GEOGRAPHIC INFORMATION SYSTEM EMERGENCY SERVICES RESPONSE CAPABILITIES ANALYSIS

FINAL REPORT

International Association of Fire Fighters
1750 New York Avenue, N.W.
Washington, DC 20006

LYNCHBURG FIRE DEPARTMENT

Lynchburg, Virginia

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Dedication

This Report is Dedicated to the Citizens of Lynchburg, Virginia who Deserve the Most Efficient and Effective Fire, Rescue, and Emergency Medical Services Available.

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Executive Summary

The International Association of Fire Fighters (IAFF) Headquarters was engaged by the Lynchburg Firefighters Association, IAFF Local 1146, to provide information and resources to decision makers of the City of Lynchburg regarding the importance of staffing apparatus to meet NFPA 1710 staffing standards. The National Fire Protection Association (NFPA®) Standard 1710: *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments* states that apparatus whose primary function is fire suppression should be staffed with a minimum of four firefighters. Inadequate staffing levels on fire suppression apparatus exposes civilians and firefighters to increased risk. It also further drains fire department resources, and stresses the emergency response system by requiring additional apparatus to respond from further distances.

Currently, Lynchburg Fire Department (LFD) operates apparatus that are not staffed to provide for effective, efficient, and safe emergency operations required by industry standards and the Occupational Safety and Health Administration's (OSHA) rules and regulations. LFD's fire suppression apparatus are staffed with three firefighters. Staffing apparatus below NFPA 1710 staffing standard has shown to result in crews being less efficient in completing critical fireground tasks compared to the industry standard of a minimum of four firefighters. This document will discuss the importance of maintaining safe and effective staffing levels and the impact on service when these levels are not met. This document also discusses the department's travel time in comparison to NFPA 1710 standards.

Currently, LFD maintains eight fire stations that house eight engine companies, five medic units[1], two truck companies[2], one rescue company, two battalion chief cars and several pieces of reserve and specialty units. The department's medic units are equipped to perform fire suppression task, but if a medic unit participates in fire suppression operations, a second medic unit will be dispatched to the incident. LFD provides fire suppression, rescue, EMS first response, and medical transport at the advance life support (ALS) level. In addition to all-hazard emergency responses, the department performs other services for the City of Lynchburg such as

[1] Medic 5 and Medic 8 are not included in this number due to it being cross-staffed by Engine 5 and Engine 8 respectfully. Medic 5 and Medic 8 are only placed in service when all medics units are on assignment and unable to respond to an emergency. Cross-staffing is a practice whereby firefighters staff several types of emergency response vehicles simultaneously in a work period. The type and scope of an emergency (e.g., structure fire, EMS call) dictate which type of emergency apparatus responds. Cross-staffing leaves frontline suppression apparatus potentially unstaffed and creates the possibility of personnel being out of the station and unavailable when an incident occurs.
[2] The truck apparatus are quints. Quint apparatus have a permanently mounted fire pump, a water tank, a hose storage areas, an aerial device with a permanently mounted water-way and a complement of ground ladders. Quints are designed to operate as both an engine and ladder company, but if to be used as such simultaneously staffing above the minimum is required.

fire prevention and safety programs, which include fire-safety inspections.

LFD employs 179 firefighters and staffs 55 firefighters per shift. LFD has been continuously hiring firefighters, but not enough to keep up with turnover and retirements. The low staffing levels have led to the city issuing mandatory overtime to satisfy the department staffing needs. Due to the department's low staffing levels, at least one apparatus is typically browned-out per day. "Browning-out" an apparatus means that a fire suppression apparatus or ambulance is closed for a shift, or shifts, so the personnel assigned to it can be redistributed to staff other apparatus as a result of leave usage.

Currently, the department's practice is to brown-out an engine or truck company housed at Fire Stations 1 or 7. Browning-out a truck company results in the department only having one staffed truck company, which greatly reduces the department's truck response capabilities. In some situations the department will have to brown-out a second apparatus located at a fire station other than Fire Stations 1 or 7 because of the deficiency of on-duty personnel. The second browned-out apparatus could be and engine or a medic unit depending on the number of available personnel.

As of January 2018, Medic 8 which was previously staffed Monday through Friday between the hours of 12:00 PM and 8:00 PM was placed out of service. Medic 8 is now a reserved unit crossed-staffed with the personnel from Engine 8. Medic 8 is only placed into service if all the full-time medic units are engaged on an incident. The department also cross-staffs Medic 5 with the personnel from Engine 5. However, this means that when Medic 5 is on assignment, Engine 5 is out of service and unable to respond. When Engine 5 is placed out of service due to Medic 5 being on assignment, it is likely that it will take longer for the first arriving engine company to arrive on scene to an incident in First-due District 5.

The city has informed LFD that it intends on cutting the department's budget, which will result in the reduction of department resource. While no formal proposal has been presented, historical practice has shown Fire Station 2 will be recommended to be closed. The closure of Fire Station 2 will by proxy lead to Engine 2 being placed out of service permanently. Fire Station 2 is located in downtown Lynchburg and is in an area with a high concentration of incidents. The closure of this station will increase the demand on resources housed at the surrounding fire stations.

The provision of fire protection and EMS response are essential services that governments must provide. However, in order for these services to be effective and efficient, they must be staffed and positioned appropriately to address emergencies in an equitable manner, as they occur. LFD's current staffing design is inconsistent with industry standards for response to fire and EMS incidents.

Key Definitions

An examination of the department's historical call volume data was completed to evaluate the department's response capabilities and performance. The following definitions were created to identify specific characteristics of this performance evaluation.

First-due District: refers to a fixed geographical area established by the department's administration that contains a fire station and that is typically served by the personnel and apparatus assigned to that station.

Incident: refers to an emergency to which fire department mobile and personnel resources are dispatched to intervene and mitigate. An incident may require a single or multiple apparatus to respond.

End route Time: refers to the time interval that begins when units and personnel are assigned to an incident and ends at the beginning point of travel time.[3]

Arrival Time: refers to the time when the assigned units and personnel arrive at the incident location

Travel Time: refers to the time interval that begins when a unit is en route to the emergency scene and ends when the unit arrives at the scene.[4]

Key Findings

- LFD's fire suppression apparatus are staffed with less than four personnel. Apparatus not staffed with a minimum of four firefighters do not meet the company staffing objectives outlined in NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, and NFPA 1710. Because units are not staffed with four, firefighters must rely on supplemental personnel arriving later before making entry into environments that are Immediately Dangerous to Life and Health (IDLH), such as structure fires, in order to meet objectives outlined in industry standards and OSHA rules and regulations.

- LFD engine companies are all ALS equipped, but there is no policy stating a paramedic firefighter **MUST** be assigned to each engine company. NFPA 1710 states that the first arriving ALS unit must be on scene within 8 minutes or less of travel time. Staffing all

[3] NFPA 1710 §3.3.53.8 (2016)
[4] NFPA 1710 §3.3.53.7 (2016)

engine companies with a paramedic firefighter will increase the department's ability to provide personnel trained at the ALS level on scene within 8 minutes of travel.

- Currently, LFD is capable of deploying a medic unit on 77.6% of city roads within 8 minutes of travel time. When Medic 8 was staffed part-time, the department could deploy a medic unit on 83.6% of city roads within 8 minutes of travel. Placing Medic 8 out of service results in a 7.2% **reduction** in medic response capabilities.

- NFPA 1710 requires a minimum of 4 firefighters on each suppression apparatus and that the first arriving apparatus be on scene within a 4-minute travel time to 90% of incidents.[5] Currently, the department is only capable of assembling a minimum of four firefighters on 32.5% of city roads within 4 minutes. Pursuant to implementing NFPA 1710-recommended minimum staffing levels, the department would be able to assemble four firefighters on scene within 4 minutes on 46.7% of city roads, which equates to a 43.7% **increase** in coverage compared to the department's current response capabilities. The current lack of resources in the city significantly contributes to LFD's inability to meet this NFPA 1710 objective.

- NFPA 1710 requires a minimum of 14 firefighters and 1 command officer arriving on scene to a fire occurring in a typical 2,000 square foot residential structure within an 8-minute travel time to 90% of incidents. Assuming all units are available to respond immediately upon dispatch, the department is capable of assembling a minimum of 15 firefighters on 39.0% of city roads within 8 minutes of travel. Pursuant to implementing NFPA 1710-recommended minimum staffing levels, the department would be able to assemble 15 firefighters on scene within an 8 minutes of travel on 55.9% of city roads, which equates to a 43.3% **increase** in coverage compared to the department's current response capabilities.

- NFPA 1710 requires a minimum of 26 firefighters and 1 incident commander with an aide, arriving on the scene of a medium-hazard structure[6] fire within 8 minutes of travel to 90% of incidents, for a total of 28 responders. Assuming all units are available to respond immediately upon dispatch, this requirement can be met on 1.5%% of city roads. Pursuant to implementing NFPA 1710-recommended minimum staffing levels, the department would be able to assemble 28 firefighters on scene within 8 minutes of travel on 21.1% of

[5] Percentages (response capabilities for both existing and proposed configurations) given in this document are based on a desire to cover one hundred percent of all road segments within a fire department's total response area. These percentages are used as a proxy for the percentage of incidents covered, as it is impossible to predict where all of a jurisdiction's future emergencies will occur. Therefore the emergency response capabilities as are presented herein are represented by the portion of all road segments able to be reached within the specified time parameters.
[6] Medium-hazard structures consist of open-air strip shopping center and three-story, garden style apartment buildings.

city roads, which equates to a 1306.7% **increase** in coverage compared to the department's current response capabilities.

- NFPA 1710 requires a minimum of 36 firefighters, 6 officers and an incident commander to arrive on the scene of a high-rise[7] or high-hazard structure fire within 10 minutes and 10 seconds, for a total of 43 responders. Assuming all units are available to respond immediately upon dispatch, this requirement cannot be met on any of city roads. Pursuant to implementing NFPA 1710-recommended minimum staffing levels, the department would be able to assemble 43 firefighters on scene within 10 minutes and 10 seconds of travel on 12.8% of city roads. Liberty University, Lynchburg College, and downtown Lynchburg have several high-hazard structures. LFD's lack of resources significantly contributes to the department's inability to accumulate the necessary fireground staffing to assemble at least 43 firefighters within 10 minutes and 10 seconds to meet high-hazard initial full alarm requirements. A delay in response will increase the risk of injury and death for citizens and firefighters and increase economic loss to the city and business owners.

- NFPA 1710 states that the first arriving apparatus should be on scene within 4 minutes of travel to 90% of incidents. In 2016, the average travel time of the first arriving apparatus to arrive on scene was 5 minutes and 34 seconds and the 90th percentile for travel time was 10 minutes and 3 seconds.

- The highest concentration of incidents where the first arriving apparatus had a travel time greater than 4 minutes are located near Fire Stations 1 and 6. Additional resources should be deployed at fire stations located in areas with a high concentrations of incidents where the first arriving apparatus had a travel time greater than 4 minutes. The highest concentration of incidents where the first arriving apparatus had a travel time greater than 8 minutes are located near Fire Stations 1, 2, and 6. Additional resources should be deployed at fire stations located in areas with a high concentrations of incidents where the first arriving apparatus had a travel time greater than 8 minutes.

[7] Structure with the highest floor greater than 23m above the lowest level of fire department vehicle access.

Recommendations

- LFD should staff all fire suppression apparatus with a minimum of four firefighters to meet minimum staffing objectives stated in NFPA 1500 and NFPA 1710

- LFD should establish a policy where all engine companies are staffed with at least one paramedic firefighter.

- LFD should **stop** the practice of browning-out Engine 1, Engine, 7, Truck 1, or Truck 2.

- LFD should staff Medic 8 full-time to increase the department's medic response capabilities.

- LFD should **stop** the practice of cross-staffing Medic 5 and staff the unit full-time.

- The department should perform a risk assessment to identify the potential threats to the community so that stakeholders and decision makers can make informed decisions on how to best mitigate, or at least minimize, any potential threats.

Executive Summary Conclusion

LFD's fire suppression apparatus are staffed with less than four firefighters. Apparatus not staffed with a minimum of four firefighters do not meet the minimum staffing objectives outlined in NFPA 1500 and NFPA 1710. Fire suppression resources are not deployed adequately for the arrival of the first arriving company within 4 minutes to 90% of incidents. LFD's response capabilities also do not meet objectives included in the industry standard NFPA 1710, which directs the assembly of 15 firefighters to a low-hazard structure fire and 28 firefighters to a medium-hazard structure fire within 8 minutes to 90% of incidents or the assembly of 43 firefighters to a high-rise structure fire within 10 minutes and 10 seconds to 90% of incidents. Low staffing levels result in the department's emergency response capabilities being significantly limited. These finding are based on the following system evaluation results.

Currently, due to the department's low staffing levels at least one apparatus is typically browned-out per day. The department's current practice is to brown-out an engine or truck company housed at Fire Stations 1 or 7. Browning-out a truck company results in the department only having one staffed truck company greatly reducing the department's response capabilities. In some situations the department will have to brown-out a second apparatus located at a fire station other than Fire Stations 1 or 7 because of the deficiency of available personnel. Due to a lack of available medic units, LFD has had to dispatch Medic 5 and/or Medic 8 to incidents when all

full-time medic units are engaged on another incident. In order to staff Medic 5 and Medic 8, the department has to cross-staff these units with the crew of Engine 5 and Engine 8 respectfully. The browning-out of an apparatus, and the practice of cross-staffing medic units significantly limits the department's emergency response capabilities.

The ramifications of low staffing levels, as they pertain to the loss of life and property within a community, are essential when considering a fire department's deployment configuration. 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. Any proposed changes in staffing, deployment and station location should be made only after considering the historical location of calls, response times to specific target hazards, compliance with departmental Standard Operating Procedures, existing industry standards, including NFPA 1500 and NFPA 1710, and the citizens' expectations of receiving an adequate number of qualified personnel on appropriate apparatus within acceptable time frames to make a difference in their emergency.

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Background

The International Association of Fire Fighters (IAFF) Headquarters was engaged by the Lynchburg Firefighters Association IAFF Local 1146, to create a data-driven document for the City of Lynchburg and the fire department administrators to assist with informed decisions regarding emergency response and he impact that unsafe staffing levels have on response capabilities.

The City of Lynchburg is located in Campbell County, Virginia. Lynchburg covers 49.6 square miles and based on United States Census Bureau's 2016 Estimates, had a population of 80,212.[8] However, this number does not account for the increase in population that occurs during the day when commuters arrive for work and school. Liberty University and Lynchburg College are both located within the City of Lynchburg and have a combined enrollment of over 50,000 students.

Currently, LFD maintains eight fire stations that house eight engine companies, five medic units,[9] two truck companies,[10] one rescue company, two battalion chief cars and several pieces of reserve and specialty units. LFD provides fire suppression, technical rescue, and EMS first response and medical transport at the advance life support (ALS) level. In addition to all-hazard emergency responses, the department performs other services for the City of Lynchburg such as fire prevention and safety programs, which include fire-safety inspections.

Currently, LFD employs 179 firefighters and staffs 55 firefighters per shift. LFD has been continuously hiring firefighters, but not enough to keep up with turnover and retirements. The low staffing levels has resulted in the city issuing mandatory overtime to satisfy the department staffing needs. Currently, due to the department's low staffing levels at least one apparatus is typically browned-out[11] per day. The department's current practice is to brown-out an engine or truck company housed at Fire Stations 1 or 7. Browning-out a truck company results in the department only having one staffed truck company, greatly reduces the department's response capabilities. Periodically, the department will have to brown-out a second apparatus located at a

[8] https://factfinder.census.gov/faces

[9] Medic 5 and Medic 8 are not included in this number due to it being cross-staffed by Engine 5 and Engine 8 respectfully. Medic 5 and Medic 8 are only placed in service when all medics units are on assignment and unable to respond to an emergency. Cross-staffing is a practice whereby firefighters staff several types of emergency response vehicles simultaneously in a work period. The type and scope of an emergency (e.g., structure fire, EMS call) dictate which type of emergency apparatus responds. Cross-staffing leaves frontline suppression apparatus potentially unstaffed and creates the possibility of personnel being out of the station and unavailable when an incident occurs.

[10] The truck apparatus are quints. Quint apparatus have a permanently mounted fire pump, a water tank, a hose storage areas, an aerial device with a permanently mounted water-way and a complement of ground ladders. Quints are designed to operate as both an engine and ladder company, but if to be used as such simultaneously staffing above the minimum is required.

[11] "Browned-out" an apparatus means that a fire suppression apparatus or ambulance is closed for a shift, or shifts, so the personnel assigned to it can be redistributed to staff other apparatus as a result of leave usage.

fire station other than Fire Stations 1 or 7 because of the deficiency of on-duty personnel.

As of January 2018, Medic 8 which was previously staffed Monday through Friday between the hours of 12:00 PM and 8:00 PM was placed out of service. Medic 8 is now a reserved unit crossed-staffed with the personnel from Engine 8. Medic 8 is only placed into service if all the full-time medic units are engaged on an incident.

A brief risk analysis was performed on the city to assess the need for emergency services. To perform this assessment, it was important to consider the vulnerable populations in the community. A vulnerable population is defined as a group who are unable to anticipate, cope with, resist, and recover from the impact of a disaster. According to the U.S. Census Bureau, 2011 - 2015 American Community Survey 5-Year Estimates,[12] 19.7% of the population is in a vulnerable category based on age. This category consists of persons under the age of 5 (5.9%) and persons 65 years of age and older (13.8%), but does not include the special needs population. Additionally, 18.5% of households are living below the poverty line. Typically, people living within these demographic characteristics are at an increased risk for medical complications and/or fire-related injury or death.

The risk assessment also examined the characteristics of housing. Based on 2011 - 2015 American Community Survey 5-Year Estimates, there are 28,528 housing units, with the majority being single family residences (67.7%) and the remainder being multifamily (30.6%) and mobile homes (1.2%). Of these structures, 68.0% are of pre-1970 construction, and 18.1% were built in 1939 or earlier. Typically, when there are high numbers of older buildings constructed before many current fire codes were developed, there is an increased demand on emergency services. Given these numbers, the department is likely to have a high and steady call volume now and in the future.

The information provided in this document is designed to help decision makers understand the depth of fire department operations and how low staffing levels and the browning-out of apparatus have negatively impacted responders and citizens in the City of Lynchburg. These findings will provide the fire department and city officials with information on the department's past performance and current response capabilities.

[12] https://factfinder.census.gov/faces/tableservices

Fire Suppression 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.

A small flame can quickly burn out of control and become a major fire in a short period of time. This is because fire grows and expands exponentially as time passes. In the time frame of fire growth, the temperature of a fire rises to above 1,000° Fahrenheit (F). It is generally accepted in the fire service that for a medium growth rate fire,[13] flashover--the very rapid spreading of the fire due to super heating of room contents and other combustibles—can occur. Assuming an immediate discovery of a fire, followed by an un-delayed call to 9-1-1, and dispatch of emergency responders, flashover is likely to occur within 8 minutes of fire ignition. However, studies conducted by the Underwriters Laboratory (UL) and the National Institute of Standards and Technology (NIST) have proved that, due to new building construction materials and room contents that act as fuel, flashover may occur much sooner.

At the point of flashover, the odds of survival for unprotected individuals inside the affected area 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.

This section will explain fire growth and the importance of fire department response to a low-hazard structure fire. A low-hazard structure fire is defined as a fire that occurs in a typical, 2,000 square foot, single-family residential home with no basement or exposures.

[13] 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.

Fire Growth

The Incipient Phase

The first stage of any fire is the incipient stage. In this stage a high heat source is applied to a combustible material. The heat source causes chemical changes to the material's surface which converts from a solid and begins to release combustible gases. If enough combustible gases are released the material will begin to burn freely.

This process is exothermic, which means that it produces heat. The heat being generated raises the temperature of surrounding materials, which in turn begin to release more combustible gases into the environment and begins a chemical chain reaction of heat release and burning. At this point the fire may go out if the first object completely burns before another begins or the fire can progress to the next stage, which is called the Free Burning Phase.

The Free Burning Phase

The second stage of fire growth is the "free" or "open burning" stage. When an object in a room starts to burn, (such as the armchair in Figure 1, following page), it burns in much the same way as it would in an open area. In this phase of the fire, oxygen in the air is drawn into the flame and combustible gases rise to the ceiling and spread out laterally. Simultaneously, the materials that are burning continue to release more heat, which heats nearby objects and materials to their ignition temperature, and they begin burning as well. Inside a room, unlike in an open area, after a short period of time confinement begins to influence fire development. The combustible gases that have collected on the ceiling will eventually begin to support fire and will begin to burn. Thermal radiation from this hot layer begins to heat the ceiling, the upper walls, and all the objects in the lower part of the room which will augment both the rate of burning of the original object and the rate of flame spread over its surface.

When this occurs, the structure fire reaches a critical point: either it has sufficient oxygen available to move on to the next stage or the fire has insufficient oxygen available to burn and it progresses back to the incipient stage. However, since structures are not airtight, there is a low likelihood of the fire depleting the available oxygen. During this stage of fire growth, toxic chemicals released by the fire and high heat are enough to burn people in the immediate area and disorient and/or incapacitate people in the structure. Without rapid response by an adequately staffed fire department, the fire will likely spread to the rest of the structure.

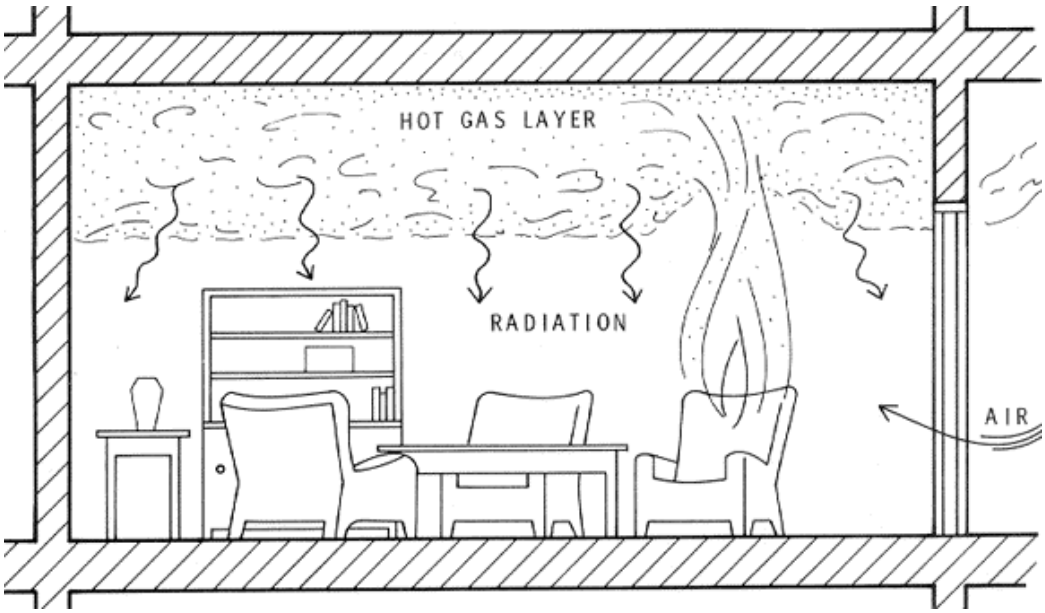

Figure 1: Fire Growth in a Compartment.[14] The above figure depicts the growth of fire in a compartment, which is an enclosed space or room in a building. In a compartment the walls, ceiling, floors, and objects absorb radiant heat produced by the fire. Unabsorbed heat is reflected back to the initial fuel source, which is depicted by the armchair above. This reflected heat continues to increase the temperature of the fuel source and therefore the rate of combustion. Hot smoke, combustible gases, and super-heated air will then rise to the ceiling and spread at first laterally across the ceiling, but later downward towards other fuel sources and the floor of the compartment. As this toxic, super-heated cloud touches cooler materials, the heat is conducted to them, thus increasing their temperature and eventually leading to pyrolysis, which is the process where a fuel source begins to release flammable vapor. This release of flammable vapor leads to further fire growth and eventually flashover. Flashover is the point at which all exposed fuel sources in a compartment ignite.

If there is sufficient oxygen, then the fire will continue to grow and the heating of the other combustibles in the room will continue to the point where they reach their ignition temperatures more or less simultaneously. If this occurs, all combustible materials in the room will spontaneously ignite. This transition from the burning of one or two objects to full room involvement is referred to as flashover. [15]

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

[14] Image courtesy of University of California at Davis Fire Department
[15] J.R. Mehaffey, Ph.D., Flammability of Building Materials and Fire Growth, Institute for Research in Construction (1987)

ceiling can quickly reach temperatures of 1,200˚ F and higher. With enough existing oxygen at the floor level, flashover occurs, which is when everything in the room ignites at once. The instantaneous eruption of flames generates a tremendous amount of heat, smoke, and pressure. The pressure generated from this explosion has enough force to push fire beyond the room of origin and into the rest of the structure, as well as through doors and windows.

As has been noted, at the time of flashover, windows in the room will break. When these windows break, as a result of the increased pressure in the room, a fresh supply of air from the outside of the building is available to help the fire grow and spread. 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

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 ladder company responding to any type of fire.

A prime objective of fire service agencies is to maintain enough strategically located personnel and equipment so that the minimum effective firefighting force can reach a reasonable number of fire scenes before flashover occurs.[16] Of utmost importance in limiting fire spread is the quick arrival of sufficient numbers of personnel and equipment to attack and extinguish the fire, as well as rescue any trapped occupants and care for the injured. 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

Staffing deficiencies on primary fire suppression apparatus negatively affects the ability of the fire department to safely and effectively mitigate emergencies and therefore correlate directly with higher risks and increased losses, both physically and economically. 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.

[16] University of California at Davis Fire Department website; site visited June 7, 2004.
< http://fire.ucdavis.edu/ucdfire/UCDFDoperations.htm >

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.[17] The above table compares and contrasts the efficiencies of suppression companies in the completion of critical tasks for fire control and extinguishment. The smaller the crew size, the more tasks an individual must complete as a team member, which contributes to the delay in initiating fire attack and contributes to diminished efficiency in stopping fire loss. Currently, LFD staffs all suppression apparatus with 3 firefighters.

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% to 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 its assigned duties, the second-in company does not need to support first-in company operations and is therefore capable of performing other critical fireground tasks that are likely to improve safety and outcomes.

At the scene of a structure fire, the driver/operator of the first engine company on the scene must remain with the apparatus to operate the pump. This leaves one firefighter to assist the operator in securing a water source from a hydrant and two firefighters to deploy a hoseline and stretch it to the fire. After assisting the operator, the third firefighter should begin to assist the other two firefighters with advancing the hoseline into the building and to the location of the fire. Before

[17] Averill, J.D. et al. (2010). Report on Residential Fireground Field Experiments. NIST Technical Note 1661. National Institute of Standards and Technology; Gaithersburg, MD, April 2010.

initiating fire suppression, the supervising officer of the first arriving engine company is also responsible for walking around the building to assess the situation, determine the extent of the emergency, and request any additional resources necessary to mitigate the fire.

Similarly, the driver/operator of the first arriving ladder company must remain with the apparatus to safely position and operate the aerial device while the other three firefighters also perform critical fireground tasks such as ventilation and search and rescue. Due to the demands of fireground activities, a fire attack initiated by companies with only three or fewer firefighters is not capable of effecting a safe and effective fire suppression and/or rescue operation until additional personnel arrive.

Insufficient numbers of emergency response units, or inadequate staffing levels on those units, exposes civilians and firefighters to increased risk. It also 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.

The Importance of Crew Size to Overall Scene Time

Studies have shown that the more personnel that arrive on engine and ladder truck companies to the scene of a fire, the less time it takes to do all aspects of fire suppression, search and rescue, and other critical fireground tasks. As dispatched units arrive with sufficient numbers of firefighters, the overall time on the scene of an emergency decreases since critical fireground tasks can be completed simultaneously rather than in sequence. This also results in the decrease of on-scene risk levels. 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		
Scenario	**Total Time**	**Efficiency**
4-Person Close Stagger	0:15:14	
3-Person Close Stagger	0:20:30	25% Less Efficient
2-Person Close Stagger	0:22:16	29% Less Efficient
4-Person Far Stagger	0:15:48	
3-Person Far Stagger	0:21:17	26% Less Efficient
2-Person Far Stagger	0:22:52	31% Less Efficient

Table 2: The Relationship between Crew Size and Scene Time.[18] The above table displays how companies staffed with larger crew sizes will be on the scene of an emergency for a shorter time than smaller sized companies. This lag on scene could be translated to mean that emergency resources will be unavailable longer to address other emergencies that may arise. Currently, LFD suppression apparatus are staffed with 3 firefighters.

