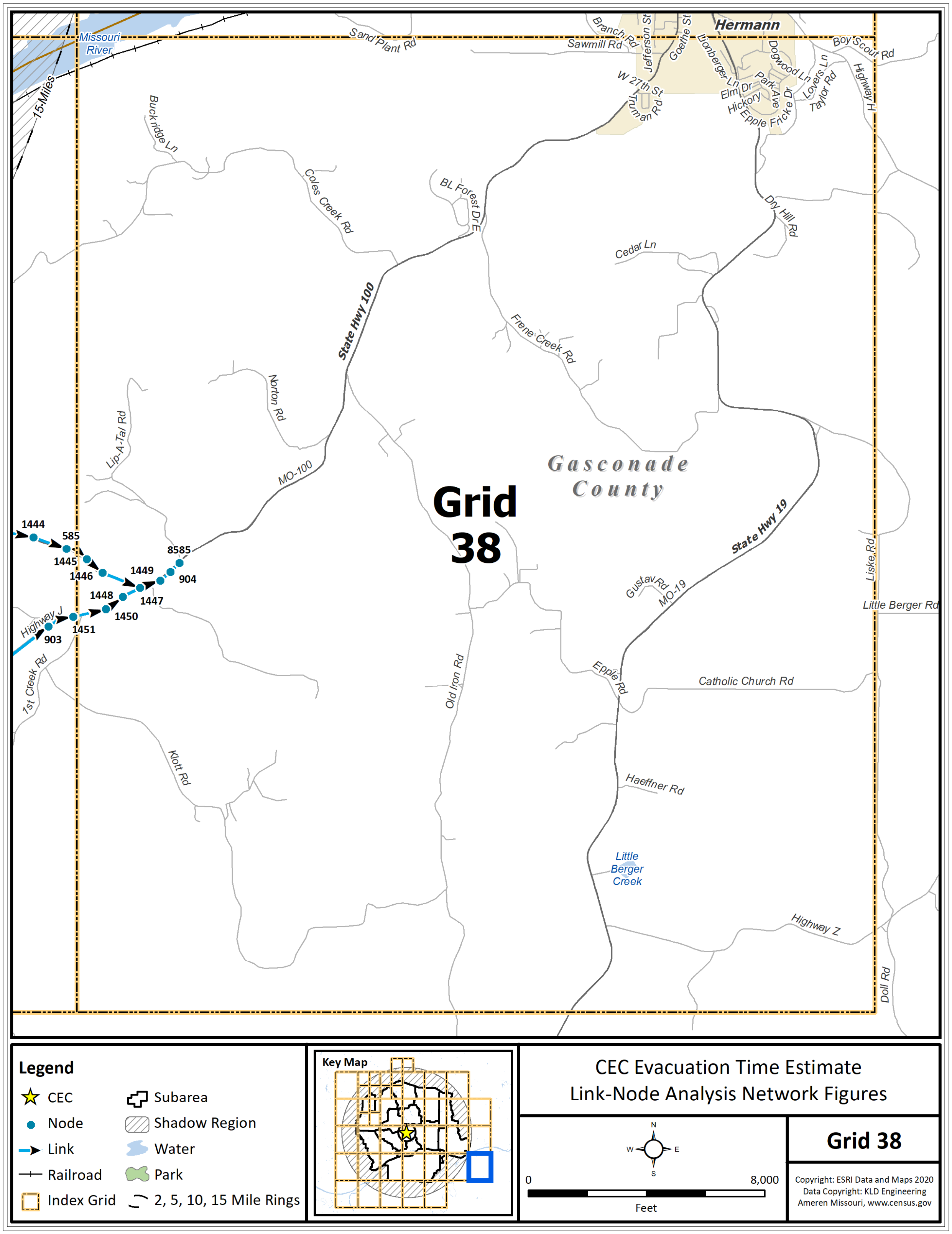


Figure K-39 Link-Node Analysis Network – Grid 38

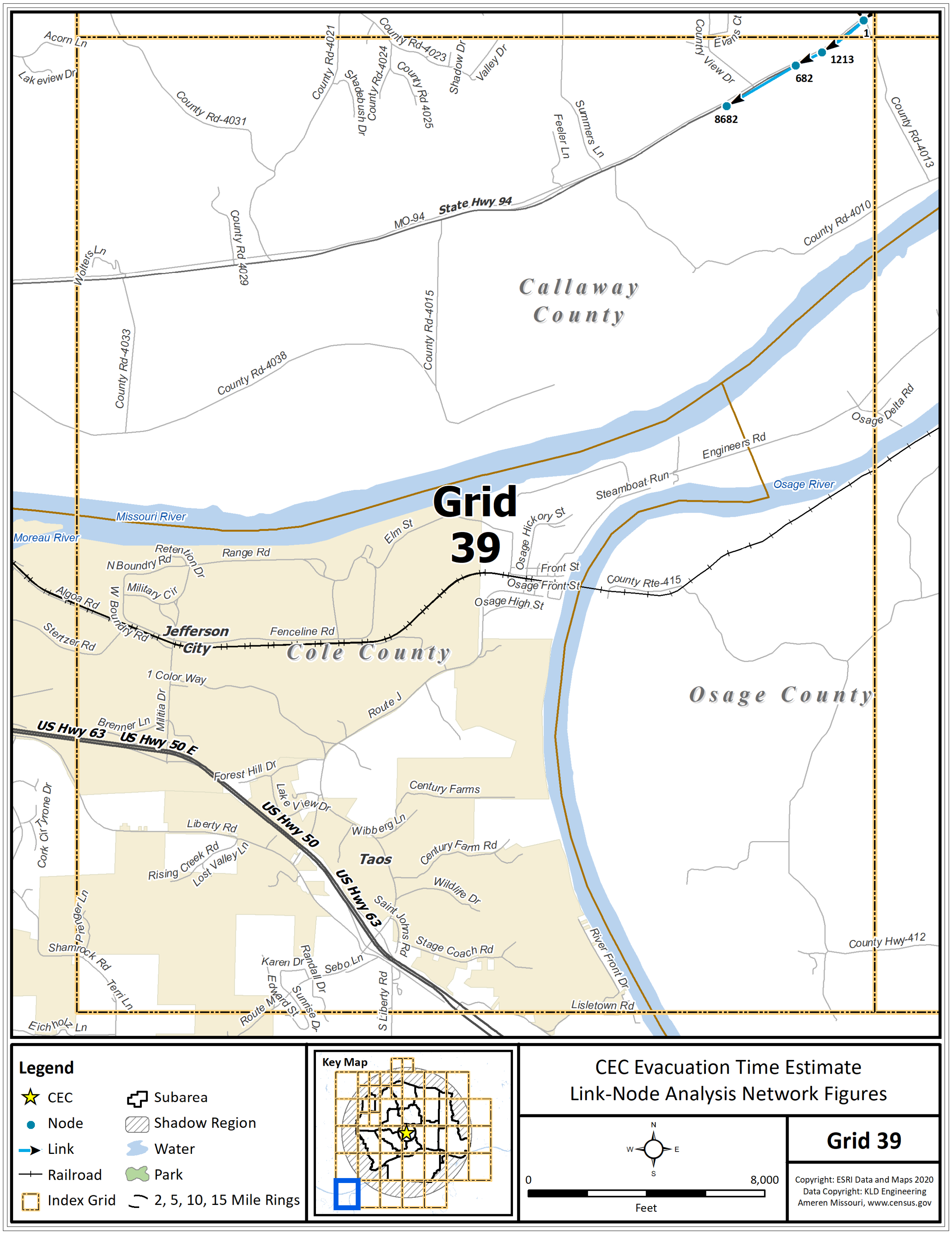


Figure K-40 Link-Node Analysis Network – Grid 39

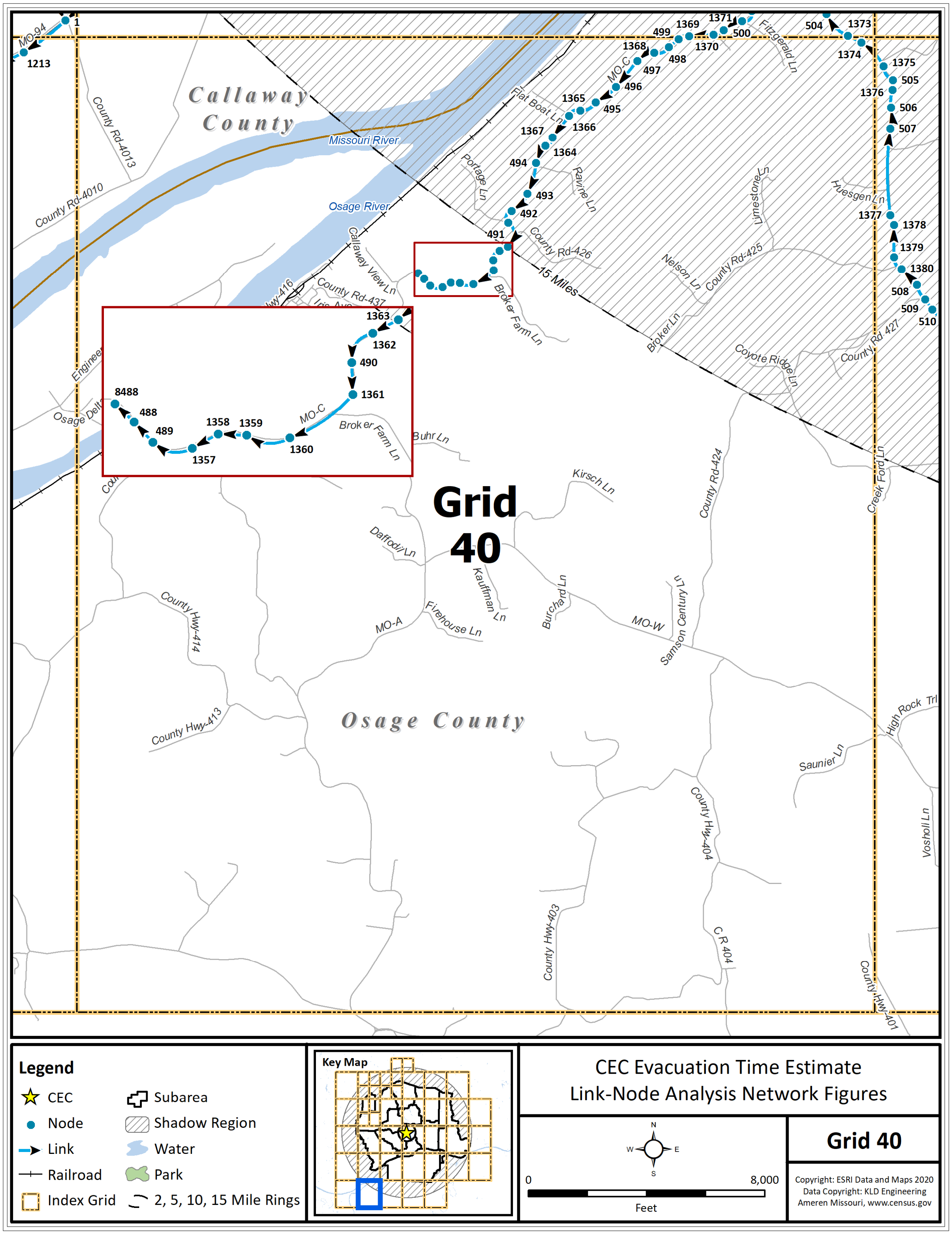


Figure K-41 Link-Node Analysis Network – Grid 40

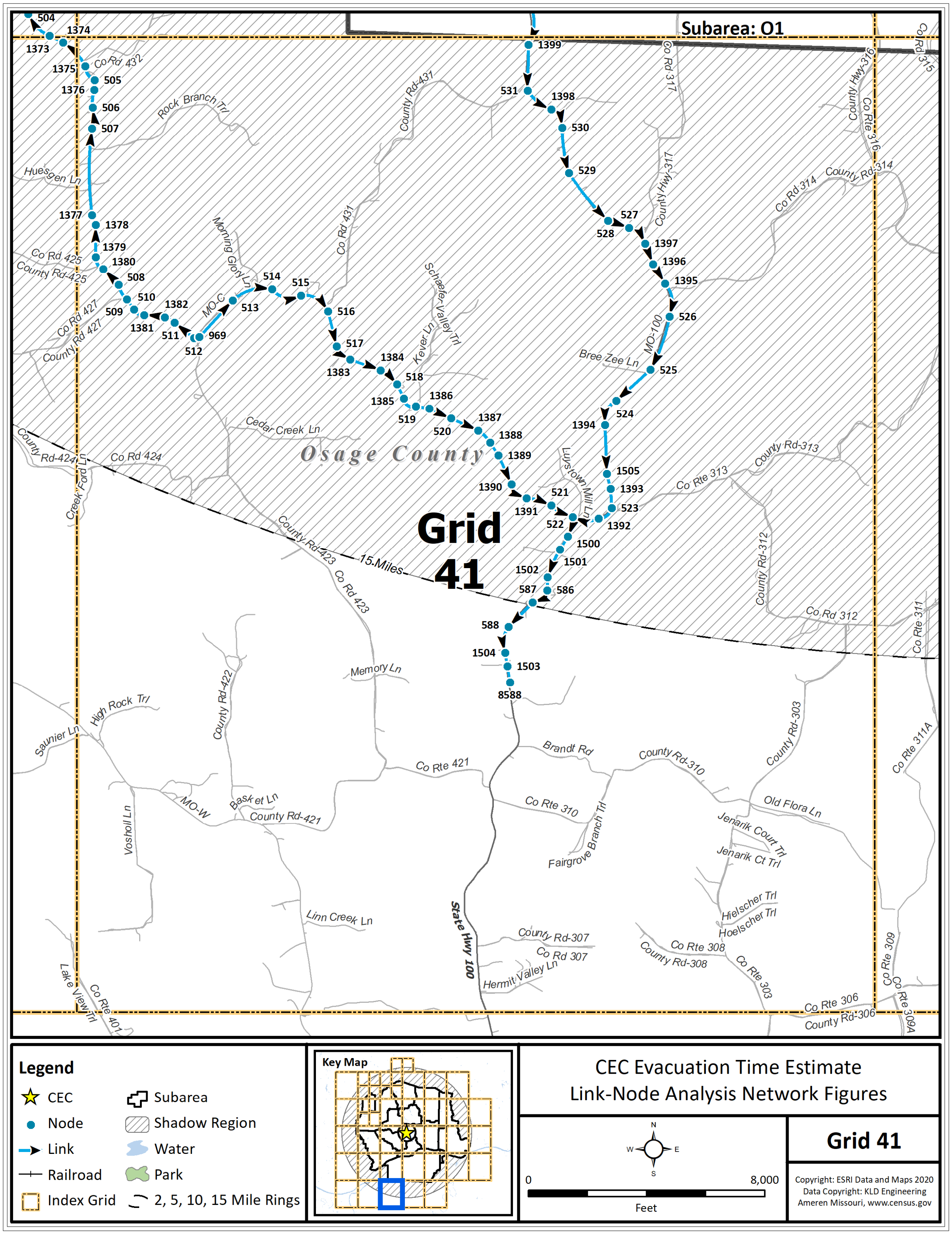


Figure K-42 Link-Node Analysis Network – Grid 41

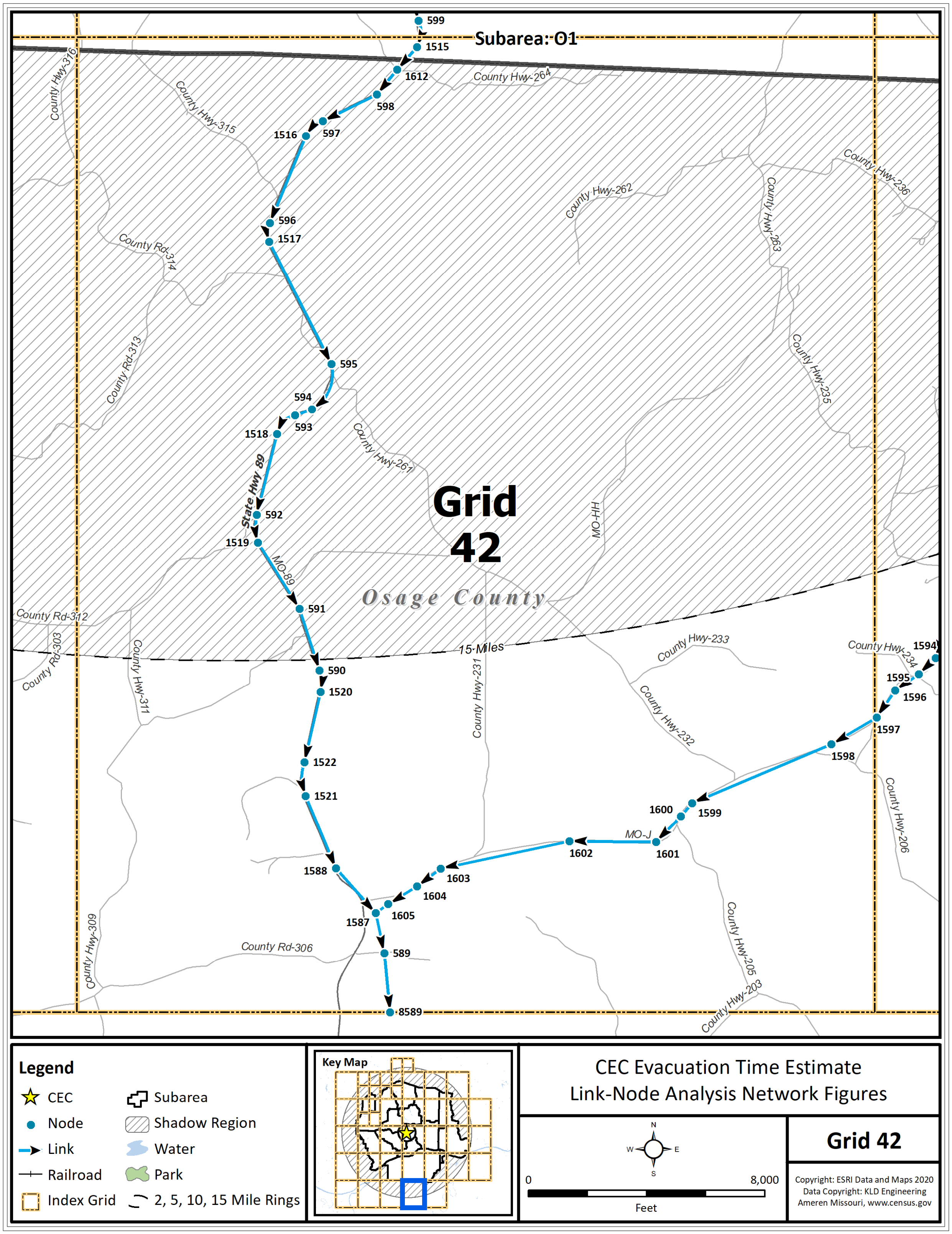


Figure K-43 Link-Node Analysis Network – Grid 42

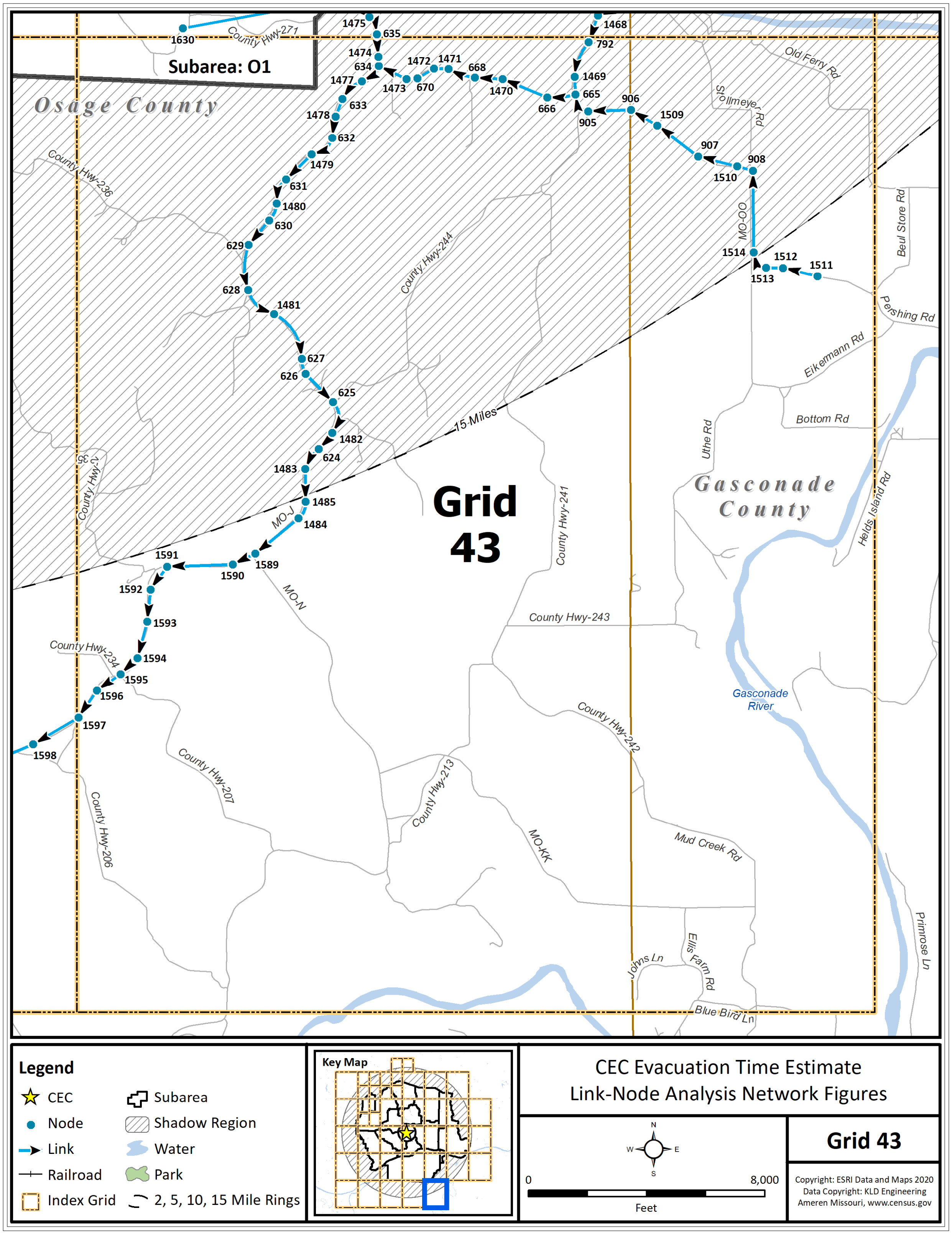


Figure K-44 Link-Node Analysis Network – Grid 43

APPENDIX L

Subarea Boundaries

L. SUBAREA BOUNDARIES

Subarea C1

County: Callaway

Defined as the area within the following boundary: The area within a two mile radius of the Callaway Energy Center.

Subarea C2

County: Callaway

Defined as the area within the following boundary: The area bounded by Route UU on the north; Route AD and County Road (CR)-428 on the south; CR-111 and CR-419 on the west; and CR-133 on the east.

Subarea C3

County: Callaway

