GEOGRAPHIC INFORMATION SYSTEM EMERGENCY SERVICES RESPONSE CAPABILITIES ANALYSIS

A PROPOSAL

International Association of Fire Fighters
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Covington Fire Department

COVINGTON, KENTUCKY

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Executive Summary

The International Association of Fire Fighters (IAFF) Headquarters was engaged by the Covington Professional Firefighters Local 38 to create a proposal to assist the Department in budget hearings. The purpose of the hearing is the appropriation of money intended to replace an aging apparatus fleet and increasing staffing in order to better serve the citizens and visitors of the City of Covington.

The Covington Fire Department, herein to be referred to as the Department, is a municipal fire department in Northern Kentucky. The Department provides fire suppression, technical rescue, and EMS operations at both the first response and patient transport level to the City of Covington, Kentucky, herein to be referred to as the City. The Department provides emergency protection to a total area of 13.7 square miles of which 0.5 square miles is water and to a population of 40,640[1].

The Department maintains five fire stations which are staffed with a minimum of 27 career employees, this number includes: 25 firefighters, one Safety Officer, and one Battalion Chief on each shift. In addition to all-hazard emergency responses, the Department also performs other services for the City such as prevention and safety programs, including fire-safety inspections.

National Performance Standards

The National Fire Protection Association (NFPA) produced NFPA® 1710 *Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*. NFPA 1710 is the consensus standard for career firefighter deployment, including requirements for fire department arrival time, staffing levels, and fireground responsibilities.[2]

Key Sections included in the 1710 Standard are:

- 5.2.3
    - **Operating Units**. Fire company staffing requirements shall be based on minimum levels necessary for safe, effective, and efficient emergency operations.

- 5.2.3.1 & 5.2.3.1.1
    - Fire companies, whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue… shall be staffed with a minimum of four on-duty personnel.

[1] 2010 U.S. Census, http://quickfacts.census.gov/qfd/states/21/2117848.html
[2] NFPA 1710, 2010

- 5.2.3.2 and 5.2.3.2.1
    - Fire companies whose primary functions are to perform the variety of services associated with Truck work, such as forcible entry, ventilation, search and rescue, aerial operations for water delivery and rescue, utility control, illumination, overhaul and salvage work… shall be staffed with a minimum of four on-duty personnel.

- 5.2.3.1.2 & 5.2.3.2.2
    - In jurisdictions with tactical hazards, high hazard occupancies, high incident frequencies, geographical restrictions, or other factors as identified by the AHJ[3], these companies shall be staffed with a minimum of five or six on-duty personnel.

- 5.2.3.4.1
    - A fire company that deploys with quint apparatus designed to operate as either an engine company or a ladder company, shall be staffed as specified in 5.2.3.

- 5.2.3.4.2
    - If the company is expected to perform multiple roles simultaneously, additional staffing, above the levels specified in 5.2.3, shall be provided to ensure that those operations can be performed as required.

- 5.2.4.1.1
    - The fire department's fire suppression resources shall be deployed to provide for the arrival of an engine company within a 240-second travel time to 90 percent of the incidents.

- 5.2.4.2.1
    - The fire department shall have the capability to deploy an initial full alarm assignment within a 480-second travel time to 90 percent of the incidents.

- 5.2.4.2.2
    - The initial full alarm assignment to a structure fire in a typical 2000 ft^2 … two-story single-family dwelling without basement and with no exposures shall provide for the following.

[3] AHJ- Authority Having Jurisdiction

Assignment	*Required Personnel*
Incident command	1 Individual
Uninterrupted Water supply	1 Pump Operator
Water flow from two handlines	4 Individuals (2 for each line)
Support for hand lines	2 Individuals (1 for each line)
Victim search and rescue team	2 Individuals
Ventilation team	2 Individuals
Aerial operator	1 Individual
Initial Rapid Intervention Crew (IRIC)	2 Individuals
Required minimum personnel for full alarm	**14 firefighters & 1 scene commander**

The National Fire Protection Association (NFPA) produced NFPA® 1901 *Standard for Automotive Fire Apparatus*. NFPA 1901 is the consensus standard for specifications regarding the manufacturing of fire apparatus[4]. Annex D of NFPA 1901 contains guidelines for first-line and reserve apparatus.

Key Sections included in the 1901 Standard are:

- D.1 General
  - It is recommended that apparatus greater than 15 years old that have been properly maintained and that are still in serviceable condition be placed in reserve status and upgraded in accordance with NFPA® 1912, *Standard for Fire Apparatus Refurbishing*, to incorporate as many features as possible of the current fire apparatus standard.
  - Apparatus that were not manufactured to the applicable NFPA fire apparatus standards or that are over 25 years old should be replaced.

- D.3 Upgrading Fire Apparatus
  - Any apparatus, whether in first-line or reserve service, should be upgraded in accordance with NFPA 1912…

[4] NFPA 1710, 2010

- D.4 Proper Maintenance of Fire Apparatus
    - In addition to needed upgrades to older fire apparatus, it is imperative that all fire apparatus be checked and maintained regularly to ensure that they will be reliable and safe to use.

- D.5 Refurbishing or Replacing Fire Apparatus
    - Fire department administrators and fire chiefs should exercise special care when evaluating the cost of refurbishing or updating an apparatus versus the cost of a new fire apparatus. Apparatus that are refurbished should comply with the requirements of NFPA 1912. A thorough cost-benefit analysis of the value of upgrading or refurbishing a fire apparatus should be conducted. In many instances it will be found that refurbishing costs will greatly exceed the current value of similar apparatus.

Key Findings

There are two items to identify when examining the performance of a Department. The first is adequate concentration of firefighters. The second item is distribution of resources. The Department is not currently in compliance with performance objectives outlined in NFPA Standard 1710. This finding is based on the following facts.

- All engines are staffed with a minimum of three firefighters, Truck 1 is staffed with three firefighters, Truck 7 is staffed with two firefighters, and Rescue 1 is staffed with two firefighters. Apparatus not staffed with a minimum of four firefighters are not in compliance with the company staffing objectives outlined in NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, and NFPA 1710.

- At a minimum, 27 firefighters are on staff per shift deploying 10 apparatus and two staff vehicles. NFPA 1710 requires 15 firefighters arriving on scene of an initial full alarm within 8 minutes. Although this requirement can be met in the northern portion of the City, it is not possible for the portion of the City that lies South of East 41st Street. The lack of resources significantly contributes to the fire department's inability to accumulate necessary fireground staffing to assemble at an initial full alarm assignment with at least 15 firefighters in accordance with NFPA 1710.

The Department has an aging fleet of fire apparatus that has been plagued with numerous mechanical, electrical and safety issues in the last several years. It is a generally accepted fact that fire apparatus has a finite life, although the length of that life depends on a number of factors including vehicle mileage and engine hours, quality of preventative maintenance programs, quality of driver training programs, and quality of components used in manufacturing and

repair[5]. The City could control costs if it replaced apparatus that have experienced high maintenance costs and safety concerns due to age. The Department is not currently in compliance with apparatus recommendations outlined in NFPA Standard 1901 Annex D. This finding is based on the following facts:

- The Department has four first-line apparatus that are over 15 years old: Pumper 2 is 18 years old, Pumper 5 is 17 years old, Rescue 1 is 17 years old, and Truck 1 is 20 years old. NFPA 1901 Annex D recommends that fire apparatus over 15 years of age should be refurbished per NFPA 1912 and placed in reserve status.

- The Department has three reserve apparatus that that are over 15 years old and have never been refurbished to align them with current safety requirements: Pumper 3 is 15 years old, Pumper 4 is 24 years old, and Rescue 2 is 18 years old.

- The Department has a number of issues with the truck companies. These issues effectively make these apparatus unreliable and unsafe. Truck 1, in addition to being 20 years old, has had its motor rebuilt, has electrical problems, and recently had to have its alternator replaced. Additionally, hydraulically driven outriggers for ladder stabilization have started to show indications that they have reached the end of their usable life by being unable to remain in the stowed position when the apparatus is parked. Truck 7 has motor issues with diesel fuel contaminating motor oil and issues that prevent safe operations of the aerial device. These unsafe issues include but are not limited to: cables and pulleys responsible for extending and retracting the aerial device failing; resulting in inconsistent and unsuccessful operation. The failing cable and pulley system has caused repeated collateral damage to an electrical cable responsible for operating the ladder and has resulted in electrocution hazards to rescuers and civilians.

It has been recommended to the Department that Pumper 8 be removed from service and that Truck 7 be used as the sole fire suppression apparatus responding from Station 8. This recommendation has been made because Truck 7 is a Quint[6]. The intent of this recommendation was for Truck 7 to perform both the tasks of a pumper and a ladder company simultaneously. However, the consolidation of Pumper 8's assigned crew with the assigned crew of Truck 7 makes the performance of simultaneous tasks out of compliance with the company staffing objectives outlined in NFPA 1710. Additionally, there are response issues with Truck 7 that prevent it from being used as an effective first-line apparatus. These findings are based on the following facts:

[5] NFPA 1901
[6] A Quint is a fire apparatus with a permanently mounted fire pump, a water tank, a hose storage area, an aerial ladder or elevating platform with a permanently mounted waterway, and a complement of ground ladders.

- Pumper 8 has three assigned personnel and Truck 7 has two assigned personnel. Combining these personnel into a crew of five would meet the requirements of NFPA 1710 when using a quint apparatus as **either** a pumper or a ladder, but does not support the requirement for the apparatus to perform simultaneous tasks.

- If personnel are consolidated, two members will be used to cross-staff[7] Ambulance 8 (this task is currently performed by personnel assigned to Pumper 8). This will cause staffing levels to be reduced below required levels, per NFPA 1710.

- Truck 7 cannot maneuver onto or down many of the streets in the northern portion of the City.

Recommendations

The recommendations listed are based on the findings of the GIS evaluation of current deployment models.

- Fire suppression apparatus in North Covington, below Highland Ave. and Howe Dr. should be staffed with a minimum of 4 firefighters at all times.
    - Staffing to this level complies with industry standards for crew size in a low hazard residential environment and reduces the risk to firefighters and trapped occupants in such an event.
    - Sending larger crew sizes on a single apparatus allows crews to assemble on scene more quickly during early stages of a fire when risks to both firefighters and building occupants are lower. Since fire growth is exponential, growing in a non-linear manner over time, extending the time for crew assembly by waiting for smaller crews to arrive from further away causes on scene risk to escalate. The higher the risks at the time firefighters engage in fire suppression, the greater the chance of poor outcomes including civilian injury or death, firefighter injury or death and property loss.
    - Staffing at this level will allow the fire department to assemble a full alarm assignment with the minimum of 15 firefighters without the need for callback. It would also put the Department in compliance with NFPA 1710.

[7] Cross-staffing is a practice whereby emergency responders staff several types of emergency response vehicles simultaneously in a work period. The type and scope of the emergency dictate which type of response vehicle the responders staff for the incident. The drawback of such an arrangement is that the deployment of secondary apparatus requires personnel to be re-assigned from first-line apparatus, thereby reducing the number of firefighters available to engage in direct fire attack or respond to other calls for service.

    - The highly urbanized, industrial, and high-rise areas would largely benefit from this increased staffing in regards to their response to the high hazard occupancies normally found in these settings.

- Pumper 5 in the southern portion of the City should be staffed with five or six personnel due to the geographic restrictions.
    - Staffing to this level complies with industry standards for the crew size in a geographically isolated response area.
- Due to current staffing levels, distribution of resources, and the physical limitations of Truck 7, it is not recommended to merge Pumper 8 personnel onto Truck 7.
- The Department should begin to replace fire suppression apparatus as a means of controlling costs and increasing safety for citizens and firefighters alike.
    - The Department should immediately replace Truck 1 with a tiller truck
    - The Department should immediately replace Truck 7 with a tiller truck
    - The Department should refurbish Truck 7 and move it to reserve status
    - The Department should immediately replace Rescue 1 with a new rescue truck
    - The Department should refurbish Rescue 1 and move it to reserve status and remove Rescue 2 from service
    - The Department should create a replacement schedule where it replaces Pumper 2, Pumper 5, and Pumper 8 over the next several years.
    - The Department should keep the most serviceable pumper as the reserve apparatus once it has been refurbished to be compliant with NFPA 1912. The other pumpers, as well as Truck 1, should be traded in, if possible, to reduce purchasing costs.
- As a further means to control costs as well as ensure the City gets the best deal, the Department and the City should use the best-value and long-term contract in the bid criteria to replace the fleet.

Introduction

IAFF Local 38 requested a Geographic Information System (GIS) analysis of the response capability of the Department. Local 38 requested that the GIS study evaluate the current deployment model against both National Fire Protection Association (NFPA®) industry standards and Occupational Health and Safety Administration (OHSA) regulations. The procedures involved in the evaluation included generating GIS maps and providing explanations of the results. The steps included in the evaluation are listed below.

1) GIS analysis of planned staffing and deployment configurations.
2) Evaluation of resource deployment outcomes measured against NFPA standards and OHSA regulations.

In addition to the requested GIS analysis, Local 38 requested that the IAFF make proposals regarding the cost of increasing staffing and replacing the aging apparatus fleet in order to be in compliance with applicable NFPA standards.

Scope and Objectives

This report provides the results of the emergency response system evaluation and the GIS assessment of Department's response capability. The report refers both to the current performance of the department and to their staffing and deployment practices. Items specifically covered in this report include the following:

- Fire department response capabilities and compliance with industry standards
- Staffing configurations and safe work practices
- Strengths and weaknesses of the Fire Department
- Recommendations to improve service

Fire Department Operations

The business of providing emergency services has always been labor intensive, and remains so today. Although new technology has improved firefighting equipment and protective gear and has led to advances in modern medicine, it is the firefighters who still perform the time-critical tasks necessary to contain and extinguish fires, rescue trapped occupants from a burning structure, and provide emergency medical and rescue services.

In less than 30 seconds a small flame can burn out of control and become a major fire. During fire growth, the temperature of a fire rises to between 1,000° and 1,200° F. It is generally accepted in the fire service that for a medium growth rate fire[8], flashover- the very rapid spreading of the fire due to super heating of room contents and other combustibles- occurs in less than 10 minutes. Allowing time for discovery of the fire, a call to 911, and dispatch of emergency responders, flashover is likely to occur within 8 minutes of firefighter dispatch. It is also worth noting that flashover may occur more quickly depending on newer building construction materials and room contents that act as fuel.

At the point of flashover, the odds of survival for unprotected individuals inside the structure are virtually non-existent. The rapid response of an appropriate number of firefighters is therefore essential to initiating effective fire suppression and rescue operations that seek to minimize fire spread and maximize the odds of preserving both life and property.

Fire Growth

The Incipient Phase

The first stage of any fire is the incipient stage. When heat is applied to a combustible material, the heat oxidizes the material's surface into combustible gases. The oxidation process is exothermic, meaning that the oxidation process itself produces heat. The heat from oxidation raises the temperature of surrounding materials, which increases the rate of oxidation and begins a chemical chain reaction of heat release and burning. A fire can progress from the incipient phase immediately or slowly, depending upon the fuel, nearby combustibles, and the availability of oxygen in the surrounding air.

[8] As defined in the *Handbook of the Society of Fire Protection Engineers*, a fast fire grows exponentially to 1.0 MW in 150 seconds. A medium fire grows exponentially to 1 MW in 300 seconds. A slow fire grows exponentially to 1 MW in 600 seconds. A 1 MW fire can be thought-of as a typical upholstered chair burning at its peak. A large sofa might be 2 to 3 MWs.

The Free Burning Phase

The second stage of fire growth is the "free" or "open burning" stage. When the temperature of a fire gets high enough, visible flames can be seen. The visible burning at this stage is still limited to the immediate area of origin. The combustible process continues to release more heat, which heats nearby objects to their ignition temperature, and they begin burning. In a wild-land fire, the surrounding growth will ignite and the flames will spread quickly if wind and dry growth are present. A structure fire is different, because the gaseous products of combustion, most of which are flammable and lighter than air, rise and are contained in the upper levels of the structure. When this occurs, the structure fire is at a critical point: either the fire has insufficient oxygen available to burn and it progresses back to the incipient stage, or it has sufficient oxygen available to move on to the next stage.

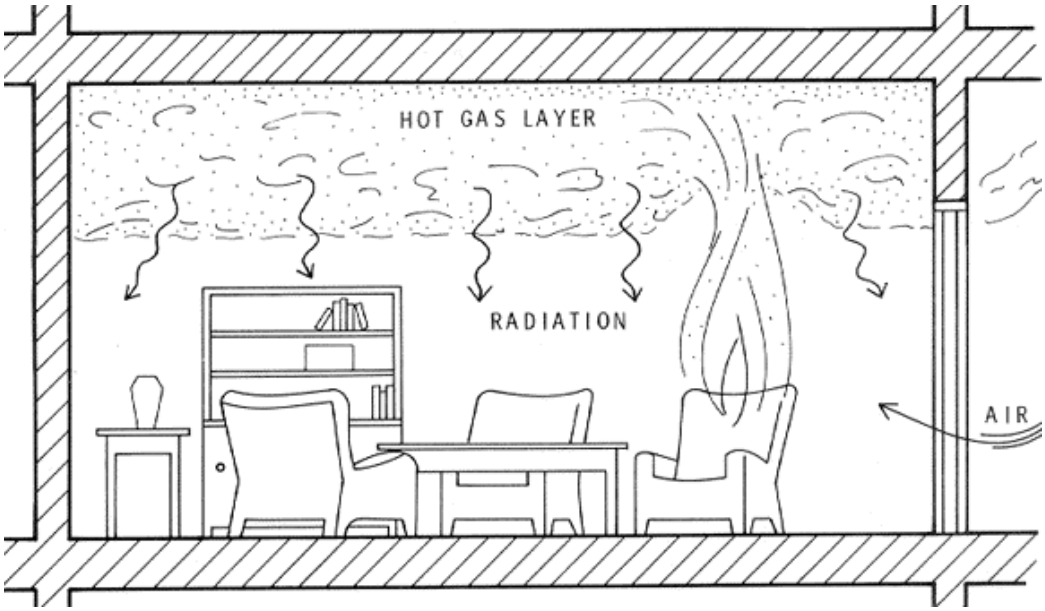


Figure 1: Fire Growth in a Confined Space[9]

When an object in a room starts to burn (such as the armchair in Figure 1), it burns in much the same way as it would in an open area. After a short period of time, however, confinement begins to influence fire development. The smoke produced by the burning object rises to form a hot gas layer below the ceiling; this layer heats the ceiling and upper walls of the room. Thermal radiation from the hot layer, ceiling, and upper walls begins to heat all objects in the lower part of the room and may augment both the rate of burning of the original object and the rate of flame spread over its surface.