As Table 2 shows, units that arrive with only two firefighters on an engine or ladder 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 three 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 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.[19] [20] 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.

Physiological Strain on Smaller Crew Sizes

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.

[18] Ibid.
[19] Ibid.
[20] 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.

- These higher heart rates were maintained for longer durations.[21]

In 2016 alone, 42% of all firefighter fatalities were related to overexertion.[22] There is strong epidemiological evidence that heavy physical exertion can trigger sudden cardiac events.[23] Smaller crews are responsible for performing a number of task that are designed to be performed by multiple people and frequently in teams of two. This means that firefighters on smaller crews are required to work harder than larger crews to accomplish multiple tasks. Additionally, as discussed earlier, firefighters on smaller crews will also be working longer than larger sized crews. Working harder and longer in high heat and dangerous, stressful environments increases the likelihood of firefighters suffering an injury, or worse dying, as a result of overexertion.

Charts 1 and 2, on the following pages, highlight the cardiovascular impact on firefighters based on crew size for the first arriving engine and truck company. The heart rates of firefighters of crew sizes ranging from 2 to 5 firefighters were measured as they participated in the NIST study. The study was able to conclude that not only do smaller crews work harder and longer than larger crews, their heart rates are also more elevated for longer periods of time as well. This increases the risk of firefighters suffering an injury or death from overexertion. A firefighter suffering a medical emergency on the scene of a working fire, EMS, or rescue incident negatively impacts outcomes and increases the risk to the community, the citizen requiring assistance, and the firefighter.

[21] Averill, J.D. et al. (2010). Report on Residential Fireground Field Experiments. NIST Technical Note 1661. National Institute of Standards and Technology; Gaithersburg, MD, April 2010.
[22] Fahy, R.F., LeBlanc, P.R., Molis, J.L. (June, 2017) Firefighter Fatalities in the United States-2016. NFPA.
[23] Albert, C.A., Mittleman, M.A., Chae C.U., Lee, I.M., Hennekens, C.H., Manson, J.E. (2000) Triggering Sudden Death from Cardiac Causes by Vigorous Exertion. N Engl J Med 343(19):1355-1361

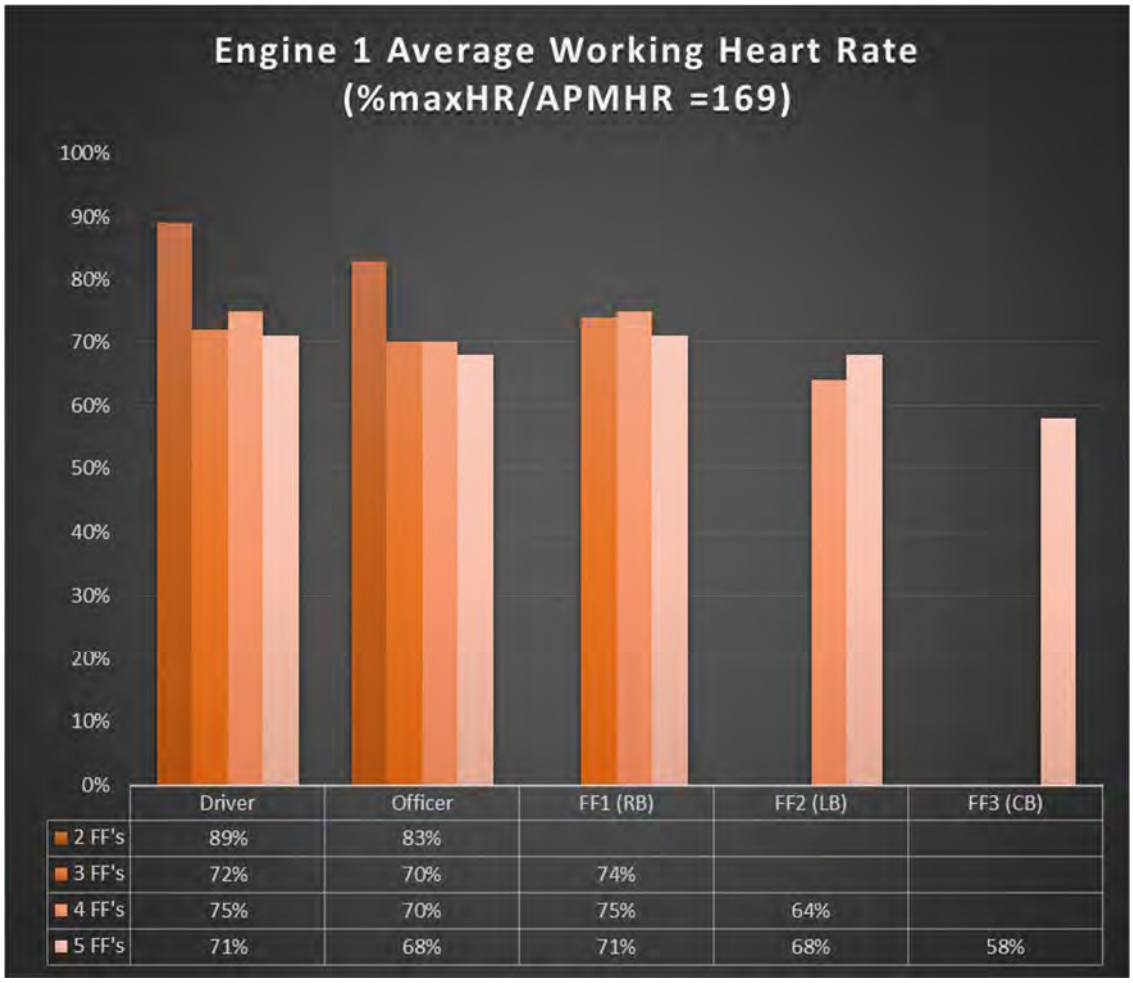

Chart 1: Average Peak Heart Rate of First Engine (E1) with Different Crew Sizes by Riding Position.[24] *In Chart 1, heart rates are expressed as a percent of maximal age-predicted maximal HR.* The average heart rates for firefighters on the first engine company were above 80% of age-predicted maximum values when only 2 firefighters were working. When staffing was at 2 firefighters, the driver of the apparatus had an average peak heart rate of nearly 90% of the age-predicted maximum. This is largely due to the number of additional tasks the driver must perform to prepare the engine to pump water to the fire and then join the officer to stretch hose to the fire. As can be seen, the larger the crew size, the lower the heart rate.[25] Decision makers could potentially reduce their liability for firefighter injury and death by ensuring staffing is compliant with the minimum recommended industry standards of four firefighters per apparatus.

[24] Riding position for Chart 1 are as follows: Driver, Officer, Firefighter 1-Right Bucket (RB) seat, Firefighter 2-Left Bucket (LB) seat, Firefighter 3- Center Bucket (CB) seat. A fire company that is staffed with 2 will consist of a Driver and an "Officer."

[25] Smith, D.L., Benedict, R. Effect of Deployment of Resources on Cardiovascular Strain of Firefighters. April, 2010. Pp 5-7

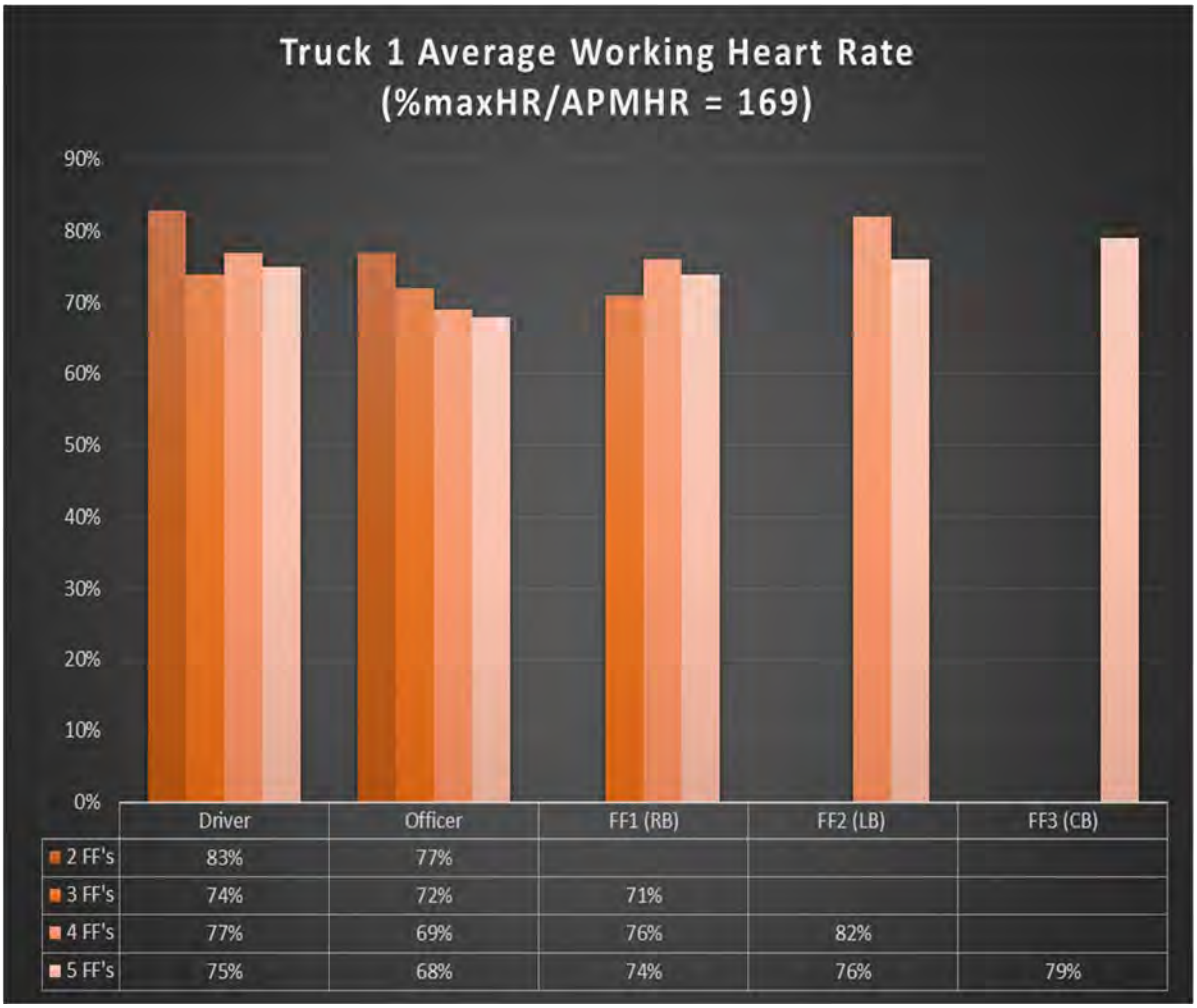

Chart 2: Average Peak Heart Rate of First Truck (T1) with Different Crew Sizes by Riding Position.[26] *In Chart 2, heart rates are expressed as a percent of maximal age-predicted maximal HR.* The average heart rates for firefighters on the first truck company were above 80% of age-predicted maximum values when only 2 firefighters were working.[27] Decision makers could potentially reduce their liability for firefighter injury and death by ensuring staffing is compliant with the minimum recommended industry standards of four firefighters per apparatus.

[26] Riding position for Chart 2 are as follows: Driver, Officer, Firefighter 1-Right Bucket (RB) seat, Firefighter 2-Left Bucket (LB) seat, Firefighter 3- Center Bucket (CB) seat. A fire company that is staffed with 2 will consist of a Driver and an "Officer."

[27] Smith, D.L., Benedict, R. Effect of Deployment of Resources on Cardiovascular Strain of Firefighters. April, 2010. Pp 5-7

The Importance of a Rapid Response

Uncontained fire in a structure grows exponentially with every passing minute. Any delay in the initiation of fire suppression and rescue operations, such as the 5- to 7-minute delay that results from smaller sized crews of firefighters, translates directly into a proportional *increase* in expected property, life, and economic losses as is shown in Table 3, following page. 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 support members, compromising the structural integrity of a building and forcing operations to shift from an offensive to defensive mode.[28] As with inadequate staffing, this type of operation will continue until enough resources can be amassed to mitigate the event.

In the NIST study on the low-hazard residential fire, researchers also used fire modeling 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 when arriving later. The modeling proved 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.

[28] 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			
Flame Spread:	**Civilian Deaths**	**Civilian Injuries**	**Average Dollar Loss per Fire**
Confined fires (identified by incident type)	0.00	10.29	$212.00
Confined to object of origin	0.65	13.53	$1,565.00
Confined to room of origin, including confined fires by incident type[29]	1.91	25.32	$2,993.00
Beyond the room, but confined to floor of origin	22.73	64.13	$7,445.00
Beyond floor of origin	24.63	60.41	$58,431.00

Table 3: The Relationship between Fire Extension and Fire Loss.[30] The above table displays the rates of civilian injuries and deaths per 1,000 fires, as well as the average property damage. Following the far left column from top to bottom, each row represents a more advanced level of fire involvement in a residence. Typically, the more advanced the fire, the larger the delay in suppression. Assuming an early discovery of a fire, companies staffed with larger crew sizes help to minimize deaths, injuries, and property loss. This highlights why a 5- to 7- minute delay in suppression activities by smaller sized crews results in higher economic losses to a residence.

[29] 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. Homes include one- and two-family homes (including manufactured housing) and apartments or other multifamily housing. These statistics are national estimates based on fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies. National estimates are projections. Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Property damage has not been adjusted for inflation.

[30] National Fire Protection Association, NFPA 1710 (2016), Table A.5.2.2.2.1(b) Fire Extension in Residential Structures, 2006-2010.

OSHA's "2 In/2 Out" Regulation

The "2 In/2 Out" Regulation is part of paragraph (g)(4) of the United States Occupational Safety and Health Administration's revised respiratory protection standard, 29 CFR 1910.134. The focus of this important section is the safety of firefighters engaged in interior structural firefighting. OSHA's requirements for the number of firefighters required to be present when conducting operations in atmospheres that are immediately dangerous to life and health 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 environment 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 firefighters may enter the building.[31] [32] 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."

NFPA Standard 1710 also supports the OSHA Regulation by requiring a minimum of four personnel on all suppression apparatus. Portions of the 1710 Standard recommend 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 members**,"[33] 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 members**."[34] 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.[35]

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[31] 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.
[32] Paula O. White, letter to Thomas N. Cooper, 1 November 1995 (OSHA)
[33] NFPA 1710, § 5.2.3.1 and §5.2.3.1.1.
[34] NFPA 1710, § 5.2.3.2 and §5.2.3.2.1.
[35] NFPA 1710, § 5.2.3.1.2, §5.2.3.1.2.1, §5.2.3.2.2, and §5.2.3.2.2.1.

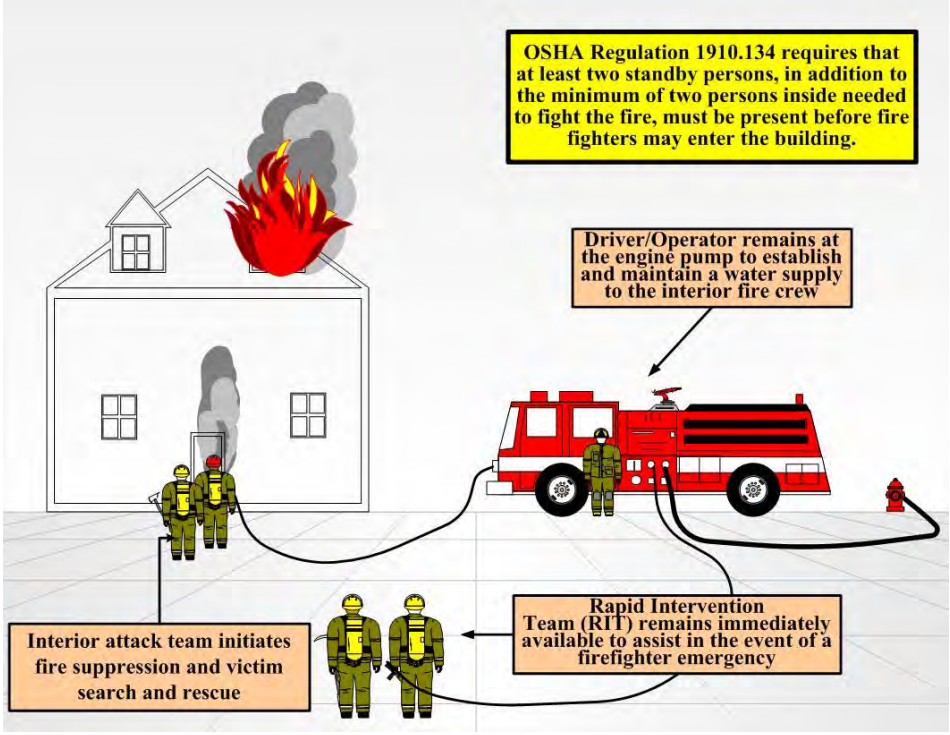

Figure 2: The OSHA "2 IN/2 Out" Regulation. The above figure depicts the number of firefighters required to meet OSHA regulation 1910.134, which demands one firefighter outside for every firefighter inside. The firefighters outside can support a secondary attack line and facilitate the rescue of trapped or disabled firefighters should the need arise. In this scenario, the driver/operator of the apparatus is not counted towards the total number of firefighters.

A number of incidents exists in which the failure to follow the "2 In/2 Out" Regulation have contributed to firefighter 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 by the firefighters, it wasn't responded to promptly as there was no Incident Safety Officer or Rapid Intervention Team (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 RIT was re-assigned to firefighting duties, and the back-up RIT did not arrive on scene until after the victims were removed.

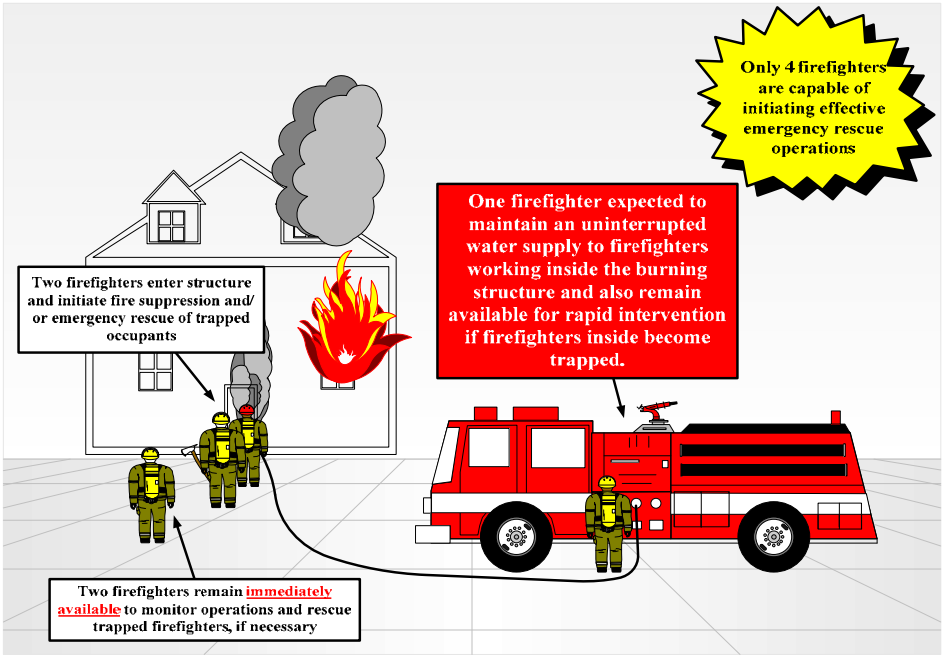

Figure 3: Emergency "2 In/2 Out" Operations. In the emergency model depicted above, the arriving fire apparatus is staffed with a crew of 4 personnel and operates under emergency conditions. In this case, the driver/operator of the fire apparatus is also counted as a firefighter, which means that firefighter must be dressed in personal protective equipment (PPE) and be ready to participate in rescue if the need should arise.

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 the "2 In/2 Out" Regulation. 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" Regulation, 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 a minimum of 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.

Initial Full Alarm Assignment

Single-Family Dwelling Initial 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 a 480-second travel time to 90 percent of the incidents… [and that the] initial full alarm shall provide for the following:

Assignment	*Required Personnel*
Incident Command	1 Officer
Uninterrupted Water Supply	1 Pump Operator
Water Flow from Two Handlines	4 Firefighters (2 for each line)
Support for Handlines	2 Firefighters (1 for each line)
Victim Search and Rescue Team	2 Firefighters
Ventilation Team	2 Firefighters
Aerial Operator	1 Firefighter
Initial Rapid Intervention Crew (IRIC)	2 Firefighters
Required Minimum Personnel for Full Alarm	**14 Firefighters & 1 Scene Commander**

Table 4: NFPA 1710, §5.2.4.1.1. This breakdown of the expected capabilities of a full alarm assignment, in compliance with NFPA 1710, requires a minimum contingent of 15 fire suppression personnel. NFPA 1710 also requires that supervisory chief officers shall be assisted by a staff aide[36] which will increase on-scene staffing to 16 personnel required to arrive at the scene of a structure fire within 8 minutes of travel. Although not specifically discussed in the standard, an industry best practice is to have a second uninterrupted water supply which requires a second dedicated engine pump operator. This second, dedicated pump operator brings the total count of firefighters to 17.

[36] NFPA 1710, § 5.2.2.2.4 and § 5.2.2.2.5

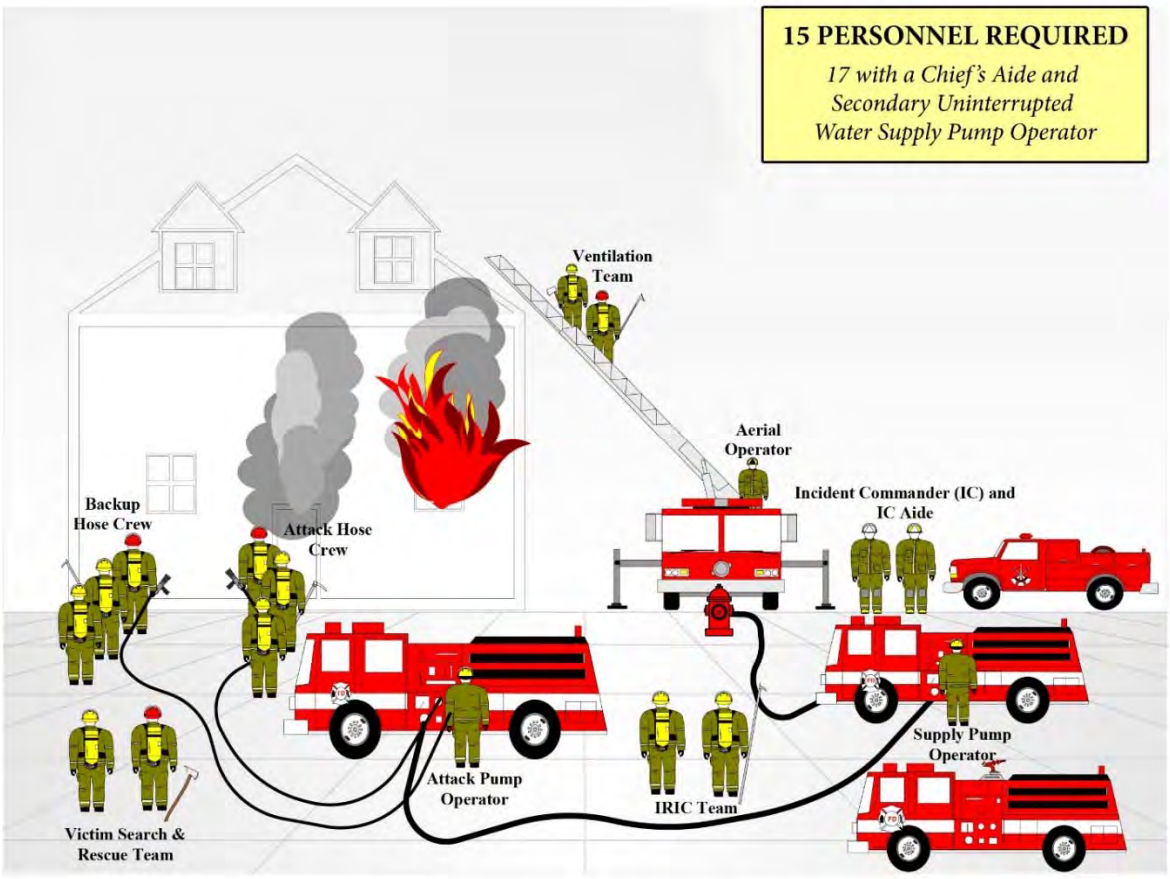

Figure 4: Initial Full Alarm Assignment Deployed Within 8 Minutes. The above figure depicts the full alarm assignment discussed in NFPA 1710, with an additional firefighter to act as the incident commander's aide, and another additional firefighter to act as a pump operator for a supply apparatus.

In addition, NFPA 1710, §5.2.4.5.2 states, "The fire department shall have the capability for additional alarm assignments that can provide for additional command staff, members, 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…"

The ability of adequate fire suppression forces to greatly influence the outcome of a structural fire is undeniable and predictable. 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.

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High-Rise Operations

Although this section specifically addresses fire response to high-rise buildings, it is important to note that the discussion can be extrapolated to large area buildings such as manufacturing centers, warehouses, grocery stores, schools, and other structures with a high fire load and populations.

Overview of High-Rises

High-rise buildings were once found exclusively in urban cities. However, today they are commonly found in small and mid-sized suburban communities as well. Many high-rise buildings in suburban areas are newer, shorter, and protected by automatic sprinkler systems, although this is not always a guarantee. NFPA 101, Life Safety Code, 2015 Edition and the International Code Council's International Building Code both define a high-rise structure as a building more than 75 ft. (23 m) in height, measured from the lowest level of fire department vehicle access to the bottom of the highest occupied floor. High-rises, which are described in NFPA 1710 §A.3.3.28 as high-hazard occupancies, represent an extraordinary challenge to fire departments and are some of the most challenging incidents firefighters encounter.

High-rise buildings may hold thousands of people above the reach of fire department aerial devices and the chance of rescuing victims from the exterior is greatly reduced once a fire has reached flashover. The risk to firefighters and occupants increases in proportion to the height of the building and the height of the fire above grade level.[37] This is especially true once firefighters are operating above the reach of aerial ladders on truck companies. In these situations, the only viable means of ingress or egress is the interior stairs. Therefore, a sound fire department deployment strategy, effective operational tactics, and engineered fire protection systems cannot be separated from firefighter safety. As in any structure fire, engine company and truck company operations must be coordinated.

High-rise buildings present a unique threat to the fire service. Multi-floor fires such as the Interstate Building Fire, One Meridian Plaza Fire, World Trade Center collapse, Cook County Administration Building Fire, and Deutsche Bank Building Fire each represented serious challenges to the operational capabilities of a modern fire department. According to the NFPA, between 2009 and 2013, there were an estimated 14,500 reported high-rise structure fires per year that resulted in average annual losses of 40 civilian deaths, 520 civilian injuries, and $154

[37] Klaene, B. and Sanders, R. (2007). Structural Firefighting: Strategies and Tactics- High-Rise. Jones and Bartlett 2007.

million in direct property damage. Office buildings, hotels, apartment buildings, dormitories and health care facilities accounted for almost three-quarter (73%) of these high-rise fires.[38]

Although the frequency of fires in high-rise structures is low, they pose a high consequence of loss with regards to injury, loss of life, and property damage. Even if a department does not respond to high-rise buildings at present, it may in the future as urban sprawl continues and/or jurisdictional border restrictions and population growth require taller buildings to meet residential needs.

High-Rise Firefighting Tactics

As has been stated, in a high-rise fire the risk to firefighters and occupants increases in proportion to the height of the building and the height of the fire above ground level. As the level of the fire floor gets higher, firefighters are required to carry more equipment further and must rely more on the building's standpipe system. A standpipe system is a piping system with discharge outlets at various locations usually located in stairwells on each floor in high-rise buildings that is connected to a water source with pressure supplemented by a fire pump[39] located in the building and/or a fire apparatus with pumping capabilities.

A fire in a high-rise building can threaten occupants and responding firefighters. Because of the amount of time it takes firefighters encumbered with equipment to access the involved floors, the fire may have expanded well past the area of origin. This means that firefighters can encounter a large volume of fire and darkened conditions when they arrive on the involved floors. This can be further complicated if the building is not equipped with a sprinkler system. Additionally, open-layout floor plans such as office buildings with cubicle farms can challenge both the standpipe's flow capacity and fire department resources in regards to search, rescue, and hoseline deployment. The most effective way to extinguish a high-rise fire is by mounting an offensive attack as early as possible, because in the vast majority of historic high-rise fires, the best life safety tactic is extinguishing the fire. Good high-rise firefighting tactics and firefighter/occupant safety cannot be separated. As with a residential structure fire, the first arriving suppression apparatus should be on the scene within four minutes of travel time. However, when responding to any high-hazard buildings or structures, which include high-rises, first responding fire apparatus should be staffed with five to six firefighters per NFPA 1710, upon the determination of the AHJ.