Defined as the area within the following boundary: The area bounded by CR-132 and CR-134 on the north; Route O on the south; Route D on the east; and CR-133 on the west.

Subarea C4

County: Callaway

Defined as the area within the following boundary: The area bounded by Routes O and K on the north; the Missouri River on the south; the Montgomery County line on the east; and CR-469 and CR-448 on the west.

Subarea C5

County: Callaway

Defined as the area within the following boundary: The area bounded by CR-469 and CR-448 on the east; CR-459, Highway 94 and Auxvasse Creek on the west; the Missouri River on the south, and two miles from the plant on the north.

Subarea C6

County: Callaway

Defined as the area within the following boundary: The area bounded by Route AD and CR- 428 on the north; Highway 94 on the south; CR-459 on the east; and Routes C, VV, and CR- 447 on the west.

Subarea C7

County: Callaway

Defined as the area within the following boundary: The area south of Hams Prairie bounded on the north by Route C from Hams Prairie extended directly west to the Middle River; by Routes C, VV and CR-447 on the east; the Middle River on the west; and the Missouri River on the south.

Subarea C8 County: Callaway

Defined as the area within the following boundary: The area southeast of Fulton bounded by Route JJ, Route UU, CR-111 and CR-419, and Route AD on the east, Route C from Hams Prairie extended directly west to the Middle River on the south; and Route NN, Fulton city limits and Route Z on the west and north. This does not include the City of Fulton.

Subarea C9 County: Callaway

Defined as the area within the following boundary: The City of Fulton

Subarea C10 County: Callaway

Defined as the area within the following boundary: The area bounded by Route Z and Interstate (I)-70 on the north, CR-132 and CR-134 on the south, Route D on the east; and Route JJ on the west.

Subarea C11 County: Callaway

Defined as the area within the following boundary: The area bounded by I-70 on the north; Route K on the south; the Montgomery County line on the east; and Route D on the west.

Subarea G1 County: Gasconade

Defined as the area within the following boundary: The area south of the Missouri River, east of the Osage County line, and northwest of Shawnee Creek, including Morrison.

Subarea M1 County: Montgomery

Defined as the area within the following boundary: The area bounded by I-70 on the north; Route K on the south; the Callaway County line on the west; and CR-278 (Graveyard Hill Rd), CR-283 (Mill Pond Rd) and Route HH on the east.

Subarea M2 County: Montgomery

Defined as the area within the following boundary: The area bounded by Route K on the north; the Missouri River on the south; the Callaway County line on the west; and Route P, CR-295 and Route EE on the east, including the town of Rhineland.

Subarea O1 County: Osage

Defined as the area within the following boundary: The area east of St. Aubert, west of Route N, and within five miles of the Missouri River.