At this point, the fire may go out, for example, if the first object completely burns before another begins, or if sufficient oxygen cannot get into the room to keep the object burning. Sometimes,

[9] Image courtesy of University of California at Davis Fire Department

however, the heating of the other combustibles in the room continues to the point where they reach their ignition temperatures more or less simultaneously. If this occurs, flames suddenly sweep across the entire room, involving all combustibles. This transition from the burning of one or two objects to full room involvement is referred to as "flashover." [10]

Flashover

Flashover, when it occurs, is the most significant event during a structure fire. As combustible gases are produced by the two previous stages they are not entirely consumed and are therefore available fuels. These "available fuels" rise and form a superheated gas layer at the ceiling that continues to increase, until it begins to bank down to the floor, heating all combustible objects regardless of their proximity to the burning object. In a typical structure fire, the gas layer at the ceiling can quickly reach temperatures of 1,500 degrees Fahrenheit. With enough existing oxygen at the floor level, flashover occurs, burning everything in the room at once. The instantaneous eruption into flame generates a tremendous amount of heat, smoke, and pressure. The pressure has enough force to push beyond the room of origin and through doors and windows. Usually at the time of flashover, windows in the room will break, allowing for the entry of fresh air. The introduction of fresh air serves to further fuel the growth of the fire by increasing the fire's temperature and spreading the fire beyond the room of origin.

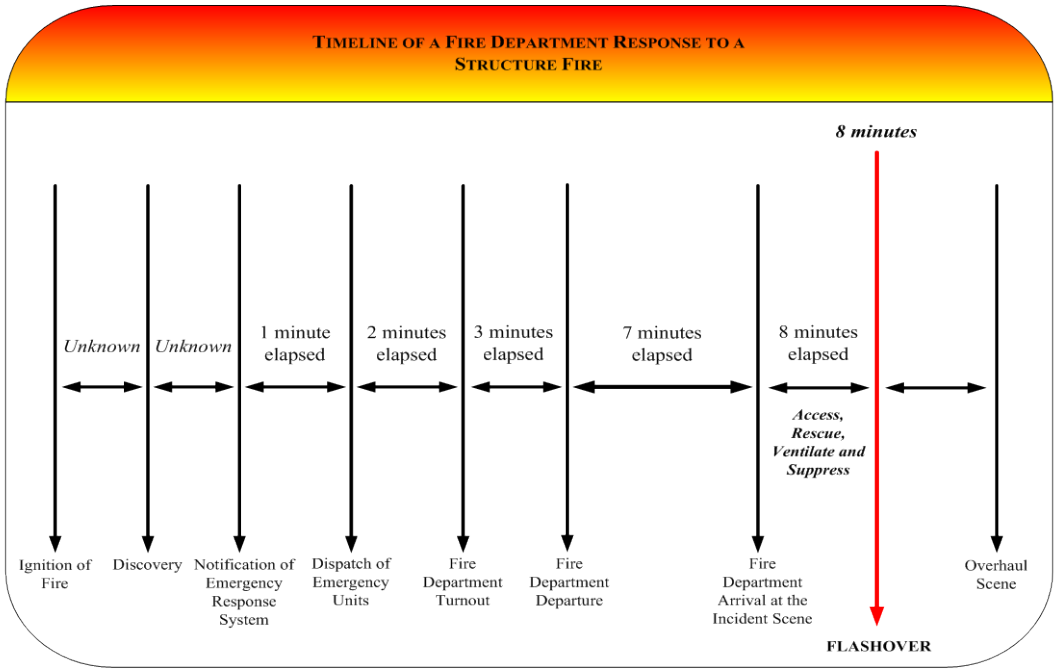


Figure 2: Fire Department Response Timeline

[10] J.R. Mehaffey, Ph.D., Flammability of Building Materials and Fire Growth, Institute for Research in Construction (1987)

Based on the dynamics of fire behavior in an unprotected structure fire, any decrease in emergency unit response capabilities will correlate directly with an increase in expected life, property, and economic loss.

The Importance of Adequate Staffing: Concentration

Staffing deficiencies on primary fire suppression apparatus also negatively affect the ability of the fire department to safely and effectively mitigate emergencies and therefore correlate directly with higher risks and increased losses. Continued fire growth beyond the time of firefighter on scene arrival is directly linked to the time it takes to initiate fire suppression operations. As indicated in Table 1, responding companies staffed with four firefighters are capable of initiating critical fire ground operational tasks more efficiently than those with crew sizes below industry standards.

	Engine Company Duties				**Ladder Company Duties**			
Fireground Tasks	**Advance Attack Line**	**% Change**	**Water on Fire**	**% Change**	**Primary Search**	**% Change**	**Venting Time**	**% Change**
4 Firefighters	0:03:27		0:08:41		0:08:47		0:04:42	
3 Firefighters	0:03:56	12% Less Efficient	0:09:15	6% Less Efficient	0:09:10	4% Less Efficient	0:07:01	32% Less Efficient
2 Firefighters	0:04:53	29% Less Efficient	0:10:16	15% Less Efficient	0:12:16	28% Less Efficient	0:07:36	38% Less Efficient

Table 1: Impact of Crew Size on a Low-Hazard Residential Fire[11]

First-arriving companies staffed with four firefighters are more efficient in all aspects of initial fire suppression and search and rescue operations compared to two or three-person companies. There is a significant increase in time for all the tasks if a company arrives on scene staffed with only three firefighters compared to four firefighters. According to the NIST Report on Residential Fireground Field Experiments, four-person crews are able to complete time critical fireground tasks 5.1 minutes (nearly 25%) faster than three-person crews. The increase in time to task completion corresponds with an increase in risk to both firefighters and trapped occupants.

With four-person crews, the effectiveness of first-arriving engine company interior attack operations *increases* by 12% to 29% efficiency compared to three- and two-person crews respectively. The efficacy of search and rescue operations also *increases* by 4% and 28% with four-person crews compared to three and two person crews. Moreover, with a four-person company, because the first-in unit is staffed with a sufficient number of personnel to accomplish

[11] Derived from NIST "Report on Residential Field Experiments", Jason D. Averill, et. al., 2010.

its assigned duties, the second-in company does not need to support first-in company operations and is therefore capable of performing critical second-in company duties.

Insufficient numbers of emergency response units or inadequate staffing levels on those units exposes civilians and firefighters to increased risk, further drains already limited fire department resources, and stresses the emergency response system by requiring additional apparatus to respond from further distances. Failing to assemble sufficient resources on the scene of a fire in time to stop the spread and extinguish the fire, conduct a search, and rescue any trapped occupants puts responding firefighters and occupants in a dangerous environment with exponential risk escalation such that it is difficult to catch up and mitigate the event to a positive outcome.

A prime objective of fire service agencies is to maintain enough strategically located personnel and equipment so that the minimum acceptable response force can reach a reasonable number of fire scenes before flashover is likely.[12] Two of the most important elements in limiting fire spread are the quick arrival of sufficient numbers of personnel and equipment to attack and extinguish the fire as close to the point of origin as possible, as well as rescue any trapped occupants and care for the injured. Rapid and aggressive interior attack of structure fires, as close as possible to the point of origin, can reduce human and property losses. Sub-optimal staffing of arriving units may delay such an attack, thus allowing the fire to progress to more dangerous conditions for firefighters and civilians. "If the arriving units have adequate resources to handle the situation, then they will fight the fire aggressively and offensively. They will attack the problem head-on and, following department standards, will accomplish their objectives efficiently, effectively, and safely. If they do not have adequate resources to aggressively handle the situation, then they will have to fight the fire in a defensive mode of attack. This mode will continue until enough resources can be massed to then change to an aggressive, offensive attack."[13]

NFPA 1500 and 1710 both recommend that a minimum acceptable fire company staffing level should be four members responding on or arriving with each engine and each ladder company responding to any type of fire. Recall that at the scene of an emergency, the driver/operator of the pumper must remain with the apparatus to operate the pump. Likewise, the driver/operator of the ladder truck must remain with the apparatus to safely operate the aerial device. Due to the demands of fireground activities, a fire attack initiated by three firefighters is not capable of affecting a safe and effective fire suppression and/or rescue operation until sufficient personnel

[12] University of California at Davis Fire Department website; site visited June 7, 2004.
< http://fire.ucdavis.edu/ucdfire/UCDFDoperations.htm >
[13] National Institute for Occupational Safety and Health, High-Rise Apartment Fire Claims the Life of One Career Fire Fighter (Captain) and Injures Another Career Fire Fighter (Captain) – Illinois, 13 October 2001

arrive. Industry studies have confirmed that four firefighters are capable of performing the rescue of potential victims 80% faster than a crew of three firefighters.[14]

Typically, the first company arriving on scene is responsible for many critical tasks. These include removing the hose line(s), stretching the hose line from the apparatus to the point of entrance for interior attack (with a second hose line stretched to protect the exterior), connecting the hose lines to either the engine pump or water source, and primary search and rescue activities. The first arriving company is also responsible for assessing the situation and determining the extent of the emergency to establish the type and number of additional resources necessary to mitigate the event. Three or fewer firefighters cannot accomplish any of these tasks as efficiently as four firefighters, perhaps for the exception of initial assessment. By the time other firefighters arrive on scene, the fire may be beyond control and property and lives lost.

The Importance of Crew Size to Overall Scene Time

Studies have shown that the more personnel that arrive on pumper and ladder truck companies to the scene of a fire, the less time it takes to do all aspects of fire suppression and search and rescue. As units arriving with more firefighters increases, the overall time on scene of the emergency decreases. In other words, the more firefighters available to respond and arrive early to a structure fire, the less time it takes to extinguish the fire and perform search and rescue activities, thus reducing the risk of injury and death to both firefighters and trapped occupants and reducing the economic loss to the property.

Overall Scene Time Breakdown By Crew Size					
2 Person Close Stagger	3 Person Close Stagger	4 Person Close Stagger	2 Person Far Stagger	3 Person Far Stagger	4 Person Far Stagger
0:22:16	0:20:30	0:15:44	0:22:52	0:21:17	0:15:48
29% Less Efficient	25% Less Efficient		31% Less Efficient	26% Less Efficient	

Table 2: The Relationship between Crew Size and Scene Time [15]

As Table 2 shows, units that arrive with only two firefighters on an engine or truck are on the scene of a fire almost 7 minutes longer than units that arrive with four firefighters on each crew. Responding units arriving with only 3 firefighters on an apparatus are on the scene of a fire 5 to 6 minutes longer than units that arrive with four firefighters on each apparatus. In addition to

[14] McManis Associates and John T. O'Hagan & Associates, Dallas Fire Department Staffing Level Study, (June 1984); pp. 1-2 and II-1 through II-7; Richard C. Morrison, Manning Levels for Engine and Ladder Companies in Small Fire Departments, (1990)

[15] NIST "Report of Residential Fireground Field Experiments", Jason D. Averill, et. al., 2010

crew size, the time between the arriving crews matters to overall effectiveness and total on scene time.

In the NIST study on the low hazard residential fire, close stagger was defined as a 1-minute time difference in the arrival of each responding company. Far stagger was defined as a 2-minute time difference in the arrival of each responding company.[16] [17] The results show a consistent pattern of units arriving with four firefighters in a close stagger or far stagger will decrease the overall time at the scene of the emergency compared to units that arrive with two or three firefighters, and are more efficient in fire suppression tasks as well.

The same NIST study also examined the relationship between crew size and physiological strain. Two important conclusions were drawn from this part of the experiments.

- Average heart rates were higher for members of small crews.
- These higher heart rates were maintained for longer durations.[18]

Fire modeling was also used by researchers to mark the degree of the toxicity of the environment for a range of growth fires (slow, medium, and fast). Occupant exposures were calculated both when firefighters arrive earlier to the scene, and those arriving later. The modeling provided that the longer it takes for firefighters to rescue trapped occupants, the greater the risk posed to both the firefighters and occupants by increasing atmospheric toxicity in the structure.

The Importance of a Rapid Response

Any delay in the initiation of fire suppression and rescue operations translates directly into a proportional *increase* in expected property, life, and economic losses as is shown in Table 3. It warrants emphasizing that if a structure has no automatic suppression or detection system, a more advanced fire may exist by the time the fire department is notified of the emergency and is able to respond. Fires of an extended duration weaken structural members, compromising the structural integrity of a building and forcing operations to shift from an offensive to defensive mode.[19] As with inadequate staffing, this type of operation will continue until enough resources can be amassed to then change to an aggressive, offensive attack.

[16] NIST "Report on Residential Fireground Field Experiments", Jason D. Averill, et. al., 2010, pg. 24
[17] One minute and two minute arrival stagger times were determined from analysis of deployment data from more than 300 U.S. fire departments responding to a survey on fire department operations conducted by the International Association of Fire Chiefs and the International Association of Firefighters.
[18] NIST "Report on Residential Fireground Experiments", Jason D. Averill,, et. Al, 2010, pg. 50.
[19] According to the NFPA, "it's important to realize that every 250 GPM stream applied to the building can add up to one ton per minute to the load the weakened structure is carrying."

Rate Per 1,000 Fires			
Fire Extension in Residential Structures:	Civilian Deaths	Civilian Injuries	Average Property Damage
Confined fires (identified by incident type)	0.08	9.25	$313.00
Confined to room of Origin	4.99	47.00	$8,948.00
Confined to room of origin, including confined fires by incident type*	2.15	25.18	$3,958.00
Beyond the room, but confined to floor of origin	17.62	80.45	$34,001.00
Beyond floor of origin	27.48	59.38	$58,820.00

Table 3: "The Relationship between Fire Extension and Fire Loss" [20]

*NFIRS 5.0 has six categories of confined structure fires, including cooking fires confined to the cooking vessel, confined chimney or flue fire, confined incinerator fire, confined fuel burner or boiler fire or delayed ignition, confined commercial compactor fire, and trash or rubbish fire in a structure with no flame damage to the structure or its contents. Although causal information is not required for these incidents, it is provided in some cases. In this analysis (NFPA Fire Extension in Residential Structures 2002-2005), all confirmed fires were assumed to be confined to the room of origin.

Typical Initial Attack Response Capabilities

The following list of response capabilities represents the minimally required apparatus and personnel to three levels of hazards: high, medium and low. These response capabilities are constructed under the assumption that the Department will perform an aggressive interior attack, search for victims, perform ventilation, and other essential fireground tasks under an established unified chain of command. It is likely that if the Department were to encounter a fire where an interior attack was prohibitive due to a number of factors, more resources would be required.

[20] Source: National Fire Protection Association, NFPA 1710 (2010), Table A.5.2.2.2.1(b) Fire Extension in Residential Structures, 2002-2005.

High-Hazard Environments

Type of Occupancy

- Schools
- Hospitals
- Nursing Homes
- Explosives Plants
- Refineries
- High-Rise Buildings
- Mercantile and Industrial
- Other high life hazard or large fire potential occupancies.

Response Capability

- 4 Engines / Staffed with 5 firefighters
- 2 Ladder Trucks/ staffed with 5 firefighters (or combination apparatus with equivalent capabilities.)
- 2 Chief Officers
- Other Specialized Apparatus as may be needed to cope with the combustible involved.

Personnel Resources

- 30 Firefighters
- 2 Chief Officers
- Extra staffing of units first due to high-hazard occupancies is advised.
- One or more safety officers
- Rapid intervention team(s) also necessary.

Medium-Hazard Environments

Type of Occupancy

- Apartments, four or more family dwellings
- Offices

Response Capability

- 3 Engines/ Staffed with 4 or 5 firefighters
- 1 Ladder Truck/ Staffed with 4 or 5 firefighters (or combination apparatus with equivalent capabilities.)
- 1 Chief Officer
- Other Specialized Apparatus as may be needed or available.

Personnel

- 16 – 20 Firefighters
- 1 Chief Officer
- Safety Officer
- Rapid Intervention Team

Low-Hazard Environment

Type of Occupancy

- One-, two-, or three-family dwellings
- Scattered Small Business
- Scattered Light Industrial Occupancies

Response Capability

- 3 Engines/ Staffed with minimum of 4 firefighters
- 1 Ladder Truck/ staffed with minimum of 4 firefighters (or combination apparatus with equivalent capabilities.)
- 1 Chief Officer
- Other Specialized Apparatus as may be needed or available.

Personnel

- 16 Firefighters
- 1 Chief Officer
- Safety Officer
- Rapid Intervention Team

The Importance of the 4-Minute Engine Company Response

One of the first priorities in a fire is to get water on the fire to extinguish it. When initiating fire attack, a single engine company would not be capable of affecting a safe and effective fire attack or rescue operation in compliance with "2 In/2 Out" requirements unless staffed with *at least* four firefighters. Engine crews with less than four personnel must wait until a second fire suppression company arrives with sufficient personnel to support the fire attack and/or rescue operation and to assist the first crew in the event of an unexpected emergency during interior attack.

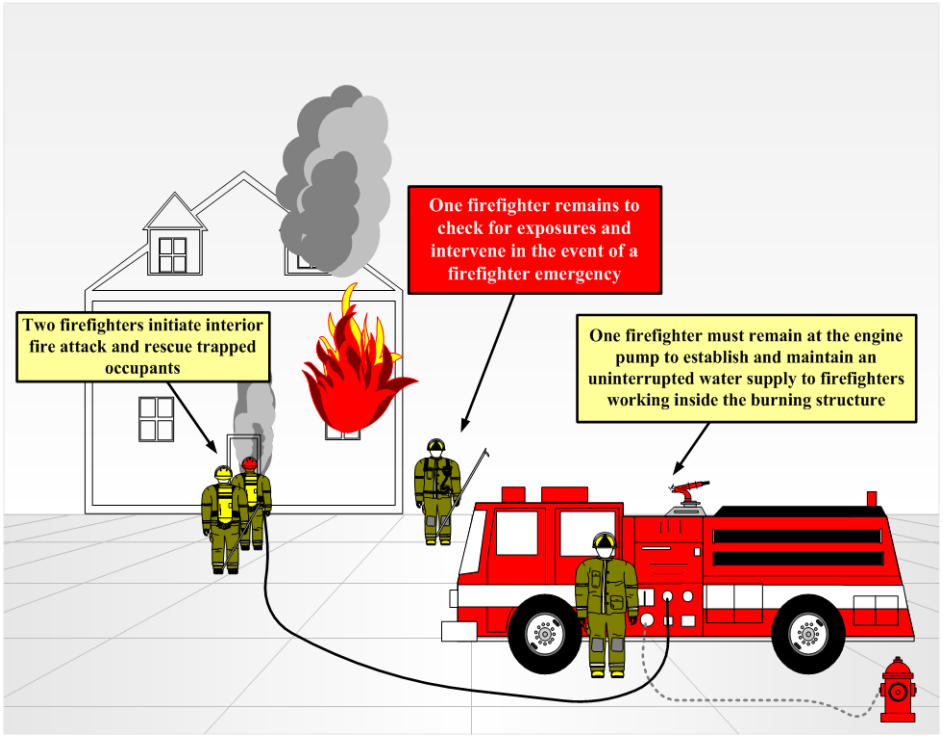


Figure 3: Engine Company Fireground Operations

For these reasons, it is recommended that the Department ensure the safe and effective delivery of emergency services by staffing fire suppression apparatus with *at least* four multi-role firefighters cross-trained to at least the level of EMT-B.[21]

[21] NFPA 1710, §5.2.3.1.2- "In jurisdictions with tactical hazards, high hazard occupancies, high incident frequencies, geographical restrictions, or other pertinent factors as identified by the authority having jurisdiction, these companies shall be staffed with a minimum of five or six on-duty members."