Studies have shown that the more personnel that arrive on engine and ladder truck companies to the scene of a fire, the less time it takes to do all aspects associated with fire suppression, search and rescue, and other critical fireground tasks. As dispatched units arrive with sufficient numbers

[38] Ahrens, Marty. (2016), High-Rise Building Fires. NFPA.
[39] Structural Firefighting Strategy and Tactics 2nd Edition. Klaene B., Sanders R. NFPA 2008

of firefighters, the overall time on the scene of the emergency decreases since critical fireground tasks can be completed simultaneously rather than in sequence. 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.

Search and Rescue

Search and rescue are critical fireground tasks that comprise a systematic approach to locating possible victims and removing those victims from known danger to a safe area. In a residential structure fire, searches are normally conducted by a crew of two firefighters, supplemented by an attack or ventilation crew. However, high-rise structures pose challenges regarding search and rescue that are not typically encountered in residential housing. For commercial high-rises and wide-area structures, large open areas and cubicle farms require additional search and rescue teams so that thorough searches can occur over a larger area than found in most residences. In addition to these larger areas, search and rescue can be further complicated because conscious victims may retreat to areas in an attempt to find shelter from heat and smoke. These areas may differ from places where they are typically seen by coworkers, making locating them difficult if they are unaccounted for.

In residential high-rises, apartments typically lack two exits and usually share a common hallway for egress. Doors left open by victims fleeing fire can allow fire and smoke to spread into the hallway and impact escape attempts. Firefighters will be slowed in their search since they will be required to force their way into numerous apartments to search for victims. For this reason, regardless of commercial or residential, it is essential for there to be multiple search and rescue teams operating per involved floor to quickly locate victims in large surface areas. It is also necessary for additional search and rescue teams to search the floors above the fire and the highest floor of the building, due to how fire and smoke spread to the rest of the building. Search and rescue teams should also be supplemented with evacuation management teams to assist injured or disabled victims down the stairwells so searching can continue. Because of the larger search area, NFPA 1710 requires a minimum of four firefighters for searching and a minimum of four firefighters for evacuation management teams.

Fire Extinguishment

Fire extinguishment is a critical factor, since the intensity and size of the fire will determine the extent to which combustion gases are heated and how high they will rise inside the building. Building suppression systems, both active and passive, can impact fire growth, occupant safety, and firefighter safety and effectiveness. Such features include active fire detection and automatic

sprinkler systems that are designed to either extinguish the fire or contain it until firefighters arrive.

Once firefighters are on scene, they will complete a series of fire confinement and extinguishment tasks. Firefighters access the structure, locate the fire, locate any avenues of spread, place hoselines, and establish a water supply. Once a water supply is established, water should be placed at the seat of the fire or in the compartment containing the fire to extinguish it. Unlike residential structure fires where hoselines can be stretched from the fire apparatus into the structure, high-rise structures require the use of standpipe systems to combat fire. This requires firefighters to carry multiple sections of hose to the affected floors and connect into the system to fight fire. Minimally, firefighters must deploy two hoselines to the involved floor and one hoseline to the floor above the fire. The third hoseline supports a number of critical tasks in the suppression effort. Principally, it is used to protect search and rescue teams, but also to stop the spread of fire as a result of conduction and convection through exposed pipes, metal framing, and ventilation systems.

Ventilation[40]

Ventilation affects both search and rescue and fire extinguishment. Coordinated ventilation may be implemented at any time during the operation, but it should be coordinated with suppression and interior rescue activities. Ventilation is used to channel and remove heated air, smoke, fire gases, and other airborne contaminants. Applying proper ventilation at the right time and place is key to firefighter and occupant safety. Venting at the wrong time or place can draw active fire toward fresh air, which will injure or kill anyone in its path. In instances of high-rise fire suppression, adequate and appropriate ventilation is important to keep stairways free of smoke and noxious gases for victims who are evacuating.

Because of the size of high-rise buildings and high-hazard structures in general, a larger number of firefighters is required for a ventilation team than would be for a residential structure. NFPA 1710 requires a minimum of four firefighters to be assigned to ventilation.

Support

Similar to residential structure fires, there are several critical tasks that must be accomplished. However, unlike residential firefighting in a 2,000 square foot residence, firefighters working at a high-rise fire must travel upwards of more than three stories and carry additional equipment beyond the normal requirements. Additionally, as it takes longer to assemble an effective

[40] Due to varying differences in building designs, occupancy levels, evacuation procedures, etc., the NIST High-Rise Report marked ventilation complete as time stamps rather than actual tasks to be performed and completed. Both Positive Pressure Ventilation (fans) and Roof Ventilation were marked as occurring one minute after Fire Out.

firefighting force and to access the fire floor, firefighters are likely to encounter a large volume of fire and will therefore have an extended fire attack. Because of this, it is necessary to establish an equipment supply chain to transport equipment and resources up and down the building. As has been discussed, fire suppression in a high-rise or high-hazard structure requires the establishment of a supply chain to shuttle equipment to different locations. Additionally, with increased resources and personnel, there is an increased need for additional supervision and accountability.

One critical support variable in high-rise fire operations is the availability of reliable elevators. If firefighters can safely use the elevators to move people and equipment, fire-ground logistics may be significantly improved. When the fire is located several floors above ground level, there is a strong inclination to use the elevators. However, fire service access elevators[41] may not be available in all buildings. Therefore, adequate stairways are necessary for firefighters to transport equipment and reach the fire floor for suppression.

Moving supplies and staff up 10, 20, 30, or more stories is an arduous task. If it is not properly managed, firefighters may be exhausted and unable to fight the fire or rescue trapped occupants. Additionally, joint use of stairways by firefighters moving upward and occupants attempting to evacuate may increase the overall evacuation time of the occupants, as well as delay the firefighters' efforts to begin critical tasks such as fire suppression or search and rescue operations. As such, it is important to have multiple firefighters to help carry equipment upstairs and manage resource distribution.

To accomplish the critical fireground tasks associated with high-rise firefighting and meet the minimum staffing objectives for task completion, NFPA 1710 recommends the following company sizes for the first arriving unit(s) on the scene within four minutes of travel time for response to high-hazard structures:

- In jurisdictions with a high number of incidents or geographical restrictions, as identified by the AHJ, these companies shall be staffed by a minimum of five on-duty members.[42]
- In jurisdictions with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these fire companies shall be staffed with a minimum of six on-duty members.[43]

As indicated by the tasks that must be accomplished on a high-rise fireground, understanding the required resources is critical. The number of firefighters needed to safely and effectively combat

[41] A fire service elevator is engineered to operate in a building during a fire emergency and complying with prescriptive building code requirements and the American Society of Mechanical Engineers (ASME) A 17.1 safety standard for elevators.
[42] NFPA 1710. §5.2.3.1.2
[43] NFPA 1710. §5.2.3.1.2.1, §5.2.3.2.2, and §5.2.3.2.2.1.

a high-rise fire may be large. Although an offensive fire attack is the preferred strategy whenever conditions and resources permit, a defensive attack that limits operations to the outside of a building and generally results in more property damage must be considered when risks to firefighter safety are too great and benefits to building occupants are negligible. The offensive vs. defensive decision is based on a number of factors: fireground staffing available to conduct an interior attack, a sustained water supply, the ability to conduct ventilation, and risk vs. benefit analysis regarding firefighter and occupant safety. Table 5, on the next page, displays the minimum number of firefighters required to arrive in the first full alarm assignment to a high-rise fire.

Assignment	*Required Personnel*
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply	1 Building Fire Pump Observer 1 Fire Engine Operator
Water Flow from Two Handlines on the Involved Floor	4 Firefighters (2 for each line)
Water Flow from One Handline One Floor Above the Involved Floor	2 Firefighters (1 for each line)
Rapid Intervention Crew (RIC) Two Floors Below the Involved Floor	4 Firefighters
Victim Search and Rescue Team	4 Firefighters (2 per team)
Point of Entry/Oversight Fire Floor	1 Officer 1 Officer's Aide
Point of Entry/Oversight Floor Above	1 Officer 1 Officer's Aide
Evacuation Management Teams	4 Firefighters (2 per team)
Elevator Management	1 Firefighter
Lobby Operations Officer	1 Officer
Trained Incident Safety Officer	1 Officer
Staging Officer Two Floors Below Involved Floor	1 Officer
Equipment Transport to Floor Below Involved Floor	2 Firefighters
Firefighter Rehabilitation	2 Firefighters (1 must be ALS)
Vertical Ventilation Crew	1 Officer 3 Firefighters
External Base Operations	1 Officer
2 EMS ALS Transport Units[44]	4 Firefighters
Required Minimum Personnel for Full Alarm	**36 Firefighters** **1 Incident Commander** **6 Officers**

Table 5: Number of Firefighters for an Initial Full Alarm to a High-Rise Fire. Fighting fire in high-rise structures poses many unique obstacles and challenges other than are found in a residential structure fire. Hose cannot be deployed directly from fire apparatus and needs to be carried, with other equipment, to the location of the fire. Search and rescue is impacted by large areas and accessibility concerns. Additionally, because of delays in access, firefighters are likely to encounter a high volume of fire which will necessitate a supply chain to equip ongoing suppression efforts. A single alarm response to a high-rise building minimally requires 43 responders, consisting of 36 firefighters, 1 incident commander, and 6 officers.

[44] NFPA 1710. §5.2.4.4.1 (12) requires, "Provision of a minimum of two members to manage member rehabilitation. At least one of the members shall be trained to the ALS level"…and (17)"Provision of a minimum of two crews trained in emergency medical services with on-scene transport capability, each crew with a minimum of two members. At least one of the members shall be trained to the ALS level. . Where this level of emergency medical care is provided by outside agencies or organizations, these agencies and organizations shall be included in the deployment plan and meet these requirements."

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Fire Department EMS Operations

In recent years, the provision of emergency medical services has progressed from an amenity to a citizen-required service. More than 90% of career and combination fire departments provide some form of emergency medical care, making fire departments the largest group of prehospital EMS providers in North America. In many fire departments that deliver prehospital care, EMS calls can equate to over 75% of total call volume.

There are six main components of an EMS incident from start to finish.[45] These are (1) detection of the incident, (2) reporting of the incident to a 9-1-1 center, (3) response to the incident by the appropriate emergency resources, (4) on scene care by emergency response personnel, (5) care by emergency personnel while in transit to a medical care facility, and (6) transfer of the patient from emergency response personnel to the medical care facility. Not all EMS events will necessitate all six components, as when a patient refuses treatment, or is treated at the scene and not transported.

In an analysis of data from over 300 fire departments in the United States, first responder units, which are typically fire engines, arrived prior to ambulances approximately 80% of the time.[46] This is likely due to the fact that fire stations housing first responder units, which are equipped and staffed with multi-role firefighter/emergency medical service technicians and supplies, are more centrally located and are able to effect a quicker response and provide life-saving procedures in advance of an ambulance. This reinforces why it is in the best interest of the public good for the fire department to provide EMS transport as well as first response.

The benefit of supporting EMS transport within fire department operations is that fire departments are already geared towards rapid response and rapid intervention. Strategically located stations and personnel are positioned to deliver time critical response and effective fire suppression and are therefore equally situated to provide effective response to time critical requests for EMS service. Both fire suppression and EMS response are required by industry standards to have adequate personnel and resources operating on scene within 4 minutes. In both fire suppression and EMS incidents, time is directly related to the amount of damage, either to the structure or the patient.

When ambulance response is prolonged, a patient will be further delayed in reaching a medical facility to receive definitive care. This is especially dangerous for incidents of chest pain, stroke,

[45] The Star of Life, designated by Leo R. Schwartz, Chief of EMS Branch, National Highway Traffic Safety Administration (NHTSA) in 1997.
[46] Moore-Merrell, L. et al. (2010) Report on Residential EMS Field Experiments, Fire Fighter Safety and Deployment Study; Washington, DC, September 2010.

and survivable cardiac arrest. Many times, patients experiencing symptoms associated with these events may not recognize the onset indicators and immediately call for assistance.[47] [48] [49] [50] Acute Coronary Syndrome (ACS), or heart attack, is the number one leading cause of death in the United States. Experts agree that an ACS event should receive definitive care from a hospital within one hour of onset of symptoms. One study found that definitive care for ACS within one hour of onset improves survivability by 50% and 23% if definitive care was given within 3 hours.[51]

Strokes, which are the number three cause of death in the U.S., as well as a leading cause of disability, also benefit from expedient treatment in definitive care. Ischemic stroke, which is a stroke caused from a blood clot, can be effectively treated if definitive care is received within 3 to 4.5 hours[52] of onset of symptoms. The sooner a patient receives definitive treatment from onset of symptoms, the less likely a patient is to suffer disability from this type of stroke. However, it is important to emphasize that before the time critical treatment can be administered to the patient in the hospital, there is a time intensive assessment that must be performed to ensure the patient is qualified to receive the treatment. The current benchmark for an ischemic stroke patient "door to needle"[53] is less than or equal to 60 minutes. However, Steps Against Recurrent Stroke (STARS) registry shows that the median door to needle time is 96 minutes or 1 hour and 36 minutes.[54]

In two-tiered EMS systems that deploy with sufficient resources, there is an increased likelihood that a patient will receive an ambulance and a first responding fire apparatus in not only a timely manner, but also frequently at the same, or close to the same time. This is extremely beneficial to the patient as most EMS responses, particularly the previously mentioned conditions, are labor intensive. Patients suffering from ACS should not perform any form of exertion as to minimize any damage that is occurring. Patients suffering from strokes are frequently unable to exert due to physical disabilities caused by the incident. An adequately sized crew is able to provide simultaneous interventions while assessment is being performed, thereby reducing the on-scene

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[47] American Heart Association, *Heart Disease and Stroke Statistics-2005 update,* Dallas, TX: AHA 2005

[48] Time from Symptom Onset to treatment and outcomes after thrombolytic therapy. Newby LK, et al. *J Am Coll Cardiol.* 1996:27:1646-1655

[49] An International Perspective on the Time to Treatment of Acute Myocardial Infarction. Dracup, K. et al. *J Nurs Scholarsh* 2003;35:317-323

[50] Prehospital and In-hospital Delays in Acute Stroke Care. Evanson, KR, et al. *Neuroepidemiology* 2001;20:65-76

[51] Association of patient delays with symptoms, cardiac enzymes, and outcomes in acute myocardial infarction. Rawles, JM. Et al. *Eur Heart J.* 1990; 11:643-648.

[52] Thrombolysis with Alteplase 3 to 4.5 Hours after Acute Ischemic Stroke. Hacke, W. et al. *N Engl J Med*. 2008;359:1317-1329

[53] "Door to Needle" is an industry specific term that refers to the time the patient entered the emergency department to the time the received the treatment. A drug named recombinant tissue plasminogen activator (rt-PA) is utilized to dissolve the thrombosis causing the stroke. Current FDA approvals limit this drug's use to 3-4.5 hours from initial symptoms and require a CT scan and labs before administration.

[54] Improving Door-to-Needle Times in Acute Ischemic Stroke: The Design and Rational for the American Heart Association/American Stroke Association's Target: Stroke Initiative. Fonarow, Gregg, et al. *Stroke* 2011;42:00-00

time. Following completion of critical tasks, the crew can then facilitate a safe removal of the patient to the ambulance and minimize the risk of injury to patient and provider.[55]

One of the most labor intensive and time critical requests for EMS response is cardiac arrest, which globally affects 20-140 out of every 100,000 people. Traditionally, the American Heart Association (AHA) taught a method of cardiac resuscitation that involved single rescuer performance of prioritized action.[56] However, there was a gap between instruction and practice which led to confusion and may have potentially reduced survival. In reality, providers respond and function in teams larger than two.

The AHA's guidelines for cardiac resuscitation focus on a team-centric approach. Evidence-based research suggested that the manner in which CPR was being performed was inherently inefficient and only provided 10-30% of the normal blood flow to the heart and 30-40% to the brain.[57] [58] This was linked to provider fatigue from administering chest compressions, and as such, these studies indicate that providers should be rotated to ensure effective depth and rhythm of chest compressions. Consensus documents from the AHA recommend that providers should rotate with every two-minute cycle of CPR. It is also recommended that requests for EMS service for cardiac arrest also have a team leader to organize priorities and direct resources as they arrive or are needed. The team leader would also be responsible for identifying symptoms of fatigue and making appropriate assignment adjustments to ensure maximally efficient CPR.

Although the AHA and other researchers have not identified what an optimally sized crew for effective team-centric CPR should be, some consensus literature from AHA has mentioned that five providers were best suited to perform resuscitation. However, providers may be required to perform multiple tasks. Industry best practices, through the guidance of medical directors, have suggested six providers would be most successful in minimizing confusion and redundancy.

An EMS crew consisting of six personnel would require four personnel arriving with the first responding fire apparatus and two with the ambulance.[59] For an all-ALS system, two of the six should be paramedics, with a minimum of one assigned to each of the responding apparatus. Some ALS systems require two paramedics on the ambulance and a minimum of one on the first responding fire apparatus. However, these deployment options are determined by state directive

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[55] Moore-Merrell, L. et al. (2010) Report on Residential EMS Field Experiments, Fire Fighter Safety and Deployment Study; Washington, DC, September 2010.

[56] Highlights of the 2010 American Heart Association Guidelines for CPR and ECC

[57] Determinants of Blood Flow during Cardiac Resuscitation in Dogs. Halperin, HR et al. *Circulation* 1986;73:539-550

[58] Increased Cortical Cerebral Blood Flow with LUCAS, a New Device for Mechanical Chest Compressions Compared to Standard External Compressions during Experimental Cardiopulmonary Resuscitation. Rubertson S, et al. *Resuscitation*. 2005;65:357-363

[59] NFPA 1917: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments

or medical director's discretion. Regardless of the make-up of the EMS certification level of the providers on scene, an ALS integrated cardiac arrest response should provide for the following: a lead provider, an airway manager, two providers to interchangeably deliver chest compressions, a provider to establish an intravenous medication line and administer medications, and a provider to operate the monitor.

Fire Department Deployment

Before discussing the staffing and deployment analysis of LFD resources, it is important to understand the basics of distribution and concentration. Although adequate staffing is a key element contributing to positive outcomes, fire station location and apparatus deployment are equally important.

The Importance of Adequate Resources: Distribution

Distribution involves locating geographically distributed, ideal first-due resources for all-risk initial intervention. Distribution describes 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.[60] In this case, distribution is measured by the percentage of roads that are covered from each fire station within 4 minutes, 8 minutes, and 10 minutes and 10 seconds to adhere to NFPA 1710 standards.

Distribution study requires geographical analysis of first due resources. Distribution measures may include:[61]

- 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)

[60] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.
[61] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.

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 analyzed to determine whether or not the fire department is achieving a reasonable response performance to handle emergencies.[62]

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 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.[63]

[62] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[63] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53

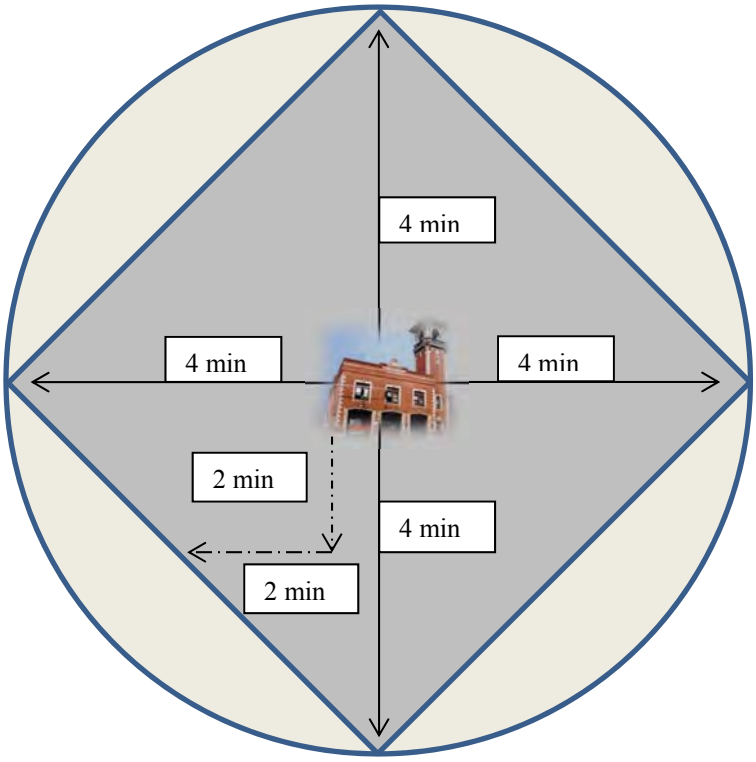


Figure 5: Normal Distribution Model for an Initial 4-Minute Response Area.[64] As depicted in the above figure, fire stations and emergency resources should be distributed throughout a community so that citizens receive equitable coverage and protection. However, there are additional points of concern when modeling a response district such as road network, traffic patterns, and building occupancies.

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 the probability that all areas experience 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 of Lynchburg may 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 fire stations near high risk areas to provide 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.[65]

[64] Derived from Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[65] Commission on Fire Accreditation International, 5th Edition. 2008. Page 55

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.[66] 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 a 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.[67]

[66] Commission on Fire Accreditation International, 5th Edition. 2008. Page 62
[67] Commission on Fire Accreditation International, 5th Edition. 2008. Pages 62-63

Mapping Analysis of the Lynchburg Fire Department

In creating this document, it was important to ascertain where stations were located and if they were located to provide fair and equitable coverage to the citizens. In order to make this assessment, the IAFF created maps of LFD's response boundary and plotted the fire stations. Computer modeling was then used to determine the distance apparatus could travel in 4 minutes, 8 minutes, and 10 minutes and 10 seconds.

Travel times were modeled using ESRI ArcGIS version 10.5. Fire stations were identified on GIS maps as starting points with vehicles traveling at posted road speeds.

When generating the maps a number of assumptions needed to be addressed prior to drawing conclusions from the analysis. These assumptions are as follows:

- Modeled travel speeds are based on reasonable and prudent historical traffic speeds occurring on Wednesdays at 5:00 PM.[68] 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 added 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.[69]

[68] Historical traffic data contained in ESRI's StreetMap Premium, Version 17.1.
[69] David Shrank and Tim Lomax, The 2003 Urban Mobility Report, (Illinois Transportation Institute, Illinois A&M University: September 2003).

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.

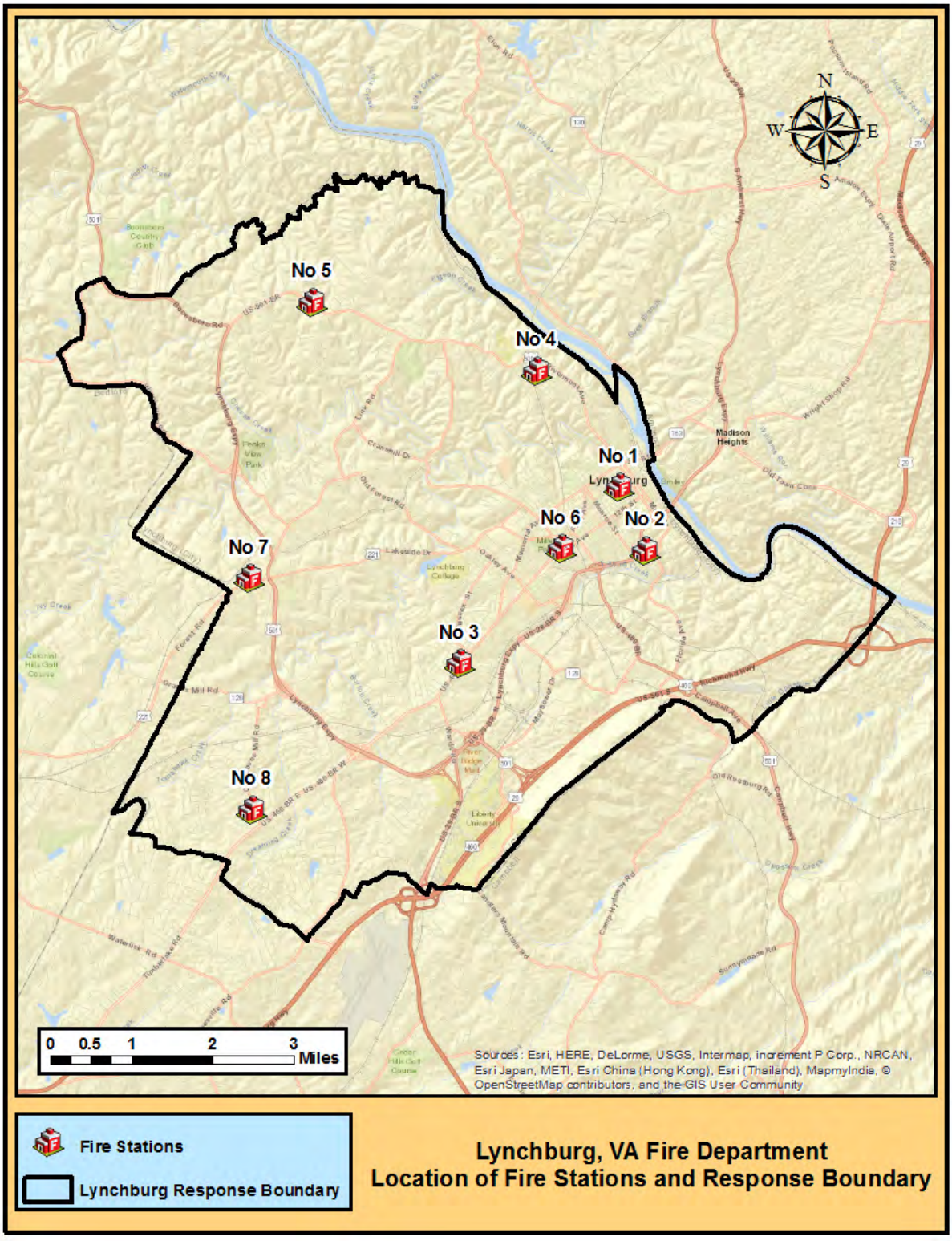
As discussed, computer modeling only considers travel time of apparatus. Decision makers should understand that once apparatus and personnel arrive on the incident scene there are other essential tasks that must be completed which require additional time before access, rescue, and suppression can take place. Tasks such as establishing a water supply, forcible entry (access), and deployment of an attack line are not considered in the computer modeling. Other additional factors also include:

- 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.
- The reliability of a community's hydrant system to supply water to fire apparatus.