APPENDIX M

Evacuation Sensitivity Studies

M. EVACUATION SENSITIVITY STUDIES

This appendix presents the results of a series of sensitivity analyses. These analyses are designed to identify the sensitivity of the Evacuation Time Estimates (ETE) to changes in some base evacuation conditions.

M.1 Effect of Changes in Trip Generation Times

A sensitivity study was performed to determine whether changes in the estimated trip generation time have an effect on the ETE for the entire Emergency Planning Zone (EPZ). Specifically, if the tail of the mobilization distribution were truncated (i.e., if those who responded most slowly to the Advisory to Evacuate (ATE), could be persuaded to respond much more rapidly) or if the tail were elongated (i.e. spreading out the departure of evacuees to limit the demand during peak times), how would the ETE be affected? The case considered was Scenario 6, Region 3; a winter (school in session), midweek, midday, with good weather evacuation of the entire EPZ. Table M-1 presents the results of this study.

If evacuees mobilize one hour quicker, the 90th and 100th percentile ETE are reduced by 25 minutes and 1 hour, respectively. If evacuees mobilize one hour slower, the 90th and 100th percentile ETE are increased by 30 minutes and 1 hour, respectively.

As discussed in Section 7.3, traffic congestion within the EPZ clears at 2 hours and 50 minutes after the ATE, well before the completion of trip generation time. As such, congestion dictates the 100th percentile until 2 hours and 50 minutes after the ATE. After this time, trip generation (plus a 10-minute travel time to the EPZ boundary), dictates the 100th percentile ETE. See Table M-1.

M.2 Effect of Changes in the Number of People in the Shadow Region Who Relocate

A sensitivity study was conducted to determine the effect on ETE due to changes in the percentage of people who decide to relocate from the Shadow Region. The case considered was Scenario 6, Region 3; a winter, midweek, midday, with good weather evacuation of the entire EPZ. The movement of people in the Shadow Region has the potential to impede vehicles evacuating from an Evacuation Region within the EPZ. Refer to Sections 3.2 and 7.1 for additional information on population within the Shadow Region.

Table M-2 presents the ETE for each of the cases considered. The results show that the ETE is not impacted by the elimination, reduction or increase in shadow evacuation. (Note that the demographic survey results presented in Appendix F, indicate that 10% of households would elect to evacuate if advised to shelter, which is half the base assumption of 20% non-compliance suggested in the NUREG/CR-7002, Rev. 1).

The Shadow Region is sparsely populated. As shown in Figure 7-3 through Figure 7-7, the only congestion in the Shadow Region outside of Fulton and is caused by evacuees from Fulton, not from those evacuating from the Shadow Region. In addition, this congestion dissipates by 2 hours and 50 minutes after the ATE. Any additional shadow residents that decide to voluntarily evacuate

are accommodated by the excess capacity available in the study area such that ETE are not impacted.

M.3 Effect of Changes in EPZ Resident Population

A sensitivity study was conducted to determine the effect on ETE due to changes in the permanent resident population within the study area (EPZ plus Shadow Region). As population in the study area changes over time, the time required to evacuate the public may increase, decrease, or remain the same. Since the ETE is related to the demand to capacity ratio present within the study area, changes in population will cause the demand side of the equation to change and could impact ETE.

As per the NRC's response to the Emergency Planning Frequently Asked Question (EPFAQ) 2013-001, the ETE population sensitivity study must be conducted to determine what percentage increase in permanent resident population causes an increase in the 90th percentile ETE of 25% or 30 minutes, whichever is less. The sensitivity study must use the scenario with the longest 90th percentile ETE (excluding the roadway impact scenario and the special event scenario if it is a one day per year special event).

Thus, the sensitivity study was conducted using the following planning assumptions:

1. The percent change in population within the study area was increased by up to 20%. Changes in population were applied to permanent residents only (as per federal guidance), in both the EPZ area and the Shadow Region.
2. The transportation infrastructure remained fixed (as presented in Appendix K); the presence of future proposed roadway changes and/or highway capacity improvements were not considered.
3. The study was performed for the 2-Mile Region, the 5-Mile Region and the entire EPZ (Full EPZ).
4. The scenario (excluding roadway impact and special event) which yielded the highest 90th percentile ETE values for the Full EPZ was selected as the case to be considered in this sensitivity study (Scenario 8 – Winter, Midweek, Midday with Heavy Snow).

Table M-3 presents the results of the sensitivity study. Section IV of Appendix E to 10 CFR Part 50, and NUREG/CR-7002, Section 5.4, require licensees to provide an updated ETE analysis to the NRC when a population increase within the EPZ causes the longest 90th percentile ETE values (for the 2-Mile Region, 5-Mile Region or entire EPZ) to increase by 25% or 30 minutes, whichever is less. Note that the base ETE Values for the 2-Mile Region (R01) is less than 2 hours; R01 criterion for updated is 25 minutes (100 minutes multiplied by 25%). Base ETE values for 5-mile Region and the entire EPZ (R03) are greater than 2 hours; therefore, the criterion for updating is 30 minutes.

Those percent population changes which result in a 90th percentile ETE greater than the respective criterion for each region are highlighted in red below – a 19% or greater increase in the 2-mile Region permanent resident population. Ameren Missouri will have to estimate the

EPZ population on an annual basis. If the EPZ population increases by 19% or more, an updated ETE analysis will be needed.

Table M-1. Evacuation Time Estimates for Trip Generation Sensitivity Study

Trip Generation Period	Evacuation Time Estimate for Entire EPZ	
	90th Percentile	100th Percentile
3 hours and 45 minutes	2:25	3:55
4 hours and 45 minutes (Base)	2:50	4:55
5 hours and 45 minutes	3:20	5:55

Table M-2. Evacuation Time Estimates for Shadow Sensitivity Study

Percent Shadow Evacuation	Evacuating Shadow Vehicles[1]	Evacuation Time Estimate for Entire EPZ	
		90th Percentile	100th Percentile
0	0	2:50	4:55
10	386	2:50	4:55
20 (Base)	772	2:50	4:55
40	1,543	2:50	4:55
60	2,315	2:50	4:55
80	3,086	2:50	4:55
100	3,858	2:50	4:55

[1] The Evacuating Shadow Vehicles, in Table M-2, represent the residents and employees who will spontaneously decide to relocate during the evacuation. The basis, for the base values shown, is a 20% relocation of shadow residents along with a proportional percentage of shadow employees. See Section 6 for further discussion.