Initial Full Alarm Assignment

Initial Full Alarm Assignment Capability, as outlined in NFPA Standard 1710, recommends that the "fire department shall have the capability to deploy an initial full alarm assignment within 480 second travel time to 90 percent of the incidents… [and that the] initial full alarm shall provide for the following:

1. A minimum of one individual dedicated to establishing incident command outside of the hazard area for the overall coordination and direction of the initial full alarm assignment with a minimum of one individual dedicated to the task.
2. Establishment of an uninterrupted water supply of a minimum of 400 gpm (1520 L/min) for 30 minutes with supply line(s) maintained by an operator.
3. Establishment of an effective water flow application rate of 300 gpm (1140 L/min) from two handlines, each of which has a minimum flow rate of 100 gpm (380 L/min) with each handline operated by a minimum of two individuals to effectively and safely maintain the line.
4. Provision of one support person for each attack and backup line deployed to provide hydrant hookup, and to assist in laying of hose lines, utility control, and forcible entry
5. Provision of at least one search and rescue team with each team consisting of a minimum of two individuals.
6. Provision of at least one team, consisting of a minimum of two individuals, to raise ground ladders and perform ventilation.
7. If an aerial device is used in operations, one person to function as an aerial operator and maintain primary control of the aerial device at all times.
8. Establishment of an IRIC consisting of a minimum of two properly equipped and trained individuals.[22]

This breakdown of the expected capabilities of a full alarm assignment, in compliance with NFPA Standard 1710, requires a minimum contingent of fifteen fire suppression personnel. NFPA Standard 1710 also requires that supervisory chief officers shall a staff aide[23] which will increase on-scene staffing to 16 personnel required to arrive at the scene of a structure fire within 8 minutes of receiving the alarm.

[22] NFPA 1710, § 5.2.4.2.1 and § 5.2.4.2.2, (1-8)
[23] NFPA 1710, § 5.2.2.2.4 and § 5.2.2.2.5

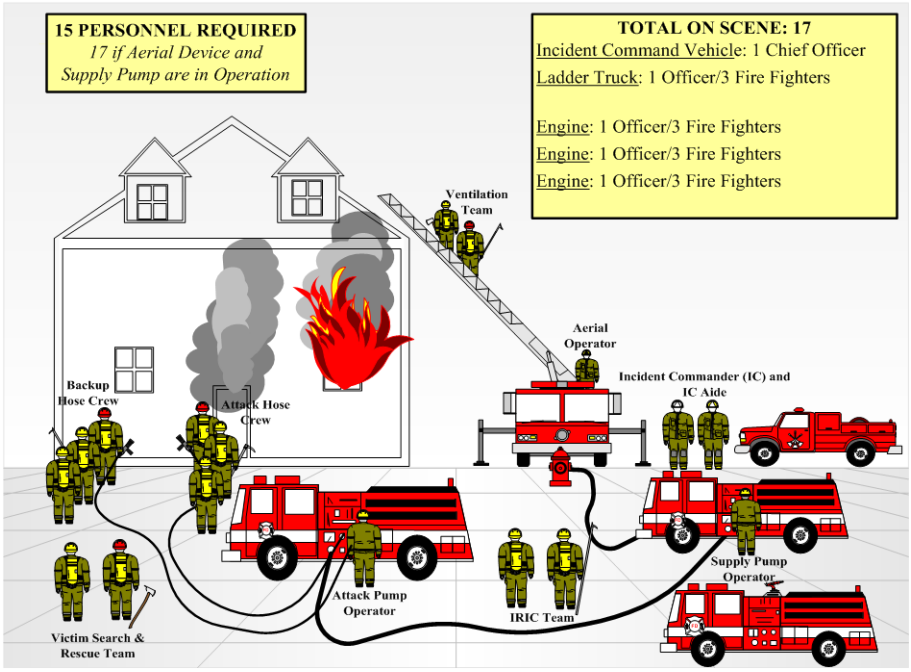
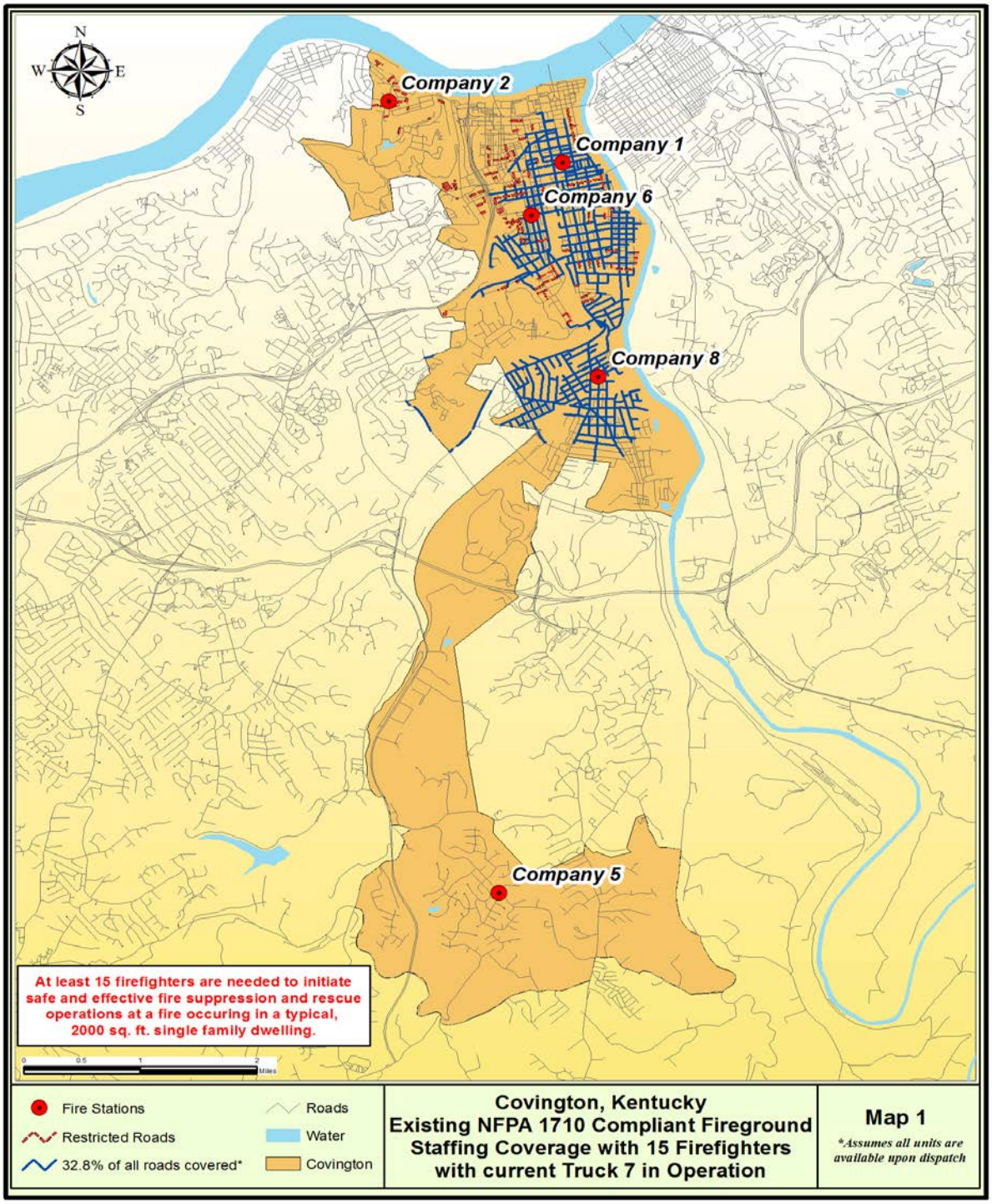
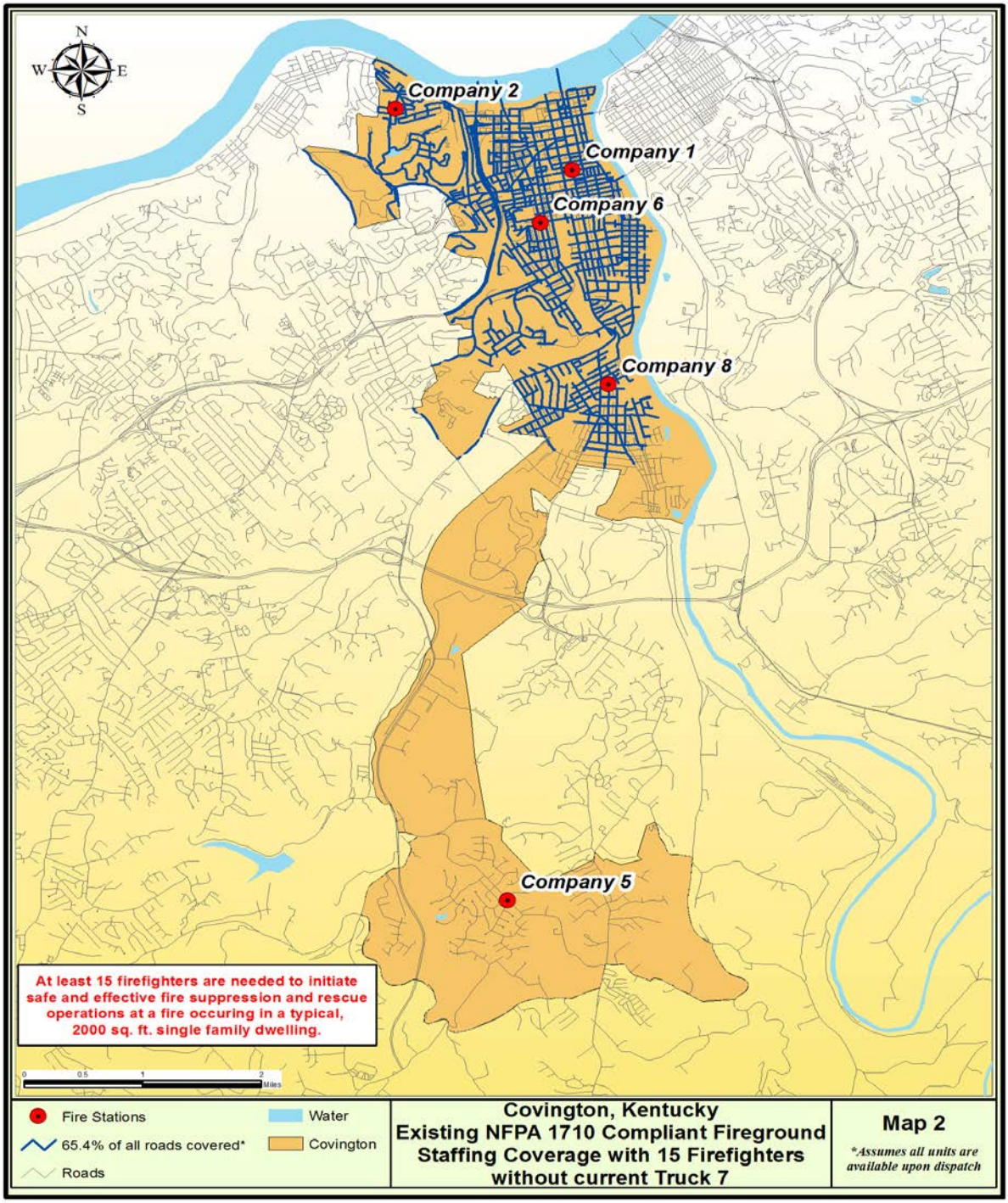


Figure 4: Initial Full Alarm Assignment Deployed Within 8 Minutes

In addition, NFPA 1710, §5.2.4.3.1 states, "The Fire Department shall have the capability for additional alarm assignments that can provide for additional command staff, personnel, and additional services, including the application of water to the fire; engagement in search and rescue, forcible entry, ventilation, and preservation of property; safety and accountability for personnel; and provision of support activities…" Currently, the Department does have the capability of providing for a full alarm response without the use of automatic or mutual aid. However, it can only do so in 32.8% of the City as will be seen later. Response to a larger area is diminished due to the low staffing of suppression apparatus outside of the minimum requirements of NFPA 1710, the absence of Pumper 1, and the diminished access capabilities of Truck 7, as can be seen in Map 1. Replacing Truck 7 with a tiller-style ladder truck, similar to Truck 1, would increase NFPA 1710 compliant response coverage to 65.4% of the City, as can be seen in Map 2.



Map 1. NFPA 1710 Compliant Response Areas With Truck 7. This map examines the ability to respond to incidents with at least *fifteen* personnel within an 8-minute time frame in accordance with NFPA 1710. Using all personnel from every Company including Truck 7 and its restricted roads, it is predicted that **32.8% of all roads currently receive a sufficient number of fire suppression personnel within 8 minutes of receiving an alarm to comply with NFPA Standard 1710**, *assuming all units are fully staffed at existing staffing levels and available to respond immediately upon dispatch.* Red marks on the map indicate where road restrictions begin, while blue reflects areas where travel is possible within 8-minutes.



Map 2. NFPA 1710 Compliant Response Areas <u>Without</u> Current Truck 7. This map examines the ability to respond to incidents with at least *fifteen* personnel within an 8-minute time frame in accordance with NFPA 1710. Using all personnel from every Company with a second tiller-style ladder truck, it is predicted that **65.4% of all roads currently receive a sufficient number of fire suppression personnel within 8 minutes of receiving an alarm to comply with NFPA Standard 1710**, *assuming all units are fully staffed at existing staffing levels and available to respond immediately upon dispatch.*

The ability of adequate fire suppression forces to greatly influence the outcome of a structural fire is undeniable and predictable. Data generated by the NFPA provides empirical proof that a rapid and aggressive interior attack can substantially reduce loss of life and the loss of property associated with structural fires. Each stage of fire extension beyond the room of origin directly increases the rate of civilian deaths, injuries, and property damage.

Fire growth is exponential, growing in a non-linear manner over time. Extending the time for crew assembly by waiting for additional crews to arrive causes on-scene risk to escalate. The higher the risks at the time firefighters engage in fire suppression, the greater the chance of poor outcomes including civilian injury or death, firefighter injury or death, and increased property loss.

OSHA's "2 In/ 2 Out" Regulation:

The "2 In/2 Out" policy is part of paragraph (g)(4) of the United States Occupational Safety and Health Administration's (OSHA) revised respiratory protection standard, 29 CFR 1910.134. The focus of this important section is the safety of fire fighters engaged in interior structural firefighting. OSHA's requirements for the number of workers required to be present when conducting operations in atmospheres that are immediately dangerous to life and health (IDLH) also covers the number of persons who must be on the scene before firefighting personnel may initiate an interior attack on a structural fire. An interior structural fire (*an advanced fire that has spread inside of the building where high temperatures, heat and dense smoke are normally occurring*) would present an IDLH atmosphere and, therefore, require the use of respirators. In those cases, at least two standby persons, in addition to the minimum of two persons inside needed to fight the fire, must be present before fire fighters may enter the building.[24, 25] This requirement is mirrored in NFPA 1500, which states that "a rapid intervention team shall consist of at least two members and shall be available for rescue of a member or a team if the need arises. Once a second team is assigned or operating in the hazardous area, the incident shall no longer be considered in the 'initial stage,' and at least one rapid intervention crew shall be required."