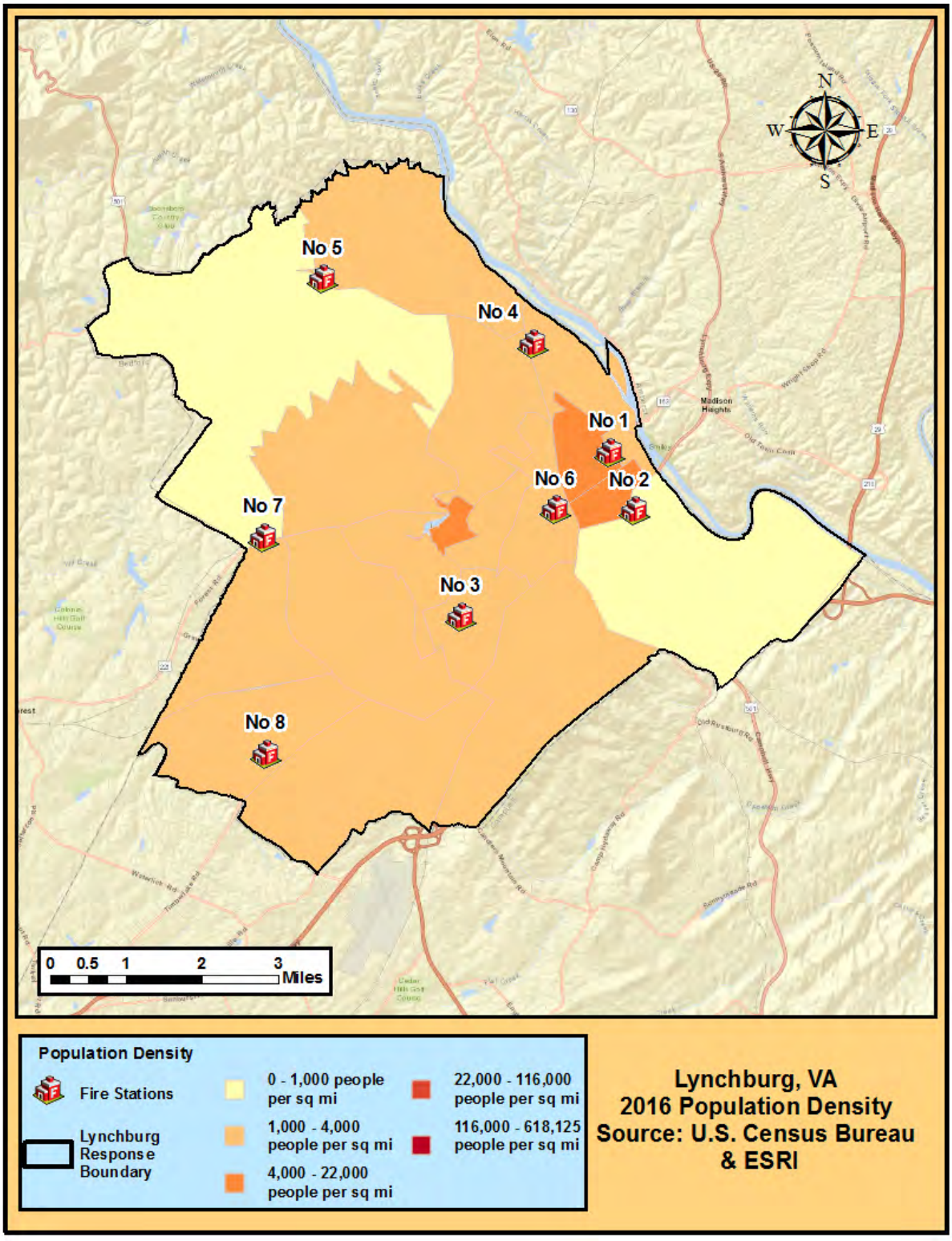
- Weather conditions

Fire Station	Address	Apparatus	Staffing
Station 1	801 Clay Street	Engine 1 Truck 1 Medic 1 Battalion 1	3 FF 3 FF 1 FF/EMT, 1 FF/Medic 1 Battalion Chief
Station 2	2006 Grace Street	Engine 2	3 FF
Station 3	4701 Fort Avenue	Engine 3 Rescue 1 Medic 3	3 FF 3 FF 1 FF/EMT, 1 FF/Medic
Station 4	410 Birch Street	Engine 4 Medic 4	3 FF 1 FF/EMT, 1 FF/Medic
Station 5	4800 Boonsboro Road	Engine 5 Medic 5	3 FF Cross-Staffed
Station 6	2084 Fort Avenue	Engine 6 Medic 6	3 FF 1 FF/EMT, 1FF/Medic
Station 7	2624 Lakeside Drive	Engine 7 Truck 2 Battalion 2 Medic 7	3 FF 3 FF 1 Battalion Chief 1 FF/EMT, 1FF/Medic
Station 8	13 Old Graves Mill Road	Engine 8 Medic 8	3 FF Crossed-Staffed

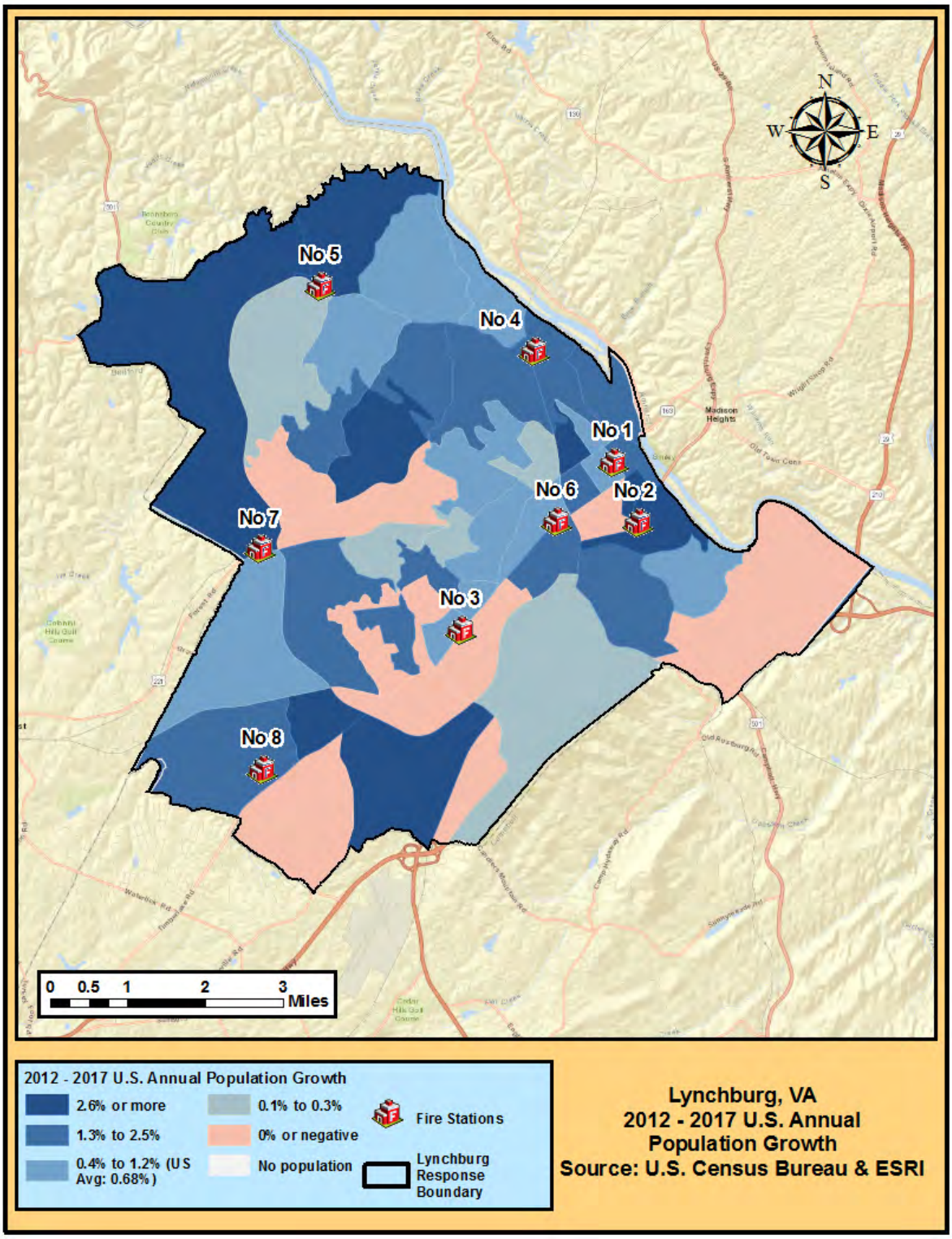
Table 6: Current Fire Station Locations and Staffing. Table 6 displays where apparatus are housed and the current staffing levels for each apparatus.



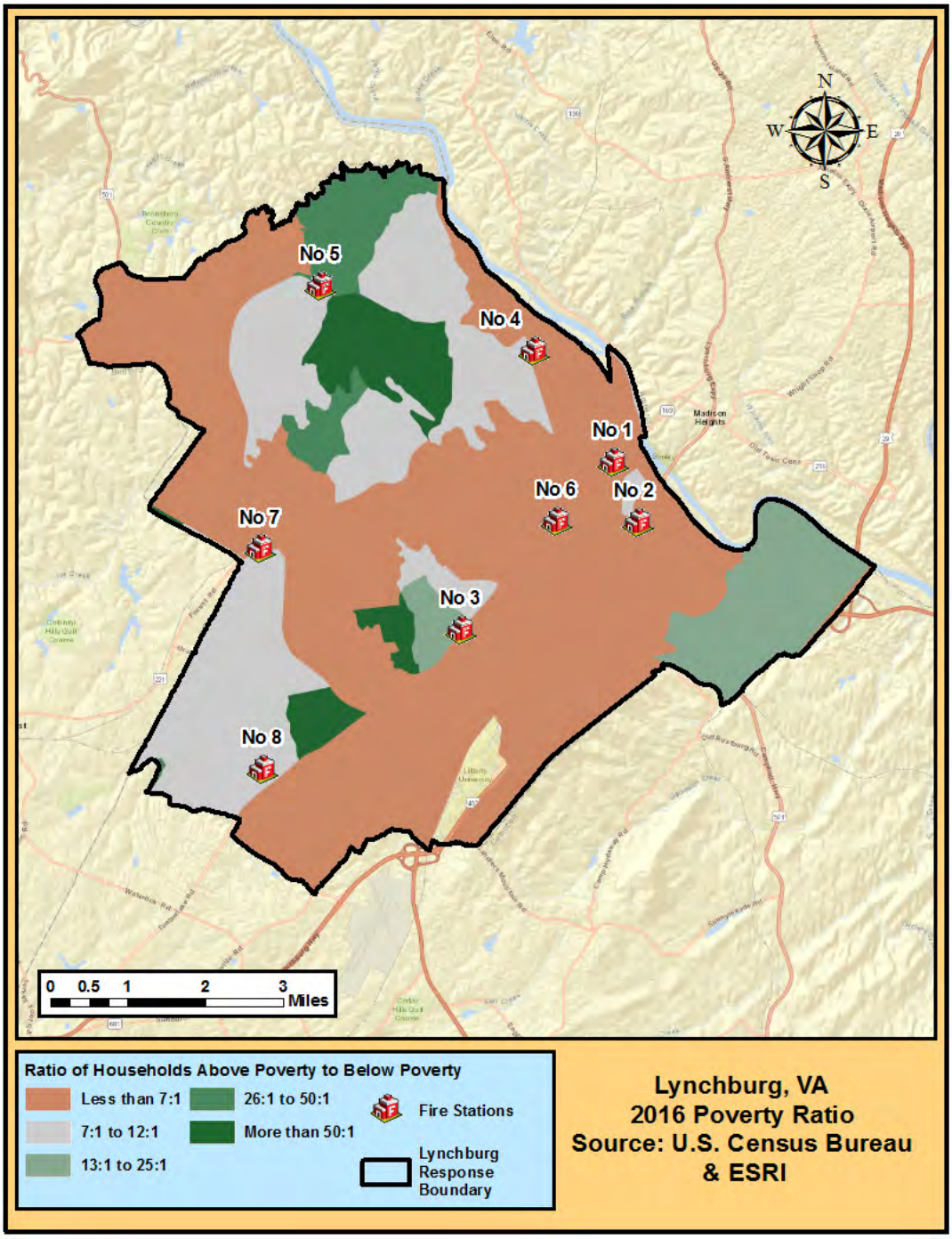
Map 1: Location of Fire Stations and Response Boundary. Map 1 depicts the current locations of fire stations and AFD's response boundary. The response boundary does not include areas outside of the department's primary response area or areas where department provides mutual aid.



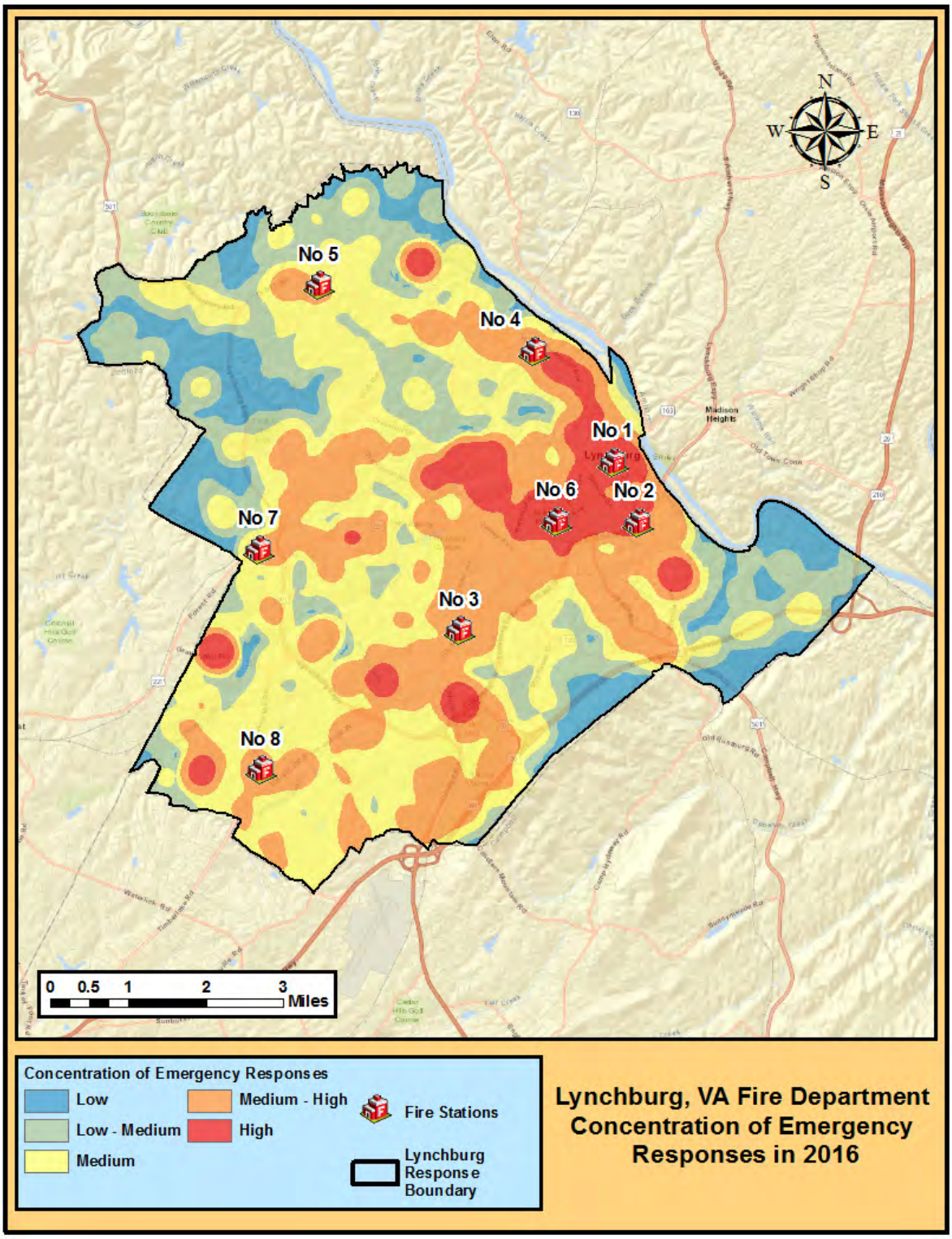
Map 2: 2016 Population Density. Map 2 depicts the City of Lynchburg's population density in 2016. Although, not reflected in census estimates, these areas are also likely to have a high daytime population as commuters and students enter the city for work and school. Areas with a high population density are likely to have a high volume of emergency incidents, resulting in a larger demand placed on the department in these areas.



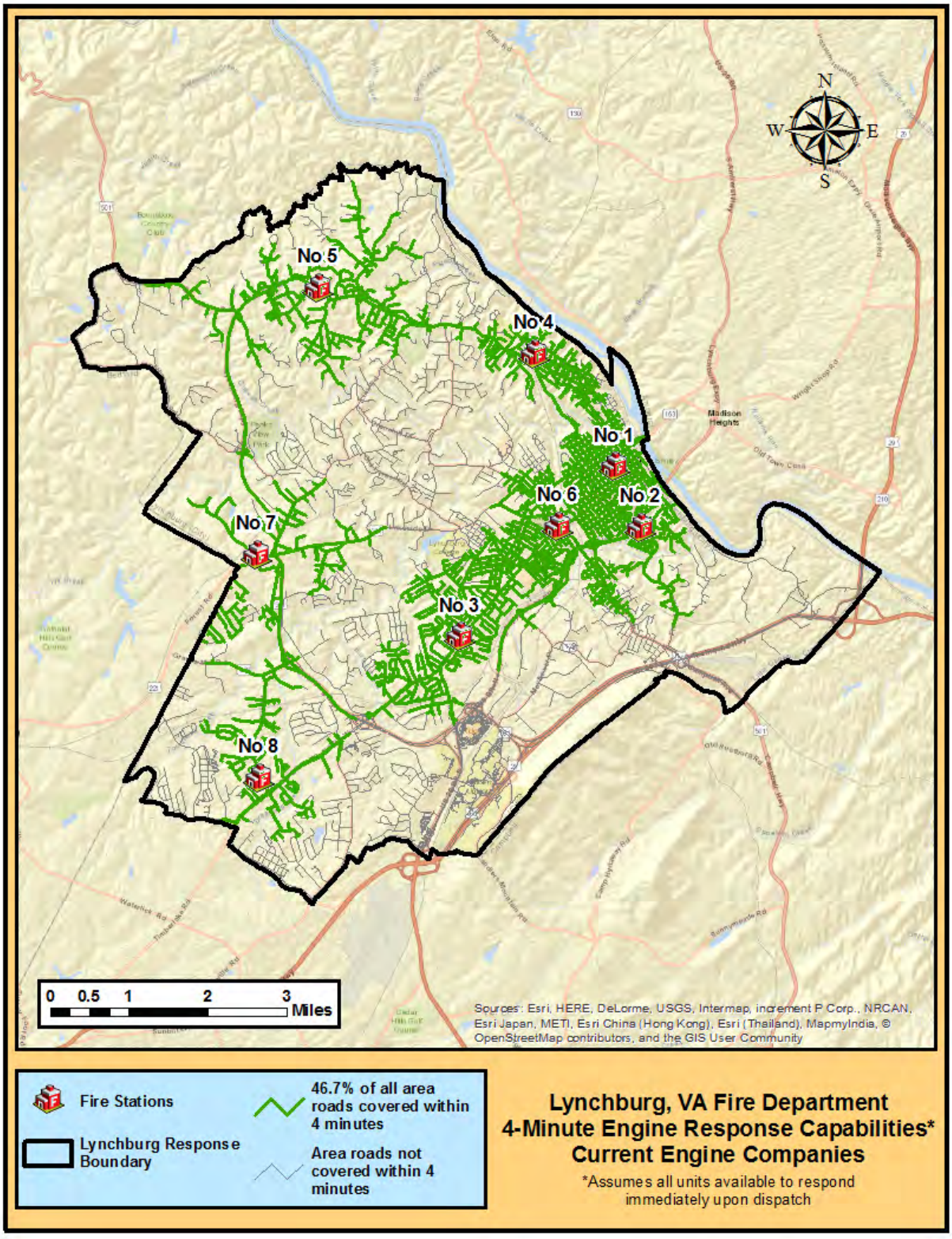
Map 3: 2012 – 2017 U.S. Annual Population Growth. Map 3 depicts the City of Lynchburg's annual population growth from 2012 – 2017. Total Population is the total number of residents in an area. Residence refers to the "usual place" where a person lives. Typically, as population increases so does demand.



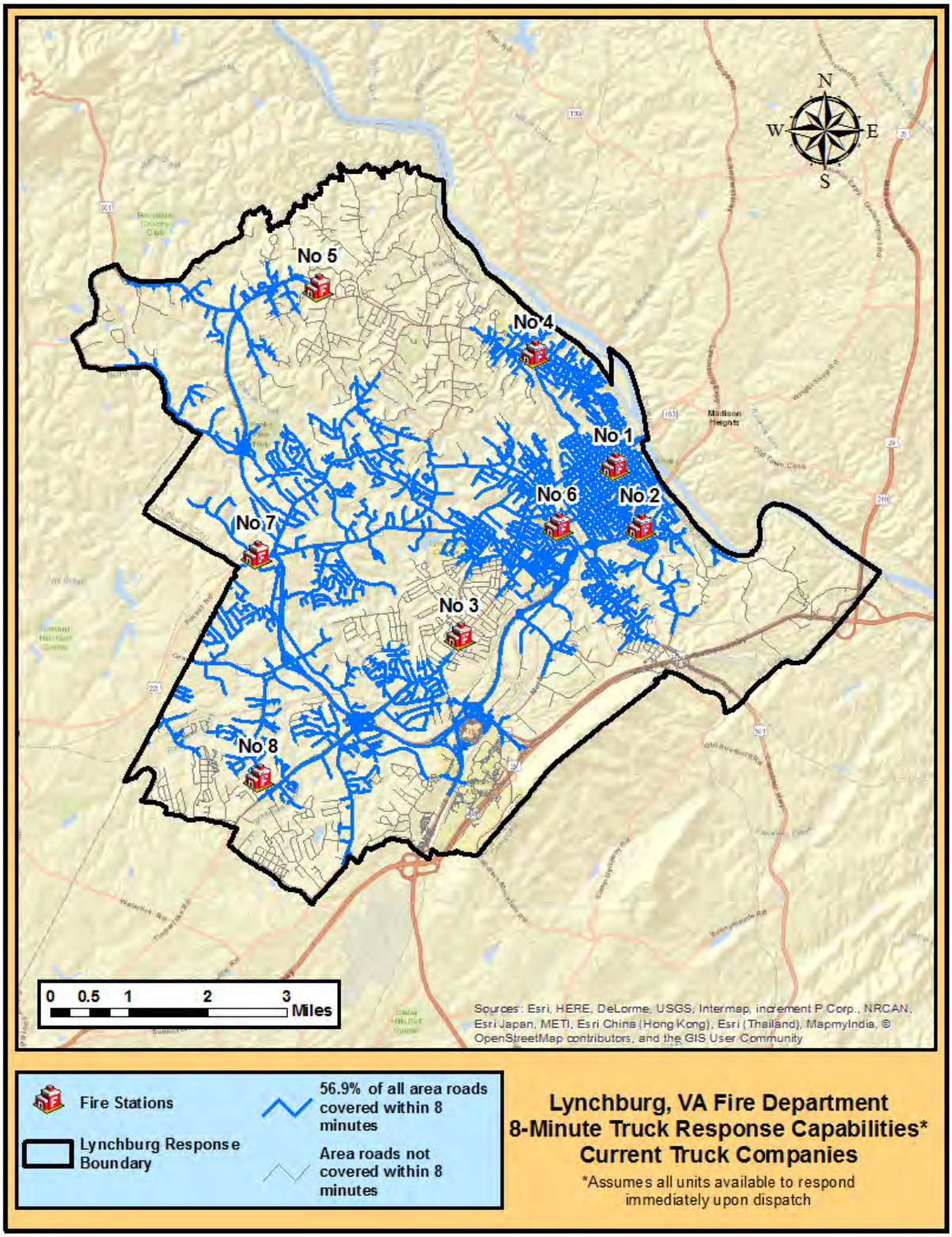
Map 4: 2016 Poverty Ratio. Map 4 compares the number of households living above the poverty line to the number of households living below. In the U.S. overall, there are 6.2 households living above the poverty line for every 1 household living below. The map shades areas in green which have a higher than normal number of households living above compared to below poverty line. Areas in brown have a higher than normal number of households living below the poverty line compared to those above in that same area. Areas in white do not have residential population so no poverty data is available for these areas. Typically, people that live at or below the poverty level are at a higher risk for medical complications and/or having a fire in their residence resulting in fire-related injury or death.



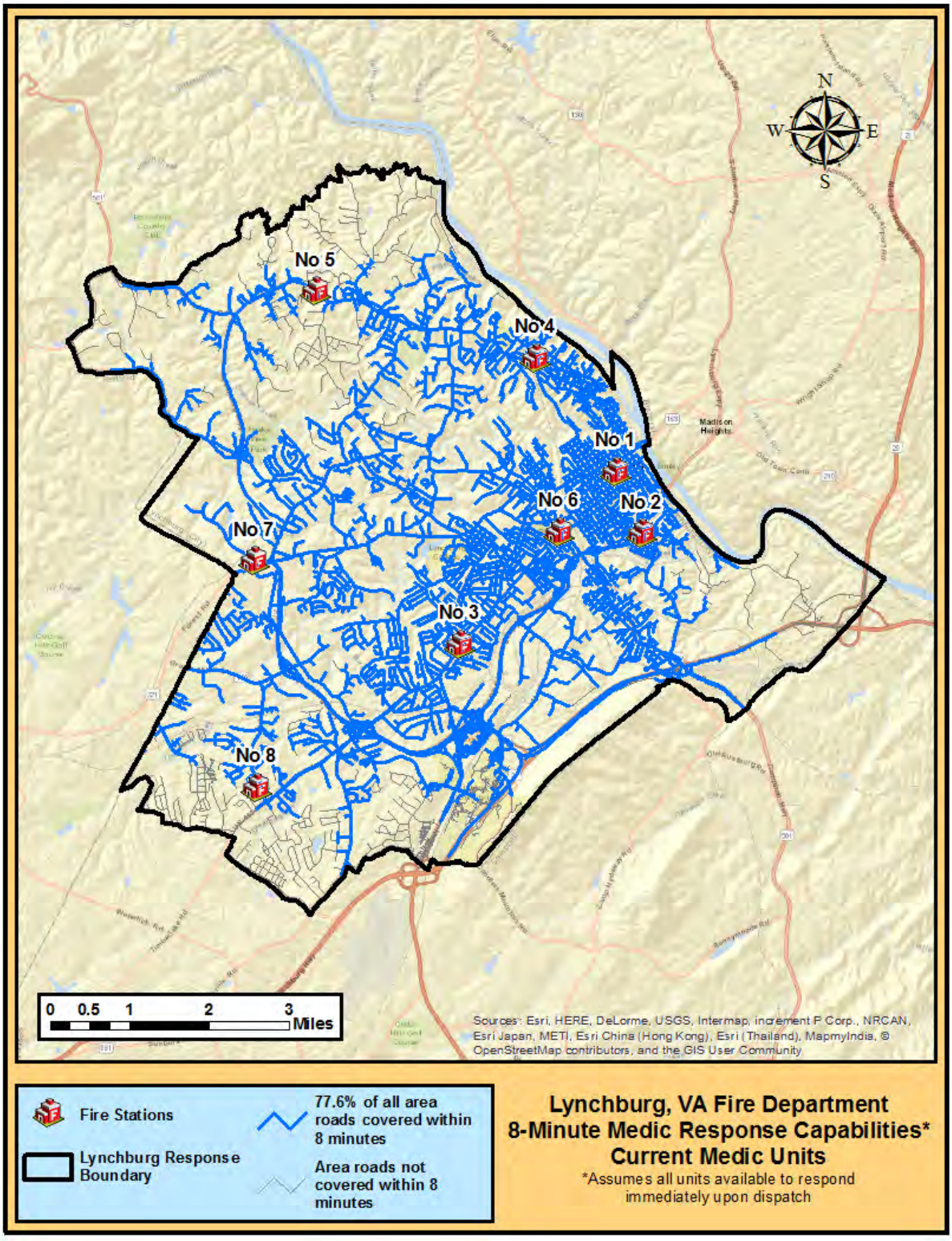
Map 5: Concentration of Emergency Responses in 2016. Map 5 depicts the concentration levels of emergency responses in 2016. The highest concentration of emergency responses in 2016 occurred near Fire Station 1, 2, 4, and 6. Additional resources should be positioned at fire stations that experience a high concentration of emergency responses to ensure timely, safe and effective fire suppression and EMS response.