Table M-3. ETE Variation with Population Change

EPZ and 20% Shadow Permanent Resident Population	Base	Population Change		
		18%	19%	20%
	20,870	24,627	24,835	25,044
ETE (hrs:mins) for the 90th Percentile				
Region	**Base**	**Population Change**		
		18%	**19%**	**20%**
2-MILE	1:40	1:55	2:05	2:05
5-MILE	4:00	4:10	4:10	4:10
FULL EPZ	4:10	4:10	4:10	4:10
ETE (hrs:mins) for the 100th Percentile				
Region	**Base**	**Population Change**		
		18%	**19%**	**20%**
2-MILE	6:45	6:45	6:45	6:45
5-MILE	6:50	6:50	6:50	6:50
FULL EPZ	6:55	6:55	6:55	6:55

APPENDIX N

ETE Criteria Checklist

N. ETE CRITERIA CHECKLIST

Table N-1. ETE Review Criteria Checklist

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
1.0 Introduction		
a. The emergency planning zone (EPZ) and surrounding area is described.	Yes	Section 1
b. A map is included that identifies primary features of the site including major roadways, significant topographical features, boundaries of counties, and population centers within the EPZ.	Yes	Figures 1-1, 3-1, 6-1
c. A comparison of the current and previous ETE is provided including information similar to that identified in Table 1-1, “ETE Comparison.”	Yes	Table 1-3
1.1 Approach		
a. The general approach is described in the report as outlined in Section 1.1, “Approach.”	Yes	Section 1.1, Section 1.3, Appendix D, Table 1-1
1.2 Assumptions		
a. Assumptions consistent with Table 1-2, “General Assumptions,” of NUREG/CR-7002 are provided and include the basis to support use.	Yes	Section 2
1.3 Scenario Development		
a. The scenarios in Table 1-3, “Evacuation Scenarios,” are developed for the ETE analysis. A reason is provided for use of other scenarios or for not evaluating specific scenarios.	Yes	Section 6, Table 6-2

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
1.4 Evacuation Planning Areas		
a. A map of the EPZ with emergency response planning areas (ERPAs) is included.	Yes	Figure 3-1, Figure 6-1
1.4.1 Keyhole Evacuation		
a. A table similar to Table 1-4 "Evacuation Areas for a Keyhole Evacuation", is provided identifying the ERPAs considered for each ETE calculation by downwind direction.	Yes	Table 6-1, Table 7-5, Table H-1
1.4.2 Staged Evacuation		
a. The approach used in development of a staged evacuation is discussed.	Yes	Section 7.2
b. A table similar to Table 1-5, "Evacuation Areas for a Staged Evacuation," is provided for staged evacuations identifying the ERPAs considered for each ETE calculation by downwind direction.	Yes	Table 7-3, Table 7-4
2.0 Demand Estimation		
a. Demand estimation is developed for the four population groups (permanent residents of the EPZ, transients, special facilities, and schools).	Yes	Section 3
2.1 Permanent Residents and Transient Population		
a. The U.S. Census is the source of the population values, or another credible source is provided.	Yes	Section 3.1
b. The availability date of the census data is provided.	Yes	Section 3.1
c. Population values are adjusted as necessary for growth to reflect population estimates to the year of the ETE.	Yes	N/A - 2020 used as the base year of the analysis

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
d. A sector diagram, similar to Figure 2-1, "Population by Sector," is included showing the population distribution for permanent residents.	Yes	Figure 3-2
2.1.1 Permanent Residents with Vehicles		
a. The persons per vehicle value is between 1 and 3 or justification is provided for other values.	Yes	Section 3.1
2.1.2 Transient Population		
a. A list of facilities that attract transient populations is included, and peak and average attendance for these facilities is listed. The source of information used to develop attendance values is provided.	Yes	Section 3.3, Table E-4 and Table E-5
b. Major employers are listed.	Yes	Section 3.4, Table E-3
c. The average population during the season is used, itemized and totaled for each scenario.	Yes	Table 3-4 and Appendix E itemize the peak transient population and employee estimates. These estimates are multiplied by the scenario specific percentages provided in Table 6-3 to estimate average transient population by scenario – see Table 6-4.
d. The percentage of permanent residents assumed to be at facilities is estimated.	Yes	Section 3.3 and Section 3.4
e. The number of people per vehicle is provided. Numbers may vary by scenario, and if so, reasons for the variation are discussed.	Yes	Section 3.3 and Section 3.4

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
f. A sector diagram is included, similar to Figure 2-1, "Population by Sector", is included showing the population distribution for the transient population.	Yes	Figure 3-6 (transients) and Figure 3-8 (employees)
2.2 Transit Dependent Permanent Residents		
a. The methodology (e.g., surveys, registration programs) used to determine the number of transit dependent residents is discussed.	Yes	Section 3.7
b. The State and local evacuation plans for transit dependent residents are used in the analysis.	Yes	Section 8.1
c. The methodology used to determine the number of people with disabilities and those with access and functional needs who may need assistance and do not reside in special facilities is provided. Data from local/county registration programs are used in the estimate.	Yes	Section 3.8
d. Capacities are provided for all types of transportation resources. Bus seating capacity of 50 percent is used or justification is provided for higher values.	Yes	Item 3 of Section 2.4
e. An estimate of the transit dependent population is provided.	Yes	Section 3.7, Table 3-8, Table 3-9
f. A summary table showing the total number of buses, ambulances, or other transport assumed available to support evacuation is provided. The quantification of resources is detailed enough to ensure that double counting has not occurred.	Yes	Table 3-9, Table 8-1

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
2.3 Special Facility Residents		
a. Special facilities, including the type of facility, location, and average population, are listed. Special facility staff is included in the total special facility population.	Yes	Table E-2 lists all medical facilities by facility name, location, and average population. Staff estimates were not provided.
b. The method of obtaining special facility data is discussed.	Yes	Section 3.5 and 3.9
c. An estimate of the number and capacity of vehicles assumed available to support the evacuation of the facility is provided.	N/A	According to Callaway RERP, all medical and correctional facilities located within the EPZ are to shelter-in-place.
d. The logistics for mobilizing specially trained staff (e.g., medical support or security support for prisons, jails, and other correctional facilities) are discussed when appropriate.	N/A	According to Callaway RERP, all medical and correctional facilities located within the EPZ are to shelter-in-place.
2.4 Schools		
a. A list of schools including name, location, student population, and transportation resources required to support the evacuation, is provided. The source of this information should be identified.	Yes	Table 3-7, Table E-1, Section 3.6
b. Transportation resources for elementary and middle schools are based on 100 percent of the school capacity.	Yes	Section 3.6
c. The estimate of high school students who will use personal vehicle to evacuate is provided and a basis for the values used is given.	Yes	Section 3.6
d. The need for return trips is identified.	Yes	Section 8.1 – no return trips are needed.