[24] According to NFPA standards relating to fire fighter safety and health, the incident commander may make exceptions to these rules if necessary to save lives. The Standard does not prohibit fire fighters from entering a burning structure to perform rescue operations when there is a "reasonable" belief that victims may be inside.
[25] Paula O. White, letter to Thomas N. Cooper, 1 November 1995 (OSHA)

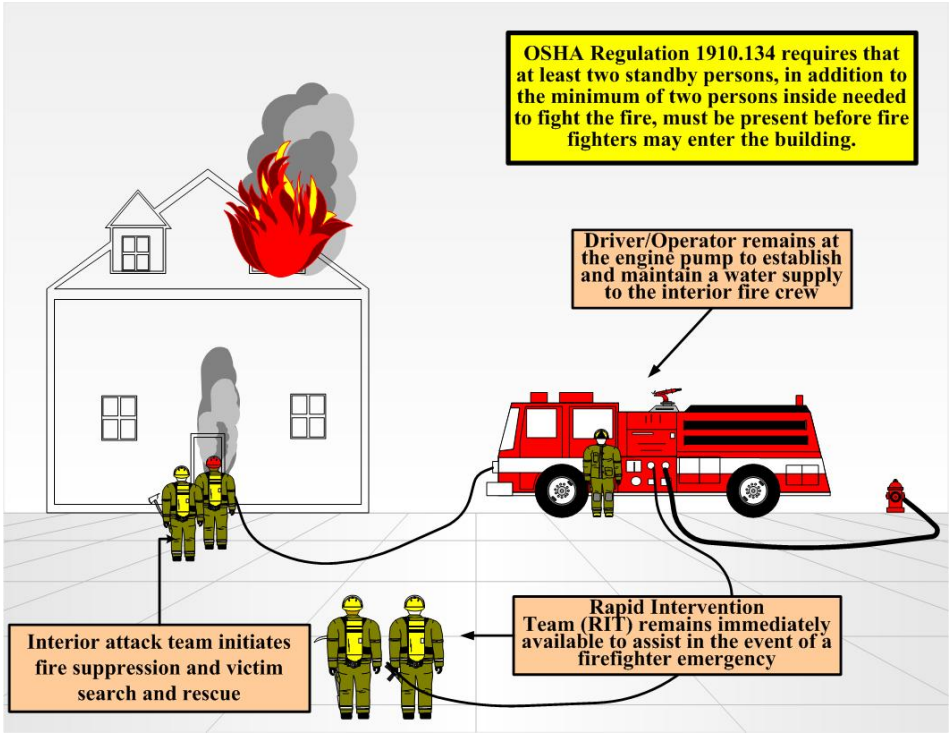


Figure 5: OSHA "2 In/ 2 Out" Illustrated

Two of the most important elements in limiting fire spread are the quick arrival of sufficient numbers of personnel and equipment to attack and extinguish the fire as close to the point of origin as possible, as well as rescue any trapped occupants and care for the injured. Several existing National Fire Protection Association standards address this time-critical issue. NFPA Standard 1710 recommends that "fire companies whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue… shall be staffed with **a minimum of four on-duty personnel**,"[26] while "fire companies whose primary functions are to perform the variety of services associated with truck work, such as forcible entry, ventilation, search and rescue, aerial operations for water delivery and rescue, utility control, illumination, overhaul and salvage work… shall [also] be staffed with **a minimum of four on-duty personnel**."[27] For either fire suppression company, NFPA 1710 states that "in jurisdictions with tactical hazards, high hazard occupancies, high incident frequencies, geographical restrictions, or other pertinent factors as identified by the authority having jurisdiction, these companies shall be staffed with a minimum of five or six on-duty members."[28]

There exist a number of incidents in which the failure to follow "2 In/2 Out" procedures have contributed to fire fighter casualties. For example, in Bridgeport, Connecticut in July 2010, two firefighters died following a fire where NIOSH later found that although a "Mayday" was called

[26] NFPA 1710, § 5.2.3.1
[27] NFPA 1710, § 5.2.3.2
[28] NFPA 1710, § 5.2.3.2.2

by the firefighters, it wasn't responded to promptly as there was no Incident Safety Officer or RIT readily available on scene. In a second case, two firefighters were killed in a fire in San Francisco, California in June 2011. The initial RIC was re-assigned to firefighting duties, and the back-up RIC did not arrive on scene until after the victims were removed.

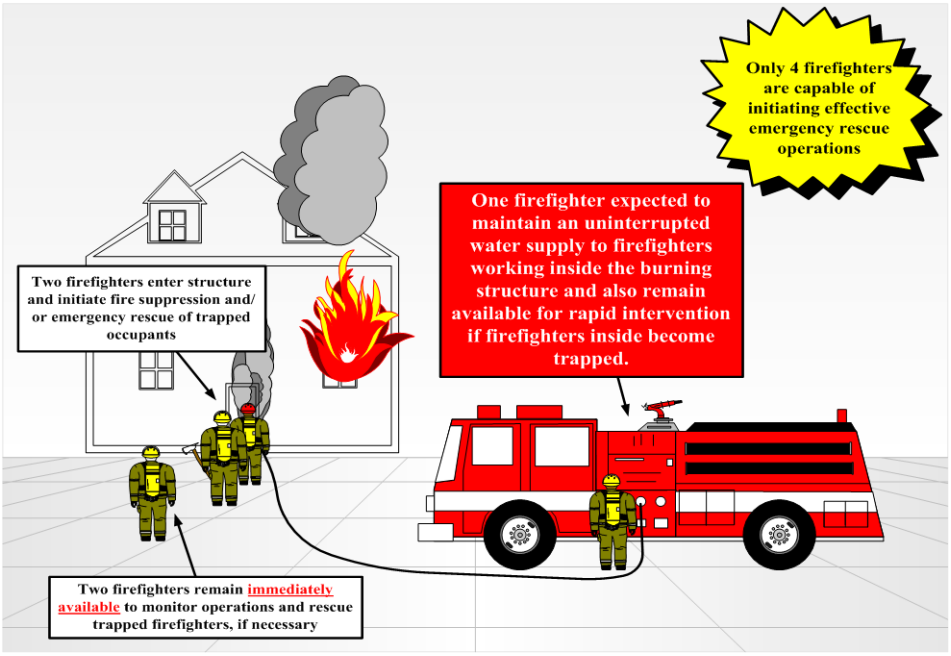


Figure 6: Emergency "2 In/2 Out" Operations

When confronted with occupants trapped in a burning structure and a single fire company is on scene, only a company staffed with four firefighters is able to initiate emergency search and rescue operations in compliance with "2 In/2 Out" policies. As indicated in the previous graphic, this requires the complete engagement of every firefighter from the first-in fire company, staffed with four, to participate in the effort, and means that the driver-operator of the apparatus must tend to the pump to ensure the delivery of water to the firefighters performing the initial attack and search and rescue operations and be prepared to make entry with the remaining firefighter should the crew operating inside become trapped.

Regardless, when there exists an immediate threat to life, only a company of four firefighters can initiate fire suppression and rescue operations in compliance with "2 In/2 Out" policies, and in a manner that minimizes the threat of personal injury. In crews with fewer than 4 firefighters, the first-in company must wait until the arrival of the second-in unit to initiate safe and effective fire suppression and rescue operations. This condition underlines the importance and desirability of fire companies to be staffed with four firefighters, and stresses the benefit of four-person companies and their ability to save lives without having to wait for the second-in company to arrive.

The Importance of Adequate Resources: Distribution

Distribution involves locating geographically distributed, first-due resources for all-risk initial intervention. Distribution is describing first due arrival. Station locations are needed to assure rapid deployment for optimal response to routine emergencies within the response jurisdiction. Distribution can be evaluated by the percentage of the jurisdiction covered by the first-due units within adopted public policy service level objectives[29]. In this case, distribution is measured by the percentage of roads that are covered from each fire station within 4- and 8-minute travel times to adhere to NFPA 1710 standards.

Distribution study requires geographical analysis of first-due resources. Distribution measures may include[30]:

- Population per first due company
- Area served per first-due company (square miles)
- Number of total road miles per first-due company (miles)
- Dwelling unit square footage per first due company
- Maximum travel time in each first-due company's protection area
- Catchment areas (4-minute road response from all fire stations) to determine gap areas and overlaps of first-due resources
- Areas outside of actual performance
    1. Population not served
    2. Area not served (square miles)
    3. Road miles not served (miles)
    4. Dwelling unit square footage not served
- First-due unit arrival times (Engine, Truck, ALS unit, etc.)

A major item to be considered in the distribution of resources is travel time. It should be a matter of public policy that the distribution of fire stations in the community is based on the element of travel time and the response goal. Travel time should be periodically sampled and

[29] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.
[30] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.

analyzed to determine whether or not the fire department is achieving a reasonable response performance to handle emergencies[31].

Setting average response times is inadequate. Average is the 50th percentile. If the average response time is measured, it states the fire department had response times higher than the average 50% of the time or response times lower than the average 50% of the time. It does not reflect a true measurement of overall response time performance made by the fire department. A better reflection is to measure response times to the 90th percentile, or what is achieved 90% of the time. The higher the percentage measurement, the better actual overall performance is shown.

Evaluating a small number of incidents for response time performance also does not reflect the true performance of the department. Analyzing tens of thousands of incidents or incidents measured over 3-5 years will provide a more accurate assessment of the delivery system performance. Completing the same analysis over a period of time will allow for trend analysis as well.[32]

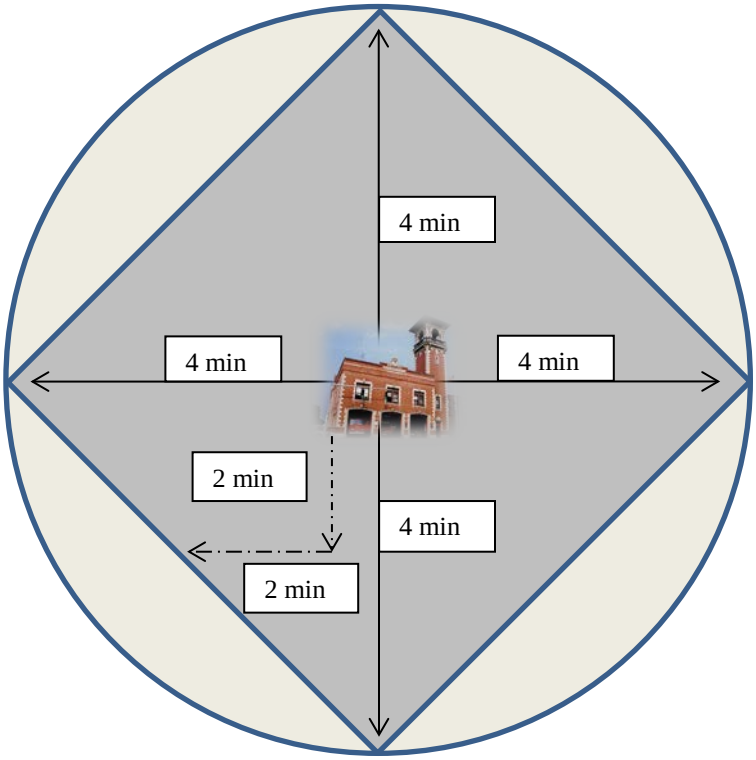


Figure 7: Normal distribution model for an initial 4-minute response area[33]

Distribution strives for an equitable level of outcome: Everyone in the community is within the same distance from a fire station. Distribution is based on probabilities that all areas experience

[31] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[32] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[33] Derived from Commission on Fire Accreditation International, 5th Edition. 2008. Page 53

equal service demands, but not necessarily the same risk or consequences as those demands for service in other areas. For example suburban communities in the City have the same service demand as an industrial factory area, but the level of risk is very different. This can have an impact on fire station locations as placement would probably put the stations near high risk areas with shorter travel times. But, would citizens in lower risk areas accept longer travel times? Additionally, EMS response times based on medical emergencies will drive equal distribution in the community and negate distribution based on risk, as the risk is equal.

First unit arrival times are the best measure of distribution. It should be noted that if an area experiences fire unit arrival times outside the adopted performance measure, in this case 4-minute travel time per NFPA 1710, it does not necessarily mean it has a distribution issue[34]. Other issues occur such as reliability, call processing times and turnout times, and traffic which can affect the overall performance of response times.

An effective response force for a fire department is impacted not only by the spacing of fire stations but also by the type and amount of apparatus and personnel staffing the stations. To assemble the necessary apparatus, personnel, and equipment within the prescribed timeframe, all must be close enough to travel to the incident, if available upon dispatch. The placement and spacing of specialty equipment is always challenging.[35] Specialty units tend to be trucks, rescue units, hazmat, or Battalion personnel. Most often there are less of these types of equipment and personnel compared to the first-line response of engines and medic units. Selecting where to put specialty units requires extensive examination of current and future operations within the fire department and a set goal of response time objectives for all-hazards emergencies within the City.

Distribution vs. Concentration

Major fires have a significant impact on the resource allocation of any fire department. The dilemma for any fire department is staffing for routine emergencies and also being prepared for the fire or emergency of maximum effort. This balancing of distribution and concentration staffing needs is one that almost all fire agencies face on an ongoing basis.

The art in concentration spacing is to strike a balance with respect as to how much overlap there should be between station areas. Some overlap is necessary to maintain good response times and to provide back-up for distribution when the first-due unit is unavailable for service or deployed on a prior emergency.

Concentration pushes and pulls distribution. Each agency, *after risk assessment and critical task analysis,* must be able to quantify and articulate why its resource allocation methodology meets the governing body's adopted policies for initial effective intervention on both a first-due and multiple-unit basis.[36]

[34] Commission on Fire Accreditation International, 5th Edition. 2008. Page 55
[35] Commission on Fire Accreditation International, 5th Edition. 2008. Page 62
[36] Commission on Fire Accreditation International, 5th Edition. 2008. Pages 62-63

Staffing and Deployment Analysis

The following table specifies the current staffing and deployment of Department:

Station	Address	Apparatus	Min. Staffing
1	100 E Robbins Street Covington, KY 41011	Pumper 1 (OOS[37])	**3 FF**
		Ambulance 1	**2 FF**
		Truck 1 (Tiller)	**3 FF**
		Rescue 1	**2 FF**
		District Car	**1 Battalion Chief**
		Inspector Car	**1 Safety Officer**
2	1252 Parkway Avenue Covington, KY 41016	Pumper 2	**3 FF**
5	1255 Hands Pike Covington, KY 41017	Pumper 5	**3 FF**
		Ambulance 3	**2 FF**
6	1502 Holman Street Covington, KY 41011	Pumper 6	**3 FF**
8	3315 Church Street Covington, KY 41015	Pumper 8	**3 FF**
		Ambulance 2	**2 FF**
		Truck 7 (Quint)	**2 FF**

Table 4: Current Fire Station Locations, Staffing and Deployment

Adjustments:

- Pumper 1, although listed in the table above and considered a first-line apparatus, was not accounted for in the GIS calculations. Pumper 1 is browned-out over 80% of the year due to scheduled and unscheduled personnel leave. Browned-out is a term used to describe apparatus that is out-of-service due to personnel vacancies as opposed to mechanical issues. Specifically, it means that the apparatus is not responding and that staffed apparatus will have farther to travel to provide coverage for the affected response area.

[37] Pumper 1 is Out of Service (OOS) due to vacancies created by scheduled and unscheduled leave. This is commonly referred to as a "Brown Out" since the reason for the apparatus being OOS is not mechanically related.

Assumptions:

Several key assumptions must be addressed prior to drawing any conclusions from this analysis.

- Modeled travel speeds are based on reasonable and prudent road speeds. Actual response speeds may be slower, and the associated travel times greater, with any unpredictable impedances including, but not limited to:
    - Traffic Incidents: Collisions and vehicle breakdowns causing lane blockages and driver distractions.
    - Work Zones: Construction and maintenance activity that can cause address travel time in locations and times where congestion is not normally present.
    - Weather: Reduced visibility- road surface problems and uncertain waiting conditions result in extra travel time and altered trip patterns.
    - Special Events: Demand may change due to identifiable and predictable causes.
    - Traffic Control Devices: Poorly timed or inoperable traffic signals, railroad grade crossings, speed control systems, and traveler information signs contribute to irregularities in travel time.
    - Inadequate Road or Transit Capacity: The interaction of capacity problems with the aforementioned sources causes travel time to expand much faster than demand.[38]

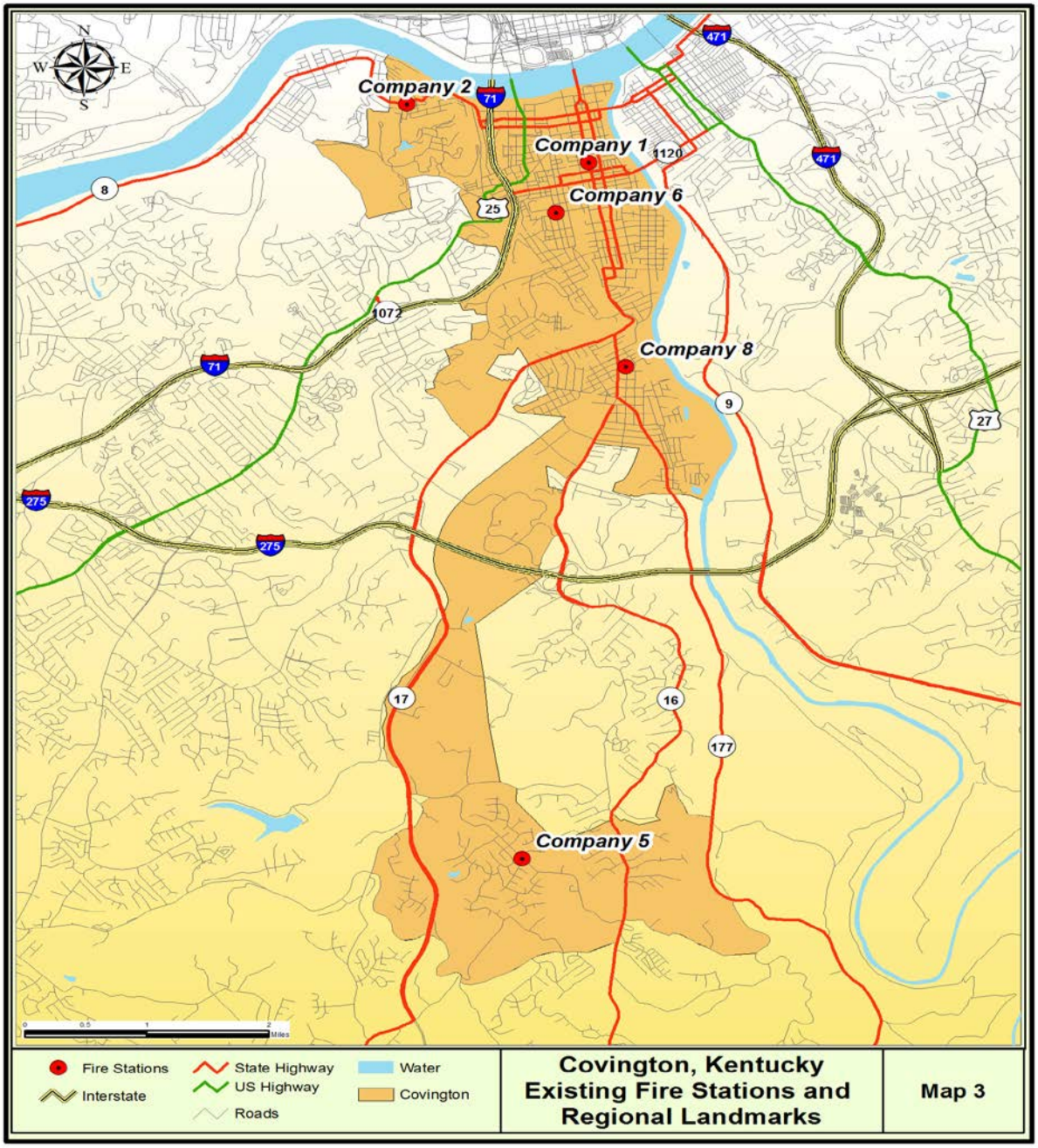
In addition, it is reasonable to suggest that because larger emergency vehicles are generally more cumbersome and require greater skill to maneuver, their response may be more negatively affected by their weight, size, and in some cases, inability to travel narrow surface streets.

- The time from arrival of the apparatus to the onset of interior fire operations (access interval) must be considered when analyzing response system capabilities.
    - The access interval is dependent upon factors such as distance from the apparatus to the task location and the elevation of the incident and locked doors or security bars which must be breached.
    - Impediments like these may add to the delay between discovery of a fire and the initiation of an actual fire attack.