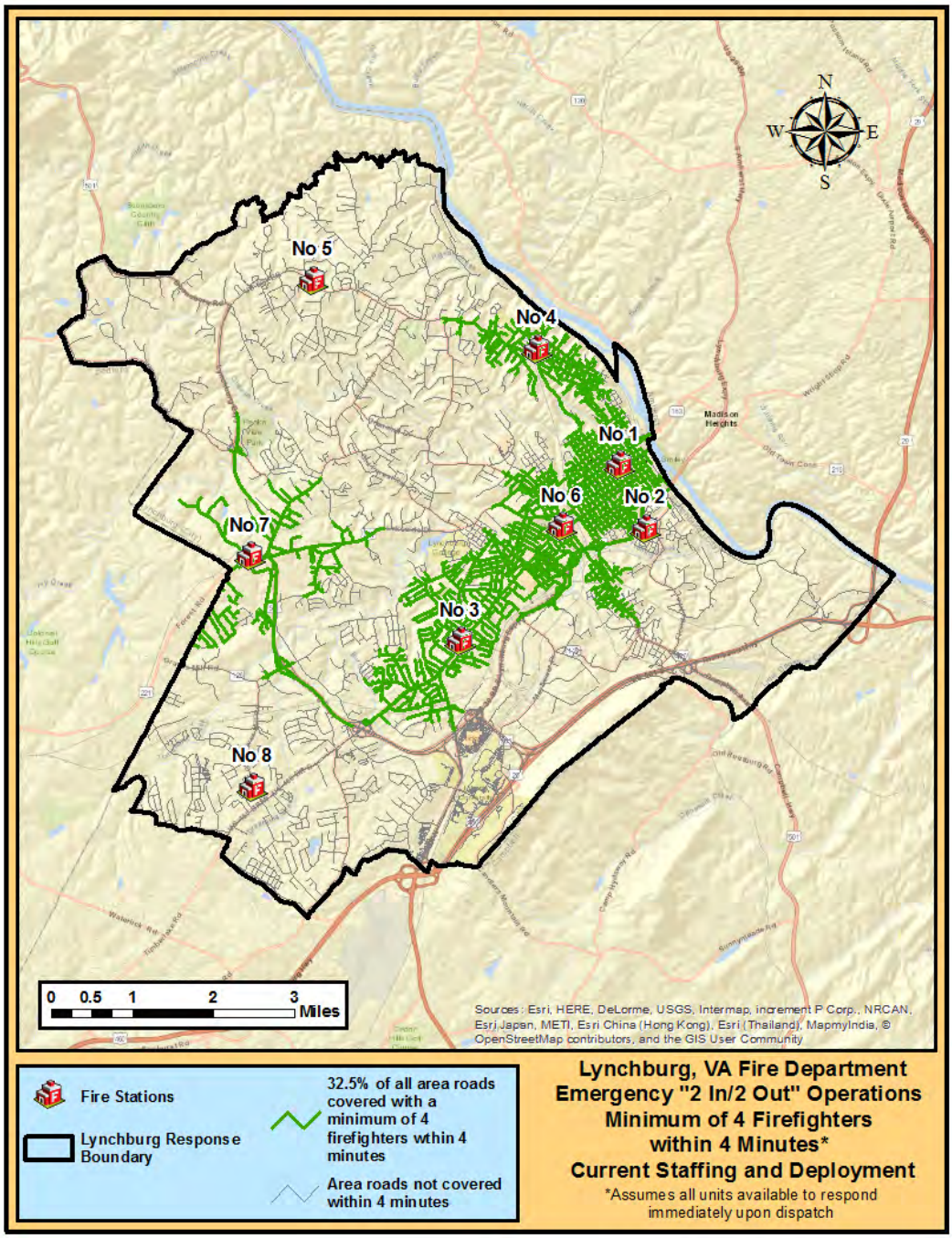
Map 6: 4-Minute Engine Response Capabilities, Current Engine Companies. Map 6 identifies those roads where LFD's engine companies can reach within 4 minutes of travel from the current fire stations. Currently, the department is capable of responding on 46.7% of city roads within 4 minutes.



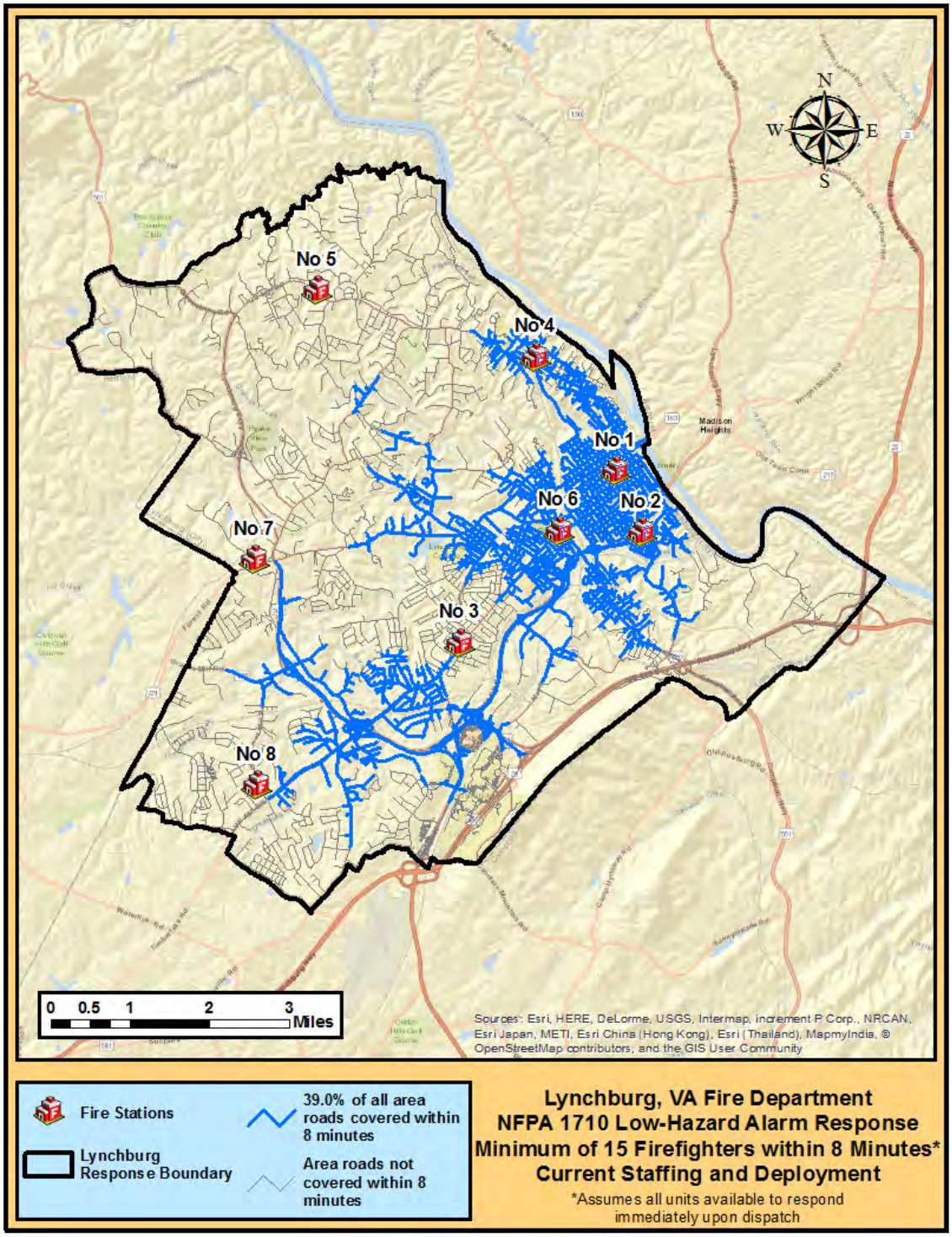
Map 7: 8-Minute Truck Response Capabilities, Current Truck Companies. Map 7 identifies those roads where LFD's truck companies can reach within 8 minutes of travel from the current fire stations. Currently, the department is capable of responding with a truck company on 56.9% of city roads within 8 minutes of travel.



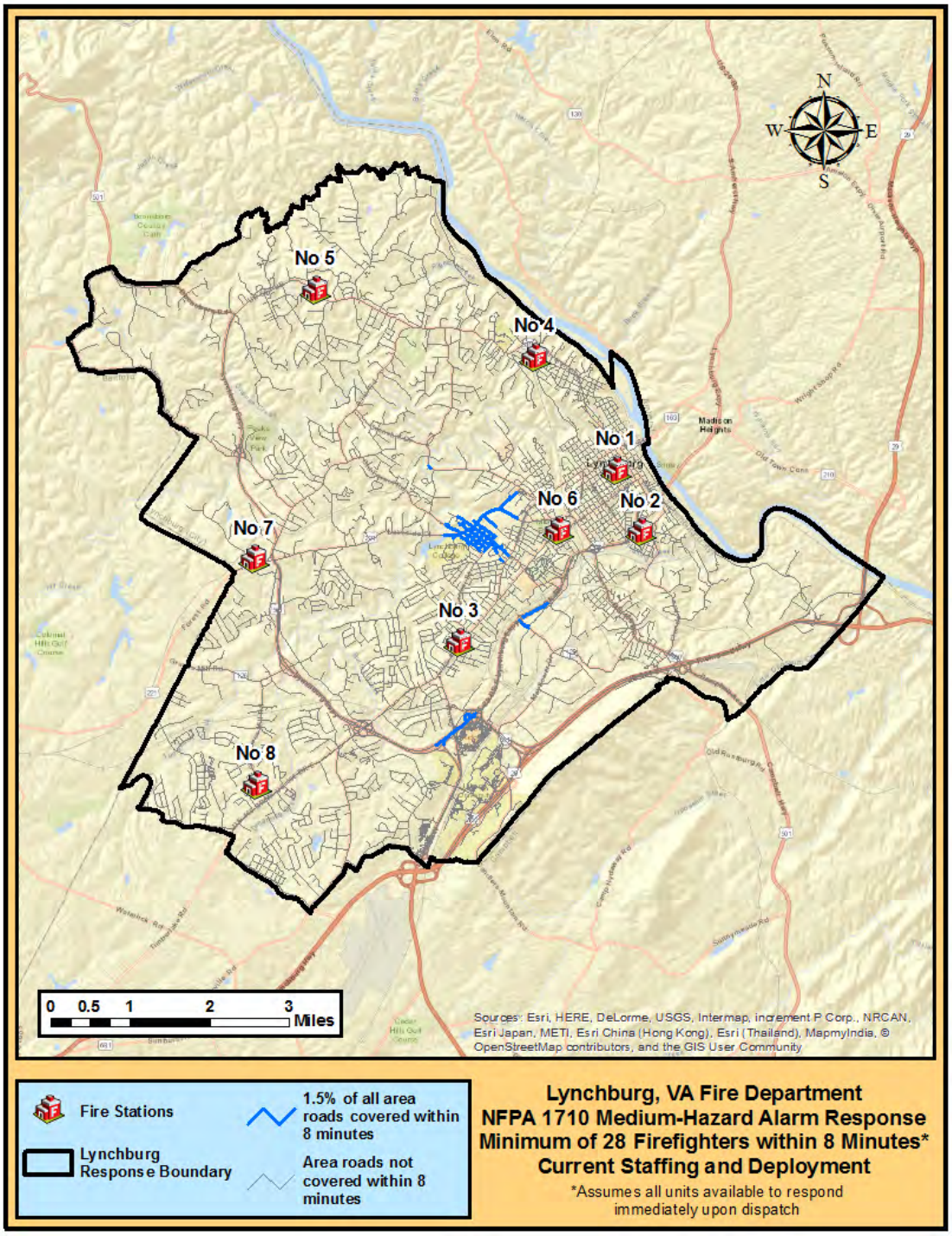
Map 8: 8-Minute Medic Response Capabilities, Current Medic Companies. Map 8 identifies those roads where LFD's medic companies can reach within 8 minutes of travel from the current fire stations. Currently, the department is capable of responding with a medic unit on 77.6% of city roads within 8 minutes of travel.



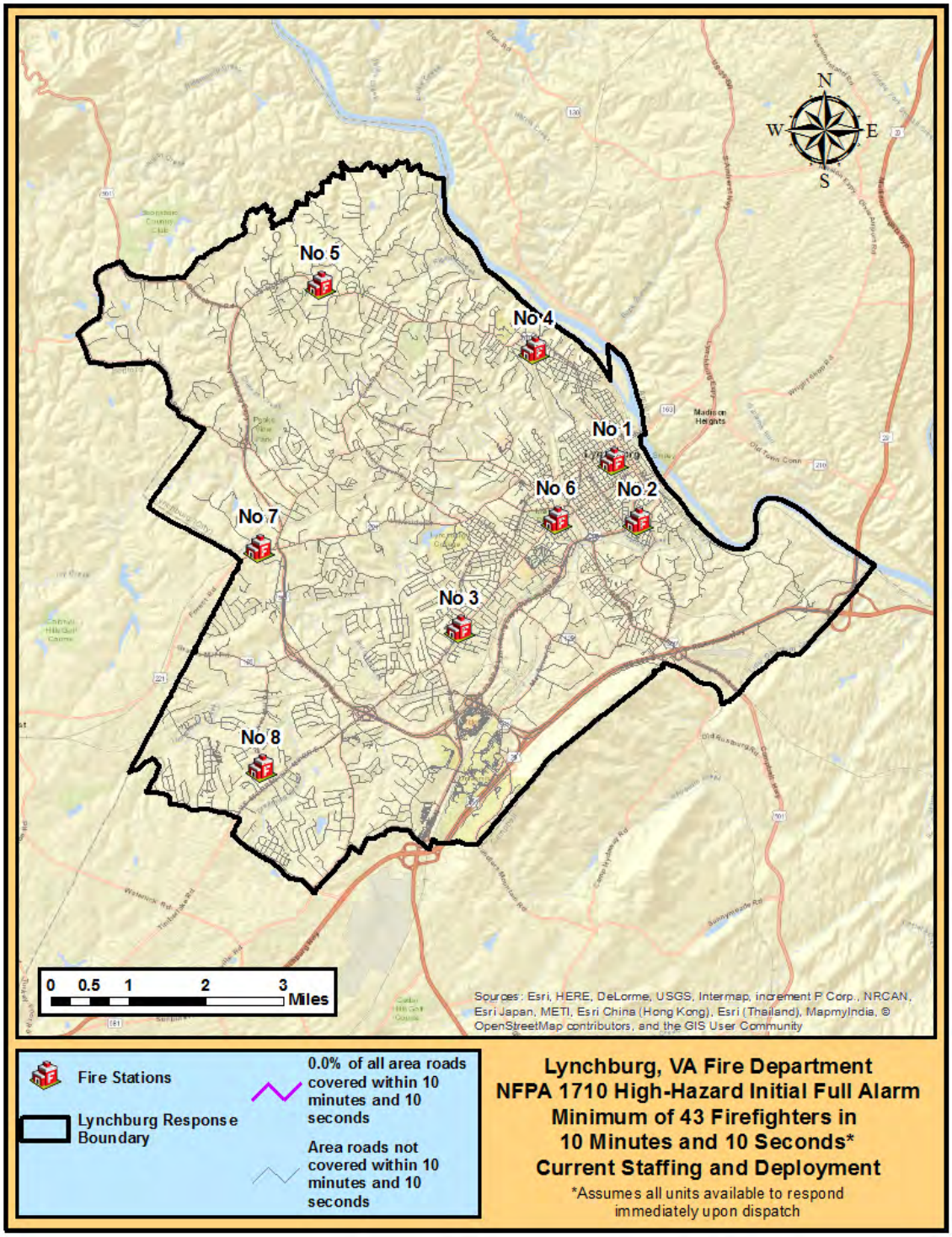
Map 9: Emergency "2 In/2 Out" Operations, 4-Minute Response Capabilities, Current Staffing and Deployment. Map 9 identifies those roads where a minimum of four firefighters can assemble on scene within 4 minutes. Currently, the department is able to assemble a minimum of four firefighters on scene within 4 minutes of travel on 32.5% of city roads. Due to department's medic units being equipped to perform fire suppression task, these units factor in to the department's ability to assemble a minimum of four firefighters on scene within 4 minutes. Staffing apparatus with less than four firefighters largely reduces the department's emergency "2 In/2 Out" operation response capabilities. When apparatus are not staffed with a minimum of four firefighters, the first arriving company will have to wait until the arrival of a second company before initiating safe and effective fire suppression and rescue operations.



Map 10: NFPA 1710 Low-Hazard Alarm Response, Minimum of 15 Firefighters within 8 Minutes, Current Staffing and Deployment. Map 10 identifies those roads where a minimum of 15 firefighters can assemble within 8 minutes of travel from the current fire stations. A typical low-hazard structure is defined as a 2,000 square foot, two-story single family dwelling without a basement and with no exposures. Currently, the department is capable of assembling a minimum of 15 firefighters within 8 minutes on 39.0% of city roads.



Map 11: NFPA 1710 Medium-Hazard Alarm Response, Minimum of 28 Firefighters within 8 Minutes, Current Staffing and Deployment. Map 11 identifies those roads where a minimum of 28 firefighters can assemble within 8 minutes of travel from the current fire stations. Currently, the department is capable of assembling a minimum of 28 firefighters within 8 minutes on 1.5% of city roads. A typical medium-hazard structure is defined as an open-air shopping center or three-story garden-style apartment building. LFD should asses where medium-hazard structures are located and add additional resources to these areas to possibly increase the department's ability to assemble a minimum of 28 firefighters within 8 minutes of travel.



Map 12: NFPA 1710 High-Hazard Initial Alarm Response, Minimum of 43 Firefighters within 10 Minutes and 10 Seconds, Current Staffing and Deployment. Map 12 identifies those roads where a minimum of 43 firefighters can assemble within 10 minutes and 10 seconds of travel. Currently, the department is unable to assemble a minimum of 43 firefighters within 8 minutes of travel to any portion of LFD's response boundary. Liberty University, Lynchburg College, and downtown Lynchburg have several high-hazard structures, which currently cannot receive the full alarm assignment to high-rise and/or high-hazard structure.

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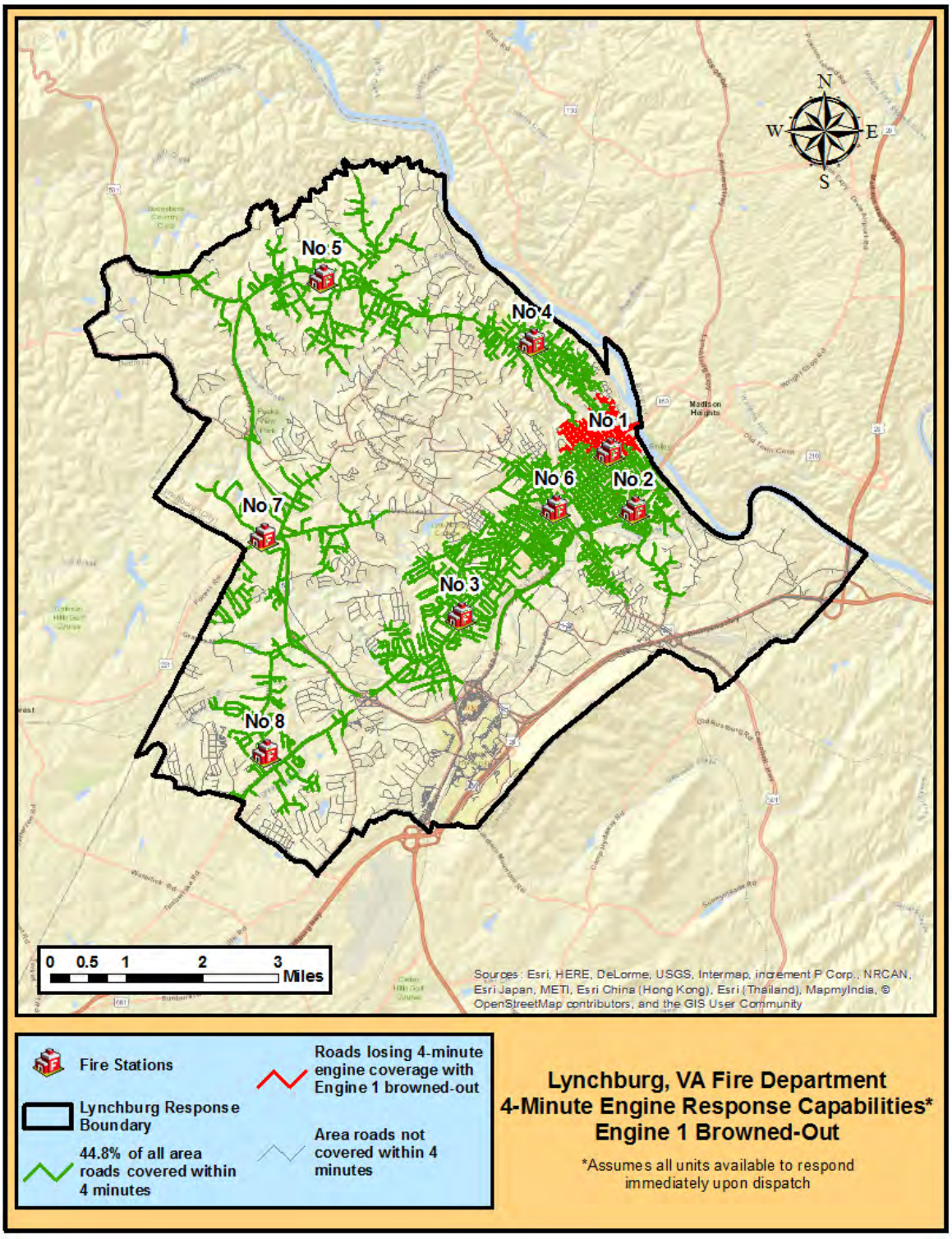
Emergency Response Capabilities, Fire Suppression Apparatus Browned-Out

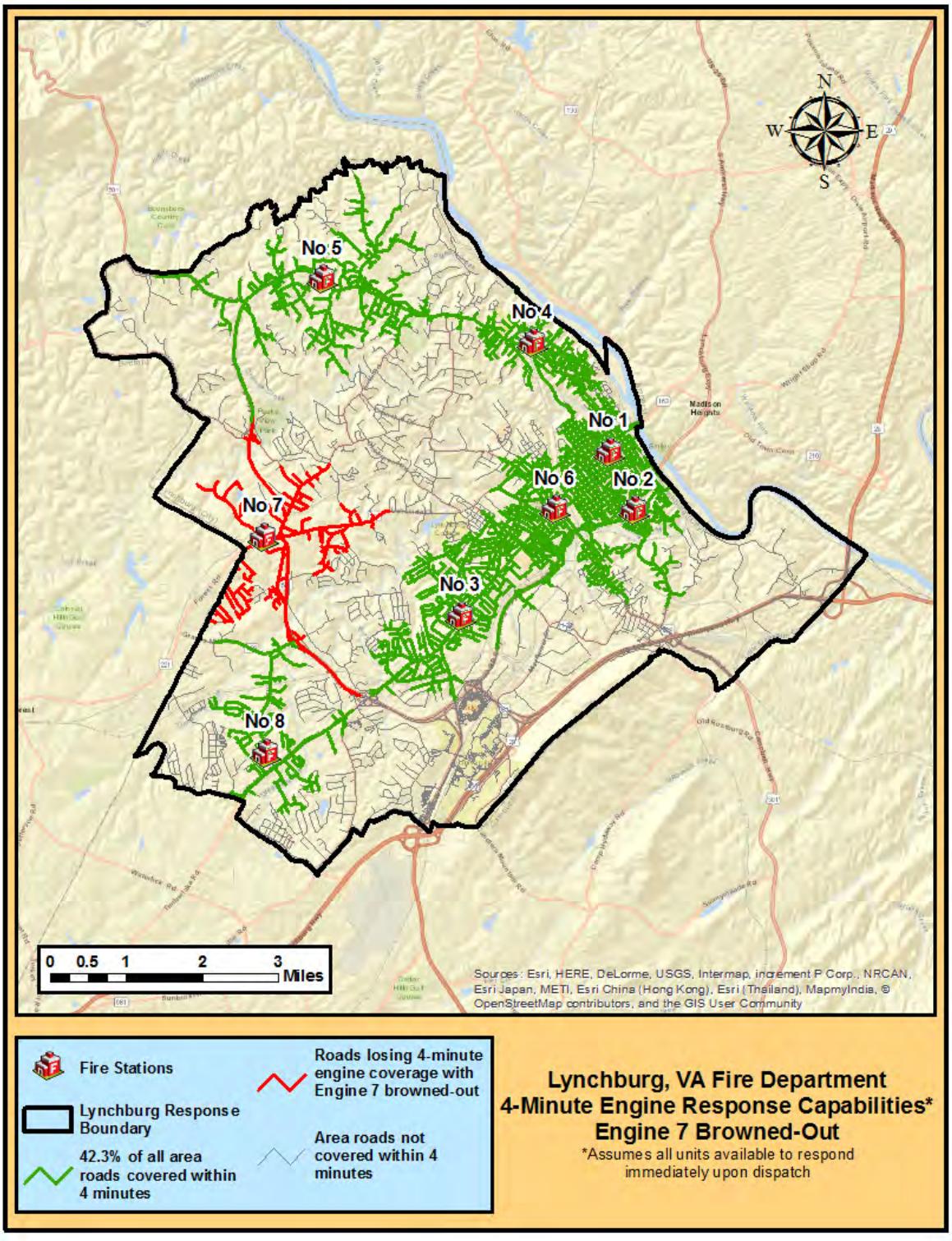
For this portion of the study, an alternate staffing and deployment scenario was examined where Engine 1, Engine 7, Truck 1, or Truck 2 are browned-out. Currently, LFD typically brown-out one of those apparatus due to a shortage of available personnel. The browning-out of apparatus can negatively affect the department's response capabilities.

Fire Station	Address	Apparatus	Staffing
Station 1	801 Clay Street	**Engine 1** **Truck 1** Medic 1 Battalion 1	**3 FF (Possible Brown-out)** **3 FF (Possible Brown-out)** 1 FF/EMT, 1 FF/Medic 1 Battalion Chief
Station 2	2006 Grace Street	Engine 2	3 FF
Station 3	4701 Fort Avenue	Engine 3 Rescue 1 Medic 3	3 FF 3 FF 1 FF/EMT, 1 FF/Medic
Station 4	410 Birch Street	Engine 4 Medic 4	3 FF 1 FF/EMT, 1 FF/Medic
Station 5	4800 Boonsboro Road	Engine 5 Medic 5	3 FF Cross-Staffed
Station 6	2084 Fort Avenue	Engine 6 Medic 6	3 FF 1 FF/EMT, 1FF/Medic
Station 7	2624 Lakeside Drive	**Engine 7** **Truck 2** Battalion 2 Medic 7	**3 FF (Possible Brown-out)** **3 FF (Possible Brown-out)** 1 Battalion Chief 1 FF/EMT, 1 FF/Medic
Station 8	13 Old Graves Mill Road	Engine 8 Medic 8	3 FF Crossed-Staffed

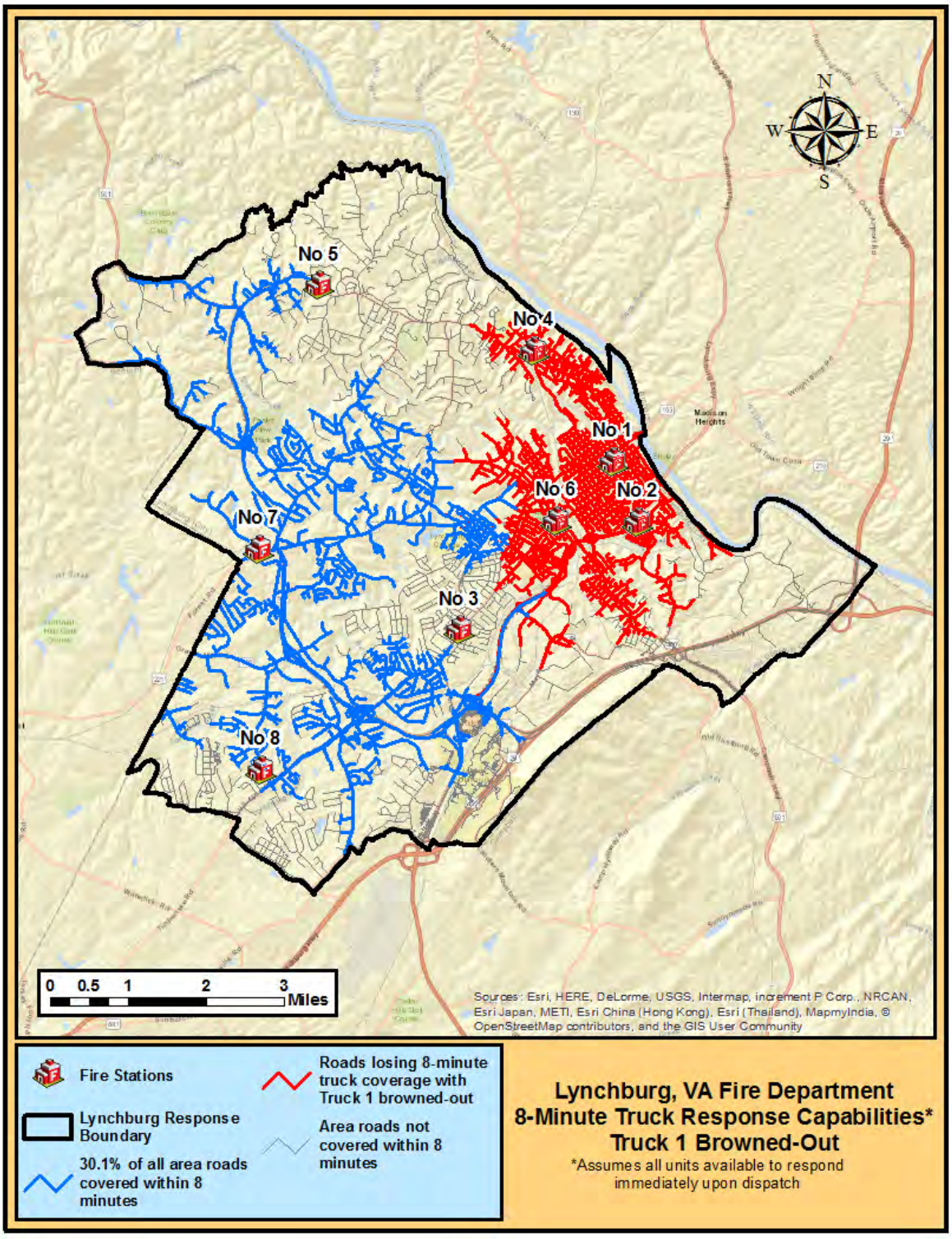
Table 7: Fire Station Locations and Browned-Out Apparatus and Staffing Levels. Table 7 displays where apparatus are housed and the apparatus that are candidates to be browned-out. This scenario evaluates the department's response capabilities when one of the following apparatus are browned-out: Engine 1, Engine 7, Truck 1, or Truck 2. The department does not brown-out two suppression units out of the same fire station.