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
2.5 Other Demand Estimate Considerations		
2.5.1 Special Events		
a. A complete list of special events is provided including information on the population, estimated duration, and season of the event.	Yes	Section 3.10
b. The special event that encompasses the peak transient population is analyzed in the ETE.	Yes	Section 3.10
c. The percentage of permanent residents attending the event is estimated.	Yes	Section 3.10
2.5.2 Shadow Evacuation		
a. A shadow evacuation of 20 percent is included consistent with the approach outlined in Section 2.5.2, "Shadow Evacuation".	Yes	Item 7 of Section 2.2, Figure 2-1 and Figure 7-1, Section 3.2
b. Population estimates for the shadow evacuation in the shadow region beyond the EPZ are provided by sector.	Yes	Section 3.2, Table 3-3, Figure 3-4
c. The loading of the shadow evacuation onto the roadway network is consistent with the trip generation time generated for the permanent resident population.	Yes	Section 5 – Table 5-8 (footnote)
2.5.3 Background and Pass Through Traffic		
a. The volume of background traffic and pass-through traffic is based on the average daytime traffic. Values may be reduced for nighttime scenarios.	Yes	Section 3.11 and Section 3.12

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
b. The method of reducing background and pass-through traffic is described.	Yes	Section 2.2 – Assumptions 9 and 10 Section 2.5 Section 3.11 and Section 3.12 Table 6-3 – External Through Traffic footnote
c. Pass-through traffic is assumed to have stopped entering the EPZ about two (2) hours after the initial notification.	Yes	Section 2.5
2.6 Summary of Demand Estimation		
a. A summary table is provided that identifies the total populations and total vehicles used in the analysis for permanent residents, transients, transit dependent residents, special facilities, schools, shadow population, and pass-through demand in each scenario.	Yes	Table 3-11, Table 3-12, and Table 6-4
3.0 Roadway Capacity		
a. The method(s) used to assess roadway capacity is discussed.	Yes	Section 4
3.1 Roadway Characteristics		
a. The process for gathering roadway characteristic data is described including the types of information gathered and how it is used in the analysis.	Yes	Section 1.3, Appendix D
b. Legible maps are provided that identify nodes and links of the modeled roadway network similar to Figure A-1, "Roadway Network Identifying Nodes and Links," and Figure A-2, "Grid Map Showing Detailed Nodes and Links."	Yes	Appendix K

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
3.2 Model Approach		
a. The approach used to calculate the roadway capacity for the transportation network is described in detail, and the description identifies factors that are expressly used in the modeling.	Yes	Section 4
b. Route assignment follows expected evacuation routes and traffic volumes.	Yes	Appendix B and Appendix C
c. A basis is provided for static route choices if used to assign evacuation routes.	N/A	Static route choices are not used to assign evacuation routes. Dynamic traffic assignment is used.
d. Dynamic traffic assignment models are described including calibration of the route assignment.	Yes	Appendix B and Appendix C
3.3 Intersection Control		
a. A list that includes the total numbers of intersections modeled that are unsignalized, signalized, or manned by response personnel is provided.	Yes	Table K-1
b. The use of signal cycle timing, including adjustments for manned traffic control, is discussed.	Yes	Section 4, Appendix G
3.4 Adverse Weather		
a. The adverse weather conditions are identified.	Yes	Assumption 2 and 3 of Section 2.6
b. The speed and capacity reduction factors identified in Table 3-1, “Weather Capacity Factors,” are used or a basis is provided for other values, as applicable to the model.	Yes	Table 2-2
c. The calibration and adjustment of driver behavior models for adverse weather conditions are described, if applicable.	N/A	Driver behavior is not adjusted for adverse weather conditions.

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
d. The effect of adverse weather on mobilization is considered and assumptions for snow removal on streets and driveways are identified, when applicable.	Yes	Assumption 4 and 5 of Section 2.6 and Table 2-2
4.0 Development of Evacuation Times		
4.1 Traffic Simulation Models		
a. General information about the traffic simulation model used in the analysis is provided.	Yes	Section 1.3, Table 1-3, Appendix B, Appendix C
b. If a traffic simulation model is not used to perform the ETE calculation, sufficient detail is provided to validate the analytical approach used.	N/A	Not applicable since a traffic simulation model was used.
4.2 Traffic Simulation Model Input		
a. Traffic simulation model assumptions and a representative set of model inputs are provided.	Yes	Section 2, Appendix J
b. The number of origin nodes and method for distributing vehicles among the origin nodes are described.	Yes	Appendix J, Appendix C
c. A glossary of terms is provided for the key performance measures and parameters used in the analysis.	Yes	Appendix A
4.3 Trip Generation Time		
a. The process used to develop trip generation times is identified.	Yes	Section 5
b. When surveys are used, the scope of the survey, area of the survey, number of participants, and statistical relevance are provided.	Yes	Appendix F
c. Data used to develop trip generation times are summarized.	Yes	Appendix F, Section 5

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
d. The trip generation time for each population group is developed from site-specific information.	Yes	Section 5
e. The methods used to reduce uncertainty when developing trip generation times are discussed, if applicable.	N/A	There was no uncertainty when developing trip generation times.
4.3.1 Permanent Residents and Transient Population		
a. Permanent residents are assumed to evacuate from their homes but are not assumed to be at home at all times. Trip generation time includes the assumption that a percentage of residents will need to return home before evacuating.	Yes	Section 5 discusses trip generation for households with and without returning commuters. Table 6-3 presents the percentage of households with returning commuters and the percentage of households either without returning commuters or with no commuters. Appendix F presents the percent households who will await the return of commuters. Section 2.3, Assumption 3
b. The trip generation time accounts for the time and method to notify transients at various locations.	Yes	Section 5
c. The trip generation time accounts for transients potentially returning to hotels before evacuating.	Yes	Section 5, Figure 5-1
d. The effect of public transportation resources used during special events where a large number of transients are expected is considered.	Yes	Section 3.8

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
4.3.2 Transit Dependent Permanent Residents		
a. If available, existing and approved plans and bus routes are used in the ETE analysis.	N/A	Established bus routes do not exist. Section 8.1 under Evacuation of Transit-Dependent Population
b. The means of evacuating ambulatory and non-ambulatory residents are discussed.	Yes	Section 8.1 under Evacuation of Transit-Dependent Population, Section 8.2
c. Logistical details, such as the time to obtain buses, brief drivers and initiate the bus route are used in the analysis.	Yes	Section 8.1, Figure 8-1
d. The estimated time for transit dependent residents to prepare and then travel to a bus pickup point, including the expected means of travel to the pickup point, is described.	Yes	Section 8.1 under Evacuation of Transit-Dependent Population
e. The number of bus stops and time needed to load passengers are discussed.	Yes	Section 8.1, Table 8-5 though Table 8-7
f. A map of bus routes is included.	Yes	Figure 10-2
g. The trip generation time for non-ambulatory persons including the time to mobilize ambulances or special vehicles, time to drive to the home of residents, time to load, and time to drive out of the EPZ, is provided.	Yes	Section 8.2
h. Information is provided to support analysis of return trips, if necessary.	Yes	Section 8.1 – no return trips are needed.
4.3.3 Special Facilities		
a. Information on evacuation logistics and mobilization times is provided.	N/A	According to Callaway RERP, all medical and correctional facilities located within the EPZ are to shelter-in-place.