[38] David Shrank and Tim Lomax, The 2003 Urban Mobility Report, (Illinois Transportation Institute, Illinois A&M University: September 2003).

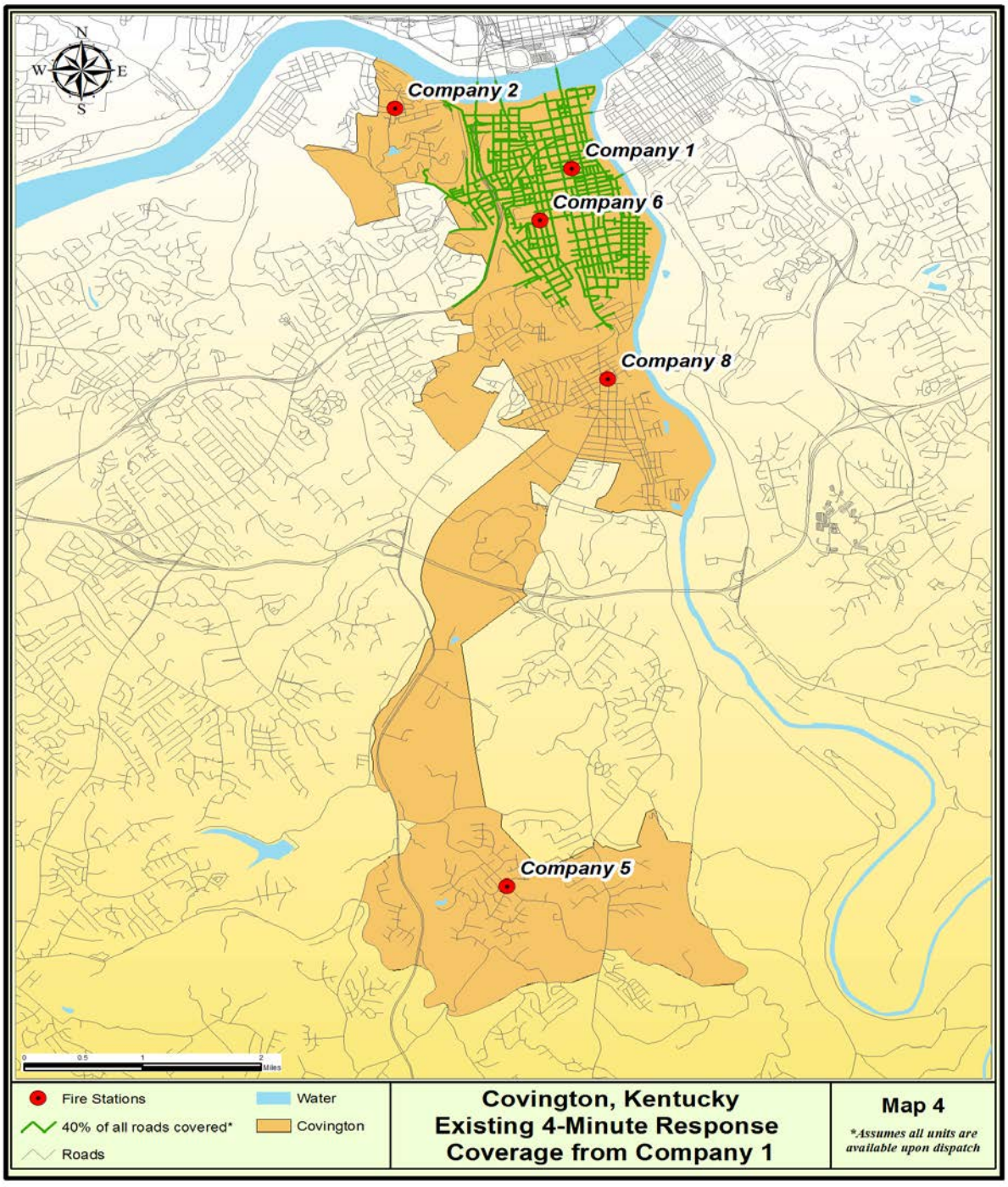
- The computer model is unable to accurately portray the response of recall personnel responding to assigned stations and then to the scene for a multiple alarm fire. As these firefighters are not available on a regular basis to respond immediately upon dispatch, their actual response times are not quantifiable. Therefore, responses by these individuals have been omitted from this analysis.

The GIS is now able to model and incorporate historical traffic demand in the service area response analysis. Traffic varies hour-by-hour and day-to-day in cities which has an impact on response times for emergency vehicles. Most common heavy traffic volume in an area is morning and afternoon rush hour during workdays. To most affectively show worst-case scenario, adverse traffic conditions the Department must respond to with heavy traffic volume, historical traffic data records were used on *May 29, 2014 at 5:00 PM* in the GIS analysis.

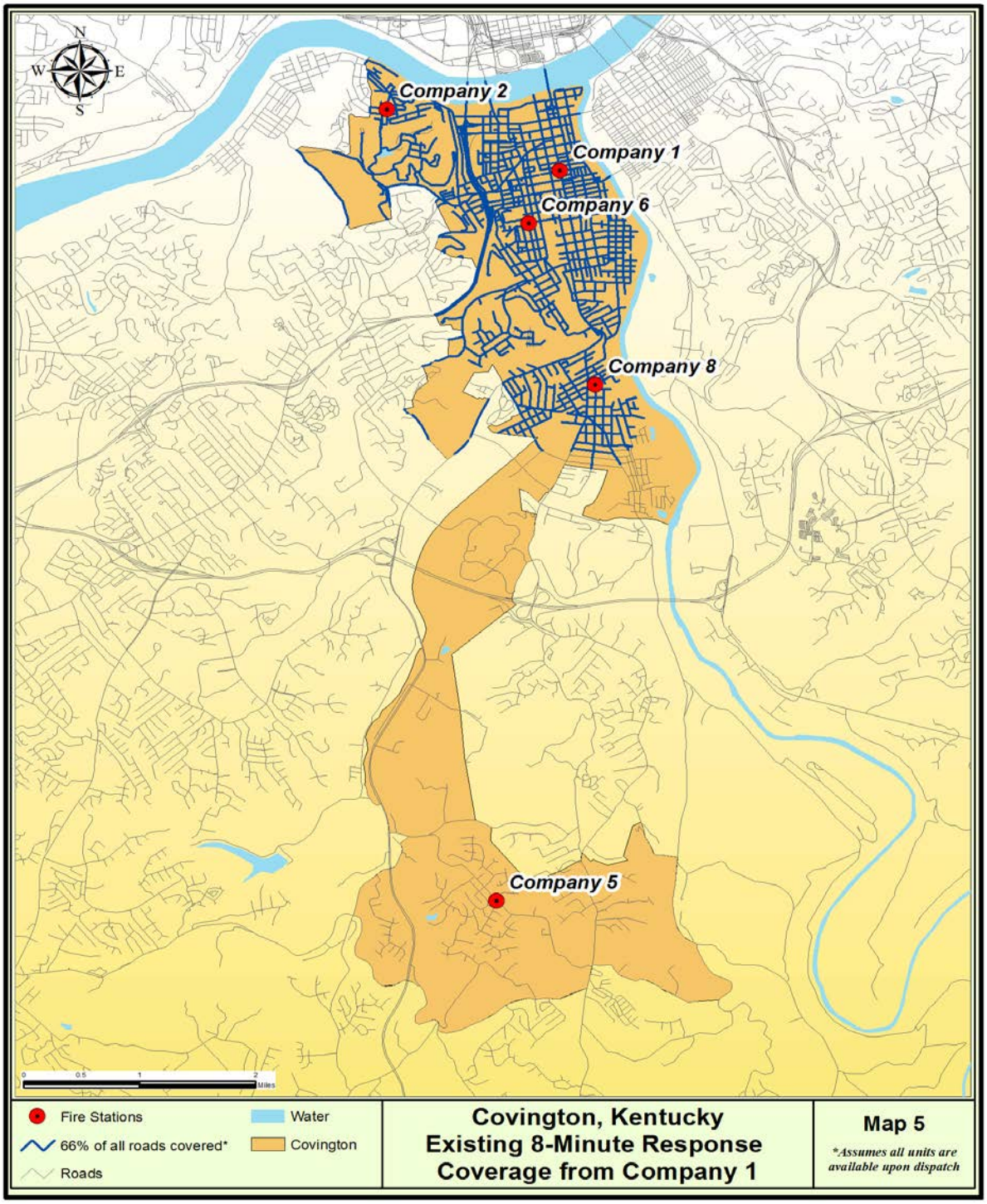


Map 3. Fire Company Locations and Road Network. The total area of the response jurisdiction is roughly 13.1 square miles of land in Covington and there are 2,966 people per square mile. The total population in 2010 was 40,640[39]. Covington is located in north central Kentucky along the Ohio River and borders Ohio. Cincinnati is across the river from Covington. The geographical area is composed of a sprawled urban landscape with highways throughout the area. Interstate 275 bisects Covington north to south. Most of the urban dwelling is north of Interstate 275 along with four fire companies. The urban landscape is more sprawled south of Interstate 275. Company 5 is the only station south of the interstate. The area has numerous schools, a historical downtown area, riverfront area, and a shopping district.

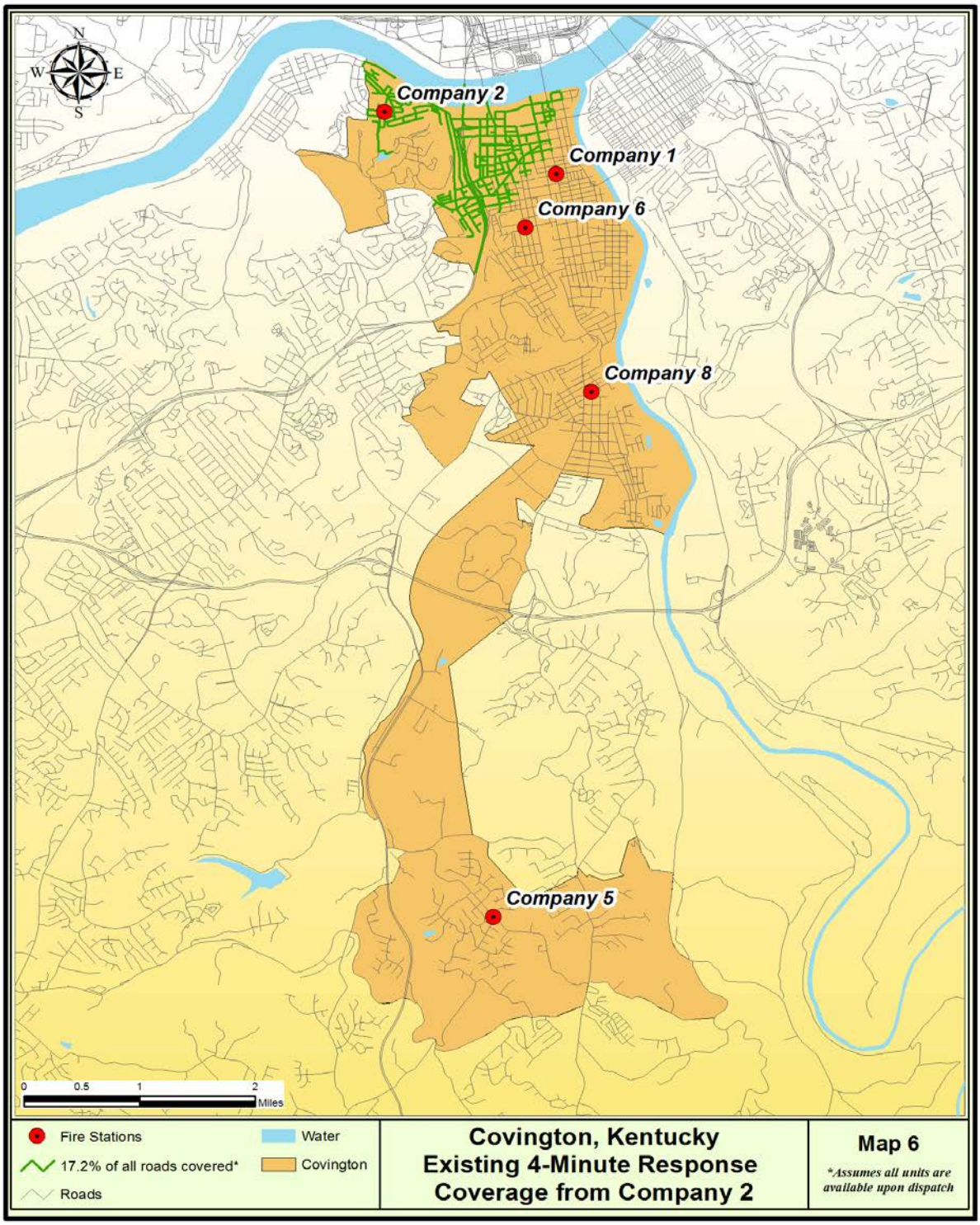
[39] Covington Kentucky website. http://www.city-data.com/city/Covington-Kentucky.html/ Site last visited 6/4/2014



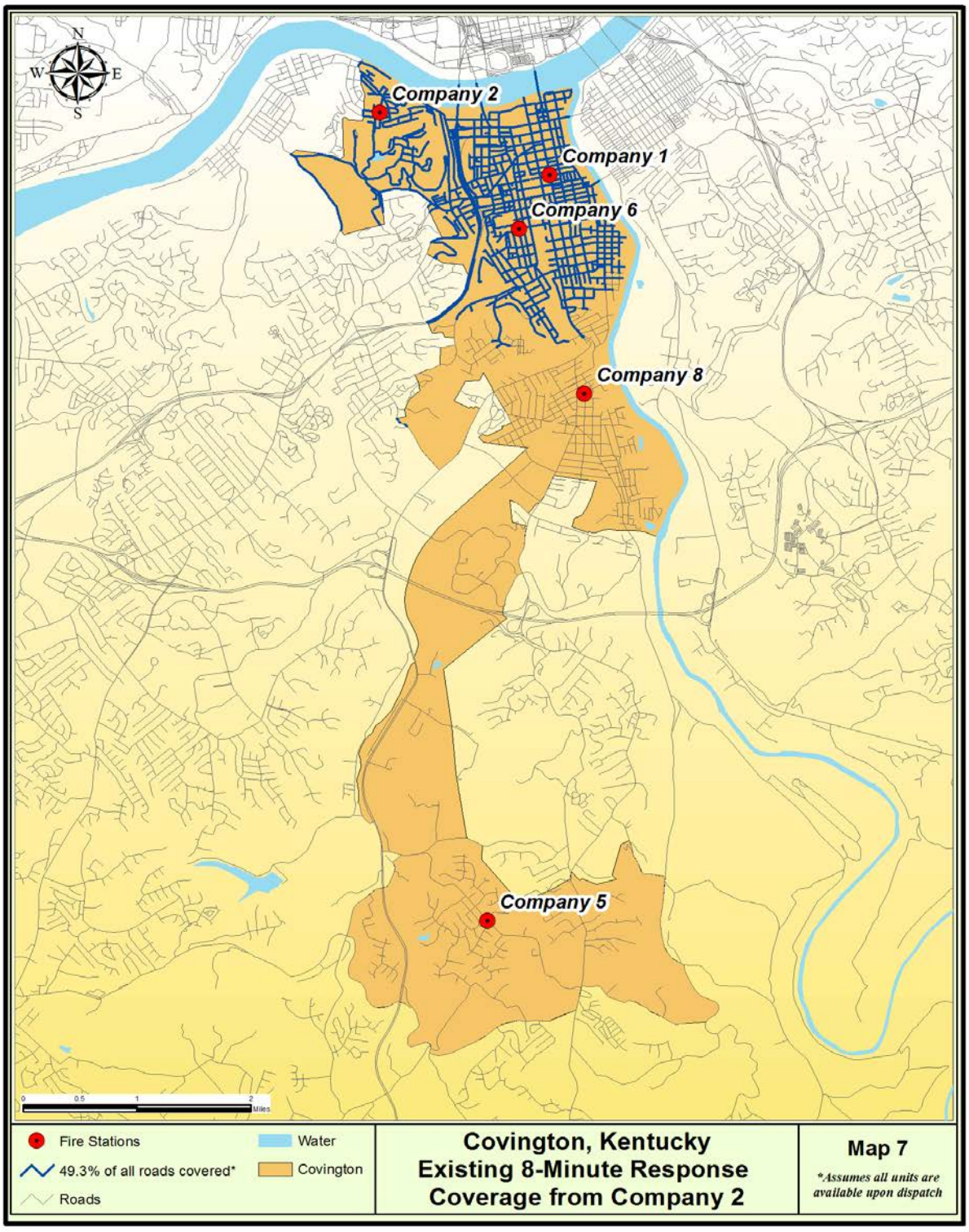
Map 4. Four-Minute Response from Company 1. This map identifies the roads where response can occur within four-minutes of travel when deploying from Company 1. Currently, apparatus and personnel that deploy from Company 1 are capable of responding to **40% of all roads located within the jurisdiction in 4 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