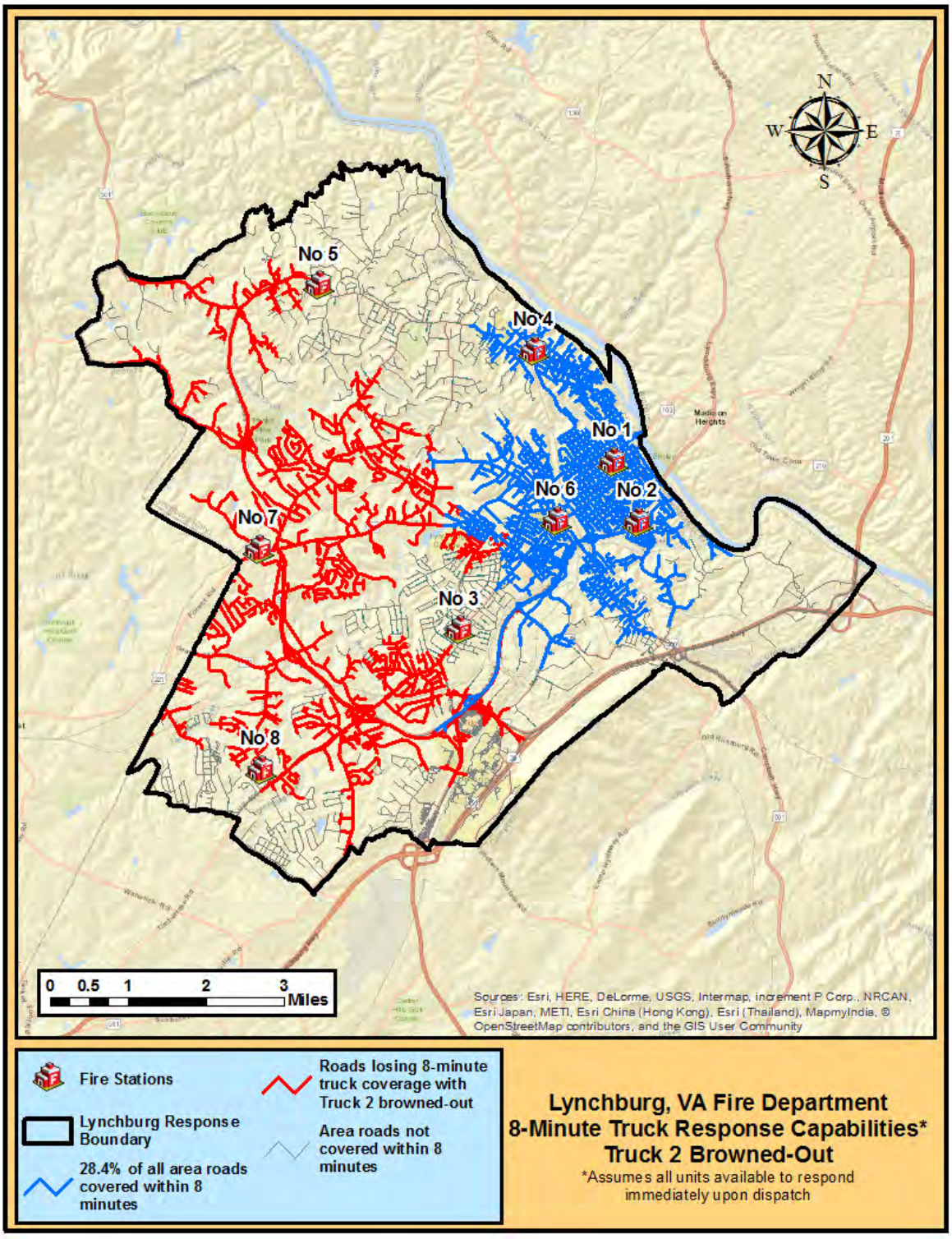
Map 13: 4-Minute Engine Response Capabilities, Engine 1 Browned-Out. Map 13 identifies those roads where LFD's engine companies can reach within 4 minutes of travel when Engine 1 is browned-out. Based on this staffing and deployment configuration, the department is capable of responding with a minimum of one engine company on 44.8% of city roads within 4 minutes, which equates to a 4.1% **reduction** in engine response capabilities compared to when all engine companies are staffed and in service.



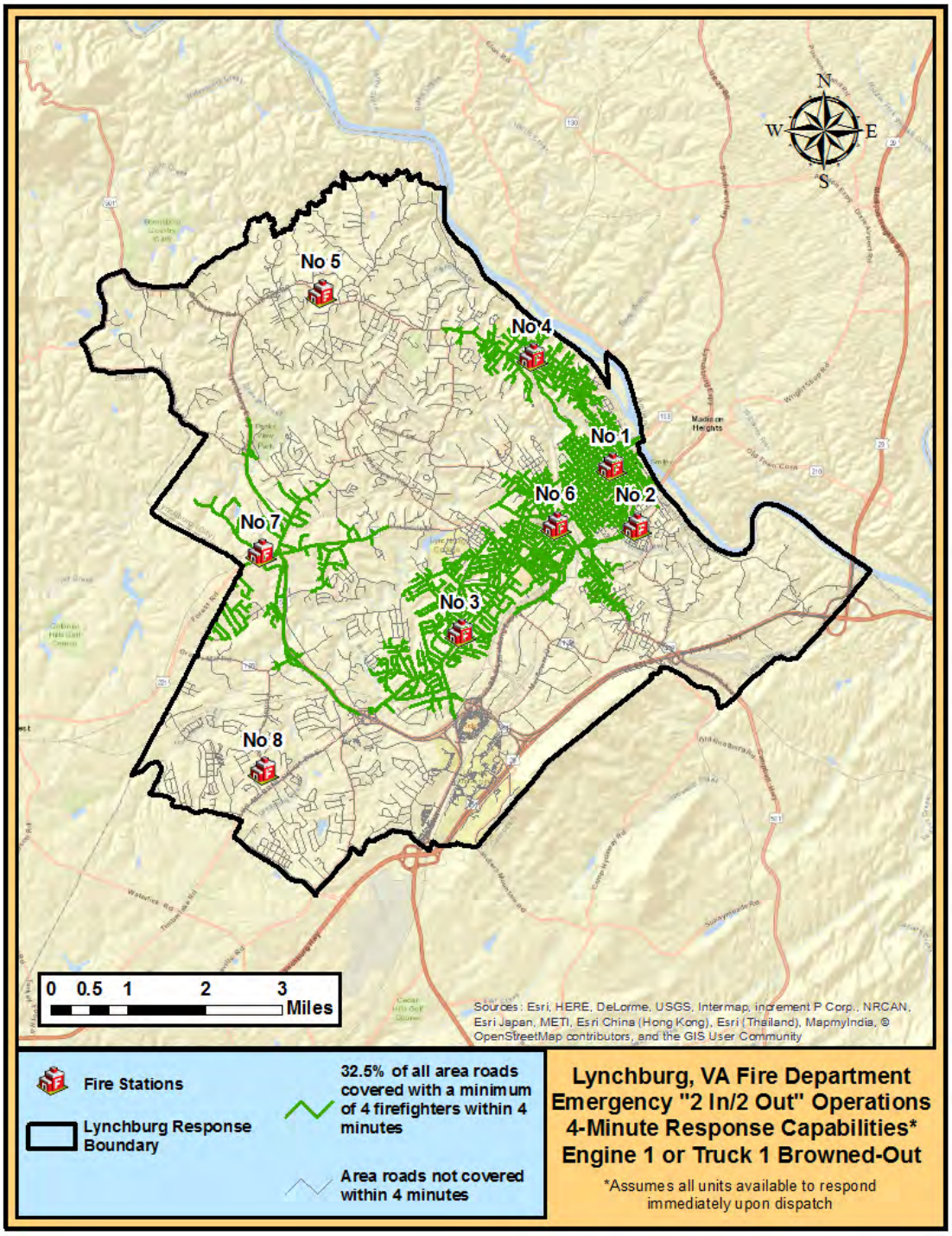
Map 14: 4-Minute Engine Response Capabilities, Engine 7 Browned-Out. Map 14 identifies those roads where LFD's engine companies can reach within 4 minutes of travel when Engine 7 is browned-out. Based on this staffing and deployment configuration, the department is capable of responding with an engine company on 42.3% of city roads within 4 minutes, which equates to a 9.5% **reduction** in engine response capabilities compared to when all engine companies are staffed and in service.



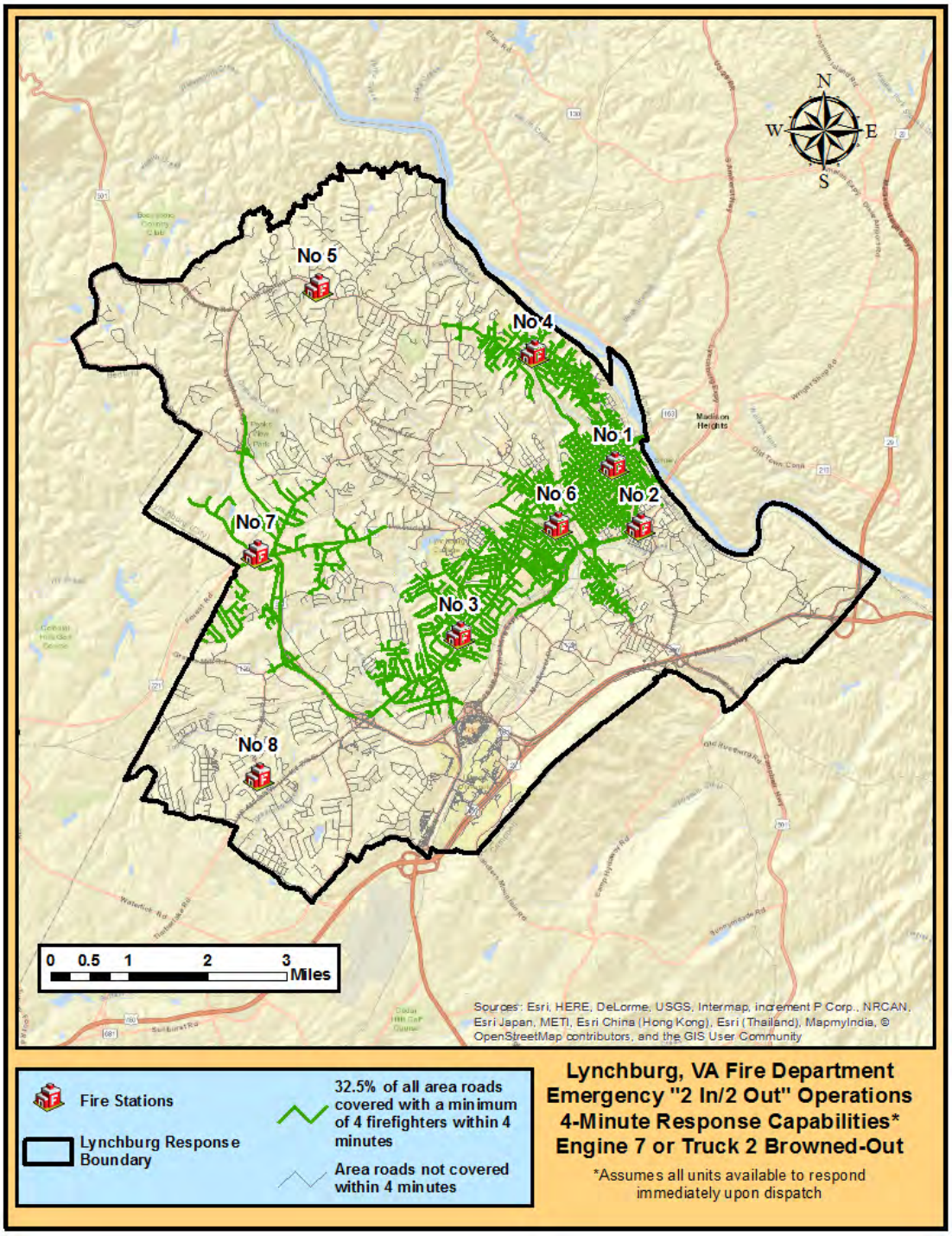
Map 15: 8-Minute Truck Response Capabilities, Truck 1 Browned-Out. Map 15 identifies those roads where LFD's truck companies can reach within 8 minutes of travel when Truck 1 is browned-out. Based on this staffing and deployment configuration, the department is capable of responding with a truck company on 30.1% of city roads within 8 minutes, which equates to a 47.1% **reduction** in truck response capabilities compared to when all truck companies are staffed and in service.



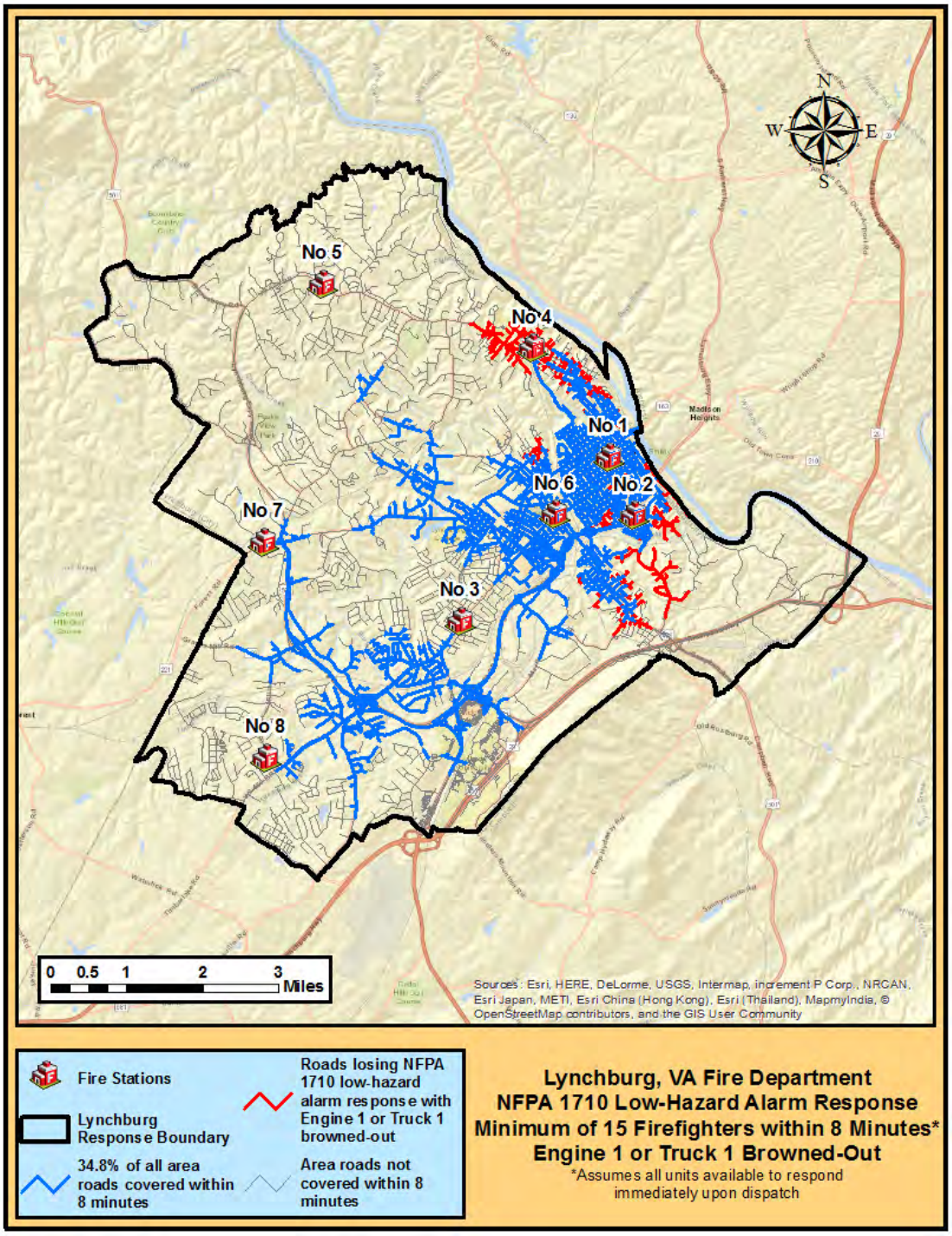
Map 16: 8-Minute Truck Response Capabilities, Truck 2 Browned-Out. Map 16 identifies those roads where LFD's truck companies can reach within 8 minutes of travel when Truck 2 is browned-out. Based on this staffing and deployment configuration, the department is capable of responding on 28.4% of city roads within 8 minutes, which equates to a 50.1% **reduction** in truck response capabilities compared to when all engine companies are staffed and in service.



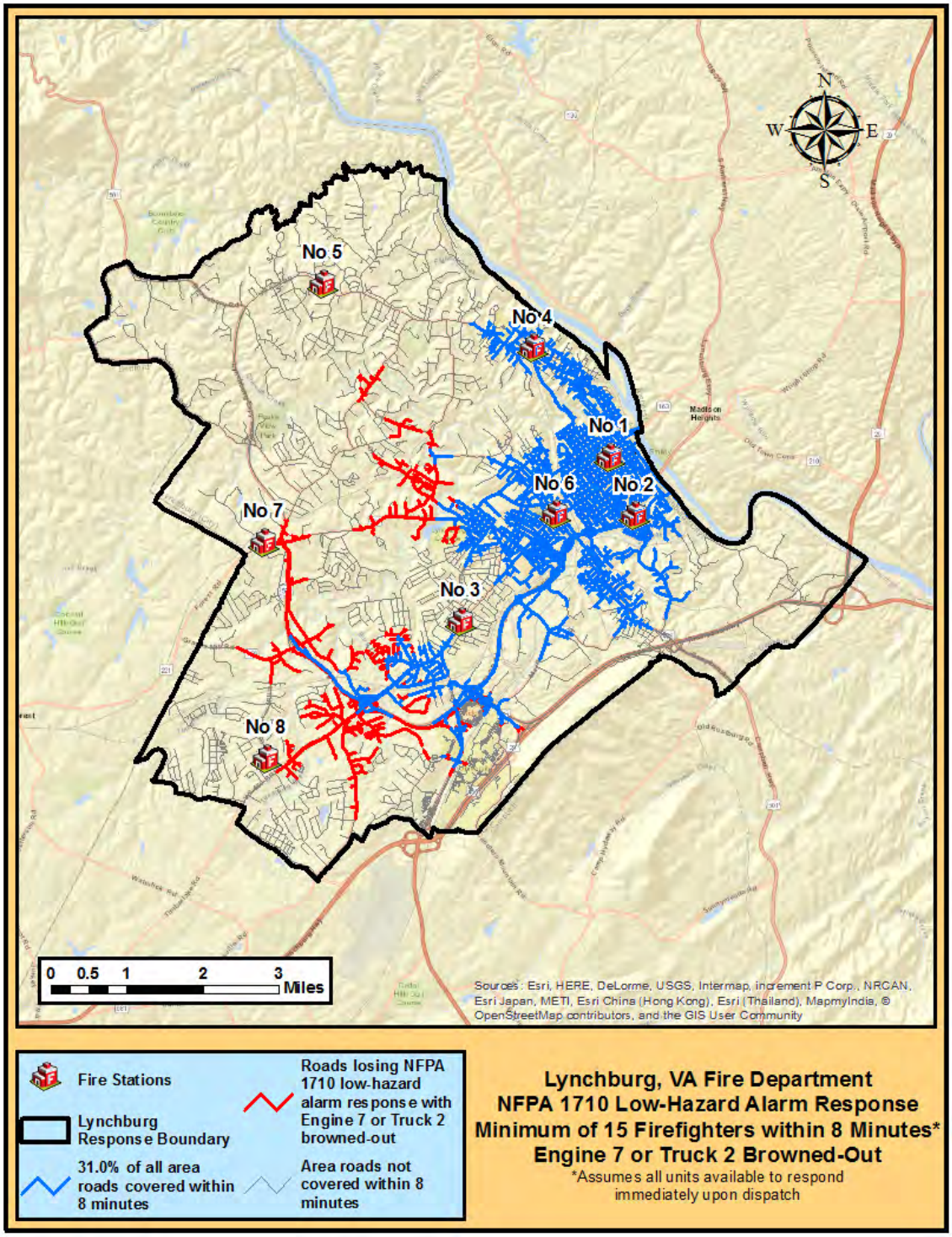
Map 17: Emergency "2 In/2 Out" Operations, 4-Minute Response Capabilities, Engine 1 or Truck 1 Browned-Out. Map 17 identifies those roads where a minimum of four firefighters can assemble on scene within 4 minutes. Based on this staffing and deployment configuration, the department is able to assemble a minimum of four firefighters on scene within 4 minutes of travel on 32.5% of city roads. Staffing apparatus with less than four firefighters largely reduces the department's emergency "2 In/2 Out" operation response capabilities. The browning-out of an engine or truck company may result in some aspects of critical firegound operations being delayed due to lack of available recourses.



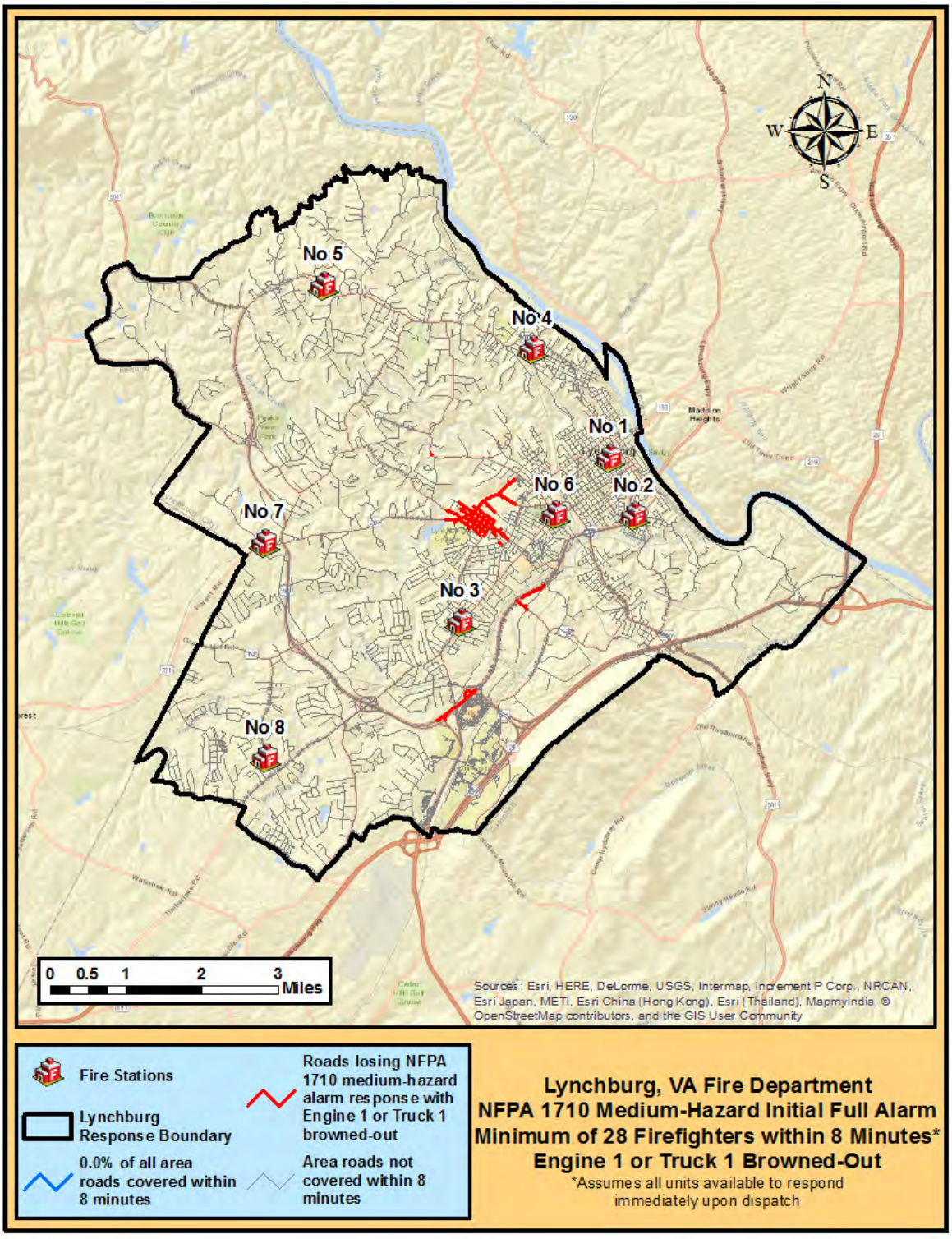
Map 18: Emergency "2 In/2 Out" Operations, 4-Minute Response Capabilities, Engine 7 or Truck 2 Browned-Out. Map 18 identifies those roads where a minimum of four firefighters can assemble on scene within 4 minutes. Based on this staffing and deployment configuration, the department is able to assemble a minimum of four firefighters on scene within 4 minutes of travel on 32.5% of city roads. Staffing apparatus with less than four firefighters largely reduces the department's emergency "2 In/2 Out" operation response capabilities. The browning-out of an engine or truck company may result in some aspects of critical firegound operations being delayed due to lack of available recourses.



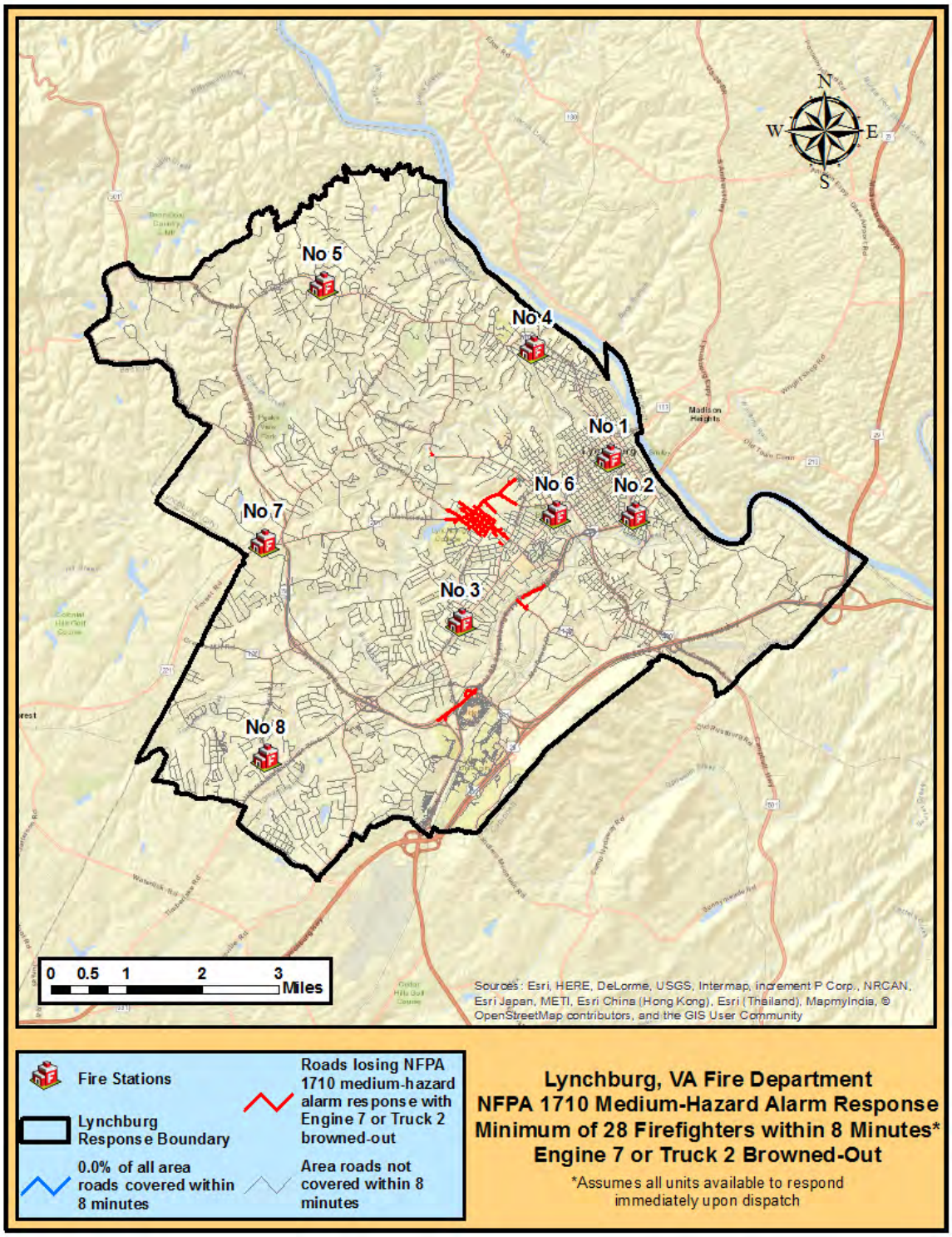
Map 19: NFPA 1710 Low-Hazard Alarm Response, Minimum of 15 Firefighters within 8 Minutes, Engine 1 or Truck 1 Browned-Out. Map 19 identifies those roads where a minimum of 15 firefighters would likely be able to assemble on scene within 8 minutes of travel. A typical low-hazard structure is a 2,000 square foot, two-story single family dwelling without a basement and with no exposures. Based on this staffing and deployment configuration, the department is capable of assembling a minimum of 15 firefighters within 8 minutes of travel on 34.8% of city roads, which equates in an 11.6% **reduction** in coverage compared to the department's current response capabilities.