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
b. The logistics of evacuating wheelchair and bed bound residents are discussed.	N/A	According to Callaway RERP, all medical and correctional facilities located within the EPZ are to shelter-in-place.
c. Time for loading of residents is provided.	N/A	
d. Information is provided that indicates whether the evacuation can be completed in a single trip or if additional trips are needed.	N/A	
e. Discussion is provided on whether special facility residents are expected to pass through the reception center before being evacuated to their final destination.	N/A	
f. Supporting information is provided to quantify the time elements for each trip, including destinations if return trips are needed.	N/A	
4.3.4 Schools		
a. Information on evacuation logistics and mobilization times is provided.	Yes	Section 2.4, Section 8.1, Table 8-2 through Table 8-4
b. Time for loading of students is provided.	Yes	Section 2.4, Section 8.1, Table 8-2 through Table 8-4
c. Information is provided that indicates whether the evacuation can be completed in a single trip or if additional trips are needed.	Yes	Section 8.1
d. If used, reception centers should be identified. A discussion is provided on whether students are expected to pass through the reception center before being evacuated to their final destination.	Yes	Section 8.1, Table 10-3

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
e. Supporting information is provided to quantify the time elements for each trip, including destinations if return trips are needed.	Yes	Section 8.1, Table 8-2 through Table 8-4
4.4 Stochastic Model Runs		
a. The number of simulation runs needed to produce average results is discussed.	N/A	DYNEV does not rely on simulation averages or random seeds for statistical confidence. For DYNEV/DTRAD, it is a meso-scopic simulation and uses dynamic traffic assignment model to obtain the "average" (stable) network work flow distribution. This is different from microscopic simulation, which is monte-carlo random sampling by nature relying on different seeds to establish statistical confidence. Refer to Appendix B for more details.
b. If one run of a single random seed is used to produce each ETE result, the report includes a sensitivity study on the 90 percent and 100 percent ETE using 10 different random seeds for evacuation of the full EPZ under Summer, Midweek, Daytime, Normal Weather conditions.	N/A	
4.5 Model Boundaries		
a. The method used to establish the simulation model boundaries is discussed.	Yes	Section 4.5
b. Significant capacity reductions or population centers that may influence the ETE and that are located beyond the evacuation area or shadow region are identified and included in the model, if needed.	Yes	Section 4.5

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
4.6 Traffic Simulation Model Output		
a. A discussion of whether the traffic simulation model used must be in equilibration prior to calculating the ETE is provided.	Yes	Appendix B
b. The minimum following model outputs for evacuation of the entire EPZ are provided to support review: 1. Evacuee average travel distance and time. 2. Evacuee average delay time. 3. Number of vehicles arriving at each destination node. 4. Total number and percentage of evacuee vehicles not exiting the EPZ. 5. A plot that provides both the mobilization curve and evacuation curve identifying the cumulative percentage of evacuees who have mobilized and exited the EPZ. 6. Average speed for each major evacuation route that exits the EPZ.	Yes	1. Appendix J, Table J-2 2. Table J-2 3. Table J-4 4. None and 0%. 100 percent ETE is based on the time the last vehicle exits the evacuation zone 5. Figures J-1 through J-14 (one plot for each scenario considered) 6. Table J-5, Network wide average speed also provided in Table J-3
c. Color coded roadway maps are provided for various times (e.g., at 2, 4, 6 hrs.) during a full EPZ evacuation scenario, identifying areas where congestion exists.	Yes	Figure 7-3 through Figure 7-7
4.7 Evacuation Time Estimates for the General Public		
a. The ETE includes the time to evacuate 90 percent and 100 percent of the total permanent resident and transient population.	Yes	Table 7-1 and Table 7-2
b. Termination criteria for the 100 percent ETE are discussed, if not based on the time the last vehicle exits the evacuation zone.	N/A	100 percent ETE is based on the time the last vehicle exits the evacuation zone.

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
c. The ETE for 100 percent of the general public includes all members of the general public. Any reductions or truncated data is explained.	Yes	Section 5.4.1 – truncating survey data to eliminate statistical outliers Table 7-2 – 100th percentile ETE for general population
d. Tables are provided for the 90 and 100 percent ETEs similar to Table 4-3, "ETEs for a Staged Evacuation," and Table 4-4, "ETEs for a Keyhole Evacuation."	Yes	Table 7-3 and Table 7-4
e. ETEs are provided for the 100 percent evacuation of special facilities, transit dependent, and school populations.	Yes	Section 8
5.0 Other Considerations		
5.1 Development of Traffic Control Plans		
a. Information that responsible authorities have approved the traffic control plan used in the analysis are discussed.	Yes	Section 9, Appendix G
b. Adjustments or additions to the traffic control plan that affect the ETE is provided.	Yes	Section 9, Appendix G
5.2 Enhancements in Evacuation Time		
a. The results of assessments for enhancing evacuations are provided.	Yes	Appendix M
5.3 State and Local Review		
a. A list of agencies contacted is provided and the extent of interaction with these agencies is discussed.	Yes	Table 1-1

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
b. Information is provided on any unresolved issues that may affect the ETE.	Yes	Results of the ETE study were formally presented to state and local agencies at the final project meeting. Comments on the draft report were provided and were addressed in the final report. There are no unresolved issues.
5.4 Reviews and Updates		
a. The criteria for when an updated ETE analysis is required to be performed and submitted to the NRC is discussed.	Yes	Appendix M, Section M.3
5.4.1 Extreme Conditions		
a. The updated ETE analysis reflects the impact of EPZ conditions not adequately reflected in the scenario variations.	N/A	This ETE is being updated as a result of the availability of US Census Bureau decennial census data.
5.5 Reception Centers and Congregate Care Center		
a. A map of congregate care centers and reception centers is provided.	Yes	Figure 10-3