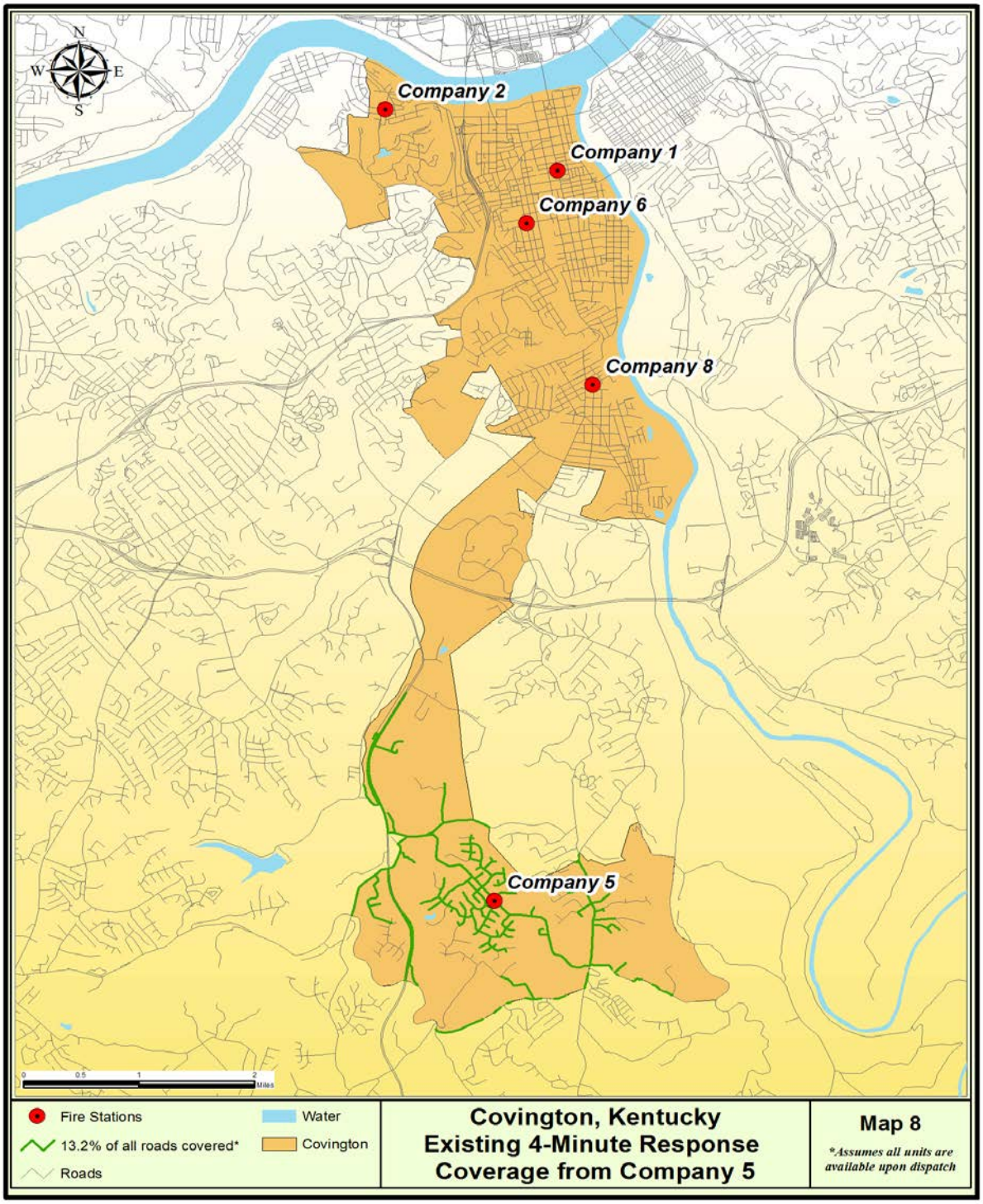
Map 5. Eight-Minute Response from Company 1. This map identifies the roads where response can occur within 8 minutes of travel when deploying from Company 1. Currently, apparatus and personnel that deploy from Company 1 are capable of responding to **66% of all roads located within the jurisdiction in 8 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



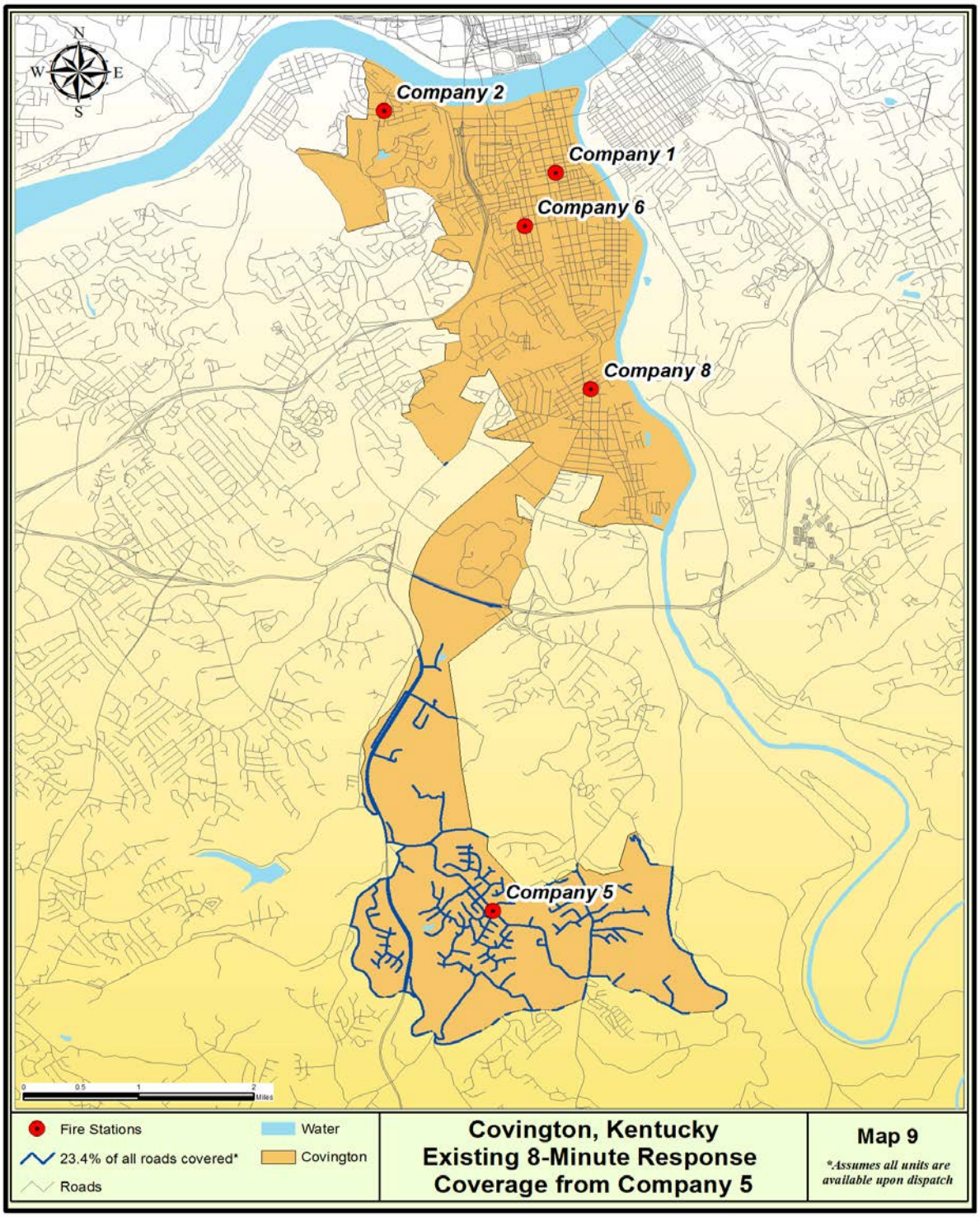
Map 6. Four-Minute Response from Company 2. This map identifies the roads where response can occur within 4 minutes of travel when deploying from Company 2. Currently, apparatus and personnel that deploy from Company 2 are capable of responding to **17.2% of all roads located within the jurisdiction in 4 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



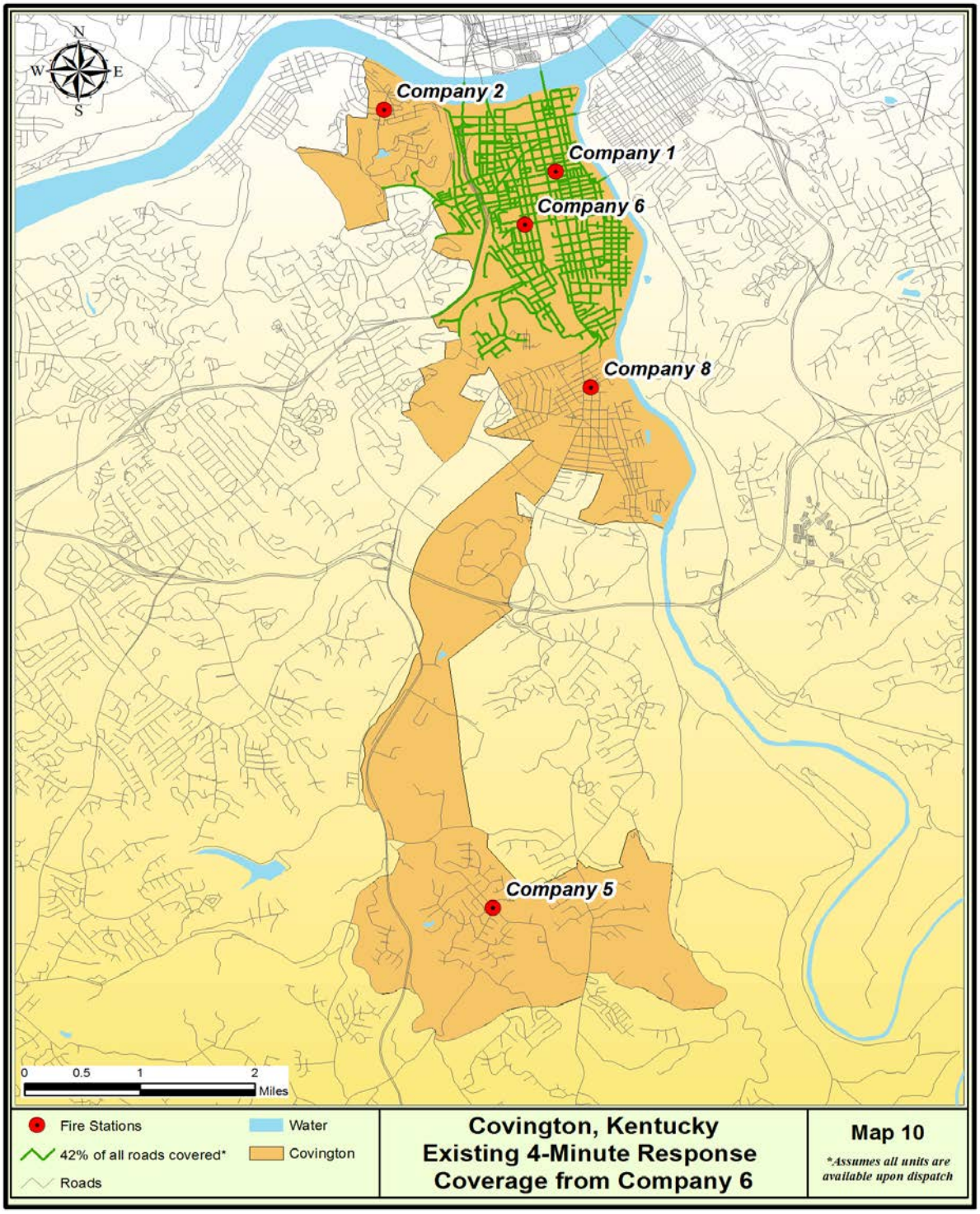
Map 7. Eight-Minute Response from Company 2. This map identifies the roads where response can occur within 8 minutes of travel when deploying from Company 2. Currently, apparatus and personnel that deploy from Company 2 are capable of responding to **49.3% of all roads located within the jurisdiction in 8 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



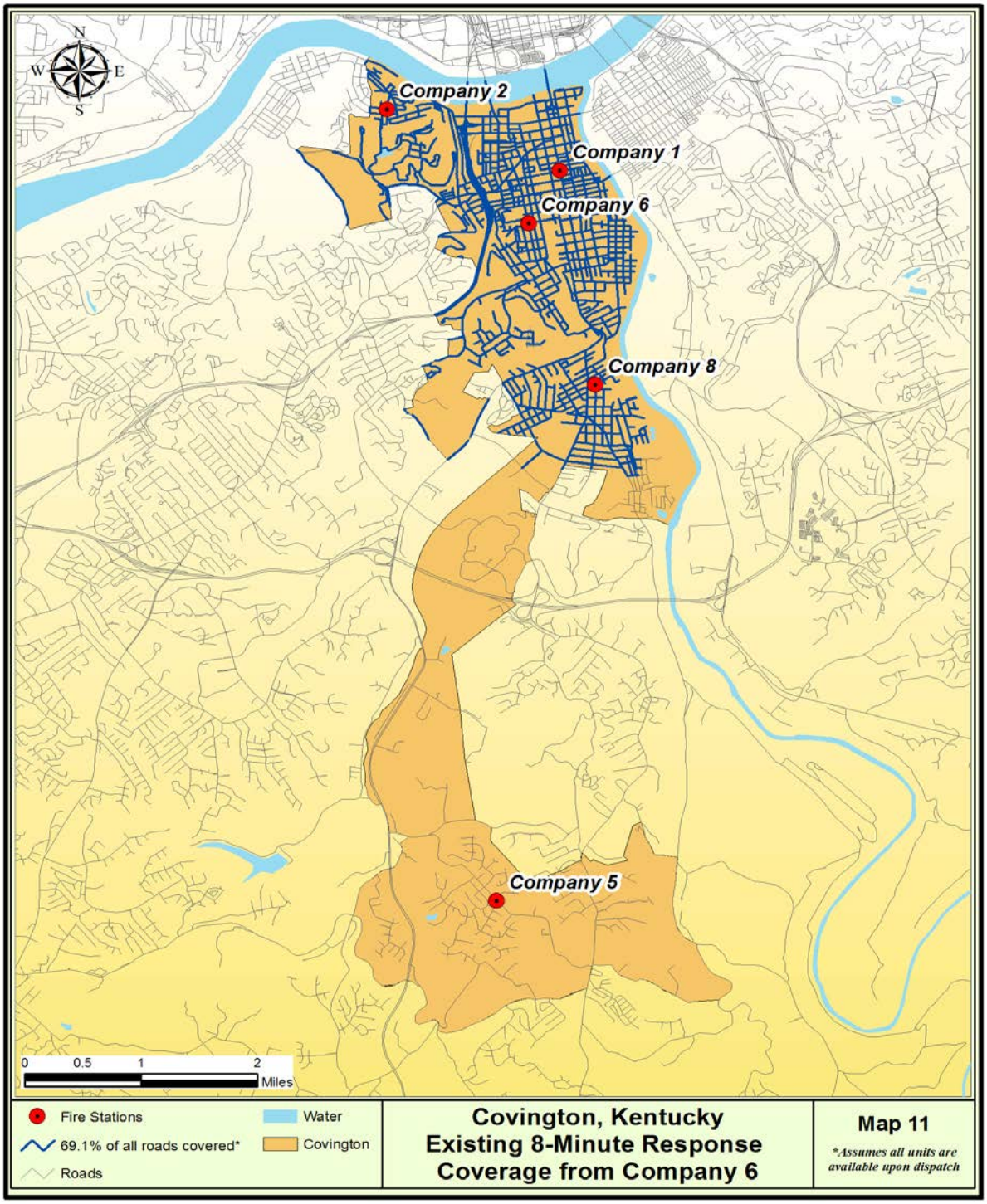
Map 8. Four-Minute Response from Company 5. This map identifies the roads where response can occur within 4 minutes of travel when deploying from Company 5. Currently, apparatus and personnel that deploy from Company 5 are capable of responding to **13.2% of all roads located within the jurisdiction in 4 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



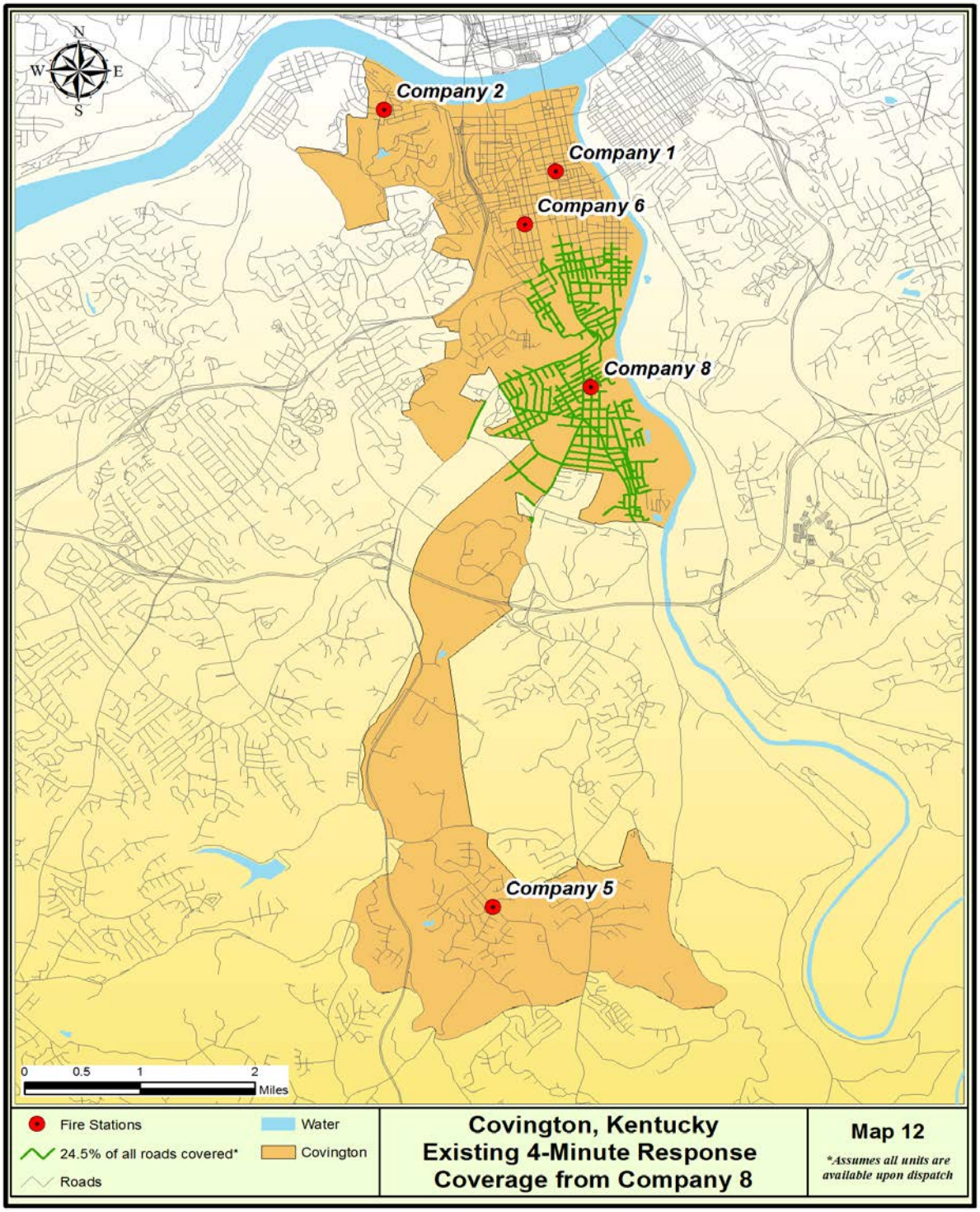
Map 9. Eight-Minute Response from Company 5. This map identifies the roads where response can occur within 8 minutes of travel when deploying from Company 5. Currently, apparatus and personnel that deploy from Company 5 are capable of responding to **23.4% of all roads located within the jurisdiction in 8 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