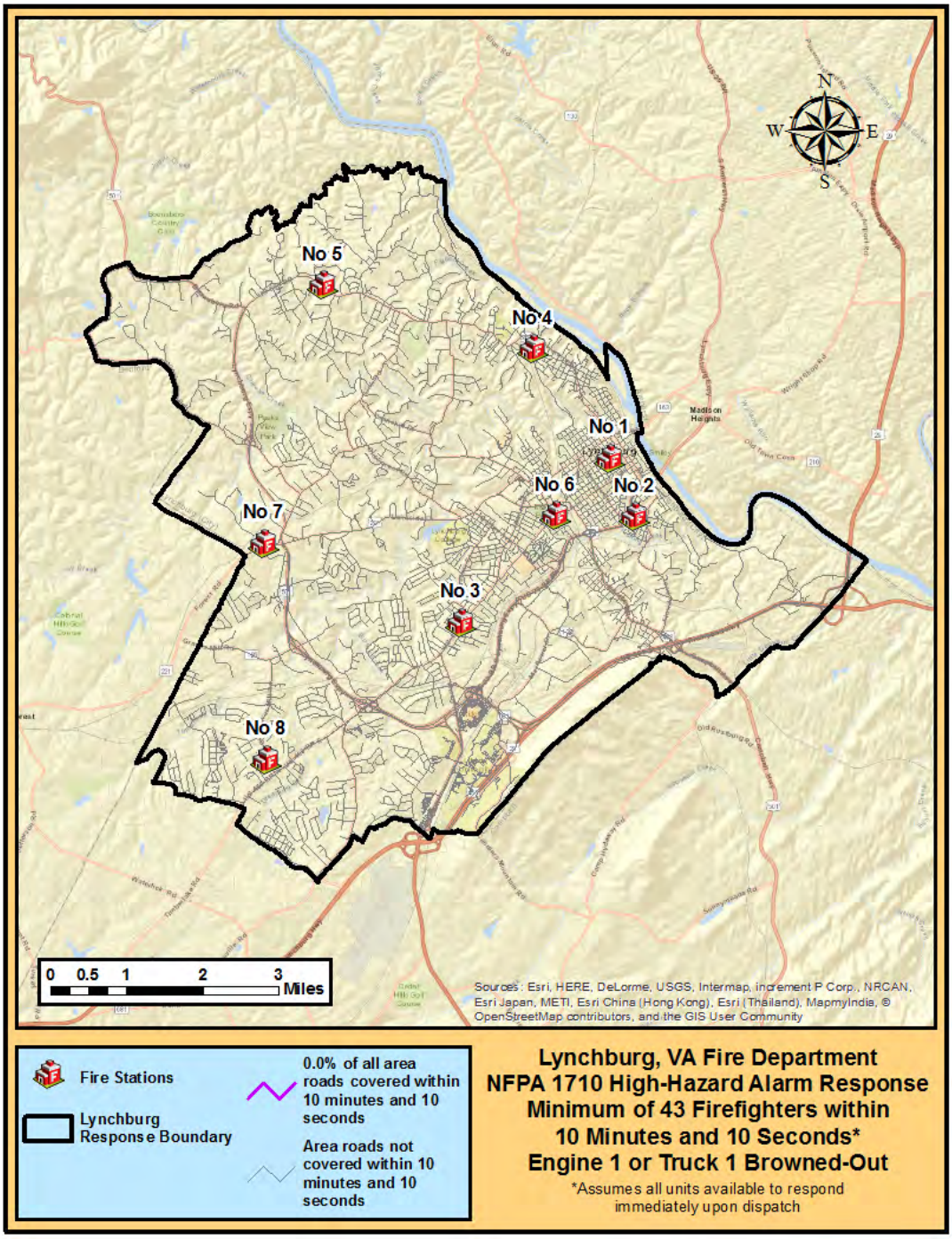
Map 20: NFPA 1710 Low-Hazard Alarm Response, Minimum of 15 Firefighters within 8 Minutes, Engine 7 or Truck 2 Browned-Out. Map 20 identifies those roads where a minimum of 15 firefighters can assemble within 8 minutes of travel from the current fire stations. A typical low-hazard structure is a 2,000 square foot, two-story single family dwelling without a basement and with no exposures. Based on this staffing and configuration, the department is capable of assembling a minimum of 15 firefighters within 8 minutes of travel on 31.0% of city roads, which equates to a 21.3% **reduction** in coverage compared to the department's current response capabilities.



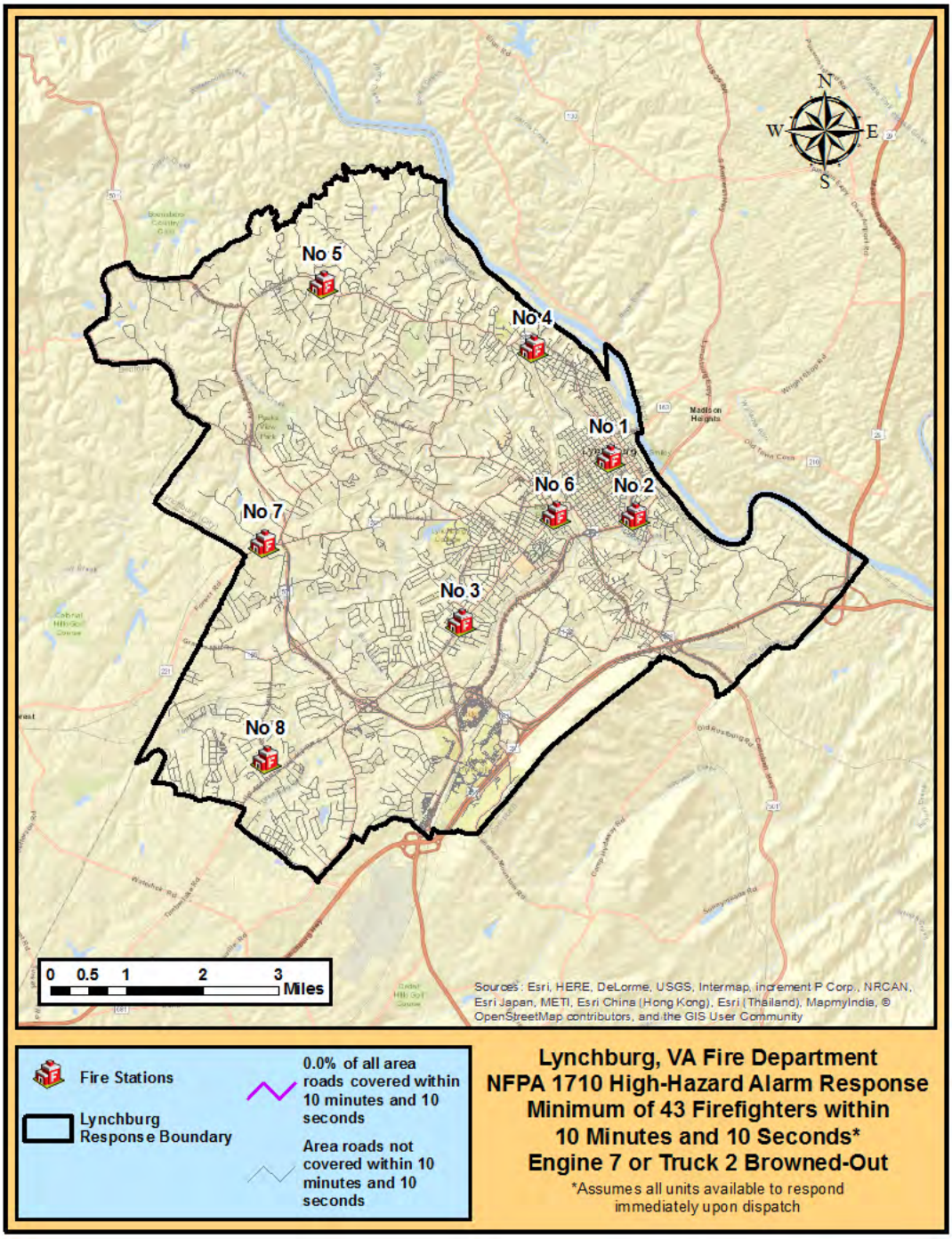
Map 21: NFPA 1710 Medium-Hazard Alarm Response, Minimum of 28 Firefighters within 8 Minutes, Engine 1 or Truck 1 Browned-Out. Map 21 identifies those roads where a minimum of 28 firefighters can assemble within 8 minutes of travel. A typical medium-hazard structure is defined as an open-air shopping center or three-story garden-style apartment building. Based on this staffing and configuration, the department would be capable of assembling a minimum of 28 firefighters within 8 minutes on 0.0% of city roads.



Map 22: NFPA 1710 Medium-Hazard Alarm Response, Minimum of 28 Firefighters within 8 Minutes, Engine 7 or Truck 2 Browned-Out. Map 22 identifies those roads where a minimum of 28 firefighters can assemble within 8 minutes of travel. A typical medium-hazard structure is defined as an open-air shopping center or three-story garden-style apartment building. Based on this staffing and configuration, the department would be capable of assembling a minimum of 28 firefighters within 8 minutes on 0.0% of city roads.



Map 23: NFPA 1710 High-Hazard Alarm Response, Minimum of 43 Firefighters within 10 Minutes and 10 Seconds, Engine 1 or Truck 1 Browned-Out. Map 23 identifies those roads where a minimum of 43 firefighters can assemble within 10 minutes and 10 seconds of travel. Based on this staffing and configuration, the department would be capable of assembling a minimum of 43 firefighters within 10 minutes and 10 seconds on 0.0% of city roads. Liberty University, Lynchburg College, and downtown Lynchburg have several high-hazard structures, which currently cannot receive the full alarm assignment to a high-rise and high-hazard structure.



Map 24: NFPA 1710 High-Hazard Alarm Response, Minimum of 43 Firefighters within 10 Minutes and 10 Seconds, Engine 7 or Truck 2 Browned-Out. Map 24 identifies those roads where a minimum of 43 firefighters can assemble within 10 minutes and 10 seconds of travel. Based on this staffing and configuration, the department would be capable of assembling a minimum of 43 firefighters within 10 minutes and 10 seconds on 0.0% of city roads. Liberty University, Lynchburg College, and downtown Lynchburg have several high-hazard structures, which currently cannot receive the full alarm assignment to a high-rise and high-hazard structure.

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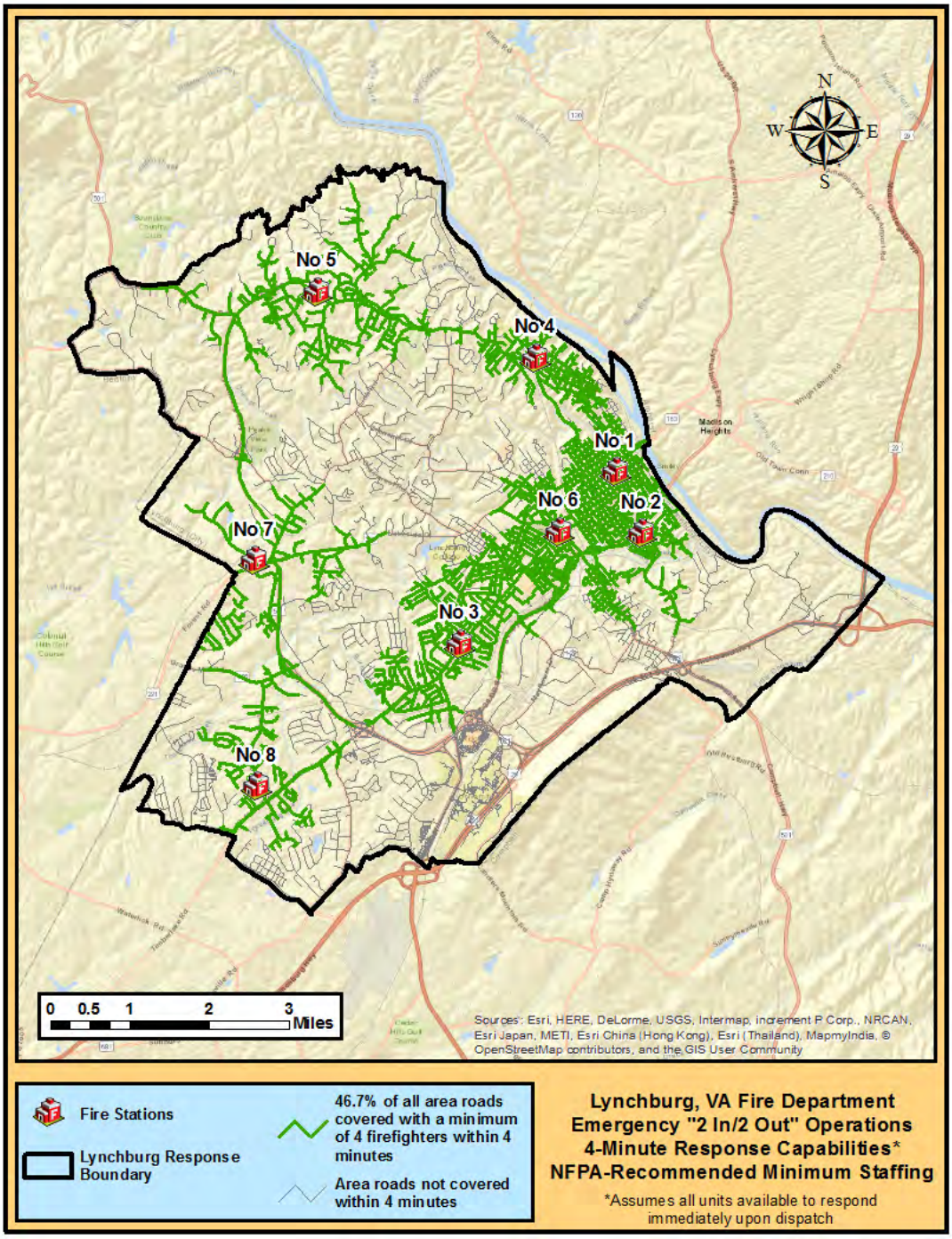
Emergency Response Capabilities, NFPA-Recommended Minimum Staffing

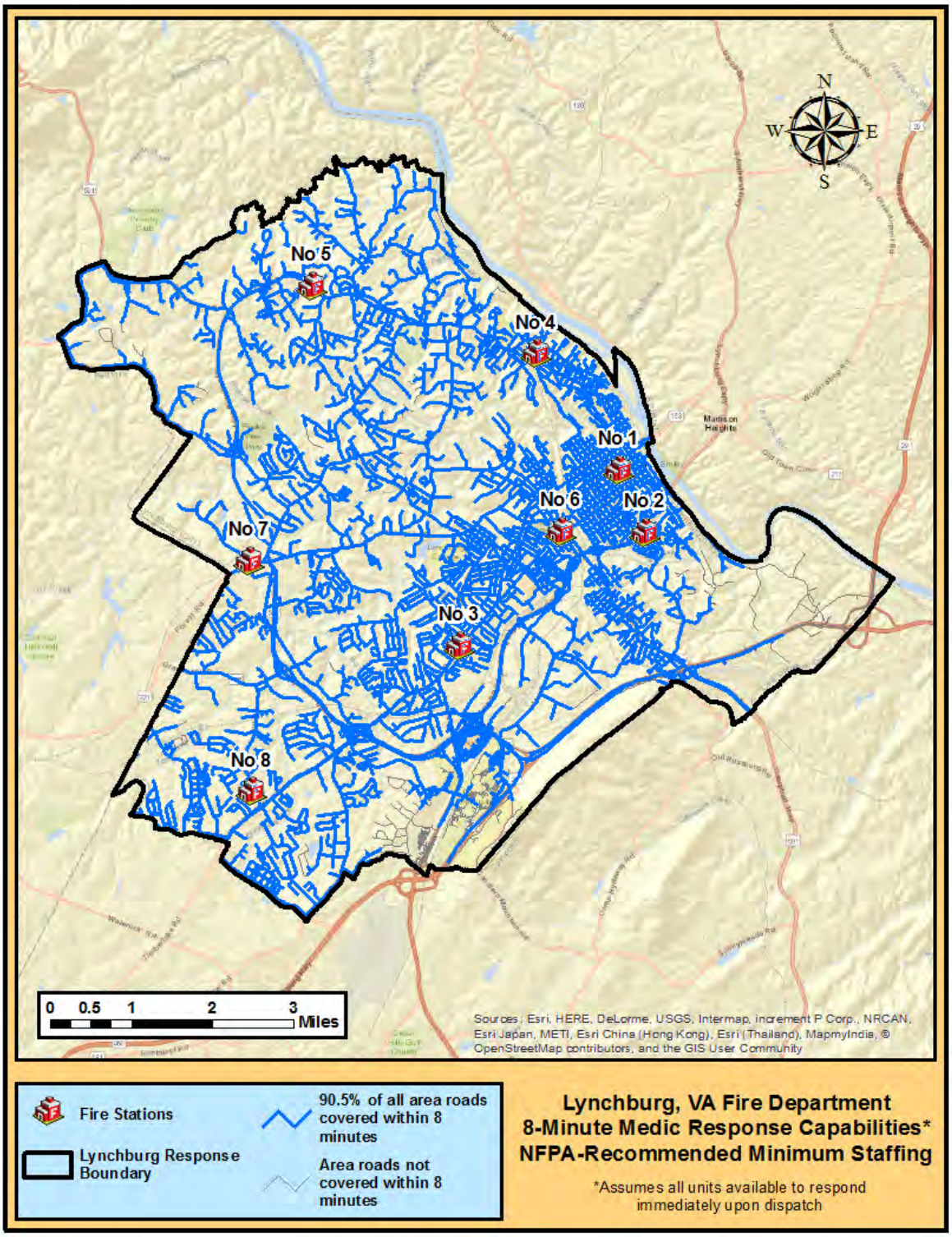
For this portion of the study, an alternate staffing and deployment scenario was examined where Medic 5 and Medic 8 are staffed full-time, no apparatus are browned-out, and all fire suppression apparatus are staffed with four firefighters, in accordance with industry standards. Staffing apparatus with four firefighters allows firefighters to begin an interior attack on a fire immediately rather than waiting for additional units to arrive on the scene with supplemental personnel.

Fire Station	Address	Apparatus	Staffing
Station 1	801 Clay Street	Engine 1 Truck 1 Medic 1 Battalion 1	**4 FF** **4 FF** 1 FF/EMT, 1 FF/Medic 1 Battalion Chief
Station 2	2006 Grace Street	Engine 2	**4 FF**
Station 3	4701 Fort Avenue	Engine 3 Rescue 1 Medic 3	**4 FF** **4 FF** 1 FF/EMT, 1 FF/Medic
Station 4	410 Birch Street	Engine 4 Medic 4	4 FF 1 FF/EMT, 1 FF/Medic
Station 5	4800 Boonsboro Road	Engine 5 Medic 5	**4 FF** **1 FF/EMT, 1 FF/Medic**
Station 6	2084 Fort Avenue	Engine 6 Medic 6	**4 FF** 1 FF/EMT, 1 FF/Medic
Station 7	2624 Lakeside Drive	Engine 7 Truck 2 Battalion 2 Medic 7	**4 FF** **4 FF** 1 Battalion Chief 1 FF/EMT, 1 FF/Medic
Station 8	13 Old Graves Mill Road	Engine 8 Medic 8	**4 FF** **1 FF/EMT, 1 FF/Medic**

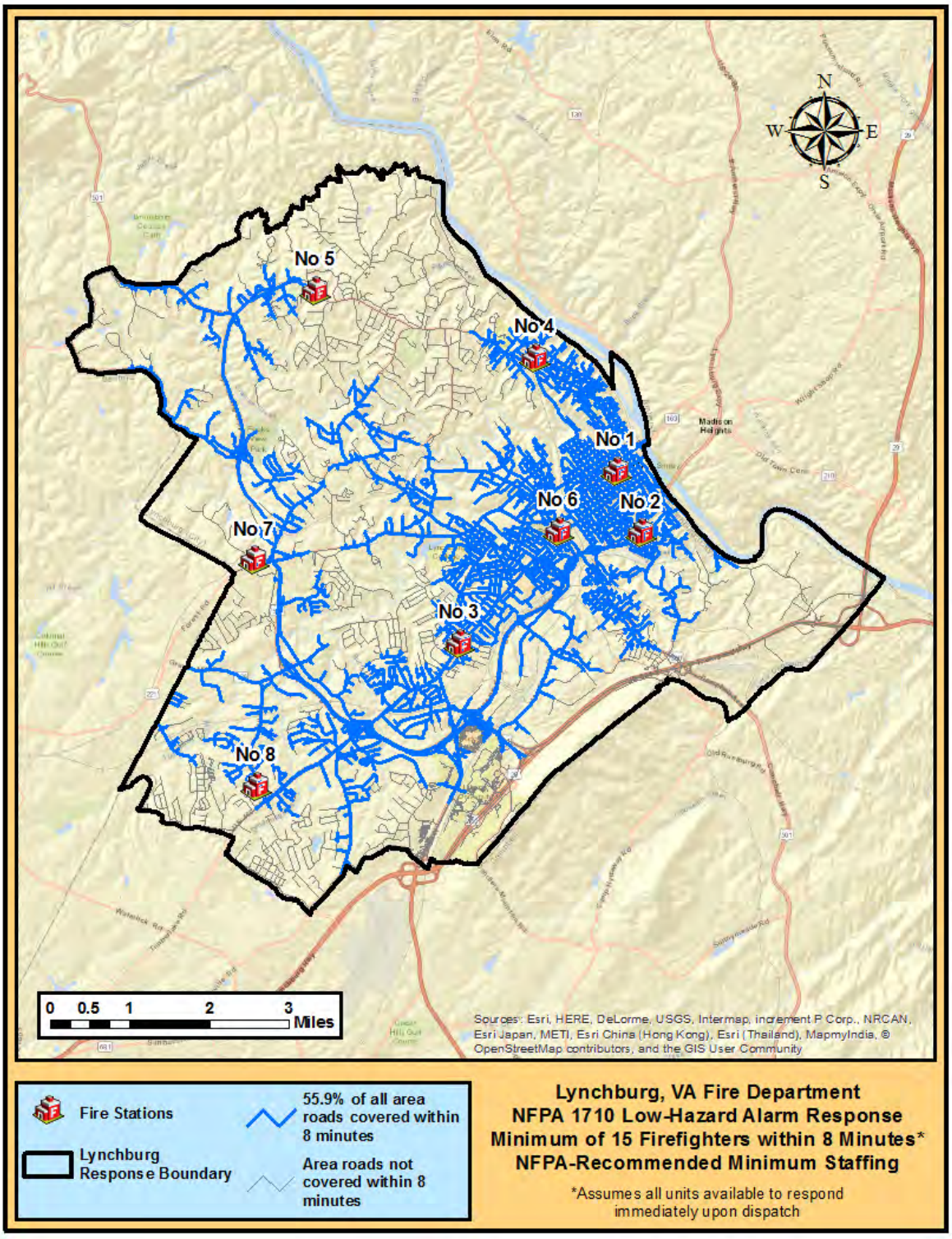
Table 8: Current Fire Station Locations and NFPA-Recommended Minimum Staffing. Table 8 displays where apparatus are housed and the recommended staffing levels for each apparatus.



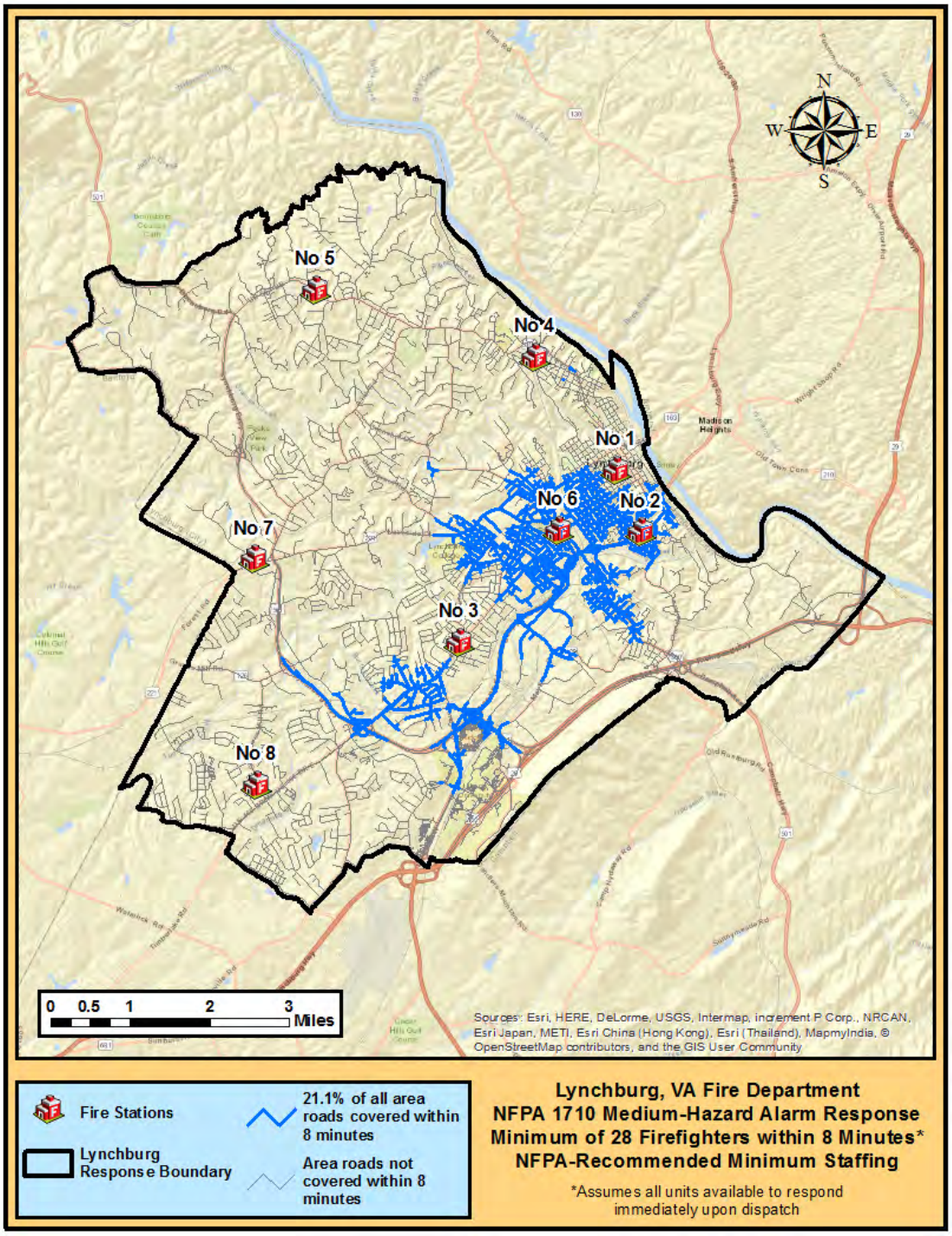
Map 25: Emergency "2 In/2 Out" Operations, 4-Minute Response Capabilities, NFPA-Recommended Minimum Staffing. Map 25 identifies those roads where a minimum of four firefighters can assemble on scene within 4 minutes. Based on NFPA-recommended minimum staffing levels, the department would able to assemble a minimum of four firefighters on scene within 4 minutes of travel on 46.7% of city roads, which equates to a 28.5% **increase** in coverage compared to the current response capabilities. Staffing apparatus with less than four firefighters largely increases the department's emergency "2 In/2 Out" 4-minute response capabilities. When apparatus are staffed with a minimum of four firefighters, the first arriving company will not have to wait for the arrival of a second company before initiating safe and effective fire suppression and rescue operations.