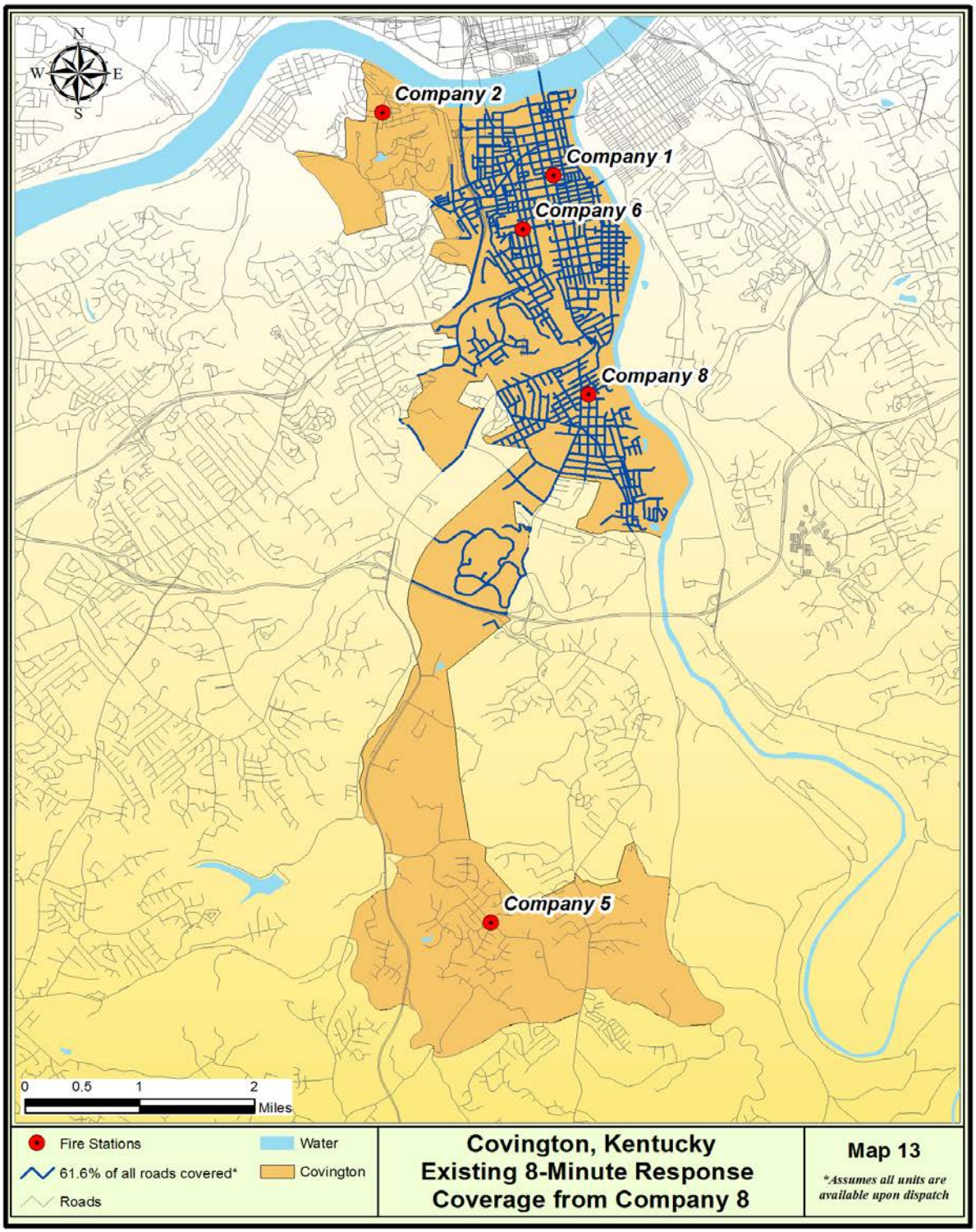
Map 10. Four-Minute Response from Company 6. This map identifies the roads where response can occur within 4 minutes of travel when deploying from Company 6. Currently, apparatus and personnel that deploy from Company 6 are capable of responding to **42% of all roads located within the jurisdiction in 4 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



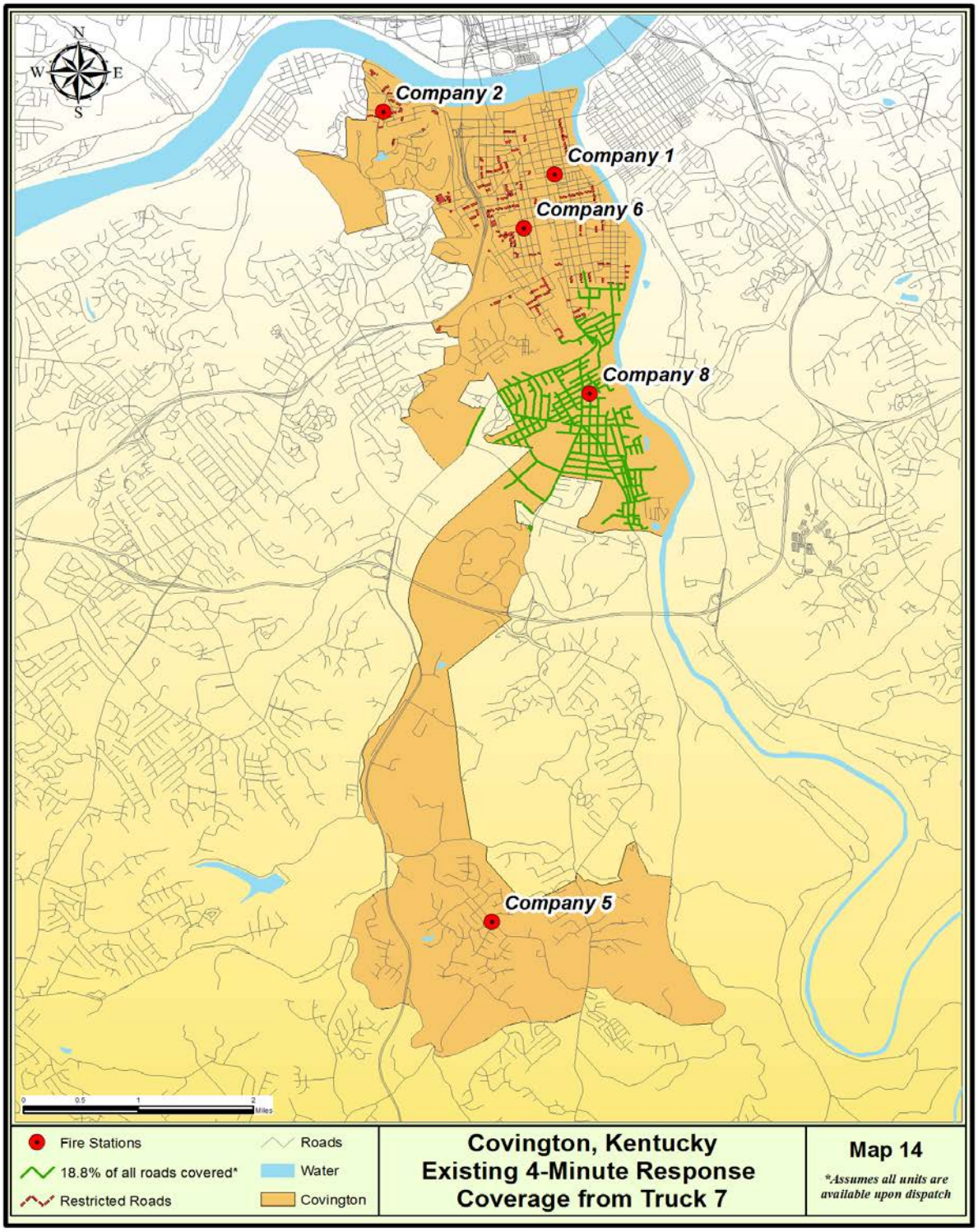
Map 11. Eight-Minute Response from Company 6. This map identifies the roads where response can occur within 8 minutes of travel when deploying from Company 6. Currently, apparatus and personnel that deploy from Company 6 are capable of responding to **69.1% of all roads located within the jurisdiction in 8 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



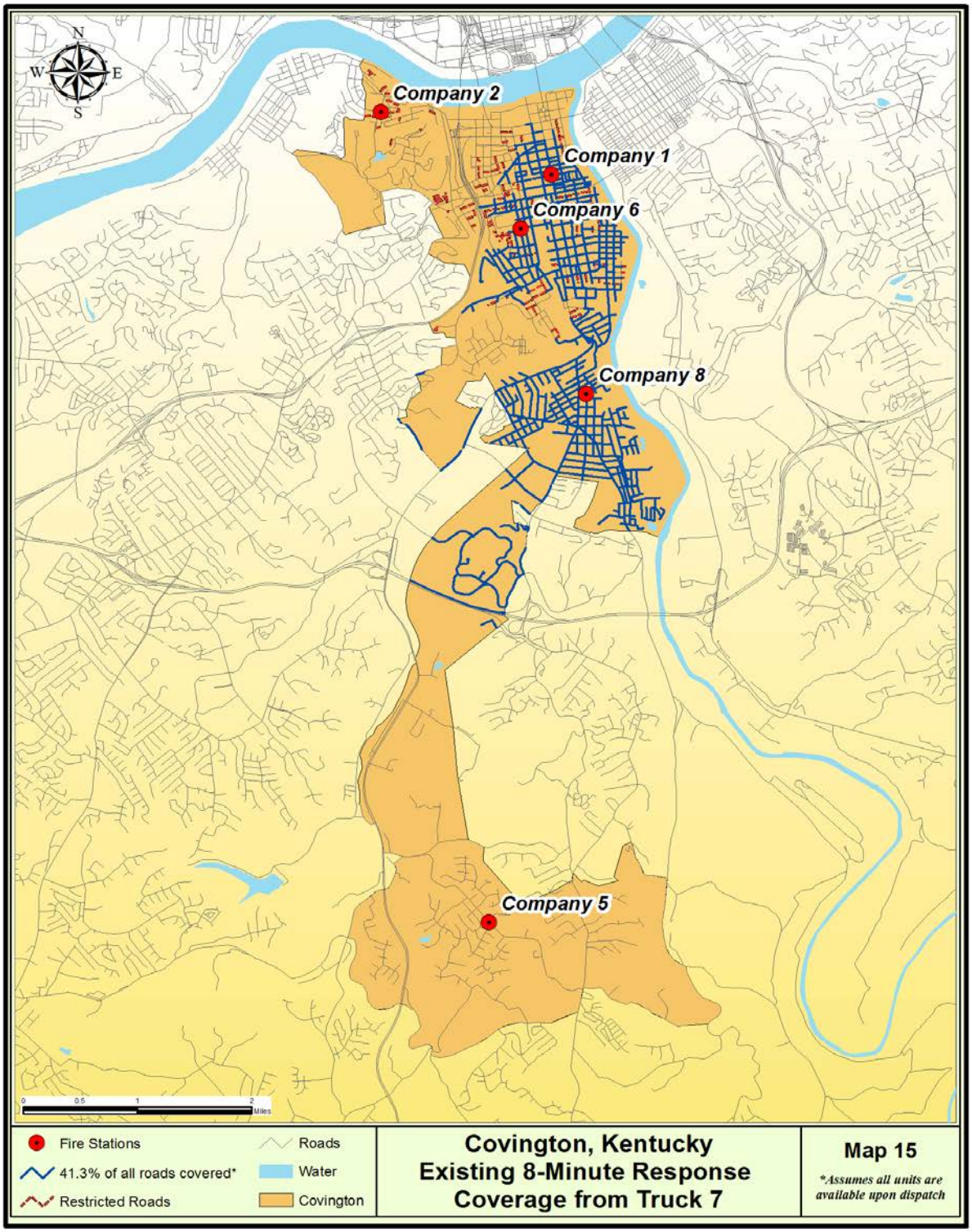
Map 12. Four-Minute Response from Company 8. This map identifies the roads where response can occur within 4 minutes of travel when deploying from Company 8. Currently, apparatus and personnel that deploy from Company 8 are capable of responding to **24.5% of all roads located within the jurisdiction in 4 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



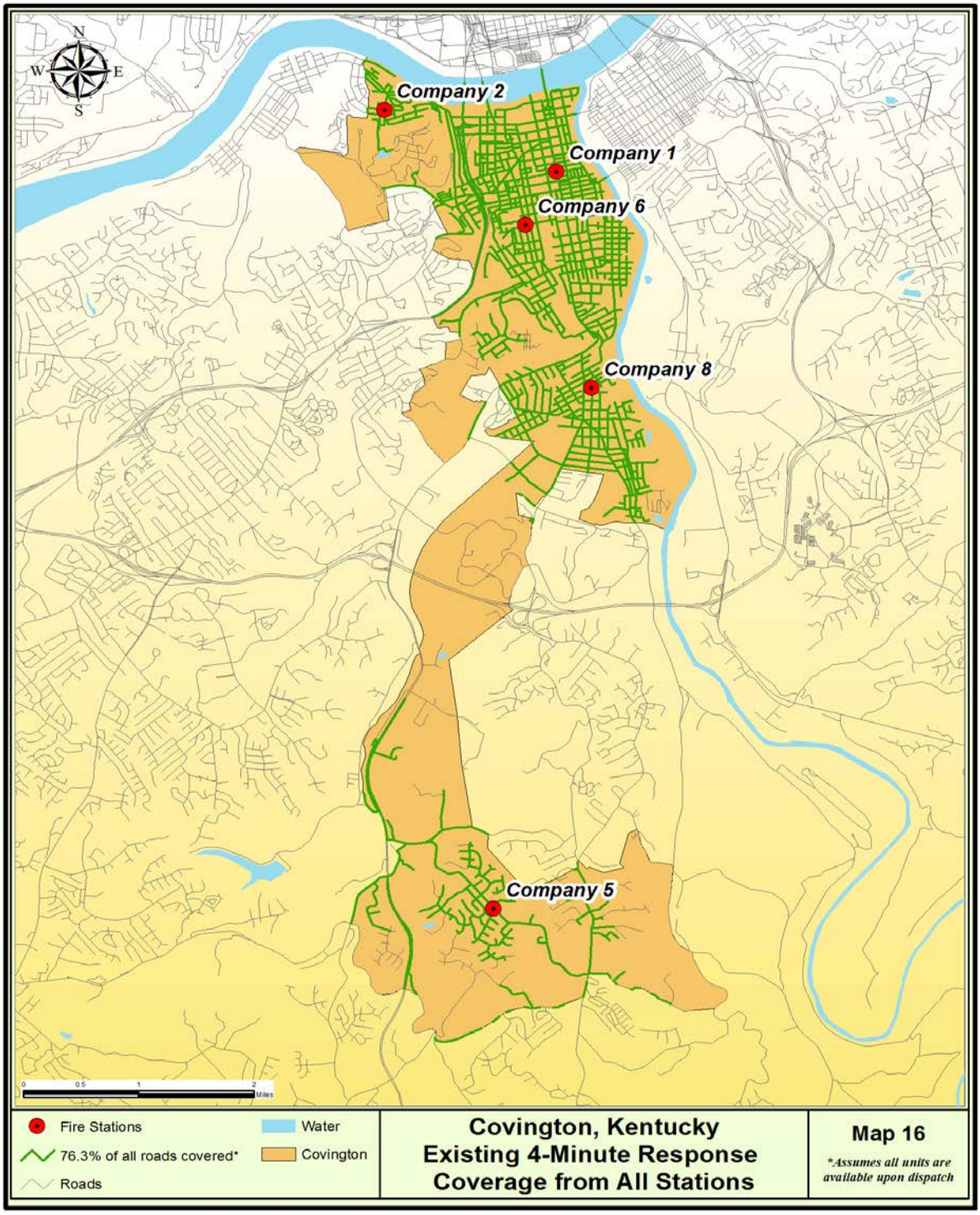
Map 13. Eight-Minute Response from Company 8. This map identifies the roads where response can occur within 8 minutes of travel when deploying from Company 8. Currently, apparatus and personnel that deploy from Company 8 are capable of responding to **61.6% of all roads located within the jurisdiction in 8 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



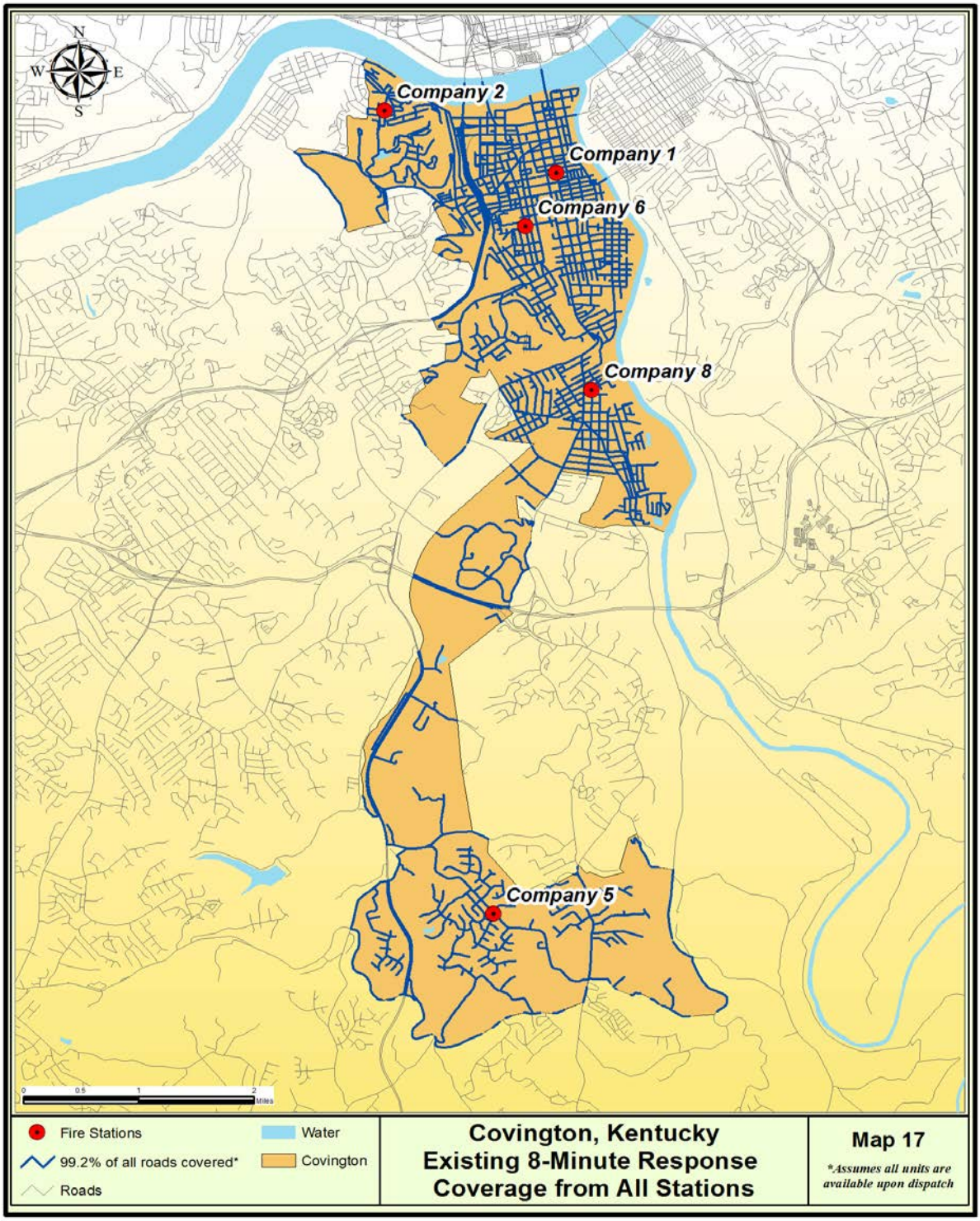
Map 14. Four-Minute Response for Truck 7, with Restrictions. This map identifies the roads where Truck 7 from Company 8 can respond within 4 minutes of travel. The analysis excludes roads that Truck 7 is restricted to travel on due to the apparatus being too large to traverse the narrow streets. Truck 7 is capable of responding to **18.8% of the roads located within the jurisdiction in 4 minutes or less,** *assuming the unit is available to respond immediately upon dispatch.*



Map 15. Eight-Minute Response for Truck 7, with Restrictions. This map identifies the roads where Truck 7 from Company 8 can respond within 8 minutes of travel. The analysis excludes roads that Truck 7 is restricted to travel on due to the apparatus being too large to traverse the narrow streets. Truck 7 is capable of responding to **41.3% of the roads located within the jurisdiction in 8 minutes or less,** *assuming the unit is available to respond immediately upon dispatch*



Map 16. Four-Minute Response for All Apparatus. This map identifies the roads where response can occur within 4 minutes of travel when deploying from every Company. Currently, apparatus and personnel that deploy from every Company are capable of responding to **76.3% of all roads located within the jurisdiction in 4 minutes or less,** *assuming units are available to respond immediately upon dispatch.*



Map 17. Eight-Minute Response for all Apparatus. This map identifies the roads where response can occur within 8 minutes of travel when deploying from every Company. Currently, apparatus and personnel that deploy from every Company are capable of responding to **99.2% of all roads located within the jurisdiction in 8 minutes or less,** *assuming units are available to respond immediately upon dispatch.*

As can be seen in the series of maps, although most of the City can be covered within eight minutes by single responding apparatus, only 32.8% to 65.4% (Maps 16 and 17) of the City can be adequately served to meet the requirements outlined in NFPA 1710[40].

It has been discussed in previous consultant reports that the Department should combine Pumper 8 and Truck 7 personnel onto Truck 7. This idea cannot be supported for a number of reasons, but the principle reason being that Truck 7 cannot maneuver onto a large portion of City streets. Maps 1, 2, and 10-13 highlight the impact of Truck 7's inability to maneuver City streets. The inability of this apparatus to maneuver all streets severely impacts the Department's response capabilities, especially in the downtown area and a few of the industrial sections of the City. Furthermore, since the apparatus will be expected to perform the operations of a pumper company and a ladder company simultaneously, the apparatus will require a minimum staffing of eight personnel, which it is not equipped to safely seat and restrain. In addition to its restricted response and insufficient staffing, Truck 7 also has a limited amount of hose, both for supply and fire attack, which limits its ability to provide multiple attack lines or provide water supply in the same manner that a pumper could. Truck 7 is not up-to-task for use as the sole suppression apparatus for Company 8, let alone the second ladder company for the City.

Another point of note is that the downtown and inner-city core of the City with its collection of high rise structures, row housing, hotels, multi-family structures, and high incident frequencies should be considered a high tactical hazard area. This means first-line suppression and rescue capable apparatus in these areas should be staffed with five to six personnel a day. Similarly, Pumper 5 should be staffed with five to six personnel due to geographical restrictions, chiefly the fact that the Department cannot muster 15 firefighters within eight minutes of the initial alarm.

[40] Assuming all apparatus is available and responding from assigned fire stations.

Fleet Assessment

The Department responds to over 10,000 requests for emergency service per year. In addition to these responses the Department is also busy with non-emergency work such as fire-safety inspections and public education programs. In addition to the mileage and hours placed on the apparatus traversing the City, the geography of the City, weather conditions of the Ohio River Valley, and vehicle maintenance issues also contribute to the wear and tear on the apparatus. These issues combined with apparatus age have impacted the way the Department responds to emergencies in the City.

In an effort to control costs, the City has made a notable attempt to repair apparatus rather than replace. However, it is possible, due to the size and frequency of some issues, that the City would save money in the long run if it allowed the Department to purchase new apparatus to replace old and worn down apparatus. NFPA 1901, recommends that, keeping mileage, hours, and use in mind, serviceable apparatus that is 15 years old should be refurbished and placed in reserve status. Additionally, apparatus that is 25 years old should be replaced. NFPA also encourages decision makers to assess the cost of refurbishing apparatus versus purchasing new since the cost of refurbishing in some instances will be more costly than purchasing.

Apparatus	Assignment	Year of Manufacture	Age
Pumper 1	Company 1	2008	6
Pumper 2	Company 2	1996	18
Pumper 5	Company 5	1997	17
Pumper 6	Company 6	2008	6
Pumper 8	Company 8	2001	13
Truck 1	Company 1	1994	20
Truck 7	Company 8	2004	10
Rescue 1	Company 1	1997	17
Pumper 3	Reserve	1999	15
Pumper 4	Reserve	1990	24
Rescue 2	Reserve	1996	18

Table 5. Age of Covington Fire Department Fleet. The above table demonstrates the age of the suppression and rescue capable apparatus maintained by the Department. Much of the fleet is out of compliance with NFPA 1901.

The current fleet of first-line apparatus used by the Department has an average age of 13.4 years and the reserve fleet has an average age of 19 years. None of the reserve apparatus has been refurbished to reflect contemporary safety standards. Some first-line apparatus have a rust problem which has begun to impact the latching mechanisms on compartment doors. All the apparatus have electrical problems. Pumpers 2, 5, 6, Trucks 1 and 7, and Rescue 1 all have motor

issues. In fact, Truck 1 has had its motor rebuilt and recently had to have its alternator replaced. Furthermore, hydraulically powered outriggers responsible for stabilizing the apparatus when the ladder is in use have begun to show signs that they have reached the end of their serviceable life by being unable to remain in the stowed position when the apparatus is parked. Truck 7, in addition to motor problems, has also been removed from service due to failure of the cable and pulley system that operates the ladder. These unsafe issues include but are not limited to: cables and pulleys responsible for extending and retracting the aerial device failing; resulting in inconsistent and unsuccessful operation. The failing cable and pulley system has caused repeated collateral damage to an electrical cable responsible for operating the ladder and has resulted in electrocution hazards to rescuers and civilians. Additionally, due to Truck 7's size and maneuverability issues, tires must be replaced with a higher frequency compared to other apparatus which contributes to the possibility of increased stopping distance and skidding hazard.

The Department and City decision makers should assess the fleet to determine the most cost effective manner of maintaining the fleet, including weighing the options of refurbishing versus purchasing. At a minimum, and assuming it is cheaper to refurbish, reserve Pumper 3, reserve Pumper 4, reserve Rescue 2 and Truck 1 should be replaced. The reserve Pumpers should be replaced with first-line Pumper 2 and 5, the reserve Rescue should be replaced with Rescue 1 after all have been refurbished to meet contemporary safety standards. These retired apparatus, including Truck 1, should be replaced with new apparatus. Truck 7 should be removed from first-line service, placed in reserve, and replaced with a Tiller truck that is able to maneuver the streets of the City.

Purchasing the New Fleet

Although it is a common practice for fire departments to directly purchase apparatus and capital investment equipment, it does pose a significant monetary hardship when multiple pieces of apparatus and equipment are purchased at once. This large investment can be a significant deterrent for agencies looking to replace large portions of the fleet, but there are more plausible options than direct purchasing. Additionally, purchasing may be an option that is better suited for replacement of apparatus on an as-needed basis or for adding apparatus a few at a time.

Another consideration for adding apparatus is through fleet leasing. Leasing apparatus is a suitable option especially if multiple vehicles need to be purchased at the same time. The lease option for apparatus is different from the traditional lease option for personal vehicles. In a fleet lease, the lease is a municipal loan from a broker with a $1.00 ownership buyout option at the end of the lease. In addition to leasing the apparatus, other capital expenditures necessary for operations can be purchased and added to the total cost. This way department decision makers can not only design the apparatus to meet their specific needs, but they can also equip the apparatus with hose, rescue equipment, cardiac monitors for EMS first response and other

equipment necessary to accomplish fireground and rescue tasks. The total cost of this will then be spread out over the length of the lease, which minimizes startup costs and allows for better budget planning of resources. Additionally, the Department should trade retired units in to the manufacturer to reduce the purchase price.

Lease options are available in three, five, and seven year plans and depending on the City's bond rating, interest rates are typically around 2-3%. With the three and five year options, the first payment is typically waived, but the seven year option normally requires a 10% down payment, which is then considered to be the first payment.

Table 6 displays the estimated cost of replacing the minimal apparatus needing replacement as discussed above and Table 7 displays the estimated cost to lease. Neither table reflects the estimated amount required to refurbish, as those costs will vary depending on the amount of work and upgrades necessary.

Apparatus	Cost per Unit	Quantity	Sub-Total
Pumper	$650,000.00	2	$1,300,000.00
Tiller Ladder	$1,000,000.00	2	$2,000,000.00
Rescue	$1,000,000.00	1	$1,000,000.00
	Total		$4,300,000.00

Table 6. Estimated Cost of Replacement Apparatus. The above table represents the estimated cost of replacement apparatus for units in immediate need of retirement due to wear and tear. It is assumed that unequipped pumpers will cost $650,000.00 and unequipped ladders and rescues will cost $1,000,000.00. The cost of these vehicles without customizable items will potentially be below these estimates and there could be a reduction in cost per unit for multiple apparatus purchases.

Lease Option	Interest	Amount Per Year	Total Repayment
3 Years	3%	$1,566,242.03	$4,698,726.10
5 Years	3%	$996,975.70	$4,984,878.52
7 Years	3%	$755,493.95	$5,288,457.62

Table 7. Estimated Cost of Apparatus with a Lease. The above table uses the total estimated cost of apparatus found in Table 6 to estimate the cost of a purchasing apparatus using a lease. The lease option was estimated over 3, 5, and 7 years at 3% interest. Interest is determined based off of the City's bond rating and is typically between 2% - 3%.

Lease option costs in Table 7 were calculated using an equation for determining the amount of money owed after a determined amount of time at a fixed rate.

$$A(t) = A_0\left(1 + \frac{R}{n}\right)^{nt}$$

Using the principal amount borrowed (A_0), which is the cost of the suppression fleet from Table 7, the annual percentage rate (R), or 3% expressed as a decimal, the number of compounding

periods (n) which is 1 (as the payment is annual), the number of years (t) which is 3, 5, or 7, it is then possible to calculate A(t) which is the total amount owed after (t) years. It should be noted that these values are estimates and are subject to change based on the City's bond ratings and if a down payment was applied towards the loan. All estimates were calculated assuming the Department had not made a payment. True cost may depend on a number of factors that the leasing agency and Department will discuss at the time of lease.

Other Consideration when Purchasing

In order to increase the likelihood of receiving a reliably manufactured fleet with a good warranty package, the Department should make a few exceptions to the bidding process. If not currently a practice, decision makers should allow for accepting a "best value bid" over the "lowest bid." By allowing the Department to purchase based on best value, vendors are de-incentivized to cut corners and offer little technical support. Instead it encourages vendors to offer better value through quality features and better technical support, as they know that there is the potential they will not be selected solely on the lowest dollar value. Additionally, the City should consider offering a long-term contract versus short-term, limited scope contracts. Besides saving on the time and costs associated with creating a periodic request for proposals (RFP), a longer contract with vendors could potentially save the City and the Department money by incentivizing vendors to offer more in terms of price, warranty, technical support, and custom or special features. This would also allow the Department to have a single supplier for a specific class of apparatus if the Department so chooses.

Conclusions

While it is impossible to predict where most of a jurisdiction's fire and medical emergencies will occur, Department should examine where emergencies have typically occurred in the past and make efforts to ensure all areas have sufficient coverage by improving resources and deployment in an effort to achieve compliance with NFPA Standard 1710.

It is generally accepted that a municipality has the right to determine the overall level of fire protection it wants. However, regardless of the level of fire protection chosen by the citizens, neither they nor their elected representatives have the right to jeopardize the safety of the employees providing those services. Citizens pay for protection of life and property through their tax dollars, and they assume that their elected and appointed officials will make informed decisions regarding that protection. Too often, however, that decision-making process has been based solely on budgetary expedience. Irrespective of the resources provided, citizens continue to believe that firefighters are prepared to provide an aggressive interior assault on fires, successfully accomplishing victim rescue, fire control, and property conservation. They do not expect firefighters to take defensive actions- to simply surround and drown a fire- because to do so would be to concede preventable loss of both life and property.

As explained by the Commission on Fire Accreditation International, Inc. in its Creating and Evaluating Standards of Response Coverage for Fire Departments manual, "If resources arrive too late or are understaffed, the emergency will continue to escalate…What fire companies must do, if they are to save lives and limit property damage, is arrive within a short period of time with adequate resources to do the job. To control the fire before it reaches its maximum intensity requires geographic dispersion (distribution) of technical expertise and cost effective clustering (concentration) of apparatus for maximum effectiveness against the greatest number and types of risks." Optimally, there needs to be a balance between both elements.

A fire department rescue operation is a race against time. It's a race between destruction and death and the rescue and suppression activities of the firefighters. If you don't have enough firefighters on the scene early during the window of opportunity that exists before the fire gets out of control, then the race will likely be lost. It is difficult, if not impossible, to "catch up" after the window closes. Subsequently, more property and lives will be lost.

A fire department should be designed to adequately respond to a number of emergencies occurring simultaneously in a manner that aims to minimize the loss of life and the loss of property that the fire department is charged to protect. Areas with accelerated development and growth will require additional coverage in the future. Changes in staffing and deployment should be made while considering historical location of calls, response times to specific target

hazards, existing industry standards, and the citizens' expectations of receiving an adequate number of qualified personnel on appropriate apparatus within acceptable time frames.

There is not an even distribution of fire department resource services in the City. Current fire station locations in the Department show significant gaps in initial 4-minute response coverage in the City. There is a gap in service in the southern area of the City below East 41st street.

The Department has a response of 76.3% road coverage from each fire station within 4 minutes of response, and 99.2% road coverage from each fire station with 8 minutes of response. Travel time does incorporate rush hour traffic. However, the Department is only able to provide NFPA 1710 compliant coverage on 32.8% of the City's roads within eight minutes.

Engines are staffed with a minimum of three firefighters, Truck 1 with a minimum of three firefighters, and Truck 7 with a minimum of two firefighters, is not in compliance with NFPA 1710. A minimum of 27 career employees, which consists of 25 firefighters, one Safety Officer, and one Battalion Chief on staff during a shift. Recall personnel would be needed to respond to a simultaneous full alarm assignment, thus increasing response times to the emergency and increasing risk to the safety of firefighters who are working below recommended staffing conditions.

Recommendations

The Department responds within their jurisdiction's boundaries to calls for fire suppression and other emergencies. Existing staffing and deployment levels are not in compliance with industry standards and are insufficient for safe operations. The recommendations listed are based on the findings of the GIS evaluation of both current and planned deployment models.

- Fire suppression apparatus in north Covington, above I-275 should be staffed with a minimum of 4 firefighters at all times.
    - Staffing to this level complies with industry standards for crew size in a low-hazard residential environment and reduces the risk to firefighters and trapped occupants in such an event.
    - Sending larger crew sizes on a single apparatus allows crews to assemble on scene more quickly during early stages of a fire when risks to both firefighters and building occupants are lower. Since fire growth is exponential, growing in a non-linear manner over time, extending the time for crew assembly by waiting for smaller crews to arrive from further away causes on scene risk to escalate. The higher the risks at the time firefighters engage in fire suppression, the greater the chance of poor outcomes including civilian injury or death, firefighter injury or death and property loss.

    - Staffing at this level will allow the fire department to assemble a full alarm assignment with a minimum of 15 firefighters without the need for callback. It would also put the Department in compliance with NFPA 1710.
    - The highly urbanized, industrial, and high-rise areas would largely benefit from this increased staffing in regards to responses to the high-hazard occupancies normally found in these settings.
- Pumper 5 in the southern portion of the City should be staffed with five or six personnel due to the geographic restrictions.
    - Staffing to this level complies with industry standards for crew size in a geographically isolated response area.
- Due to current staffing levels, distribution of resources, and physical limitations of Truck 7, it is not recommended to merge Pumper 8 personnel onto Truck 7.
- The Department should begin to replace fire suppression apparatus as a means of controlling costs and increasing safety for citizens and firefighters alike.
    - The Department should immediately replace Truck 1with a tiller truck
    - The Department should immediately replace Truck 7 with a tiller truck
    - The Department should refurbish Truck 7and move it to reserve status
    - The Department should create a replacement schedule where it replaces Pumper 2, Pumper 5, and Pumper 8 over the next several years.
    - The Department should keep the most serviceable pumper as the reserve apparatus once it has been refurbished to be compliant with NFPA 1912. The other pumpers as well as Truck 1 should be traded in, if possible, to reduce purchasing costs.
- As a further means to control cost as well as ensure the City gets the best deal, the Department and the City should use the best-value and long-term contract in the bid criteria to replace the fleet.

Following these recommendations, emergency service provided by the Department would potentially improve the delivery of emergency services.