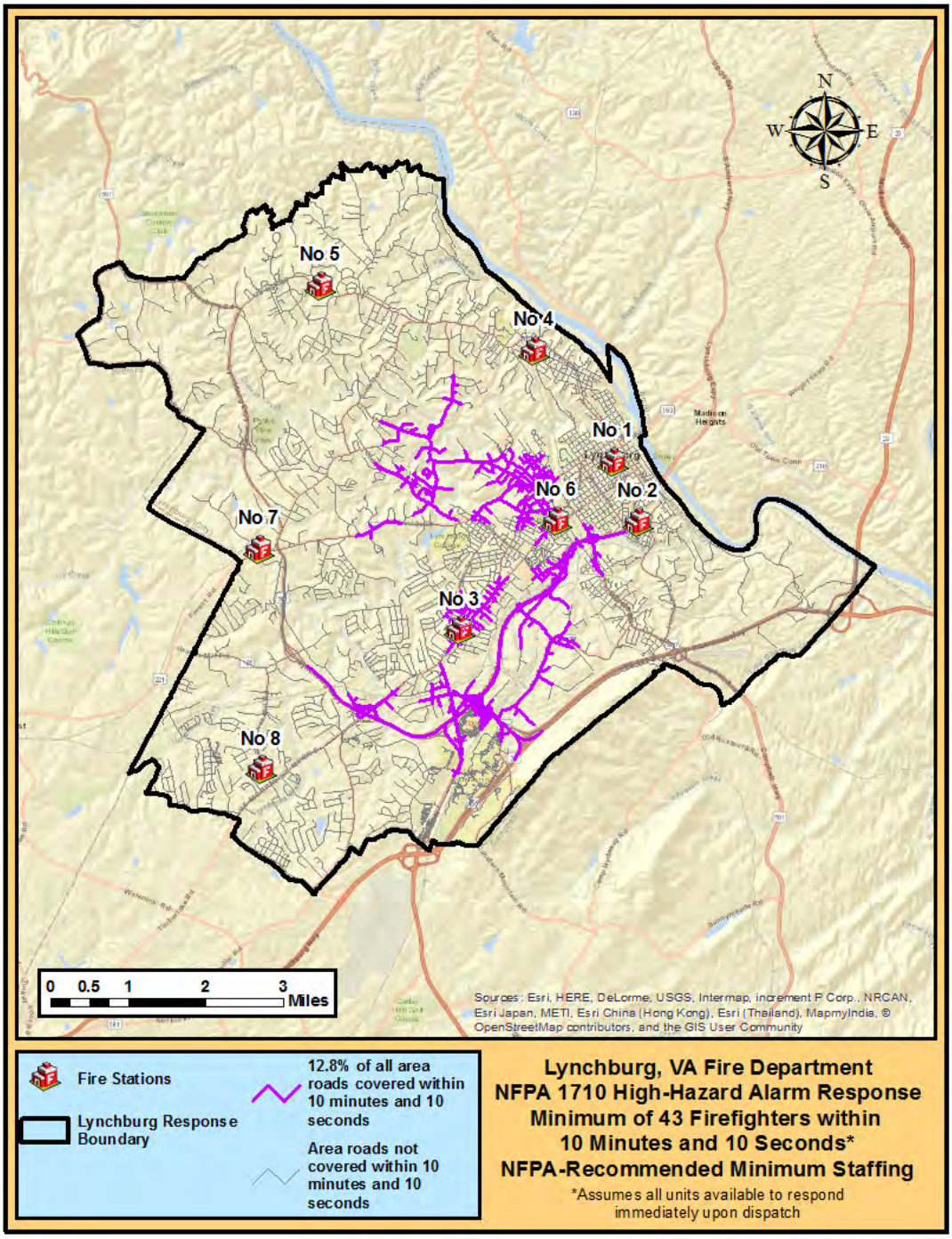
Map 26: 8-Minute Medic Response Capabilities, NFPA-Recommended Minimum Staffing. Map 26 identifies those roads where LFD's medic companies can reach within 8 minutes of travel from the current fire stations. If Medic 5 and Medic 8 were staffed full-time, the department would be capable of responding on 90.5% of city roads within 8 minutes, which equate to a 16.6% **increase** in response capabilities.



Map 27: NFPA 1710 Low-Hazard Initial Full Alarm Response Capabilities, Minimum of 15 Firefighters within 8 Minutes, NFPA-Recommended Minimum Staffing. Map 27 identifies those roads where a minimum of 15 firefighters can assemble within 8 minutes of travel. Based on NFPA-recommended minimum staffing, the department would be capable of assembling a minimum of 15 firefighters within 8 minutes of travel on 55.9% of city roads, which equates to a 29.5% **increase** in coverage compared to the current response capabilities.



Map 28: NFPA 1710 Medium-Hazard Initial Full Alarm Response Capabilities, Minimum of 28 Firefighters within 8 Minutes, NFPA Recommended Minimum Staffing. Map 28 identifies those roads where a minimum of 28 firefighters can assemble within 8 minutes of travel. Based on NFPA-recommended minimum staffing, the department would be capable of assembling a minimum of 28 firefighters within 8 minutes on 21.1% of city roads, which equates to a 1,306% **increase** in response capabilities. LFD should asses where potential medium-hazard structures are located and add additional resources to these areas to possibly increase the department's ability to assemble a minimum of 28 firefighters within 8 minutes of travel.



Map 29: NFPA 1710 High-Hazard Initial Full Alarm Response Capabilities, Minimum of 43 Firefighters within 10 Minutes and 10 Seconds, NFPA-Recommended Minimum Staffing. Map 29 identifies those roads where a minimum of 43 firefighters can assemble within 10 minutes and 10 seconds of travel. Based on NPFA-recommended minimum staffing levels, the department would be capable of assembling a minimum of 43 firefighters within 8 minutes of travel on 12.8% of city roads. LFD should asses where potential high-hazard structures are located and add additional resources to these areas to possibly increase the department's ability to assemble a minimum of 43 firefighters within 10 minutes and 10 seconds of travel. Several high-rise and high-hazard structures are located at Liberty University, Lynchburg College, and downtown Lynchburg.

Staffing	Emergency "2 In/2Out" Operations	NFPA 1710 Low-Hazard Initial Full Alarm	NFPA 1710 Medium-Hazard Initial Full Alarm	NFPA 1710 High-Hazard Initial Full Alarm
Current	32.5%	39.0%	1.5%	0.0%
Engine 1 or Truck 1 Browned-out	32.5%	34.8%	0.0%	0.0%
Engine 7 or Truck 2 Browned-out	32.5%	31.0%	0.0%	0.0%
NFPA-Recommended Minimum Staffing	46.7%	55.9%	21.1%	12.8%

Table 9: Response Scenarios and Percentages of Coverage. Table 9 displays the percentage of city roads covered for four benchmarks under four separate deployment scenarios.

Fire Station	4-Minute Coverage	8-Minute Coverage	10-Minute and 10-Second Coverage
Fire Station 1	7.6%	28.4%	43.9%
Fire Station 2	10.0%	38.3%	59.1%
Fire Station 3	9.8%	39.9%	63.4%
Fire Station 4	4.7%	17.8%	32.3%
Fire Station 5	7.3%	21.5%	30.6%
Fire Station 6	11.5%	40.7%	59.6%
Fire Station 7	4.6%	30.1%	59.5%
Fire Station 8	4.0%	19.4%	37.6%

Table 10: Percentage of Response Coverage from each Fire Station. Table 10 displays the percentage of city roads that can be reached within 4 minutes and 8 minutes and 10 minutes and 10 seconds of travel from each fire station. Results should be used when examining possible apparatus placement and changes to staffing and deployment. Increasing apparatus utilization and staffing levels will aid in improving the overall capabilities of the LFD to respond with sufficient resources to meet demand.

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Lynchburg Fire Department Call Volume and Travel Time Analysis

Lynchburg Firefighters Association provided historical CAD (Computer Aided Dispatch) data for all LFD emergency responses in 2016. The CAD data includes, but is not limited to, details such as incident identifier number, type of incident, responding apparatus, location of incidents, en route time, arrival time, and the times when apparatus and personnel have cleared the incident. Evaluating the departments past deployment procedures and travel times helps to identify how the department's performance compares to NFPA 1710 response standards. LFD assigns first-due districts to each fire station to outline which apparatus will typically be the first apparatus dispatched based on the location of the incident and unit availability. CAD data was examined to determine the number of responses each of the frontline apparatus executed in 2016. Analysis was also performed to determine the average and 90th percentile travel time of the first arriving apparatus compares to industry standards.

Key Definitions

First-due District: refers to a fixed geographical area established by the department's administration that contains a fire station and that is typically served by the personnel and apparatus assigned to that station.

Incident: refers to an emergency to which fire department mobile and personnel resources are dispatched to intervene and mitigate. An incident may require a single or multiple apparatus to respond.

En route Time: refers to the time interval that begins when units and personnel are assigned to an incident and ends at the beginning point of travel time.[70]

Arrival Time: refers to the time when the assigned units and personnel arrive at the incident location

Travel Time: refers to the time interval that begins when a unit is en route to the emergency scene and ends when the unit arrives at the scene.[71]

[70] NFPA 1710 §3.3.53.8 (2016)
[71] NFPA 1710 §3.3.53.7 (2016)

Battalion, Engine, Medic, Rescue, and Truck Companies Responses

The distribution of battalion, engine, medic, rescue, and truck companies responses were examined to determine the total number of responses performed by each apparatus in 2016. Fire stations that house apparatus that respond to a high volume of incidents should be identified as fire stations that may need to receive additional resources.

Apparatus Type	Apparatus	Apparatus Responses	Responses By Apparatus Type
Battalion	Battalion 1	346	575
	Battalion 2	229	
Engine	Engine 1[72]	794	7,430
	Engine 2	990	
	Engine 3	1529	
	Engine 4	636	
	Engine 5	495	
	Engine 6	1103	
	Engine 7[73]	836	
	Engine 8	1047	
Medic	Medic 1	2743	13,266
	Medic 2[74]	40	
	Medic 3	2850	
	Medic 4	1675	
	Medic 5[75]	750	
	Medic 6	2329	
	Medic 7	2034	
	Medic 8[76]	845	
Rescue	Rescue 1	553	553
Truck	Truck 1[77]	533	814
	Truck 2[78]	281	
Total		***22,638***	***22,638***

Table 11: Total Responses by Frontline Apparatus. Table 11 represents the total number of responses of each apparatus and each apparatus type in 2016. Apparatus that have routinely been browned-out will have lower responses compared to apparatus staffed full-time.

[72] Apparatus that is a candidate to be browned-out.
[73] Ibid
[74] Medic 2 is a reserved apparatus that is only placed in service when all medic units (including Medic 5 and Medic 8) are unavailable to respond to an incident.
[75] Cross-Staffed by Engine 5, and only placed in service when medic all units are engaged on assignment and unavailable to respond to an incident.
[76] Cross-staffed by Engine 8, and only placed in service when medic all units are engaged on assignment and unavailable to respond to an incident.
[77] Apparatus that is a candidate to be browned-out.
[78] Ibid

LFD Travel Time Analysis

Evaluating the departments past deployment procedures and travel times helps to assess the department's response capabilities and past performance. LFD assigns first-due districts to each fire station to outline which apparatus typically will be the first dispatched, based on the location of the incident and unit availability. Analysis was performed to examine how the average and 90th percentile travel time for the first arriving apparatus for each individual first-due district. First-due District with high travel times may need additional resources to ensure the first arriving apparatus is capable of arriving on scene within 4 minutes for 90% of incidents.

NFPA 1710 states that the first arriving apparatus should be on scene within 4 minutes of travel to 90% of incidents. Based on 2016 data, LFD's 90th percentile travel time was over 10 minutes. First-due District 8 had the longest average and 90th percentile travel time compared to the other first-due districts located within LFD's response boundary. The removal of Medic 8 from service will likely result in increasing the time it takes for the first arriving apparatus to arrive on scene to incident located in First-due District 8.

Data Parameters

Call volume data provided by Lynchburg Firefighters Association lists all incidents responded to by LFD in 2016. Parameters were set to accurately examine the department's travel times. Below are the parameters used when analyzing the data.

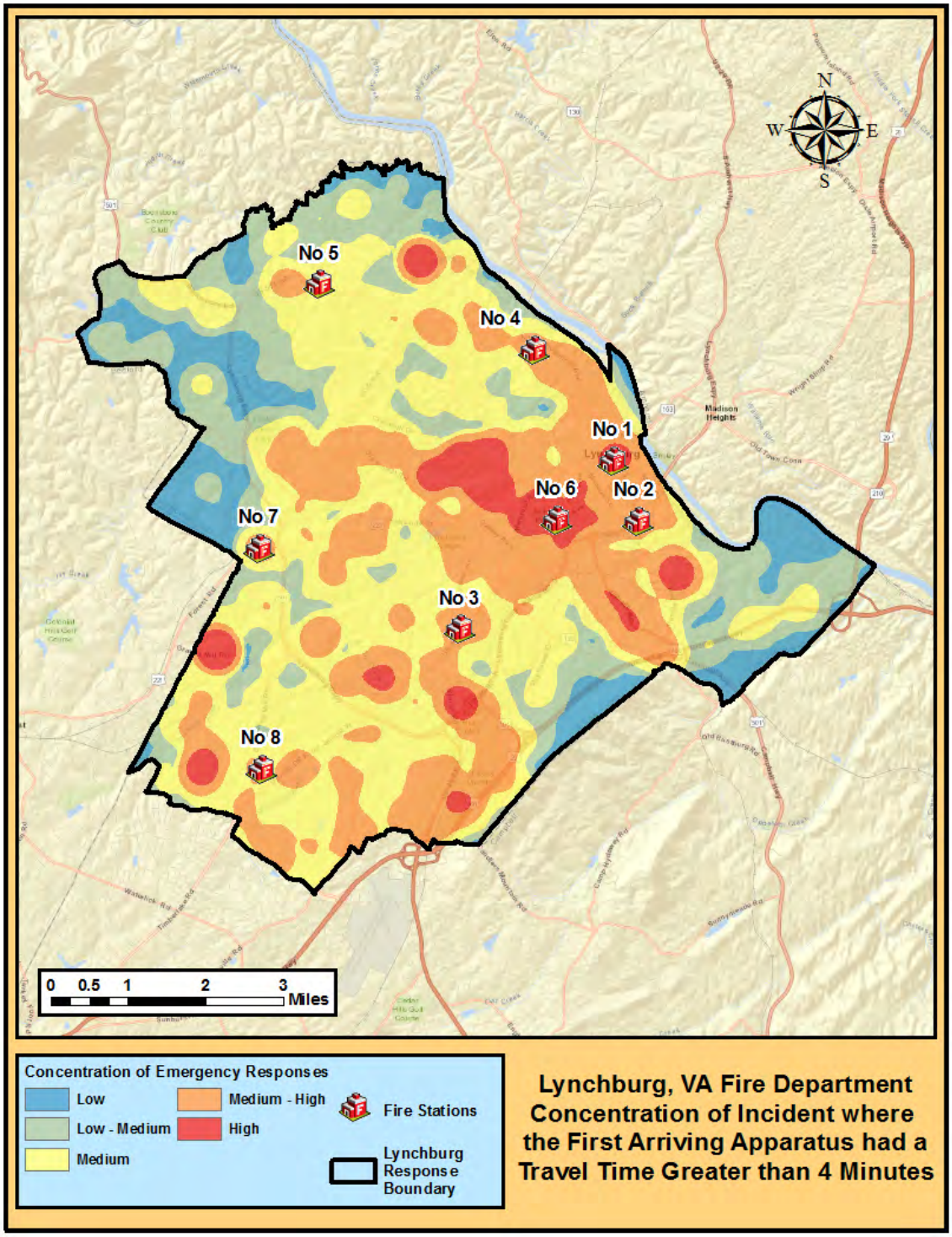
- Incidents with errors in reporting en route time or arrival time or were cancelled before the first arriving apparatus arrived on scene were excluded from the analysis.

- Incidents that weren't responded to by LFD frontline apparatus were omitted from the analysis.

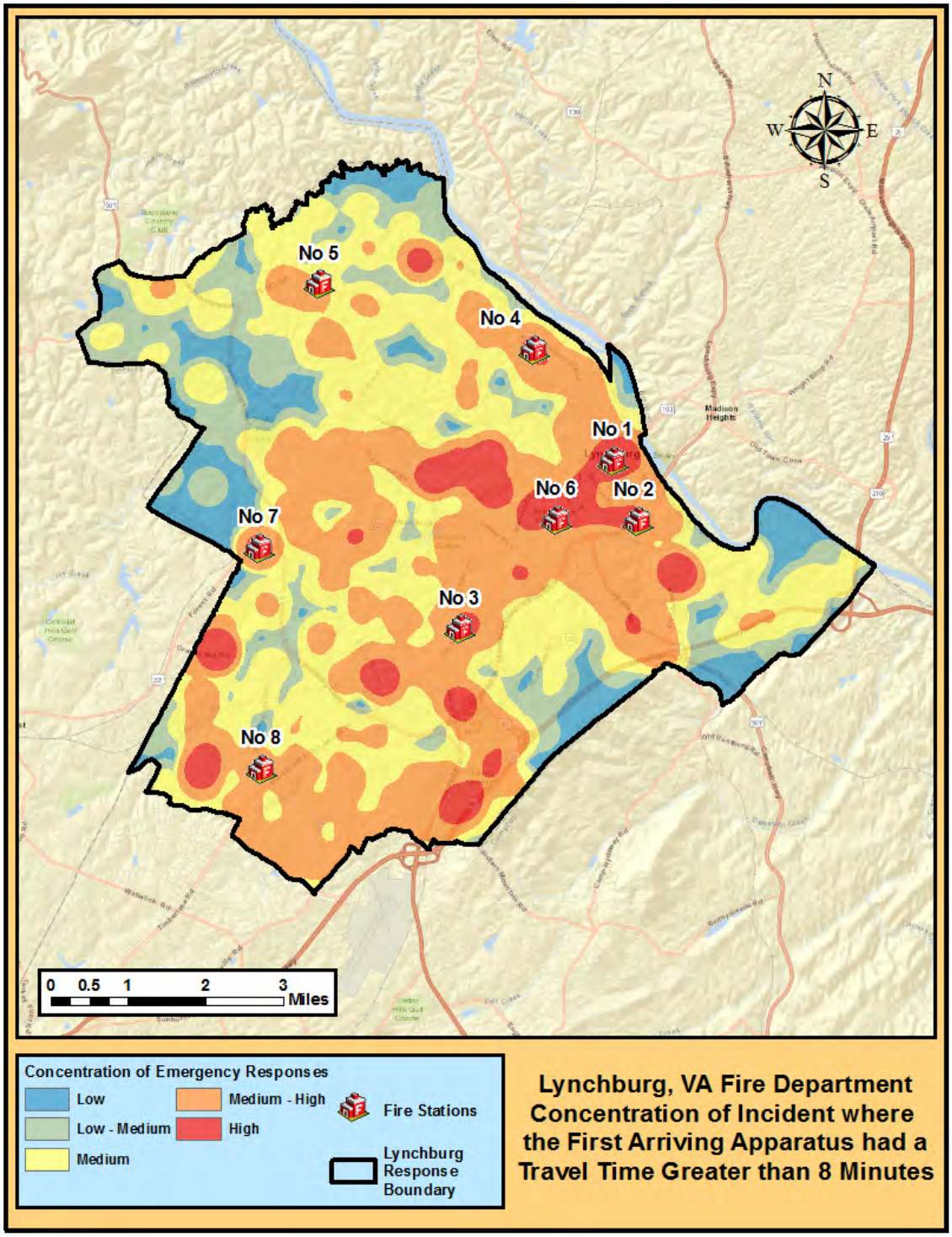
First-Due District	Total Incidents	Average Travel Time	90th Percentile Travel Time
1	1,314	0:04:15	0:08:00
2	1,452	0:05:18	0:10:38
3	2,844	0:05:30	0:10:19
4	1,153	0:04:43	0:08:45
5	789	0:06:08	0:10:32
6	3,638	0:05:31	0:09:08
7	1,845	0:06:10	0:10:49
8	1,530	0:06:28	0:10:50
Other[79]	57	0:12:37	0:19:05
All Incidents	***14,622***	***0:05:34***	***0:10:03***

Table 12: First Arriving Apparatus Average and 90th Percentile Travel Time. Table 12 represents the first arriving apparatus' average and 90th percentile travel time for incidents in 2016. In addition to assessing the 90th percentile of response, it is also important to assess the average response time for all apparatus. Although 90th percentile is typically identified as a more "accurate" assessment tool because it identifies a specific point in time it also has limitations because it does not consider the largest focus of travel time results. As such, the average travel time should be calculated as a means of identifying where the "center of gravity" lays. NFPA 1710 states that the first arriving apparatus should be on scene within 4 minutes of travel for 90% of incidents. In 2016, the average travel time of the first arriving apparatus to arrive on scene was 5 minutes and 34 seconds and the 90th percentile for travel time was 10 minutes and 3 seconds.

[79] Refers to incidents located outside of LFD's response boundary



Map 30: Concentration of Incidents where the First Arriving Apparatus had a Travel Time Greater than 4 Minutes. Map 30 depicts the concentration levels of incidents where the first arriving apparatus had a travel time greater than 4 minutes. The highest concentration of incidents where the first arriving apparatus had a travel time greater than 4 minutes are located near Fire Stations 1 and 6. Additional resources should be deployed at fire stations located in areas with a high concentrations of incidents where the first arriving apparatus had a travel time greater than 4 minutes.



Map 31: Concentration of Incidents where the First Arriving Apparatus had a Travel Time Greater than 8 Minutes. Map 31 depicts the concentration levels of incidents where the first arriving apparatus had a travel time greater than 8 minutes. The highest concentration of incidents where the first arriving apparatus had a travel time greater than 8 minutes are located near Fire Stations 1, 2, 6, and 8. Additional resources should be place at fire stations located in areas with a high concentrations of incidents where the first arriving apparatus had a travel time greater than 8 minutes.

Conclusion

In conclusion, regardless of the type of response, fire suppression companies are not staffed in compliance with industry standards for safe, efficient, and effective response to fires or rescue situations.

LFD should staff all fire suppression apparatus with a minimum of four firefighters to meet minimum staffing objectives in NFPA 1500 and NFPA 1710. LFD should discontinue the practice of browning-out either Engine 1, Engine 7, Truck 1 or Truck 2 to ensure the department's response capabilities are not negatively altered. LFD should staff Medic 5 and Medic 8 full-time to increase the department's medic unit 8-minute response capabilities. LFD should examine the possibilities of adding additional resources to assist in meeting NFPA 1710 staffing and performance objectives.

While it is impossible to predict where most of a jurisdiction's fire and medical emergencies will occur, the Lynchburg Fire Department should examine where emergencies have typically occurred in the past and make efforts to ensure these areas continue to enjoy the same level of coverage, while adjusting resources and deployment as needed in an effort to achieve complete compliance with industry standards. Areas with accelerated development and population growth will require additional coverage in the future. Any projected increase in emergency response demands should also be considered before changes are implemented, focusing on associated hazard types and planned response assignments.

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.

The ramifications of low staffing levels, as they pertain to the loss of life and property within a community, are essential when considering a fire department's deployment configuration. 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. Any proposed changes in staffing, deployment and station location should be made only after considering the historical location of calls, response times to specific target hazards, compliance with departmental Standard Operating Procedures, existing

industry standards, including NFPA 1500 and NFPA Standard 1710, and the citizens' expectation of receiving an adequate number of qualified personnel on appropriate apparatus within acceptable time frames to make a difference in their emergency.

Appendix

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.[80]

Key Sections included in the 1710 Standard that are applicable to this assessment are:

- 4.3.2
    - The fire department organizational statement shall ensure that the fire department's emergency medical response capability includes personnel, equipment, and resources to deploy at the first responder level with AED or higher treatment level.

- 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.

- 5.2.3.2 & 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.

[80] NFPA 1710, 2016

- 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[81], 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.

[81] AHJ- Authority Having Jurisdiction

- 5.2.4.1.1
    - 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

Assignment	***Minimum Required Personnel***
Incident Command	1 Officer
Uninterrupted Water Supply	1 Pump Operator
Water Flow from Two Handlines	4 Firefighters (2 for each line)
Support for Handlines	2 Firefighters (1 for each line)
Victim Search and Rescue Team	2 Firefighters
Ventilation Team	2 Firefighters
Aerial Operator	1 Firefighter
Initial Rapid Intervention Crew (IRIC)	2 Firefighters
Required Minimum Personnel for Full Alarm	**14 Firefighters & 1 Scene Commander**

- 5.2.4.2.1
  - The initial full alarm assignment to a structure fire in a typical open-air strip shopping center ranging from 13,000 ft^2 to 196,000 ft^2 (1203 m^2 to 18,209 m^2) in size
- 5.2.4.3.1
  - The initial full alarm assignment to a structure fire in a typical 1200 ft^2 (111 m^2) apartment within a three-story, garden-style apartment building shall provide for the following:

Assignment	***Minimum Required Personnel***
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply (2)	2 Firefighters
Water Flow from Three Handlines	6 Firefighters (2 for each line)
Support for Handlines	3 Firefighters (1 for each line)
Victim Search and Rescue Teams	4 Firefighters (2 per team)
Ladder/Ventilation Teams	4 Firefighters (2 per team
Aerial Operator	1 Firefighter
Rapid Intervention Crew (RIC)	4 Firefighters
EMS Transport Unit[82]	2 Firefighters
Required Minimum Personnel for Full Alarm	**27 Firefighters** **1 Incident Commander**

[82] The Standard further states, "Where this level of emergency care is provided by outside agencies or organizations, these agencies and organizations shall be included in the department plan and meet these requirements."

- 5.2.4.4.1
    - Initial full alarm assignment to a fire in a building with the highest floor 75 ft. (23 m) above the lowest level of fire department vehicle access shall provide for the following:

Assignment	***Required Personnel***
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply	1 Building Fire Pump Observer 1 Fire Engine Operator
Water Flow from Two Handlines on the Involved Floor	4 Firefighters (2 for each line)
Water Flow from One Handline One Floor Above the Involved Floor	2 Firefighters (1 for each line)
Rapid Intervention Crew (RIC) Two Floors Below the Involved Floor	4 Firefighters
Victim Search and Rescue Team	4 Firefighters
Point of Entry/Oversight Fire Floor	1 Officer 1 Officer's Aide
Point of Entry/Oversight Floor Above	1 Officer 1 Officer's Aide
Evacuation Management Teams	4 Firefighters (2 per team)
Elevator Management	1 Firefighter
Lobby Operations Officer	1 Officer
Trained Incident Safety Officer	1 Officer
Staging Officer Two Floors Below Involved Floor	1 Officer
Equipment Transport to Floor Below Involved Floor	2 Firefighters
Firefighter Rehabilitation	2 Firefighters (1 must be ALS)
Vertical Ventilation Crew	1 Officer 3 Firefighters
External Base Operations	1 Officer
2 EMS ALS Transport Units	4 Firefighters
Required Minimum Personnel for Full Alarm	**36 Firefighters** **1 Incident Commander** **6 Officers**

- 5.3.3.2.2
    - EMS staffing requirements shall be based on the minimum levels needed to provide patient care and member safety.

- 5.3.3.2.2.2 & 5.3.3.2.2.3
    - Units that provide BLS (ALS re: 5.3.3.2.2.3) transport shall be staffed and trained at the level prescribed by the state or provincial agency responsible for providing EMS licensing.

- 5.3.3.3.3
    - When provided, the fire department's EMS for providing ALS shall be deployed to provide for the arrival of an ALS company within a 480-second travel time to 90 percent of the incidents, provided a first responder with AED or BLS unit arrived in 240 seconds or less travel time as established in Chapter 4.

International Association of Fire Fighters
1750 New York Ave., NW, Washington, DC 20006
www.iaff.org

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